Development of an organisational CMMS implementation and sustainability guide for abattoirs

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I am nothing without Him.

ABSTRACT

TITLE: Development of an organisational CMMS implementation and sustainability guide for abattoirs.

KEYWORDS: Abattoirs, factories, maintenance cost, maintenance strategies, computerised maintenance management system (CMMS), maintenance management, CMMS implementation guide, CMMS sustainability guideline, training, CMMS responsibilities of management.

Throughout the years, companies have realised that, in order to consistently deliver quality products, you need to have a well-implemented and sustainable maintenance plan. For this reason, companies make use of a CMMS to help them maintain their assets and manage their maintenance cost. Despite the extensive utilisation of CMMSs at companies, the successful implementation rate is surprisingly poor. A partially implemented CMMS will not reduce the maintenance cost of any company, as not enough information is captured on the system for the optimisation of assets maintenance strategies. The dissertation investigates whether an implementation and sustainability guide can be designed and implemented at abattoirs in South Africa to ensure that the CMMS is used to its full potential.

Staff turnover, lack of data and incorrect training are some of the factors, identified by CMMS vendors, that could all lead to implementation failure of CMMSs. By not having a CMMS implementation and sustainability guide, the CMMS is nothing more than a work order system. An implementation guide, explaining how the information captured for each module is utilised, is not readily available for perusal.

The case study research methodology was decided on for this study, and a pragmatic approach was followed. This was done by collecting quantitative data by going through archives to see what the requirements were when the CMMS was initially implemented; by circulating a questionnaire, and by implementing the guide on some selected assets. Qualitative data was obtained by conducting semi-structured interviews with participants. The investigation showed a strong correlation between CMMS implementation failure and ‘partial implementation’, ‘incorrect training of staff’ and ‘staff turnover’.

A CMMS implementation guide for abattoirs has been developed to ensure that all CMMS modules, as discussed in this dissertation, are fully utilised. A sustainability guide has also been developed, indicating what infrastructure needs to be put in place, the necessary training to be done and pointing to what would be needed from management down to workshop level to ensure sustainability of the implemented CMMS - showing the steps that need to be taken by each level of management.

As radical personnel changes may be necessary to fully implement the developed guide, the guide was only implemented in some selected assets. Data from a period before and after implementing the developed guide was analysed, and it became clear that the developed guide has reduced the maintenance cost quite significantly.

The reduction in maintenance cost is a good indication that the developed guide will reduce the maintenance cost when fully implemented. Training guides and standard operating procedures (SOP's) must be developed to ensure the sustainability of the implemented CMMS guide. The study concludes by making recommendations for the developed guide and discussing future research possibilities.

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

CMMS	Computerised maintenance management system
AEL	Atmospheric emission licence
AIA	Approved inspection authority
API	Application programming interface
ASAP	As soon as possible
EAM	Enterprise asset management
ERP	Enterprise resource planning
EUT	Eindhoven University of Technology
FFT	Fast Fourier Transform
FMEA	Failure mode and effects analysis
HBS	Hardware breakdown structure
IBM	International business machines
IIOT	Industrial internet of things
IoT	Internet of things
IP	Internet protocol
ISO	International organisation of standardisation
IT	Information technology
JIT	Just in time
LAN	Local area network
MHI	Major hazard installation
MRI	Master record index

MSDS	Material safety data sheet
MSI	Maintenance significant item
MTTF	Mean time to failure
OEE	Overall equipment effectiveness
OEM	Original equipment manufacturer
OHSA	Occupational health and safety act
P&ID	Piping and instrumentation diagram
P-F	Potential-to-failure
PLIOFF	Plant level impact of functional failures
PM	Preventative maintenance
PMO	Planned maintenance order
PPE	Personal protective clothing
RCM	Reliability-centred maintenance
RPM	Revolutions per minute
RTO	Request to order
SAP	Systems applications and products
SHE	Safety, health and environment
SME	Subject matter expert
SOP	Standard operating procedure
TA	Turnaround
TPM	Total productive maintenance

LIST OF UNITS

°C	Degrees Celsius
A	Ampere
bar	Metric unit of pressure (100 kPa)
cc/rev	Centimetre cube per revolution
cfm	Cubic feet per minute
Hz	Hertz
kg	Kilogram
kPa	Kilopascal
kVA	Kilo-volt-ampere
kVAr	Kilo-volt-ampere reactive
kW	Kilowatt
L	Litre
l/min	Litre per minute
l/s	Litre per second
m	Metre
m^3	Cubic metre
m^3/min	Cubic metre per minute
mbar	Millibar
mm	Millimetre
O_2	Oxygen
R	Rand
V	Volt

TABLE OF CONTENTS

CHAPTER 1

1 INTRODUCTION TO THE STUDY

1.1 INTRODUCTION

South Africa`s economic growth and job creation strategy is directly related to factories being able to produce premium products at the lowest input and operational costs. One of the single biggest expenses contributing to the rising cost of operating a factory, is primarily the maintenance of equipment and machinery (hereafter maintenance cost). Parts and labour are seen as the two highest contributors to maintenance cost. Other factors, like over-maintenance, wasted resources and increased energy consumption also play a role in this regard - however not as significant as parts and labour.

These two categories work intertwined with each other. Proper maintenance of parts will not only reduce the cost of parts by lowering the replacement of broken or damaged parts, but will also reduce labour costs due to less man-hours spent on machine maintenance.

Therefore, maintenance does not only aim to keep the equipment in a state of working order, but also plays a decisive role in achieving production goals with optimum cost of ownership and maximum productivity (Mehmeti *et al.*, 2018:800). Maintenance costs contribute up to 10% of the operating cost in a large abattoir, with the real impact often overlooked. According to studies, the cost of maintenance can reach anything between 15%-40% of the product cost, depending on the manufacturing industry (Mehmeti *et al.*, 2018:800). The “Iceberg Model” highlights the hidden cost impact of maintenance upon the business, which is much bigger than just the direct cost associated with traditional maintenance (Wienker *et al.*, 2016:414).

Source: Michael Wienker *et al.*, 2016:414

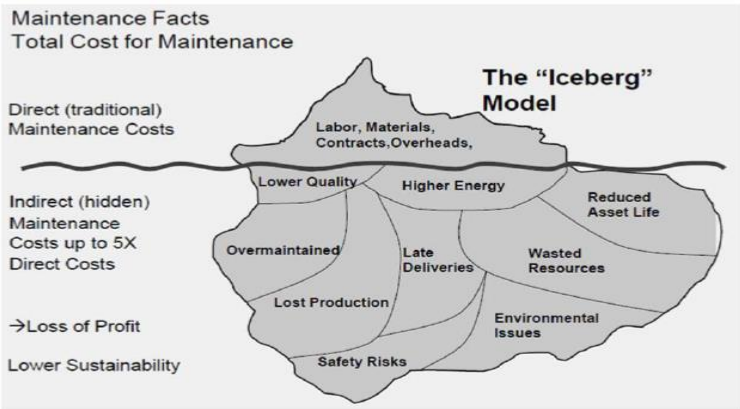

Figure 1: Total costs of maintenance - the "Iceberg" model

A combination of total productive maintenance (TPM) and reliability-centred maintenance (RCM) should be the goal in any organisation. Moubray (1997:7) defines RCM as a process used to determine the maintenance requirements of any physical asset in its operating context. The main goal of RCM is to maximise the reliability of the physical asset by identifying the failure modes of the items and components of a system, and ranking the consequence of each failure mode (Mungani & Visser, 2013:5).

Mwanza and Mbohwa (2015) state the following:

> TPM is designed to maximise equipment effectiveness (improve overall efficiency) by establishing a comprehensive productive-maintenance system covering the entire life of the equipment, spanning all equipment related fields (planning, use, maintenance, etc.) and, with the participation of all employees from top management down to shop-floor workers, to promote productive maintenance through motivation management or voluntary small group activities. (p.462)

An important tool in any organisation is a CMMS. Many different CMMSs are available on the market today. A CMMS helps you keep track of the eight pillars of TPM, discussed in paragraph 2.6. A CMMS will also help the user to keep track of the different maintenance plans, adopted for every asset, by using the RCM method (to be discussed in paragraph 2.5).

1.1.1 Maintenance

The importance of maintenance was only realised as important by the industry after the 1980s; before then it was considered to be of minor importance. Maintenance has evolved with companies scheduling monthly or yearly maintenance based on historical data or typical asset lifespans. This was certainly a good start, however it is not sufficient to mitigate the financial implications that downtime can bring (Lachance, 2016). Downtime has always affected the productive capability of physical assets by reducing output, increasing operating costs and by interfering with customer service (Moubray, 1997:3).

Maintenance has come a long way in the past 50 years, and according to Coetzee (2001:1), the technology and systems employed in the maintenance industry are of the finest in the world. There is no excuse not to be successful in maintenance anymore. RCM and TPM rely on the data captured into the CMMS to make informed decisions on maintenance strategies of machines.

Jasper Coetzee designed a maintenance cycle model at the University of Pretoria, consisting of a managerial and an operational sub-cycle. A complete generic model was designed that contains the best of the Terotechnology cycle developed by the British Ministry of Technology, the Eindhoven University of Technology (EUT) model developed by the Eindhoven University of Technology and the maintenance cycle developed by the University of Pretoria. According to Coetzee (1997:7), the model gives an adequate description of the functionality inherent in the maintenance function in and around the typical industrial concern.

Source: Coetzee, 1997:7

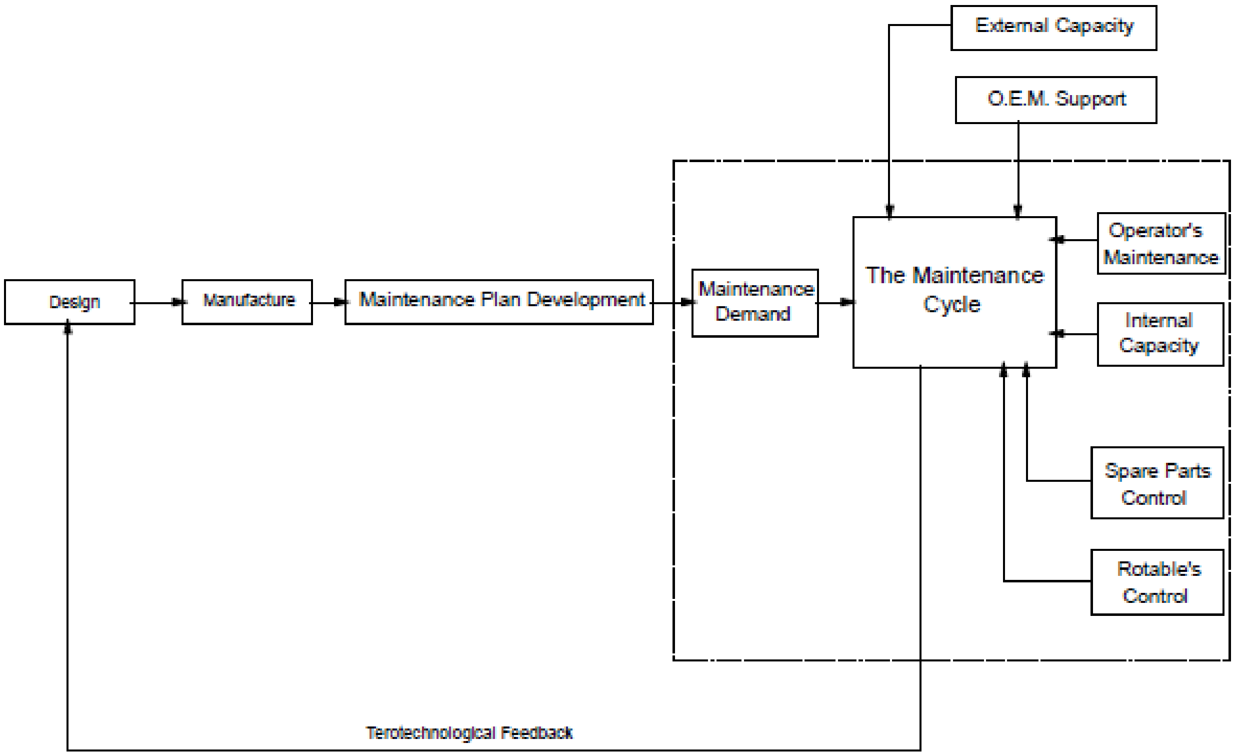

Figure 2: The complete general maintenance model

Cato and Mobley (2002) state the following:

> Controlling the maintenance activities in any facility requires an effective organisation. Also required is an accurate, comprehensive, easily accessible database of relevant information. Some maintenance organisations still manage their operations with a manual system or with no system at all. In all but the smallest of maintenance operations, manual systems break down under the burden of the vast amount of information generated and required by maintenance. For this reason, the computer is now being recognised as a powerful tool for maintenance. (p.2)

1.1.2 Computerised maintenance management systems (CMMS)

Computerised maintenance management systems are used to help organisations keep track of fixed assets in the factory and assist with maintenance processes. The implementation of a CMMS will allow quick and effective communication and will bring many benefits, such as improved planning and scheduling, easy access to historical data and report generation, as well as allowing cost reduction associated with spare parts and maintenance activities. (Lopes *et al.*, 2016:269). The main advantage of a CMMS is that it can increase overall efficiency of your plant. There is a wide variety of CMMSs on the market today, each with its own advantages and disadvantages. A best-of-breed computerised maintenance management system that has proven to reduce maintenance costs and increase uptime, can often stand alone and act independently from an enterprise resource planning (ERP) system (Lachance, 2014).

Despite the importance of a CMMS as a key tool in maintenance management, the degree of success achieved in successfully implementing such systems - even in large, well-resourced organisations - is surprisingly poor. According to internet research, the number of successful CMMS implementations is only around 25%-40% and the number of companies that use a CMMS or an enterprise asset management (EAM) at its full capability is only between 6%-15% (Wienker *et al.*, 2016:415). Effective use of this tool is crucial in reducing some or all of the hidden costs, seen in Figure 1.

Doing a quick internet research on implementation failure of a CMMS, one will find a vast amount of articles. Most of the articles have common reasons why implementation fails and give guidelines on how to prevent it. These guidelines are, however, generic and do not really explain what you need to change in the processes to successfully implement your current CMMS, but rather what needs to be done before implementing.

1.1.3 Enterprise asset management (EAM)

Enterprise asset management is an improvement of the CMMS where it incorporates extra modules like warranty-, energy monitoring- and insurance modules for better control of maintenance on typical plant and equipment. EAM also focuses on the entire lifecycle of equipment to maximise return on investment of equipment.

Pragma is a South African company established in 1990. Pragma has invested a significant amount of resources and money to build an asset management road map (Pragma, 2019). The road map helps them to assist clients to maximise their own EAM by focusing on maintenance management, zero unplanned stops and sustainable enterprise asset management.

Pragma developed the enterprise asset management program On Key in 1992. On Key can receive data for process automation and analysis from Internet of Things (IoT) devices through its meter and monitoring point application programming interfaces (API's), providing the ability to track and analyse real-time data from many things registered on the internet with unique internet protocols (IPs) from different online platforms (On Key, 2019).

1.1.4 Enterprise resource planning (ERP)

ERP is a software system that brings together all the different functions of a business. Sales-, manufacturing-, distribution- and the financial processes are incorporated into one system. When it comes to maintenance management, ERP may fall short in ease of use and quick implementation (Lachance, 2014).

SAP (Systems Applications and Products) is a world market leader in the field of ERP software, with 26.7% market ownership - nearly twice that of its closest competitor (SAP, 2018). The most important feature of every ERP is the ability to connect all the different departments across an organisation to a central live database. SAP finished its first financial accounting system in 1973 (SAP, 2019).

Microsoft Dynamics Navision is an easily adaptable ERP solution. It helps small and medium-sized businesses automate and connect their sales, purchasing, operations, accounting and stock management (Microsoft, 2019).

1.1.5 Case study

Company K is a family owned business comprising of four divisions. Company A is one of the divisions of Company K for the streamlined slaughtering of animals for human consumption. Company A has a modern deboning facility for bulk deboning of quarters for customers and an on-site rendering facility for the manufacturing of blood- and carcass meal.

Company A, used for this case study, had 1500 full-time employees split into two shifts during the 2018 financial year. Company A makes use of the most advanced equipment and technology to slaughter animals and is one of the most modern facilities of its kind in Africa. The number of animals slaughtered during the last financial year was 363 410, with a total live weight of 159,900 tons.

1.2 PROBLEM STATEMENT

Company A is a high throughput slaughtering facility with a large amount of assets for the slaughtering and deboning of animals. All of these assets need to be properly maintained, with different strategies. Keeping track of all the different strategies and legal requirements is a challenging task. Company A makes use of Microsoft Dynamics Navision with CMMS functions programmed for the maintenance of their assets.

According to the researcher, “old school” technical staff and lack of knowledge of what the proper use of a CMMS can hold for an organisation is the main reason for failure of the CMMS. To achieve full functionality of the CMMS, a walk down of the plant will have to be conducted, followed by the red-lining and codification of all assets. Although this is the opinion of the researcher, based on current experience, the correctness of the mentioned statement will be investigated as part of the dissertation.

The greatest misunderstanding of the role of a CMMS is the belief that it is the maintenance strategy itself, not just a tool to support the existing maintenance strategy of an organisation (Wienker *et al.*, 2016:416). If this is not understood correctly, the CMMS will only be an expensive tool in an organisation and will never reduce maintenance costs per se. It is not unusual that the wrong use of these tools, together with a lack of data implementation, lead to a CMMS only being used as a “work order system” without the power of analysis and reporting (Wienker *et al.*, 2016:416).

The CMMS should assist managers to make informed decisions on when to service or replace machinery. The CMMS should automatically make recommendations to the user after having analysed breakdown trends and maintenance cost incurred. The user should review these recommendations before making decisions.

By using the CMMS to its full capacity, you can go further down the evolution of maintenance to condition monitoring, RCM and TPM. A CMMS will help the company keep track of all its assets, breakdown frequencies, work orders and equipment spares - which is all relevant to effectively implementing RCM and TPM. Therefore, the successful implementation of a CMMS is vital.

Different CMMS vendors have addressed the main reason for failure of a CMMS, but this is still lacking in the successful implementation. Staff turnover is one more reason for failure, as it takes between two to five years to implement a CMMS successfully. Having a guide available for new employees, and for refreshing existing employees’ understanding of the importance and functions of CMMS modules, will help the system reach its full potential.

The guide will show what is needed from employees to successfully implement the CMMS, thus making it possible to choose the best maintenance strategy for different equipment to be maintained. A proper guide showing the links between modules and what modules should consist of, is not readily available for perusal.

Another reason for failure of a CMMS is that many companies rather incorporate ERP software for their businesses. CMMS is not the core function of these programs, but is only a module that can be added on. This could mean that all or most of the maintenance functions of these programs will easily get lost in the ERP software.

The problem to be researched is therefore to see if a guide can be designed and implemented in any company where a CMMS is utilised in order to help such company use the CMMS to its full potential. The guide will also be designed in such a way as to ensure sustainability of the CMMS implemented, and the guide should also help to ensure that maintenance add-ons modules for ERP programs do not fail.

The primary question for this dissertation is the following:

Can an implementation and sustainability guide be designed and implemented at Company A to ensure that the CMMS is used to its full potential?

1.3 RESEARCH AIM AND OBJECTIVES

1.3.1 Research aim

The aim of this research is to create a CMMS implementation and sustainability guide for abattoirs. The guide will illustrate and explain the importance of different modules that must be used for a successful CMMS and how the modules should interact with each other. The research aim includes creating a sustainability guide that must be implemented by the management team to ensure that the time and money spent on implementing a CMMS is not in vain. The guide created should be applicable to abattoirs in general.

1.3.2 Scope of research

The scope of the research will be to create a CMMS implementation and sustainability guide for Company A to implement and use.

1.3.3 Research objectives

The dissertation has only one main and one secondary objective.

1.3.3.1 Main objective

Developing a guide for abattoirs, and specifically for Company A, to successfully implement and utilise a CMMS (Chapter 5).

1.3.3.2 Secondary objective

Developing a guideline for a management team to ensure the sustainability of the implemented CMMS (Chapter 6). A guideline and procedures to follow will be outlined in this chapter.

1.3.3.3 Exclusions and assumptions

This dissertation will focus on developing a guide for the successful implementation of the existing CMMS at case study Company A. Included is developing a sustainability guide that can be followed by Company A to ensure the sustainability of the CMMS. The process of developing the implementation and sustainability guide will be explained in Chapter 3 (refer paragraph 3.3.2).

All other aspects that are not directly related to maintenance costs, including any financial functions of Microsoft Dynamics Navision, will be excluded from the research scope. The implementation of the maintenance strategies is also excluded from the dissertation.

Assumptions include that the CMMS used at Company A is the only maintenance program used for maintenance, and that the sustainability guide will be effective to ensure sustainability of the CMMS.

1.3.4 Expected outcomes and deliverables

The expected outcomes of the research is to develop and successfully implement the CMMS implementation and sustainability guide for Company A, helping them to maintain their equipment more efficiently and to reduce their maintenance costs. Implementing the guide should then free up more time for artisans to do work that is more intricate and to do root cause failure analysis, instead of running around as a result of poor planning. The outcomes will be measured by comparing data from before and after implementation of the guide on some selected assets.

1.3.5 Value to industry

The dissertation aims at developing a CMMS implementation- and sustainability guide for abattoirs. The guide can be used to help other abattoirs develop their own CMMSs and to ensure that unnecessary maintenance cost is avoided. The sustainability procedure will ensure that costs incurred to get a CMMS operational are not squandered.

The guide will ultimately help manage the company's maintenance cost so that the company can improve the effectiveness of its maintenance by using the CMMS data gathered for RCM and TPM.

1.4 RESEARCH METHODOLOGY

The methodology used will consist of a literature review and an empirical study.

1.4.1 Literature review

The review will start with the concept of maintenance and the importance of managing it. It will continue by showing the different maintenance strategies used in the industry. This will help the researcher understand the different maintenance strategies.

Secondly, an in-depth review of CMMSs will be done, discussing the eight modules needed for a successful CMMS and reasons for failure of a CMMS. Reasons for implementation failure will also be shown.

The knowledge gained will help the researcher in developing a successful implementation and sustainability guide.

1.4.2 Empirical study

An empirical study for the abattoir industry will be done. It will be a case study focusing on Company A. The empirical study will be undertaken to help develop an implementing guide for the CMMS at Company A. The sustainability procedure will also be specific for Company A.

Quantitative data will be collected by means of a questionnaire. Quantitative data obtained by means of financials will help the researcher investigate if implementing the CMMS guide on some selected assets at Company A have helped to reduce the maintenance cost of the company. Quantitative data will also be collected by going through the archives to see what the requirements were when the CMMS was initially implemented.

Qualitative data will be collected by semi-structured interviews held with Company A`s maintenance team, as well as its management team through the use of open questions.

The sustainability guide will show what needs to be put in place, what training would be necessary as well as different responsibilities - from management down to shop-floor level. The guide will show what steps need to be taken when certain activities are being performed.

1.4.3 Validity and reliability

The dissertation will be done in the field of development and management engineering. Research will lose its value if done without rigor. Methods to address reliability and validity in case studies will also be discussed. To ensure reliability of the dissertation, documentation of procedures followed will be done so that repeating of the case might be possible. To ensure validity of the research, multiple sources of evidence will be used to collect data.

1.4.4 Ethics

Certain ethical standards applied in the dissertation will help the dissertation not to lose any value. All potential participants in the research will be informed, before their participation, on how the information gathered from them will be used. The slaughtering process of the animals will not be changed or altered in any way by implementing the CMMS guide. There will also be no environmental change by implementing the guides.

1.5 OVERVIEW

- Chapter 1: Introduction to the study

The chapter starts by describing maintenance and the different systems that can be used for maintenance of assets in factories. The problem statement and research question will be presented, followed by the research aim and objectives, showing the main- and secondary objectives. The research methodology for the dissertation will be discussed.

- Chapter 2: Maintenance Strategies and CMMS

The chapter will give a comprehensive literature review of different maintenance strategies and Jasper Coetzee's complete general maintenance model, a brief overview of RCM and TPM, an in-depth review of CMMS and the MEGKON maintenance optimisation training course, as well as a brief review of EAM systems and the fourth industrial revolution.

- Chapter 3: Research Methodology

The chapter starts by defining research and the research methodology, consisting of paragraphs discussing philosophical assumptions, case study design and concerns about case studies. The chapter proceeds by discussing different data collection techniques used for the dissertation, and chapter ends with a brief overview on ethics.

- Chapter 4: Analyses of quantitative- and qualitative data

Results from going through the archives, the questionnaire, financial data and the semi-structured interviews will be discussed in this chapter.

- Chapter 5: Developing a guide to successfully implement a CMMS at an abattoir

This chapter will develop and present a guide to be used in abattoirs to implement a CMMS and will show important links between modules.

- Chapter 6: Ensuring sustainability

This chapter will discuss the guide that has been developed and how to ensure sustainability of the implemented CMMS. Validity will be demonstrated in this chapter.

- Chapter 7: Conclusions

This chapter will conclude the dissertation.

CHAPTER 2

2 MAINTENANCE STRATEGIES AND CMMS

2.1 INTRODUCTION

This chapter will conduct a literature review of different maintenance strategies, Jasper Coetzee's model, RCM and TPM, CMMS and EAM software, the MEGKON maintenance optimisation training course and the fourth industrial revolution.

A brief explanation of maintenance will be given to show the difference between planned and unplanned maintenance, followed by an overview of maintenance strategies to show how maintenance strategies have evolved over the last five decades. The different predictive maintenance techniques will be explained in a little more detail. The complete general maintenance model by Jasper Coetzee will be explained in more detail, followed by a short explanation of RCM and TPM - showing the importance thereof in the maintenance environment. The chapter will continue by giving a literature review of CMMS and its different modules, ultimately helping in developing an organisational CMMS implementation guide. The MEGKON maintenance optimisation training course will be reviewed, and a brief overview of EAM systems and the fourth industrial revolution, will follow.

The competitive market that companies find themselves in today demands proper managing of their maintenance costs. The main reason for companies to manage maintenance costs is to improve profitability. If a company is profitable, it is likely to stay in business, expand its horizons and stimulate the creation of jobs.

2.2 WHAT IS MAINTENANCE

Maintenance is the process of preserving a condition or situation or the state of being preserved. There are many divisions from the aspect of strategy, policy, type and form of maintenance, but in most literature maintenance is split into planned or unplanned maintenance (Mehmeti *et al.*, 2018:800).

Planned maintenance is well documented and normally scheduled in advance. All the spares, technical data and artisans are readily available with planned maintenance. Planned maintenance allows you to manage your calendar and to get work done faster.

Unplanned or run-to-failure maintenance is the simplest way to do “maintenance”, but it is highly inefficient. With unplanned maintenance, you need to find the reason for the breakdown while repairing the machine with limited resources.

Planned and unplanned maintenance can be further divided into smaller groups, like reactive-, preventative-, predictive- and aggressive maintenance. These groups vary slightly among different authors.

According to Duffuaa and Raouf (2015:57), the distribution by craft hours in a well-run industrial maintenance facility is expected to be as illustrated in Figure 3.

Source: Duffuaa and Raouf, 2015:58

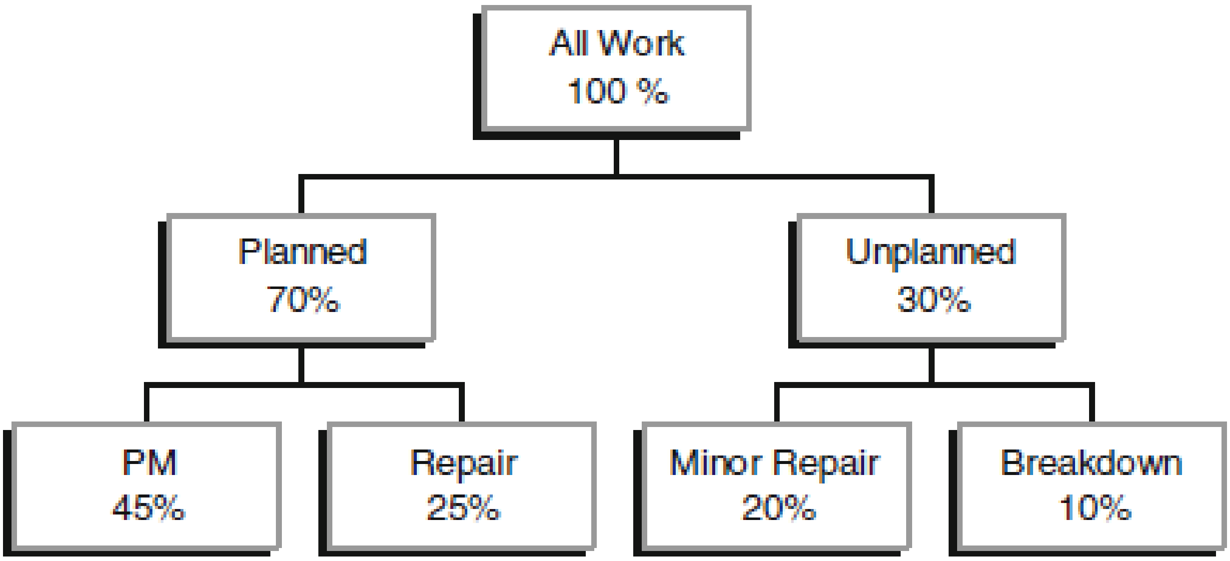

Figure 3: Maintenance work distribution

Maintenance cost is a significant percentage of the cost of any factory. Today’s competitive environment requires that industries try to sustain full production capabilities, while minimising capital investment (Eti *et al.*, 2006:1235-1236). Maintenance cost varies with every maintenance strategy. Effective scheduling and planning of maintenance activities, using a CMMS, can significantly lower maintenance cost.

Abattoirs have a large amount of assets for slaughtering and deboning cattle, and they all need proper maintenance to keep the plant running at optimum efficiency. Most abattoirs have only one slaughtering line and a breakdown will stop the entire production. All the maintenance to be done on the slaughtering line should be planned to avoid loss of production by striving to eliminate unplanned maintenance. The next paragraph will look at the different maintenance strategies used in the maintenance industry.

2.3 MAINTENANCE STRATEGIES

Different maintenance strategies include reactive-, preventative- and predictive maintenance. The amount of resources available normally determines what maintenance strategy is utilised. According to Eti *et al.* (2006:1236), a maintenance strategy consists of three steps: formulating a strategy of what needs to be done; acquiring resources needed for the proposed strategy, and implementing the strategy. It is worth noting that the maintenance strategy is one of the most influential factors affecting the effectiveness of a maintenance system (Emovon *et al.*, 2016:11). Maintenance planning also involves the development of a suitable maintenance strategy, which defines the actions that are required to achieve the selected maintenance objectives (Visser, 2006:210).

With the amount of assets that needs to be maintained in an abattoir; it is a daunting task to conduct preventative maintenance on all of the assets. Different maintenance strategies need to be adopted for every asset.

2.3.1 Reactive maintenance

Reactive or run-to-failure maintenance is maintenance done on equipment that has already broken down. Swanson (2001:238) describes it as a fire-fighting approach to maintenance. Reactive maintenance was one of the first maintenance strategies used. The period prior to 1950 was characterised by reactive maintenance. During this phase, little attention was given to defining reliability requirements or preventing equipment failures (Mckone & Weiss, 1998:339). The disadvantages of reactive maintenance far outweigh the advantages. Disadvantages include shorter asset life expectancy, no time to review safety procedures, inefficient use of time and expensiveness.

The reactive method of management forces the maintenance department to maintain extensive spare parts inventories that include spare machines or at least all major components for all critical equipment in the plant (Mobley, 2002:3). Mobley (2002:3) continues by stating that the average repair performed in a reactive mode will average about three times higher than the same repair made within preventative mode. Figure 4 shows how the cost to repair a machine increases exponentially when using reactive maintenance rather than predictive maintenance.

Source: Sail Wales, 2017

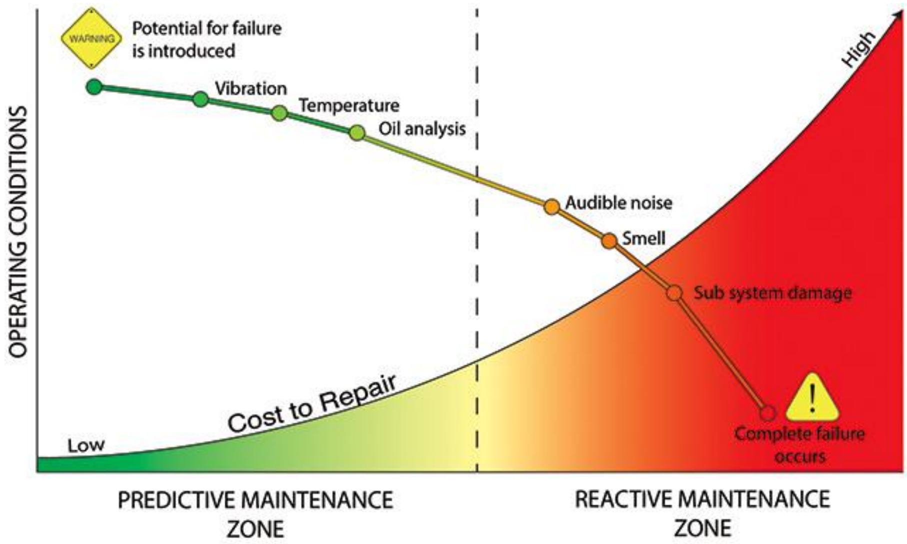

Figure 4: Cost of repair - Predictive maintenance vs Reactive maintenance

Reactive maintenance minimises the amount of maintenance cost to keep machines running, but should only be used when the cost of a breakdown - including maintenance cost – would be less than doing preventative maintenance beforehand.

Reactive maintenance is used in Company A, where the cost of preventative maintenance exceeds the cost of reactive maintenance. Stand-by machines are available for critical equipment that will stop the production line. Reactive maintenance or repair is done on one piece of machinery while the rotable spare is used. The rotable spare will then stay online until it has a functional failure and then only will it be changed with the new, repaired or overhauled machine. A functional failure is not necessarily a breakdown, but happens at a point where the machine can no longer perform as it is intended to perform.

Other examples of reactive maintenance used in abattoirs are for non-critical items, including lamps and evaporator motors.

2.3.2 Preventative maintenance

Preventative maintenance falls between reactive- and predictive maintenance in the 1950s-1970s. Preventative maintenance is probably the strategy that is implemented by most companies to reduce maintenance cost. Proper management of preventative maintenance is necessary, otherwise it is expensive and not efficient. In preventative maintenance management, machine repairs are scheduled based on the mean-time-to-failure (MTTF) statistics (Mobley, 2002:3). Figure 5 shows a typical MTTF or bathtub curve. There are three distinct regions for machines that can be seen.

First is infant mortality or break-in of new machines. A number of issues like poor design, incorrect installation, bad workmanship and incorrect installation can cause infant mortality. The next region is normal life, where only random failures occur. The third region is equipment worn out - preventative maintenance should be done on equipment before this stage is reached to prevent costly downtime. Preventative maintenance can be split into two categories, namely planned scheduled maintenance and planned unscheduled maintenance.

Planned scheduled maintenance refers to preventative maintenance that is done after a certain period of time, or is planned to take place at a certain date and is normally selected for machinery that is crucial for optimal production of any plant. Swanson (2001:238) describes it as maintenance activities undertaken after a specified period of time or amount of machine use. Use-based maintenance can also be referred to as Inspection/Fixed time maintenance.

Production losses and costs are kept to a minimum with planned scheduled maintenance. Planned scheduled maintenance considers many different factors. Some of these factors include:

- Time that the machine has been in production
- Operating conditions of the machine
- Lifetime of parts
- Production time lost if unplanned breakdown occurs

Source: Mobley, 2002:4

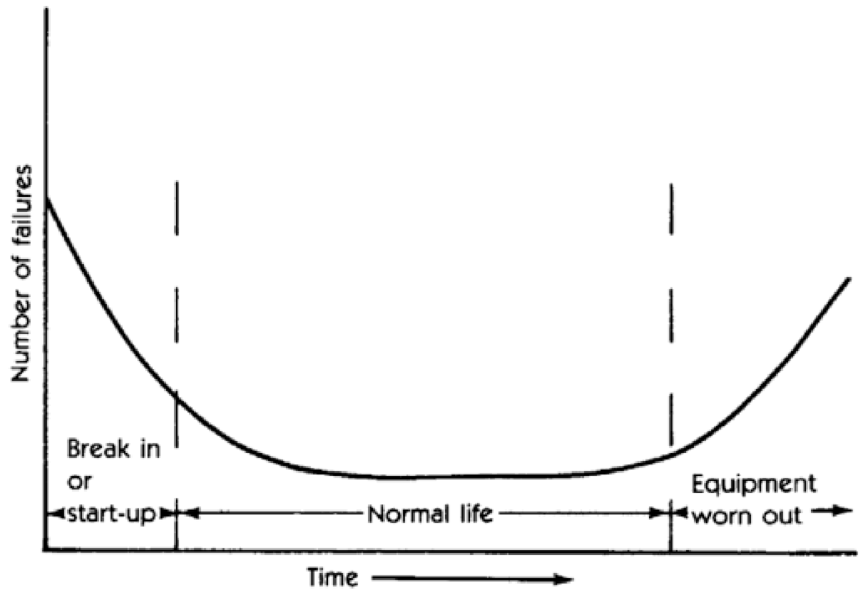

Figure 5: Typical MTTF curve

Planned unscheduled maintenance falls under the same category as run-to-failure. Planned unscheduled maintenance, however, means having a strategy to follow when assets break down so that the artisans do not need to run around looking for resources and spare parts. This approach is typically reserved for assets that have little or no impact on production. Tools such as power drills and measuring instruments are good examples. Its wasteful to pre-emptively replace these tools, as they are inexpensive and are not critical to production (Fiix, 2019).

Mobley (2002:3) states that the actual implementation of preventative maintenance varies greatly where some programs are extremely limited and consist only of lubrication and minor adjustments. He goes on saying that comprehensive preventative maintenance programs schedule repairs, lubrication, adjustments and machine-rebuild for all critical plant machinery.

Abattoirs make use of both scheduled and unscheduled preventative maintenance. Scheduled maintenance is done for critical machines, based on time. This can, however, be improved to do scheduled preventative maintenance based on tonnage that the machine has done. For example, how many tonnes of bones a pre-breaker have crushed before the orifice plate is changed? How many tonnes of meat do conveyors convey before wear strips need to be replaced? How many hocks does a hock cutter cut before the blades need to be changed or sharpened?

2.3.3 Predictive maintenance

Predictive maintenance is premised on the same principle as preventative maintenance, although it employs a different criterion for determining the need for specific maintenance activities (Swanson, 2001:238). Predictive or condition based maintenance was proposed in the 1970s-1980s as a new approach to planned maintenance, based on the knowledge of the state of equipment using condition monitoring techniques (Raposo *et al.*, 2019:65). Physical conditions of machines are measured using a wide variety of monitoring equipment, and maintenance is only done when the condition being monitored has risen to unacceptable levels. Swanson (2001:238) continues by saying that the additional benefit comes from not doing maintenance after a passage of a specified period, but only when the need is imminent. According to Mobley (2002:60), predictive maintenance cannot eliminate the continued need for either one or both of the traditional maintenance strategies; it can, however, reduce the number of unexpected failures and provide a more reliable scheduling tool for routine preventative maintenance tasks.

Mobley (2002:61) states that, with the proper use of predictive maintenance, the benefits are almost unlimited; however, when the scope of the program is artificially limited by the scope or work or restrictions imposed by the plant, the benefits may be substantially reduced. Primary uses of predictive maintenance according to Mobley (2002:61) are as:

- a reliability tool
- a plant optimisation tool
- a maintenance tool.

Conditions that can be monitored include vibration-, temperature-, acoustic- and oil analysis. Any one of these conditions will trigger a work order for a machine. The benefits derived from using predictive maintenance technologies depend on the way the program is implemented. If the predictive maintenance program is limited to prevent catastrophic failures of only select plant systems, then that is the result that will be gained. Exclusive focus on preventing failures may however result in a substantial increase in maintenance cost (Mobley, 2002:60).

The use of predictive maintenance strategies in Company A is very limited. The explanation of the diagnostic technologies to follow will highlight the benefits gained by using the different predictive maintenance technologies.

2.3.3.1 Vibration monitoring

Vibration monitoring and analysis are two of the most useful tools for predicting incipient mechanical, electrical and process-related problems within plant equipment, machinery and continuous-process systems (Mobley, 2014).

A microcontroller is placed on the machine and it will convert vibrations to electrical signals. Mobley (2014) states that all machines vibrate and that these vibrations are caused by tolerances allowed by the machine designer so that the machine can be built. If you use this vibration as a baseline, then any deviation from this baseline under normal running conditions will indicate incipient mechanical or other failure.

Source: Mobley, 2014

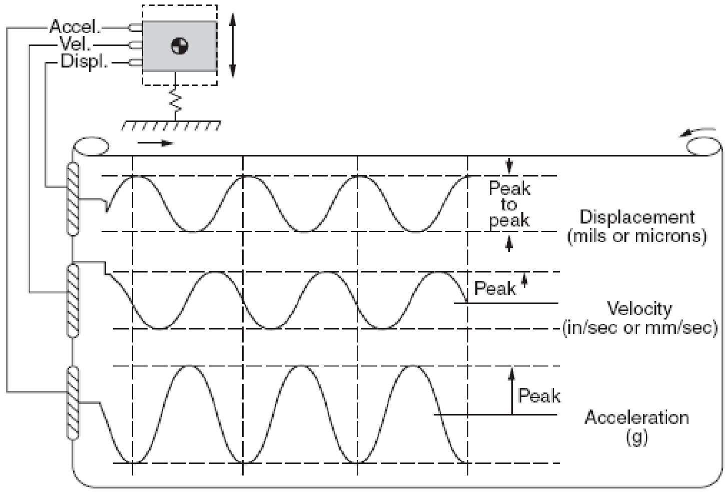

Figure 6: Relationship among displacement, velocity and acceleration

There are three different characteristics of vibration, namely amplitude (displacement), velocity and acceleration. Mobley (2014) describes the characteristics as follows: displacement as how much the machine is vibrating, and is measured in mils; velocity as how fast the machine is vibrating, and is measured in millimetre per second; and acceleration as related to the forces that are causing vibration. In general, amplitude (or displacement) sensors are more sensitive at lower frequencies, velocity sensors across the middle ranges and accelerometers at higher frequencies (Moubray, 1997:351). According to various authors, velocity is mostly used for predictive maintenance programs.

Source: Mobley, 2014

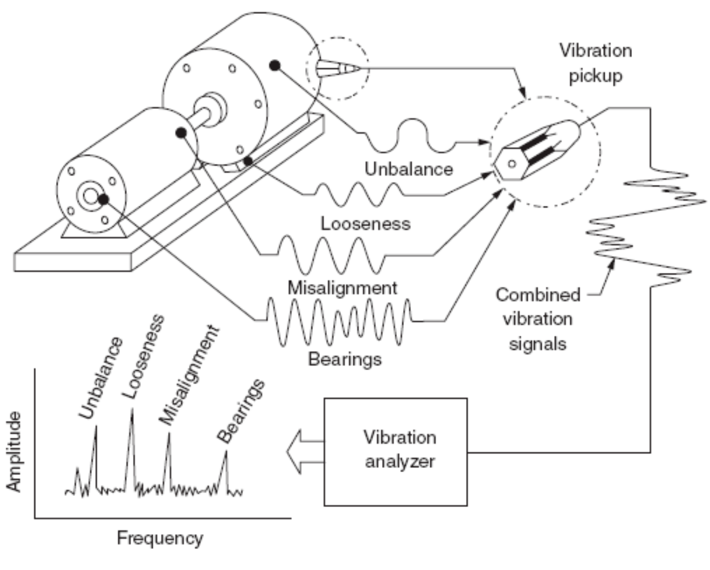

Figure 7: Pictorial representation of process of vibration analysis

Doing a ‘Fourier analysis’, a complex wave can be broken down into a variety of levels (amplitudes) at a variety of frequencies (Moubray, 1997:351). Fast Fourier Transform (FFT) is the process where the variation level against time is transformed into a constantly changing display of amplitude against frequency. Through years of experimenting and collection of data, we know the frequency at which different components or problems on a machine will vibrate. The amplitude of these frequencies will indicate how serious the problem is. Annexure A will show the different vibration identifications for different amplitudes and frequencies.

Vibration monitoring is crucial for a predictive maintenance program. Company A uses velocity measurements for its maintenance program of its crucial assets to maintain production. The process is currently highly manual, where the readings are captured into an excel spreadsheet. If the spreadsheet is not reviewed regularly, all the efforts to enter the data will be in vain. The data should be captured directly into the CMMS. The CMMS must then analyse the data and create work orders to investigate the cause of any deviation from the baseline for the specific machine. The vibration monitoring should also be extended to include all rotating assets at Company A.

2.3.3.2 Temperature monitoring

Temperature monitoring is very useful on machinery where vibration monitoring is not always possible. The temperature measurements of individual components, such as the temperature of bearings, are very important since they bring more information and can be used in different types of analysis (de Azevedo *et al.*, 2016:372). Temperature measurements on machinery can be done in a couple of different ways. Thermocouples can be mounted on machinery, infrared thermometers (point-of-use) can be used and infrared imaging can be used to detect abnormal temperatures.

Thermocouples consist of two wire legs made from different metals. The wire legs are welded together at one end, creating a junction. This junction is where the temperature is measured. When the junction experiences a change in temperature, a voltage is created. The voltage can then be interpreted to calculate the temperature (Thermocouple, 2019). Thermocouples are relatively cheap compared to other condition-monitoring sensors and allow monitoring of temperatures inside machines (Janssens *et al.*, 2017:29). Janssens *et al.* (2017:29) further state that temperature-based detection is mostly only useful after initial detection by using vibration analysis.

Mobley (2014) explains that infrared thermometers (point-of-use) can be used in conjunction with vibration monitoring to monitor the temperature on plant machinery or equipment at critical points. The only drawback is that it is limited in that the temperature represents a single point on the machine or structure. Infrared thermometers used in conjunction with vibration monitoring equipment are valuable predictive maintenance tools. Infrared thermometers can be used to monitor condensate return lines. The temperature will be very high if steam traps or valves are bypassed.

Infrared imaging enables non-contact, non-intrusive, fine-grained and single-sensor based temperature measurements, which is ideal for condition monitoring with the aim of autonomously diagnosing faults (Janssens *et al.*, 2015:79). It is based on the principle that all objects above absolute zero (0 Kelvin) emit infrared radiation (Moubray, 1997:399). Infrared imaging allows for visual temperature monitoring, as can be seen in Figure 8.

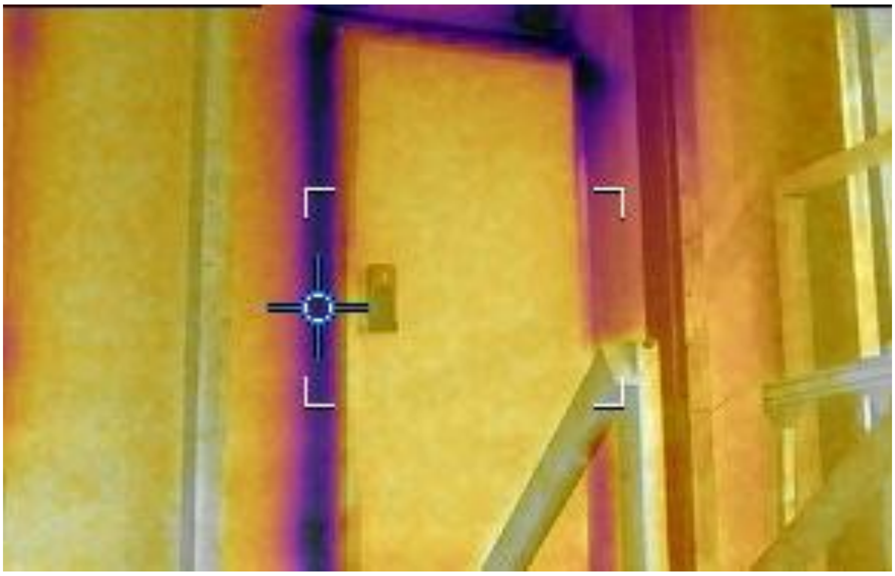

Figure 8: Visual temperature monitoring of door seals

Looking at the potential-to-failure (P-F) curve in Figure 9, you can clearly see the advantages of vibration monitoring. Fault conditions are picked up early on and preventative action can be taken before the condition of equipment starts to deteriorate rapidly. Figure 9 also shows that temperature-based condition monitoring (point-of-use) cannot be used to accurately identify potential faults early in the lifetime of rotating machines, since temperature changes are only detectable when the fault escalates (Janssens *et al.*, 2017:28). Time to failure will be imminent and repairs should be done as soon as possible.

Source: Janssens *et al.*, 2017:28

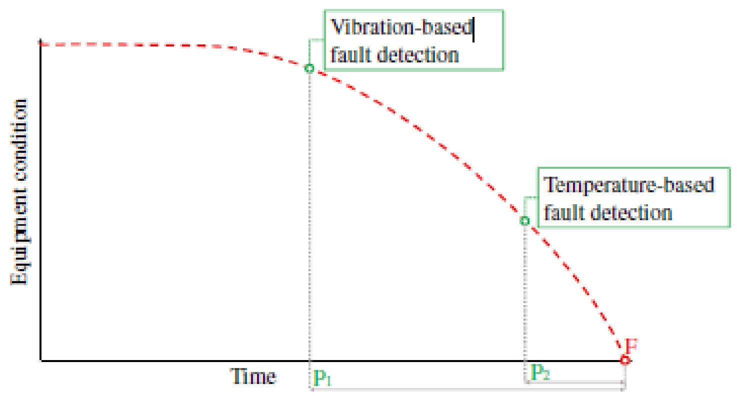

Figure 9: Time span difference between vibration based monitoring and temperature based monitoring.

By using infrared imaging, fault conditions on machinery can even be picked up before high amplitudes are measured on different frequencies, as can be seen in Figure 10. By using these two condition-monitoring techniques together, breakdowns on machinery can be greatly reduced.

Source: Janssens *et al.*, 2017:28

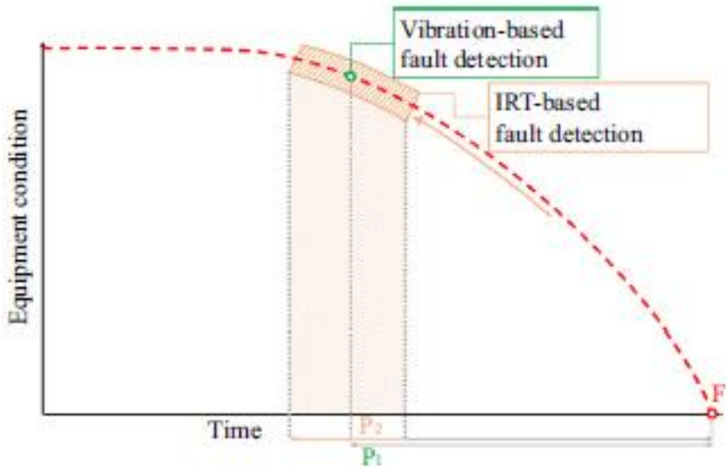

Figure 10: Vibration and infrared thermal imaging

Thermal imaging is used at Company A to do checks on electrical panel connections annually. The research shows that thermal imaging can be used for many more applications. Being an abattoir and using ammonia refrigeration to cool carcasses, the thermal imager can be used to detect leakage of cold air through the sandwich panels to the outside on an annual basis. Other equipment like transformers, bearings, steam traps, compressor motors and power factor capacitors can also be monitored.

Thermal imaging can also be used when installing a new electrical panel. After two weeks the CMMS can automatically create a work order to capture a thermal image of the newly installed panel to make sure that everything is still within specification and no lose connections are present. The CMMS should help with scheduling of all the checks to be done. The person responsible for doing the work order should be competent and take corrective action if needed.

2.3.3.3 Oil analysis

Oil lubrication and analysis in machinery is vital for longevity of moving parts. The viscosity at different temperatures is a key feature of lubricating oils. The oils undergo changes when the temperature increases and its degradation under operating conditions is a problem involving significant economic losses (Raposo *et al.*, 2019:67). Viscosity changes may also be a warning sign of many potential failure conditions (Moubray, 1997:397). Depending on the application, an increase or decrease in viscosity can have a detrimental effect on the correct operation of machinery. Mobley (2014), however, states that oil analysis is limited to maintaining optimum condition of lubricating oil and is not a means of detecting or anticipating the need for preventative maintenance of critical equipment, also stating that oil analysis is often overused as a predictive maintenance tool. The misconception that this method can replace vibration analysis and other predictive techniques is the predominant reason for this overuse. Mobley (2014) suggests that oil analysis should only be limited to applications where replacement of large quantities of oil represents a substantial loss.

The conventional way of doing oil analysis is to take an oil sample every three months and send it to a laboratory for analysis. If any metal trace elements are found in the analysis, it indicates that a potential failure has occurred somewhere else in the system. Other elements can show that the lubricating oil itself has broken down and needs to be replaced. The oil can then either be filtered or treated to remove water.

Currently developed alternative approaches aim at utilising sensors as devices providing input for on-line lubricating-monitoring systems in order to determine the current oil condition directly inside the engine (Agoston *et al.*, 2005:327).

Company A makes use of oil analysis to monitor its transformers, ammonia compressors and hydraulic power packs, as it has a significant amount of oil present. The ammonia compressors are monitored three-monthly and transformers annually. The CMMS will help to schedule the oil analysis properly.

2.3.3.4 Acoustic analysis

Acoustic emission is the phenomenon of transient elastic wave generation in materials under stress (Choudhury & Tandon, 2000:39). During the bearing operation, bursts of acoustic emissions result from the passage of the defect through the roller and raceway contacts (Li & Li, 1995:67). Acoustic analysis and vibration monitoring both monitor equipment noise, but unlike vibration monitoring, ultrasonic instruments monitor the higher frequencies generated by machines (Mobley, 2014).

Approved noise inspection authorities that conduct noise level surveys in plants to comply with the occupational health and safety regulations use ultrasonic instruments. Other companies that conduct non-destructive testing of materials and leak detection of traps use different ultrasonic instruments.

Company A uses ultrasonic measuring equipment for leak detection in steam traps. If the levels are unacceptable, the steam trap is changed to reduce the cost of producing steam and to improve the efficiency of the machine.

Paragraph 2.3 described the different maintenance strategies that can be used for maintaining assets. Predictive maintenance was discussed in more detail by showing the different techniques that can be used in the industry.

2.4 THE COMPLETE GENERAL MAINTENANCE MODEL

The complete general maintenance model, as shown in paragraph 1.1.1, is an excellent model to use for maintenance. According to Coetzee (1997:7), it gives an adequate description of the functionality inherent in the maintenance function in and around the typical industrial concern. Coetzee (1997:7) continues in saying that the complete model contains the best of the terotechnology, EUT model and maintenance cycle. A brief explanation of the terotechnology, EUT model and the maintenance cycle will follow.

2.4.1 Terotechnology cycle

The terotechnology cycle was developed in the late 1960s by the British Ministry of Technology who conducted a large scale survey on the cost of maintenance in the United Kingdom. The study showed that a production saving of 10% of the money spent on maintenance could be saved by very basic improvements in maintenance. Terotechnology is defined as follows: A combination of management, financial, engineering and other practices applied to physical assets in pursuit of economic life-cycle costs, noting that its practice is concerned with the specification and design for reliability and maintainability of plant, machinery, equipment, buildings and structures, with their installation, commissioning, maintenance, modification and replacement and with feedback of information on design, performance and costs (Harvey, 1978:15-16). According to Coetzee (1997:2), one major problem with the terotechnology model is that it intends to widen the scope of the maintenance practitioner so much that it totally neglects the process inside the maintenance organisation itself.

2.4.2 EUT maintenance model

The Eindhoven University of Technology saw this limitation and concentrated more on the inner processes of the maintenance organisation (Coetzee, 1997:2). According to Geraerds (1995:2), one of the reasons to design the EUT model was the need to be able to describe maintenance in general, independent of - but covering - the diversity of individual situations.

Geraerds (1995:3) goes on by saying that, in practice, the model serves as an instrument for maintenance management in the systematic identification of:

- sub-functions in which knowledge, available but not applied yet, provide possibilities for improvement, and
- the sub-functions that are corresponding with "cost centres", in order to provide a basis for their evaluation in respect to effectiveness and efficiency.

Source: Geraerds, 1995:15

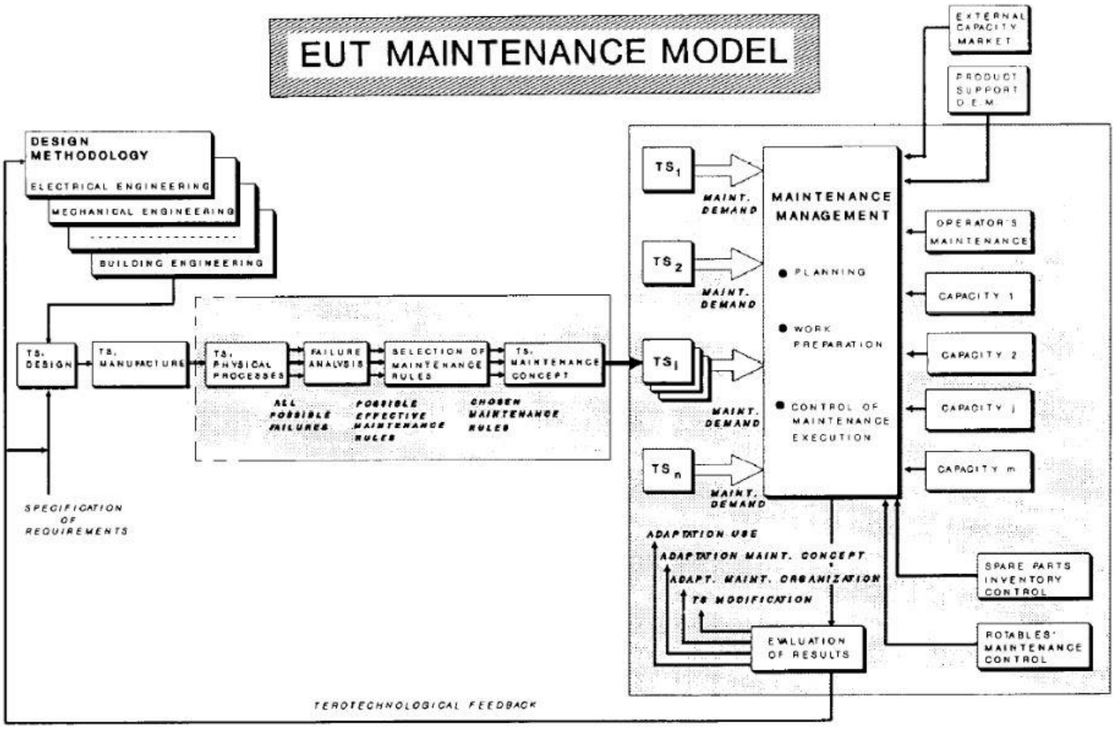

Figure 11: The EUT maintenance model

Figure 11 shows maintenance as it appears in an organisation seen from the point of maintenance management with all its sub-functions or sub-processes, connected by their interrelations (Geraerds, 1995:5).

2.4.3 The maintenance cycle

The maintenance cycle was developed in 1993 to assist in setting up logical curricula in maintenance engineering at the University of Pretoria. The cycle consists of an inner cycle that represents the technical and operational processes while the outer cycle represents the managerial processes (Coetzee, 1997:2).

Source: Coetzee, 1997:2

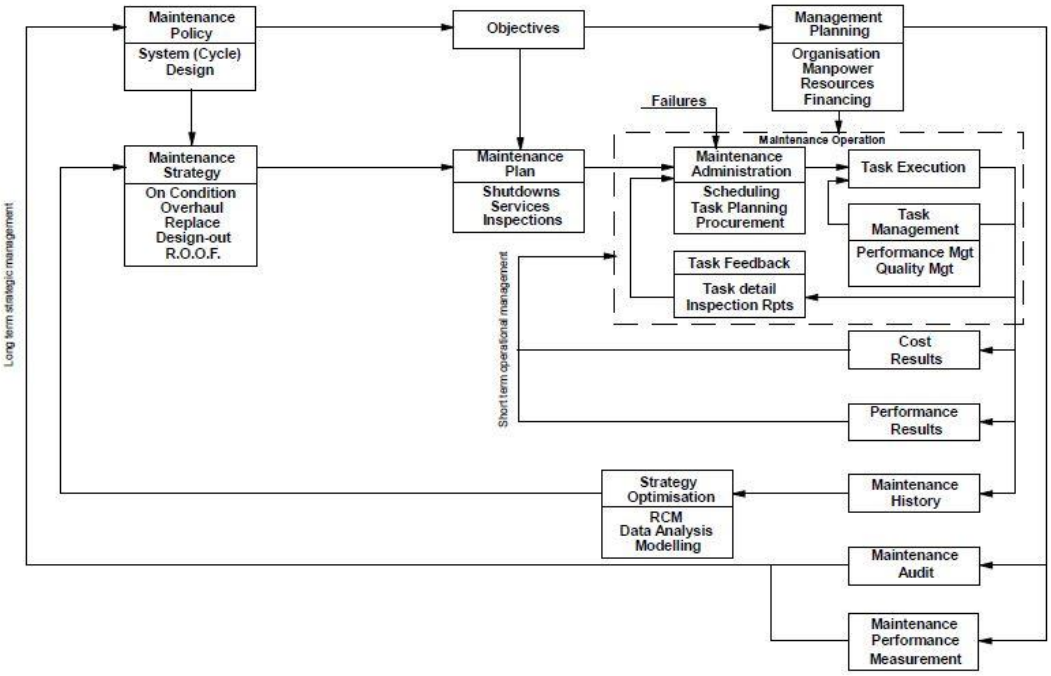

Figure 12: The maintenance cycle

2.4.3.1 Managerial cycle

The managerial cycle consists of five embedded processes which will be briefly explained below (Coetzee, 1997:3-5):

- Maintenance policy – The maintenance policy describes, in broad terms, the direction in which the maintenance management team wants to steer the maintenance organisation. The maintenance policy in a sense 'designs' its own maintenance cycle.
- Objectives – Objectives should be updated annually and be specific in terms of both the end-results that must be achieved and the dates for achieving such results.
- Maintenance planning – Maintenance planning and budgeting processes should be done annually with the new objectives in mind. It should at least include labour, resources, facility improvement, maintenance finance planning and the budget itself.
- Maintenance audit – Formal hard and soft audits should be done annually. Hard audits consist of proper inspections of the plant, using a well-defined check list and scoring system while a soft audit on the other hand audits the department's management and technical systems' ability to ensure the long-term achievement/retention of the results required by the policy and objectives.
- Maintenance performance measurement – A combination of measurements that is used to see the success to which the maintenance policies are being perused.

2.4.3.2 Operational cycle

The operational cycle consists of two main processes (Coetzee, 1997:5-6):

- Maintenance planning that includes maintenance strategy, maintenance plan and strategy optimisation:
    - Maintenance strategy – Here you will need to decide what strategy will be used to maintain the asset.
    - Maintenance plan – The maintenance plan for an asset should at least consist of the following documentation:
        - Copy of the complete RCM
        - PMO (Planned maintenance order)
        - Guidelines to do the PMO
        - List of spares or materials needed
        - Special equipment or tools needed
        - Precautionary measures that should be taken, and
        - Forecast of different trades and manpower needed.

    - Strategy optimisation – Selected strategies for assets can be optimised annually by reviewing the maintenance plan and data received from doing the PMO's.
- Maintenance operation that includes task management, task execution and maintenance administration:
    - Maintenance administration – Task scheduling, task planning, procurement, issue of task documentation and feedback of task data all form part of maintenance administration.
    - Task execution – Performing of task documented.
    - Task management – This is the supervisory process and includes tasks such as quality control, expert advice to workers, task follow-up, requisitioning, prioritising, backlog management, safety and housekeeping.

The feedback loop inside the operational cycle consists of the following managerial operational management and supervisory processes:

- Use work feedback to create additional tasks;
- Failures in the plant initiate corrective maintenance tasks;
- Cost and performance results that assist the department in achieving optimal operational excellence and control, and
- Strategy optimisation.

The complete model, as can be seen in Figure 2 in Chapter 1, will assist the researcher in developing an organisational CMMS implementation guide. The managerial cycle will help with the sustainability guide in Chapter 6. RCM that needs to form part of the maintenance plan will be discussed next.

2.5 RELIABILITY-CENTRED MAINTENANCE

RCM is the optimum mix of reactive, time or interval-based, condition based and proactive maintenance practices (Vishnu & Regikumar, 2016:1082). RCM implementation requires the collection and analysis of historical failure and maintenance data to determine current condition of the equipment (Vishnu & Regikumar, 2016:1080).

The main objective of RCM is to reduce the maintenance cost by focusing on the most important functions of the system and by avoiding or removing maintenance actions that are not strictly necessary. If a maintenance program already exists, the result of a RCM analysis will often be to eliminate inefficient preventative maintenance tasks (Rausand, 1998:121).

Rausand (1998:122) further states: “The application of preventative maintenance is often misunderstood. It is easy to erroneously believe that the more an item is routinely maintained, the more reliable it will be. Often the opposite is the case, due to maintenance-induced failures.”

Moubray (1997:7) states that the RCM process entails asking seven questions about the asset or system under review, namely:

- What are the functions and associated performance standards of the asset in its present operating context?
- In what ways does it fail to fulfil its functions?
- What causes each functional failure?
- What happens when each failure occurs?
- In what way does each failure matter?
- What can be done to predict or prevent each failure?
- What should be done if a suitable proactive task cannot be found?

RCM can reduce the perceived maintenance workload between 40% and 70%. This reduction is partly due to the reduction in the number of tasks, but mainly due to an overall increase in the intervals between tasks (Moubray, 1997:312).

Coetzee and Claasen (2002:98-99) developed a model that makes use of the best work from various authors regarding RCM. The model was tested on a high-risk chemical pump and was found to be superior to the classical RCM approach.

Source: Coetzee and Claasen, 2002:99

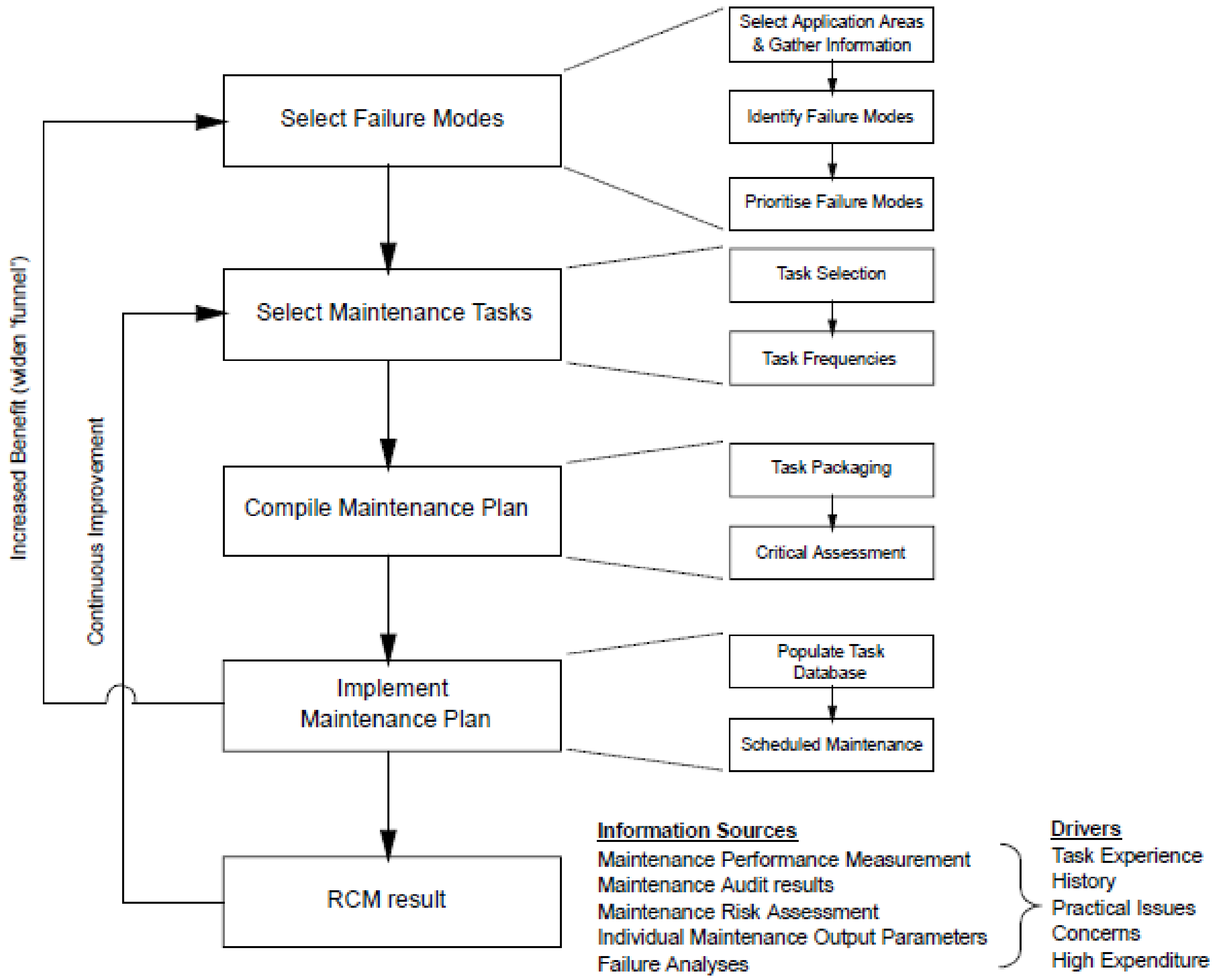

Figure 13: Framework for RCM

Explaining RCM in detail does not fall within the scope of this dissertation; however, a brief explanation of the framework presented in Figure 13 describing the methodology, will be given.

2.5.1 Select failure modes

2.5.1.1 Selection of application areas

Three methods of selection of application areas are in general use (Coetzee & Claasen, 2002:101). The three methods are partitioning, plant register and an analysis at system level. According to Coetzee and Claasen, the mostly used method is partitioning, as it ensures that no failure mode of the asset is missed.

The next step is the identification step, which is used to identify systems at a high enough level to facilitate the next step, that of choosing the most important system for further analysis (Coetzee & Claasen, 2002:102).

Coetzee and Claasen (2002:103) suggest that choosing a system of analysis should be done using the profit contribution of each of these units to prioritise the units in order of their relative contribution; however, it is still imperfect as it only emphasises profit. Other methods include looking at lost production, lost quality and maintenance cost, as well as safety and environment effects in order to calculate a combined risk figure to identify the “20” % of units with the highest maintenance-risk impact for further RCM application.

Coetzee and Claasen further suggest that prioritisation of maintenance significant items (MSI’s) should be determined by using the downtime contribution of each MSI to the downtime of the equipment to identify the 20% of MSI’s that contribute most to the downtime of the equipment. The user of the RCM methodology will, however, decide the most important factor to prioritise the MSI’s.

2.5.1.2 Gather information

One of the most important steps in designing a maintenance plan for the organisation is the assembly of information regarding a business. This is because RCM is very context-specific. The analyst thus has to understand the business, the technology involved and the operating context in order to design a plan that will be worthwhile (Coetzee & Claasen, 2002:104). Coetzee and Claasen (2002:104-105) compiled a table showing the information needed for the scientifically valid RCM maintenance plan.

Information category	**Brief explanation**
General business operation	The activities that are done on a daily basis to increase the value of the company and earn profit
Process flow diagrams	Diagram to indicate the general flow of plant equipment and processes
Operations manuals	Documents giving procedures and instructions to personnel to fulfil their duties
Operational procedures	Reference documents describing activities for employees to complete tasks
Asset register	Registers of all assets on site
Asset interdependencies	Links showing how one asset will affect another asset
Asset-specific information	Information specific to a certain asset
Design specifications	Specifications to which assets are manufactured
System schematics	Diagram of a system using symbols
Assembly drawings	Drawings explaining how an item must be assembled
Modification history	Detailed information about all the modifications that have been done on equipment
Functional block diagrams	Diagram showing the interrelationships of a system
Present maintenance plan	Maintenance plan currently used for assets
Failure data	Detailed information on all the failures of equipment
Maintenance instructions	Detailed information on how maintenance should be done on different items of an asset
Maintenance procedures	Document showing detailed steps for doing maintenance on an asset
Maintenance manuals	Document highlighting the guidelines for maintaining an asset.

Table 1: RCM information requirements

A thorough study of all the relevant information required usually leads to additional understanding and insight into the business and the asset to be maintained. This leads to further direct added value in terms of improvement of operational and maintenance procedures, early fault identification and asset reliability, operability as well as maintainability improvements through redesign (Coetzee & Claasen, 2002:105).

2.5.1.3 Identification of failure modes

The Failure Mode and Effects Analysis (FMEA) technique is used to identify the failure modes and its effects for each MSI that was identified earlier in the RCM proses. The accepted structure for the FMEA used by most authors is item> function analysis> functional failure> failure mode (Coetzee & Claasen, 200:105). Annexure B shows the RCM FMEA analysis sheet with a brief explanation.

2.5.2 Select maintenance task

2.5.2.1 Task selection process

In this step, a task decision tree is used to determine all possible task options and/or task combinations when deciding on the best maintenance strategy (Coetzee & Claasen, 200:105). Annexure C shows a task analysis sheet.

2.5.2.2 Task frequencies

Determining task frequencies is based on user experience with similar machines, manufacturer data and P-F intervals, to name only a few. Task frequencies can be revised as new data is gathered.

2.5.3 Compile maintenance plan

Coetzee and Claasen (2002:120) state that the principles of task packaging are simple: where the individual tasks derived from the RCM analysis are put together in logical work groups.

Groups are:

- Plant/system/machine
- Set-up type
- Task frequency class
- Trade
- Task timing.

Coetzee and Claasen (2002:120) explain that the RCM sheets in Annexures B and C are meant to be used per plant or system or machine, in order that the tasks resulting from such an analysis will, by definition, be grouped according to the grouping above.

2.5.4 Implement maintenance plan

One of the major contributions of the methodology by Coetzee and Claasen (2002:124) is the limiting of the number of failure modes to which the RCM process is applied. This limitation is then progressively relaxed so that RCM can be applied to more and more MSI's. Coetzee and Claasen (2002:125) state that this limitation lies in the hands of the maintenance managers. They continue by saying that the exact point at which you stop using RCM to your advantage is based on economics; whereas, if you over-apply RCM, the cost will exceed the gain achieved.

The second feature is the feedback loop system or 'continuous improvement' that is used for the continued improvement of the maintenance plan. This is normally driven through management activators such as a high rate of change of frequency, high cost and catastrophic failure incident, which indicates that the further optimisation of the maintenance plan is necessary (Coetzee & Claasen, 2002:125).

Selecting task and frequencies for maintaining of assets is an important part of optimising maintenance in any plant. Implementing RCM, if applied correctly will improve efficiency. The CMMS plays a crucial role, as all the data captured in the CMMS database will be used to optimise maintenance plans using the RCM methodology.

Figure 14 shows that after the initial use of RCM to design a maintenance plan for the "1%" of failure modes, the 'funnel' is progressively opened so that RCM is then applied to the "4%" of MSI's. Thereafter the MSI 'funnel' is opened further to apply RCM to the 'new' MSI`s. After all the MSI's have been handled for the "20%" of equipment, that funnel can be progressively opened (Coetzee & Claasen, 2002:124).

TPM, total maintenance assurance, preventative maintenance, RCM and many other innovative approaches to maintenance problems all aim at enhancing the effectiveness of machines to ultimately improve productivity (Ashayeri, 2007:614). TPM will be discussed in the next paragraph.

Source: Coetzee and Claasen, 2002:126

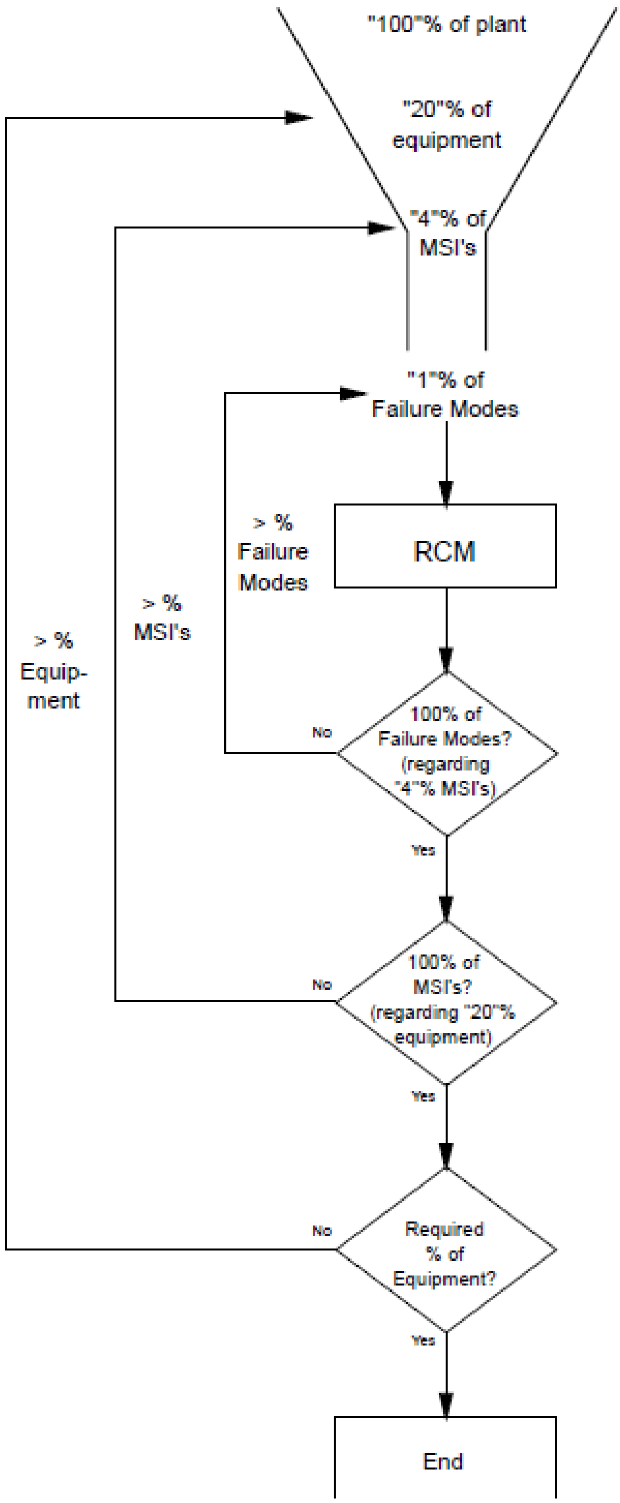

Figure 14: RCM progressive application

2.6 TOTAL PRODUCTIVE MAINTENANCE

In today's industries, the concept of TPM has been widely accepted and implemented, yet it is still possible to find industries facing maintenance challenges (Mwanza & Mbohwa, 2015:461). TPM is a system of maintaining and improving the integrity of production and quality systems through the machines' processes and employees that add business value to the organisation (Chandegra & Deshpande, 2014:117). Thus, TPM means every individual, from management to workshop level, is involved in maximising of equipment effectiveness and keeping machinery in a good condition.

In 1971, in Japan, the concept of TPM was introduced to solve maintenance problems of systems by giving operators and employees more responsibility (Pascal *et al.*, 2019:86). The following sections will discuss the 5S methodology and eight pillars of TPM, followed by the six major losses that must be monitored to improve overall equipment effectiveness.

2.6.1 5S of TPM

TPM starts with 5S (Chandegra & Deshpande, 2014:117; Venkatesh, 2007:10):

- **Sort:** The goal is to help reduce search time for parts needed to repair machinery by removing unnecessary parts from the workplace.
- **Shine:** This involves cleaning of the workplace. Clean equipment and machines will enable the artisan to notice breakages, misalignments and leaks easier than with dirty equipment.
- **Organise (Set in order):** The concept here is that each item has a place and only one place.
- **Standardisation:** Employees have to decide on standards for keeping the workplace clean. The goal of standardisation is to create best practices and get each team member to use the established best practices the same way.
- **Sustain:** A sustainability guide helping employees understand the importance of maintaining the level of workplace organisation should be developed and put in place. This can also be viewed as a management auditing process.

Source: Chandegra and Deshpande, 2014:118

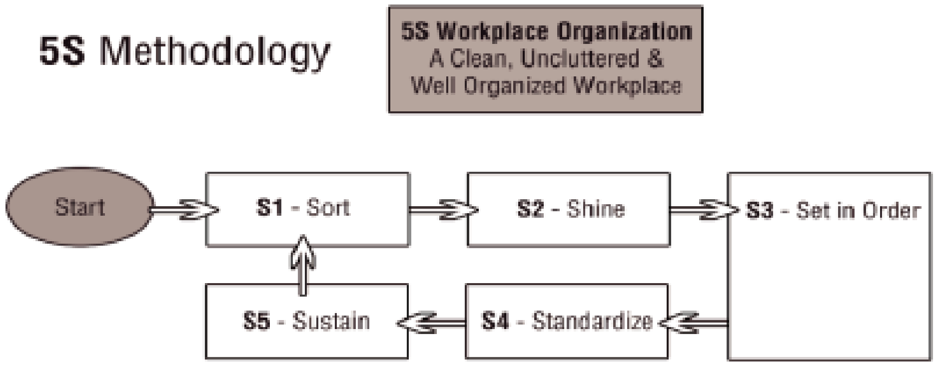

Figure 15: 5S Methodology

The 5S methodology is the building blocks of the eight pillars of TPM. Each pillar has its own responsibility. The Japan Institute of Plant Maintenance proposed the introduction of the TPM program, which is based on the implementation of a series of the eight pillars of TPM in a systematic way in order to optimise plant and equipment efficiency by creating perfect relationship between man and equipment (Rajput & Jayaswal, 2012:4383).

2.6.2 Eight pillars of TPM

Different authors describe the pillars of TPM differently. According to various authors (Adesta *et al.*, 2018:2; Chandegra & Deshpande, 2014:117; Duffuaa & Raouf, 2015:262; Nasurdin *et al.*, 2005:290; Rajput & Jayaswal, 2012:4383; Sharma *et al.*, 2012:20; Venkatesh, 2007:10), the eight pillars of TPM are as follows:

- **Autonomous Maintenance:** Training operators to do small maintenance tasks and inspections of machines will free up artisans to do more detail work and root cause analysis. Operators to perform cleaning, inspection, lubrication, adjustments and minor component change outs, but not comprehensive craftsman skills.
- **Planned Maintenance:** Planned maintenance must function in tandem with autonomous maintenance. Lowering the cost of planned maintenance can be done by monitoring equipment conditions with different diagnostic techniques.
- **Quality Maintenance:** Quality Maintenance will help eliminate non-conformances and to produce defect free products and high quality products.
- **Focused Improvement:** Continuous improvement in small steps.

- **Early Equipment Management:** There are three major categories of early equipment maintenance, namely equipment development planning, life cycle costing and maintenance prevention design.
- **Training and Education:** Bridging of the skills and knowledge gap is done through training of all workers, where spending on training is customarily in the order of 5-8% of the labour budget.
- **Safety, Health, Environment (SHE):** The main function of this pillar is to create a safe working environment that is free of accidents. Other functions also include the identification and elimination of work place hazards, and performing activities that preserve the environment. This pillar is also intertwined with the other pillars that address discipline, servicing, workplace organisation and standardisation of work procedures.
- **TPM in Administration:** Office TPM in administration must be followed to improve efficiency and productivity of administration functions.

Source: Chandegra and Deshpande, 2014:123

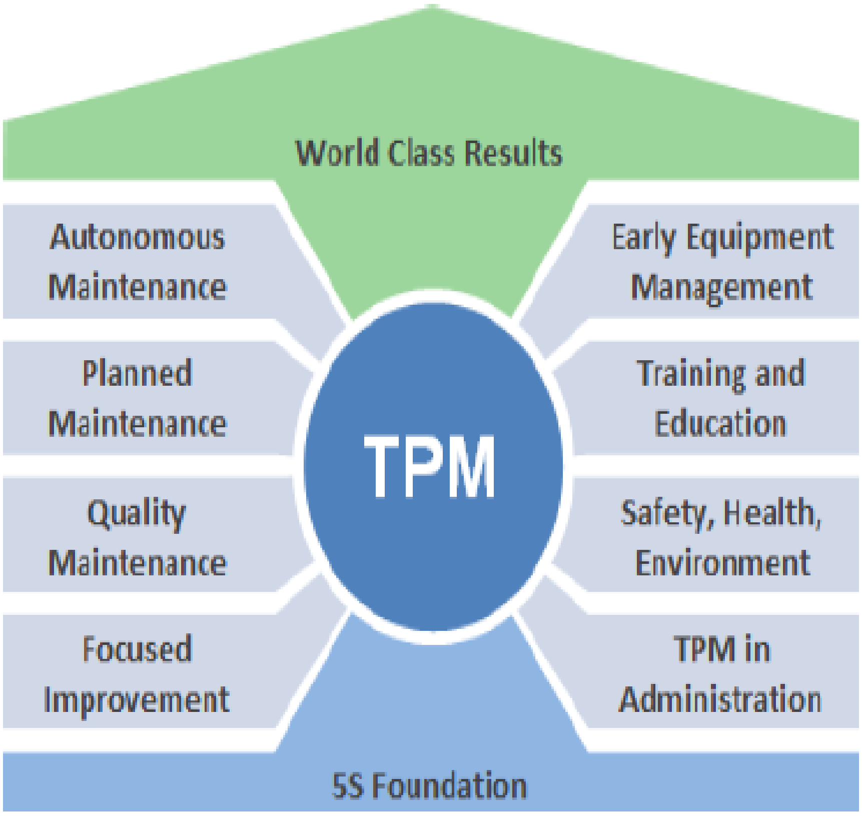

Figure 16: Eight pillars of total productive maintenance

2.6.3 Six major losses

Careful monitoring of equipment is necessary with TPM. Reduced capacity should be picked up as early as possible before it is accepted as normal. Equipment management starts with identifying the major losses of equipment (Duffuaa & Raouf, 2015:263). Six major losses (Duffuaa & Raouf, 2015:263-264; Rajput & Jayaswal, 2012:4384) that affect the overall performance of equipment, will be discussed briefly. These losses should be identified in the system and should be eliminated.

- **Equipment Failures:** Caused by defective products. Every attempt should be made to avoid equipment failures/breakdowns. Breakdowns must be reduced to zero by changing the attitude that breakdown is inevitable.
- **Setup and adjustment:** This is time taken by artisans and operators in setting-up a machine to produce a different product. Many fast moving consumer goods companies are striving towards single minute setups.
- **Idling and minor stoppages:** This occurs when the machine is in an idle state waiting for a product, or has a temporary malfunction. Automated production highly depends on eliminating such stoppages.
- **Reduced speed:** Reduced speed refers to the difference between design speed and actual running speed. This is a major loss if it goes unnoticed. Every effort should be made to identify and eliminate causes for operating at reduced speed.
- **Process defects:** This loss is when a product needs to be re-worked or re-boxed due to faulty production equipment.
- **Reduced yield:** This occurs in the early stages of production until it becomes stable.

Duffuaa and Raouf (2015:264) state that, if you want to improve equipment effectiveness, the above losses should be measured as these losses affect equipment availability, efficiency and the quality of the product as follows:

- Equipment availability = Equipment failures + Setup and adjustment
- Equipment efficiency = Idling and minor stoppages + Reduced speed
- Product quality = Process defects + Reduced yield.

An explanation of how to calculate overall equipment effectiveness (OEE), according to Duffuaa and Raouf (2015:264-265), is described in Annexure D.

2.6.4 Summary

The ultimate goal of TPM is to increase the OEE. The OEE will improve by implementing the 5S methodology and the eight pillars of TPM and the close monitoring of the six losses described. Rajput and Jayaswal (2012:4384) go on by stating that OEE is the most effective measure for driving plant improvement as it continuously focuses the plant on zero waste.

2.7 CMMS

2.7.1 Introduction

Cato and Mobley (2002) state that effective resource management and reliable equipment are essential for optimum plant performance. Both depend on accurate and timely management of massive amounts of data and on the effective use of maintenance resources, as well as the fact that CMMSs are designed to fulfil these needs. Duffuaa and Raouf (2015:223) go on by stating that a CMMS is basically information systems adapted to serve maintenance, as it aids in the process of data collection, recording, storing, updating, processing, communicating and forecasting.

All the strategies discussed in the previous section have their own advantages and disadvantages, but none of them can be effectively managed without the use of a CMMS. CMMSs are used in factories to keep track of fixed assets and assist with maintenance strategies. The following paragraph will start by showing the history and evolution of CMMSs over the past 50 years. The paragraph will continue by explaining the modules needed for a successful CMMS and will then go on and give reasons for the failure of a CMMS. The paragraph will end by giving a list of the most popular CMMSs on the market.

2.7.2 History

CMMS has constantly been developed and improved in the past 50 years. It first appeared in 1965 and was primarily used by large firms with big computers. With the emergence of the internet in the 1990s and the phenomenal growth in computing power of computers, great strides have been made to improve CMMSs and to make it more cost effective to use in small and medium sized enterprises. Throughout the short history of CMMSs, seven generations of CMMS can be distinguished in the recent decades (O’Brien, 2014).

2.7.3 Evolution of CMMS

First Generation

According to O'Brien (2014), the first generation of CMMSs was developed to remind maintenance personnel of basic recurring tasks like greasing critical bearings on equipment. Work order data was punched into punch cards that were fed into computers via card readers. Huge centralised computers from international business machines (IBM) were used and were only viable to use in the largest asset-intensive businesses.

Second Generation

The only thing distinguishing the second generation from the first generation is that punch cards were no longer used. It was replaced by work orders that were printed and distributed to maintenance teams manually. Maintenance technicians will then complete the work orders and fill in the forms before returning it to data-entry clerks, who would then type the information directly into the mainframe computer (O'Brien, 2014).

Third Generation

The mini-computer introduced in the 1980s paved the way for medium-sized businesses. The software ran on individual, green-screen terminals in the plant where data was entered by technicians after the work orders had been completed (O'Brien, 2014). More functionality built into CMMS systems included reporting on work orders captured.

Fourth Generation

Personal computers and Local Area Networks (LAN) made many applications possible. This enabled companies to install a CMMS on their server and access it from any computer connected to the network. These custom-built applications became the foundation for new CMMS software businesses. The applications had a number of downsides, including a lack of work order history, no interrelationship in the database and no cost tracking (O'Brien, 2014). Everything was still printed on paper and upgrades were expensive.

Fifth Generation

From the fourth to the fifth generation CMMSs, vendors migrated from access-based applications to browser-based applications. The CMMS software in this generation ran on local servers, so the customer could perform upgrades locally (O'Brien, 2014). Fifth generation CMMSs are expensive to operate.

Sixth Generation

The sixth generation made way for web-hosted CMMSs. In the early part of the millennium, an increasing number of vendors recognised the power of the internet and started developing web-hosted applications (O'Brien, 2014). Technicians can plan their day from the comfort of their home by using any internet-connected device, such as a laptop, tablet or smartphone.

Seventh Generation

Cloud computing is the next evolution in the CMMS software sector. There is no need for complex server set-up and configuration with cloud based CMMS (Fiix, 2019). In a cloud environment, each user simply customises the CMMS for his own needs by adding or removing modules, with a click of a button and with no need for expensive consultants to tailor and implement the CMMS (Fiix, 2019). The seventh generation makes it possible for anyone to implement a CMMS at their company, regardless of company size. It can grow with the company at a relatively low cost and is an efficient way to manage maintenance operations (O'Brien, 2014). Another advantage of cloud based CMMS is that it is stored on multiple devices and if one piece of hardware fails, another will take over the process without interruption to the user.

2.7.4 Modules of CMMS

The following paragraphs will describe the different modules that can be implemented in a CMMS. It will also show what information and files are relevant for the different modules. Great care should be taken when creating the master data for the following modules, as this data will be used for links between modules. There are core and optional modules available for a CMMS. Optional modules are used to refine a working CMMS.

2.7.4.1 Equipment

The equipment module manages your list of assets. Every asset or sub asset will be given a number that will be used to create work orders. All the necessary specification data and associated files should be linked to each asset number. According to Cato and Mobley (2002:18), the equipment/asset file is a primary and usually a mandatory file in a CMMS.

Specification data will be different for each asset. For motors, it can include revolutions per minute (RPM), amperes and volts, while for gearboxes information such as gear ratio, service factor and gearbox orientation will be necessary. It is beneficial to have as much information about the equipment/asset on the computer as possible, in order to eliminate the need to search file cabinets or desk drawers for information (Cato & Mobley, 2002:19).

Asset identification numbers, overall dimension, capacity, power connection details, foundation details, installation information, clearance, drawing reference (assembly drawings), single line diagrams, interchangeability with other units and reference number for service and operational manuals should form part of the specification details (Duffuaa & Raouf, 2015:68). Searching assets by specification data can also help determine which equipment uses the same motors and gearboxes.

A bill of materials is the list of items that make up a piece of equipment or machinery. A bill of materials for all asset and sub-asset numbers should be created for each piece of equipment. It should also include part numbers, description of parts and quantities required. Bill of materials for a gearbox will include the main drive shaft, oil seals, bearings, bearing housing, primary gear, secondary shafts, spacers and pinion gears. Having a bill of materials will enable the CMMS coordinator to add items directly to a work order or preventative maintenance order and will assist with the RCM analysis of assets.

Annexure E will show an asset registration form and different data sheets that should be captured directly into the CMMS equipment module for every asset and sub asset. The asset registration form is only the first step. After the initial registration, the next step will be to use the information gathered to create a PMO (using the RCM FMEA and task analysis) and SOP's, which will then be used to give training to the operators and technical personnel. The last step will be to monitor the asset and improve the maintenance strategy, using failure data and feedback received from the PMO's and work orders. An asset disposal form that can be used when an asset is disposed will also be shown in Annexure E. It is recommended that an asset disposal account be created and reviewed monthly. By doing this you will ensure that every asset is disposed of properly, together with any inventory item linked to the asset.

Although a building is not part of equipment on site, it is an asset and will therefore receive an asset number. The asset registration form in Annexure E can be used for the registration of the building. The most important thing is the supporting documents that must be submitted with the registration form when a building is registered.

2.7.4.1.1 Standard operating procedure (SOP)

SOP refers to a step-by-step set of instructions documenting routine or repetitive activities followed by the company. The SOP should include at least the following information:

- Scope and purpose of document
- Roles and responsibilities
- Health and safety information
- Regulatory requirements
- Detail explanation of every step necessary to complete the task
- Clarification of any terminology used
- List of all equipment and spares needed to complete the task
- List of all personal protective equipment (PPE) to be used while doing the task.

2.7.4.2 Operating locations

Operating Locations is where an asset will be working. The operator or user should enter locations where equipment operates to enable him/her to track and organise these locations into a logical hierarchy or network systems. Equipment hierarchy is also very useful and is described by Cato and Mobley (2002:20) as the relationship of one item to another item that is either higher or lower in a tree chain. These relationships are usually referred to as parent-child relationships. Duffuaa and Raouf (2015:67) go on in stating that the description of the facility, the location, type and priority of the equipment should also be added.

Establishing hierarchies is usually not mandatory, but has numerous benefits and is listed by Cato and Mobley (2002:20-22) as follows:

- Hierarchies provide a quick method of determining the physical location of an item.
- Maintenance costs may be automatically rolled up from the level in the hierarchy against which a work order was written to higher levels.
- All items above and below the hierarchy selected can be viewed.
- Hierarchies will allow the user to track performances of equipment at specific levels in the hierarchy.

Figure 17 shows an example or equipment hierarchies. Hierarchies can be used to determine if work orders will be opened against the correct asset. It might be that the order was made out for the hammer mill, instead of the hammer mill gearbox, within the system.

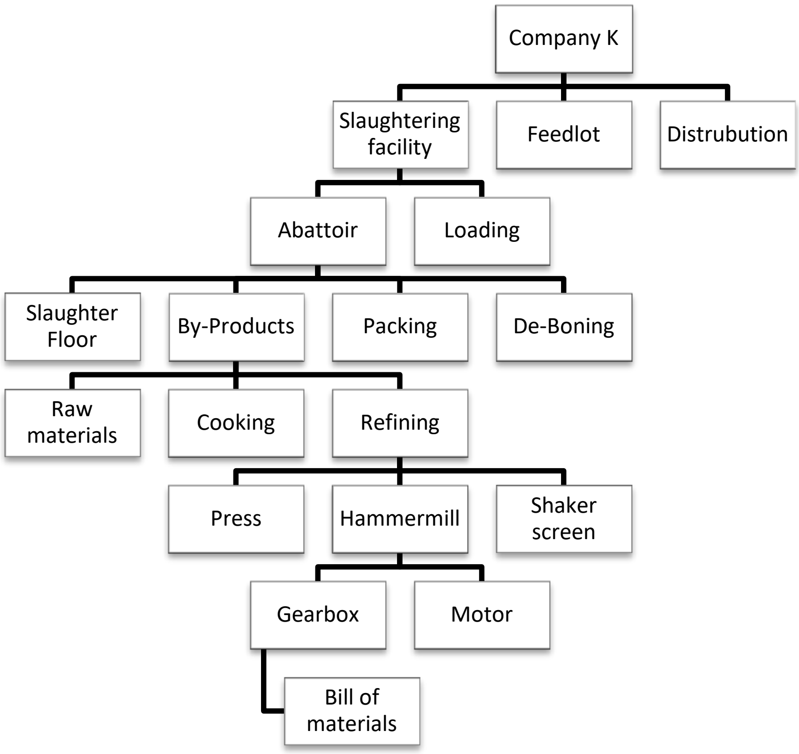

Figure 17: Equipment/Asset hierarchy

2.7.4.3 Resources

The resource module is used to track labour resources. Typically, this module includes all relevant records for maintenance personnel who will charge time to work orders (Sapp, 2016). Basic information maintained is company number, name, surname, medicals done and direct unit cost. Additional information can also be stored like job title, training received, courses attended, tertiary education, employment date, resource group, craft code and promotion history. The basic information is required for the CMMS to allocate correct time and labour resources against work orders. The baseline medicals done when an employee is employed will help the CMMS coordinator to see whether the labour resource is fit to do certain work orders, e.g. where he or she may have to work on heights or where heavy lifting is required. Yearly medicals done, which is an occupational health and safety act (OHSA) requirement, can help the employer to determine whether the engineering controls put in place to reduce hazards are still effective, or whether they need to be relooked.

The information in the resource module will help maintenance managers to track skill levels and qualifications for each labour resource (Sapp, 2016). This information plays a vital role in the training and development of employees, as it will firstly help identify which employees require training and secondly help determine the internal capacity of the resources available for the CMMS coordinator to plan work orders. External resources should be contracted if the internal capacity is not available to complete certain work orders in time.

Resources will be allocated to a craft code that will be linked to work orders. Table 2 shows an example of craft codes:

Craft Code	
Code	Definition
1	Mechanic
2	Fitter
3	Electrician
4	Welder
5	Plumber
6	Painter
7	Carpenter
8	Operator

Table 2: Craft codes

Autonomous maintenance is one of the eight pillars of TPM (refer paragraph 2.6.2). Chandegra and Deshpande (2014:123) state that autonomous maintenance aims to create a scenario where all operators look after own equipment, carrying out routine checks, oiling and greasing, replacing parts, doing repairs, spotting problems at an early stage and so on. They continue by listing seven steps of implementing autonomous maintenance as follows:

1. Initial cleaning – Cleaning will help expose hidden problems on machines.
2. Eliminating sources of contamination – Keeping the machine surroundings and tools clean.
3. Creation and maintenance of cleaning and lubrication standards.
4. General inspections – Operators should be aware of general inspections to do be done.
5. Autonomous inspections – Performing maintenance tasks on machines.
6. Standardisation of processes and procedures to be followed.
7. Fully implemented autonomous maintenance pillar.

2.7.4.4 Inventory control

The inventory control module is for the control of spares related to all asset numbers, whether the spares are stock, non-stock or a special order item. Activities that should be included in this module are: issuing (requisitions) of parts and materials to work orders (scheduled or unscheduled); return of unused items; automatic and manual creation of purchase requisitions; cycle counting; adjustments to inventory quantities and receipt of purchased items into inventory (Cato & Mobley, 2002:15). Additional inventory control functions include: location of the item in the stores; cost of items; vendors for different items; item description; item datasheet; priority of item and links to substitution or alternate items that may be used.

Requisition procedures is an essential step in withdrawing material from the stores. Among other uses, these procedures form a systematic basis for cost accounting and inventory control (Duffuaa & Raouf, 2015:119).

Cycle counting is a method used by companies where you continuously count the inventory in the stores or stock of finished products. You can do random checking or according to a schedule, but it is recommended that you do at least three complete cycle counts per year. Cycle counting gives you more complete and accurate records of the spares you have so that errors can be addressed immediately and be corrected.

Maintenance-, repair-, overhaul-, mechanical-, electrical spares and production consumables should each have its own unique prefix to the store code to be able to identify the spare easily. Annexure H shows a basic coding system for an inventory that can be used. The different spares should be grouped together to avoid unnecessary time wasting when issuing or searching spares.

Rotable spares is classified as a slow moving high-cost spare part with a long mean-time between failures that can repeatedly be restored to a fully serviced condition (Zhang & Wang, 2017:124). Rotable spares are used to keep downtime in production processes as low as possible.

Inventory control modules should be linked to other modules in the CMMS. If parts are selected from a bill of materials, the CMMS will automatically check if the spares are available, and would inform the CMMS coordinator immediately whether sufficient spares are available or not. If spares are available to complete the work order, the CMMS coordinator can create a picking slip for the spares. The picking slip is then sent to the stores for picking. This will reduce the time that artisans have to wait for spares at the stores.

One practical way to establish an inventory system is to keep count of every item issued, and to place an order for more stocks when inventories have reached a predetermined level (Duffuaa & Raouf, 2015:120). Figure 18 illustrates such a system where stock is steadily depleted until it reaches the reorder point (R1), and then an order is placed (Q1). The spares ordered are assumed to arrive after a fixed time, usually called the lead time. Safety stock is the level of stock maintained in the stores to reduce the risk of not having stock until replenishment stock has arrived.

Source: Duffuaa and Raouf, 2015:121

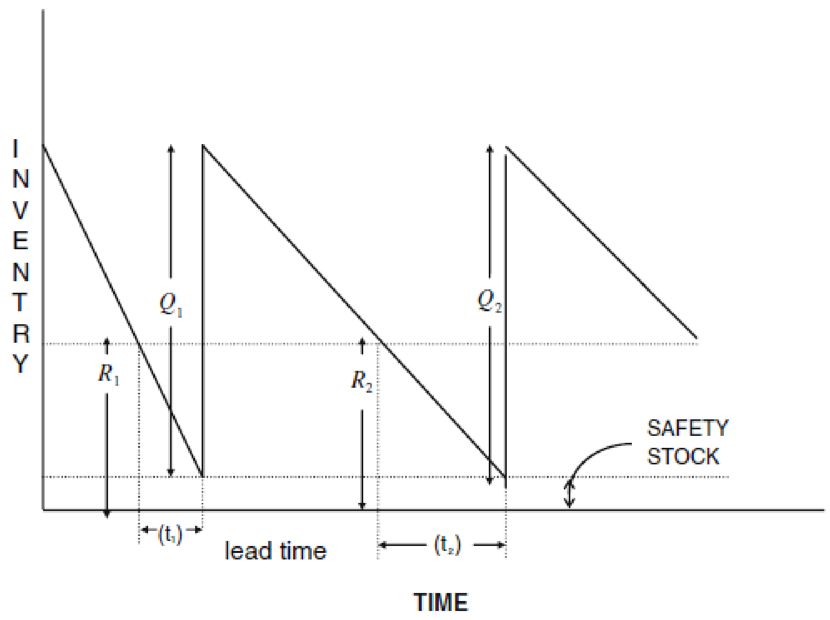

Figure 18: Q/R inventory system

Duffuaa and Raouf (2015:116) suggest the following categories for spare parts that will influence reorder points and safety stock:

- Relatively expensive parts;
- Spare parts having slow turnover;
- Spare parts having longer than normal lead times;
- Specialised parts for use on limited number of machines;
- Critical spare parts which may cause expensive downtime or which could have an adverse effect on safety. Critical spares can be further classified as follows:
    - Low criticality: Parts not essential for operation of equipment.
    - Moderately critical: Will have slight to moderate effect on operation of equipment.
    - Highly critical: Parts that are essential for the operation of equipment.

Just in time (JIT) inventory is the ability to identify and assign ideal stock levels for inventory. Order levels and quantities are calculated using data from the CMMS. If a part is being used frequently, but takes long to ship, the stock quantity should normally be higher to compensate for the longer lead time. JIT relies on the fact that all parts will be readily available from any supplier at any given time.

Cross-referencing between parts and assets is also a useful function in inventory control. It will enable the module to show you a list of different assets that uses the same item or part, as well as the quantities used by each asset. Having this link will also allow you to block requisitions if more items are being requested than are installed in an asset. The movement of parts should be reviewed annually to optimise reorder points and the quantity of spares kept in the stores.

2.7.4.5 Safety plans and legal requirements

More and more emphasis is placed on safety in an organisation. A safety module in a CMMS will help define and document safety requirements. Capabilities include step-by-step instructions to complete jobs safely (SOP`s), special instructions for lock out procedures, a check list of what should be in contractors' safety files, and also keeping track of hazards identified and precautions to such hazards. Material safety data sheets (MSDS) can be linked to all lubricants and dangerous substances for all assets. Equipment requiring special radiation certificates should also be included in the safety module.

Risk assessments form an integral part of completing jobs safely and must be included in the safety module. Hot work permits, working at height permits and permits to work in a confined space must also be included in this module. The CMMS should remind you periodically to review or revise risk assessment documents and permits so that the most current documents for jobs could be issued. All the registers will be kept current with the use of the safety module of the CMMS.

Registers normally applicable to an abattoir	
Material and goods hoists	Chain, chain slings, hooks and shackles
Fire extinguishing equipment	SHE representative inspections
Ladders (Fixed and portable)	Lifting machinery
Portable equipment	Pressure vessels and boilers
Refrigeration and cold room installations	Scaffolding
Gas welding and cutting equipment	Electrical equipment
Chain blocks and lever hoists	Earth leakage testing
Forklifts	Pressurised systems
Appointment forms	Workshop vehicles
Glass register	Cash pistols and ammunition

Table 3: Registers for OHSA

Fire extinguishing in Table 3 refers to extinguishers, hose reels, sprinkler system, breathing apparatus and hypoxic systems.

The safety module will manage all the information necessary for these registers. This will include planning of the statutory inspections, quarterly and annual inspections, repairs on assets if necessary, documentation of repairs done and collecting all necessary certificates or data books that are required.

One pillar of TPM is SHE (refer paragraph 2.6.2) and will be managed by this module. PPE issued to employees is part of the safety of employees and is the last line of defence in protecting employees from hazards. The PPE issued to employees should be captured into the CMMS. For the environment part, the monitoring of air emissions, air quality (dust levels and welding fumes), lux levels, noise levels, effluent discharge and radiation will be done either annually, biannually or three-yearly, as required.

Insurance companies require certain inspections to be done, like annual thermal imaging of electrical panels, annual building inspection and earthing readings of buildings to name a few. Extensive historical tracking of safety compliance - and the ability to drill down into the details for each procedure using the CMMS - can be used for internal audits. This will be invaluable for establishing the track record for safety compliance.

2.7.4.6 Purchasing module

The purchasing module is used to buy inventory items and acquire new assets. When a new asset is acquired, a request to order (RTO) will be filled in. The RTO will have all the relevant information (specific details) filled in to purchase this item. The RTO will, in other words, detail exactly what a vendor needs to supply in order to receive full payment. The lead time stated on quotes will be used as the expected receipt date of the goods. This will enable the CMMS to automatically send e-mails to the vendors, asking for details why the item or asset has not yet been received.

The purchasing module will use the unique code given to stock items to obtain quotes from vendors specified for the part. If there is a preferred supplier and only one quote is obtained before purchasing an item, the supplier should be checked against at least three other vendors after 50 invoices. The purchasing module will create purchase requisitions of spares at pre-determined levels that should be reviewed by a procurement manager before an order is placed. Other functions may include invoicing and automatic requests for quotations.

2.7.4.7 Work order module

An effective maintenance operation and control system is the backbone for sound asset management (Duffuaa & Raouf, 2015:131). Work order request or job request is an integral part of a CMMS. Duffuaa and Raouf (2015:124) suggest two different types of work orders. The first one is a blanket work order that is normally used for repetitive work orders, e.g. the start-up of all the abattoir departments in the morning. These jobs are fixed and are used to get the facility ready for production. The second work order is the special written work order where all the details of the job to be done are filled in. The latter option is used to create work orders on equipment. It can range from making adjustments on equipment to making something small like a table for a piece of equipment. The information necessary to create work orders except description of work to be done should be located in pop-up tables. This will eliminate people needing to memorise codes. Table 4 shows the different job designation and code numbering that can be used for work orders and maintenance orders for prioritising of work order requests. Annexures J and K will show a typical work order request and work order respectively. Depending on the size of the organisation, up to four work orders can we printed:

- Copy 1: This copy will be kept in the planning office.
- Copy 2 and 3: Both copies will go to the relevant maintenance supervisor, where one will be given to the artisan who will complete the work order, and one will stay in the office for record keeping.

- Copy 4: This copy will be given to the originator of the job request.

With the use of an ERP system the copies do not necessarily need to be printed, but can be sent electronically.

Job designation	Code numbering	Time frame for work to start	Type of work
Planned maintenance	01	Work can be appropriately scheduled.	Preventative maintenance work
Repair	02	Work can be appropriately scheduled within a week.	Planned repair work
Minor Repair	03	Work that should be done as soon as possible.	Work requiring little time to fix and will prevent unnecessary downtime.
Breakdown	04	Work that should be done immediately.	Reactive maintenance or unplanned schedule maintenance that has a direct impact on safety, quality and environment.
Modification	05	Work can be appropriately scheduled.	Modification to existing assets to improve efficiency or product quality.
Damage to property	06	Work should start within 72 hours.	Work where damage to property has an effect on safety, quality, health and environment.
Capital / Abnormal	07	Work can be appropriately scheduled.	Acquiring of new assets to improve efficiency of the process, improve product quality, increase production and decreasing of downtime. Modification to the infrastructure is also included.

External	08	Work can start immediately if asset is sent off site or scheduled appropriately if work is to be done on site.	Maintenance and repair of assets on or off site and manufacturing of equipment by external vendors

Table 4: Job designation and code numbering

From Figure 3 and Table 4 we can see that only minor repairs and breakdown will be part of unscheduled work orders. Planned maintenance, repair, modification, damage to property and capital or abnormal work orders are part of scheduled work orders that can be properly planned and executed. Except for unplanned work orders, it is useful to prioritise the planned work orders in collaboration with the period within which the work order should be completed. According to Duffuaa and Raouf (2015:161), the priority system should be communicated to all operation staff, who commonly assigns a higher priority to maintenance work than is warranted. An example of this is when operation staff members fill out a job request and write as soon as possible (ASAP) in the 'when required' field. The massage that 'if all jobs have the same priority, then no jobs are important' should be clearly conveyed to operation staff.

External maintenance orders are part of the work order module. If the backlog on work orders is more than five weeks, the backlog should be managed by outsourcing work orders to external vendors. A report of external work orders created should be scrutinised weekly and decisions regarding them should be taken immediately, when possible. External maintenance orders include: approved inspection authority (AIA) inspections on regulatory equipment; repairing of rotable spare or assets of site by external vendors; manufacturing of equipment, and maintenance on assets by vendors. When rotable spares or assets are repaired off site, the CMMS coordinator must be able to add holding points on external work orders for inspection by engineering staff before work can continue.

The work order system consists of modules and programs that allow for the creation, planning, viewing, approval, tracking, execution and completion of work requests and work orders (Cato & Mobley, 2002:15). The work order statuses also form an integral part of this module. It should also contain summaries of planned maintenance, repairs, rehabilitation, modifications, additions, construction and other work affecting the configuration or condition of the items (Sapp, 2016).

Figures 19 and 20 show the flow diagram for a work order, as illustrated by Duffuaa and Raouf (2015:228-229).

Source: Duffuaa and Raouf, 2015:228

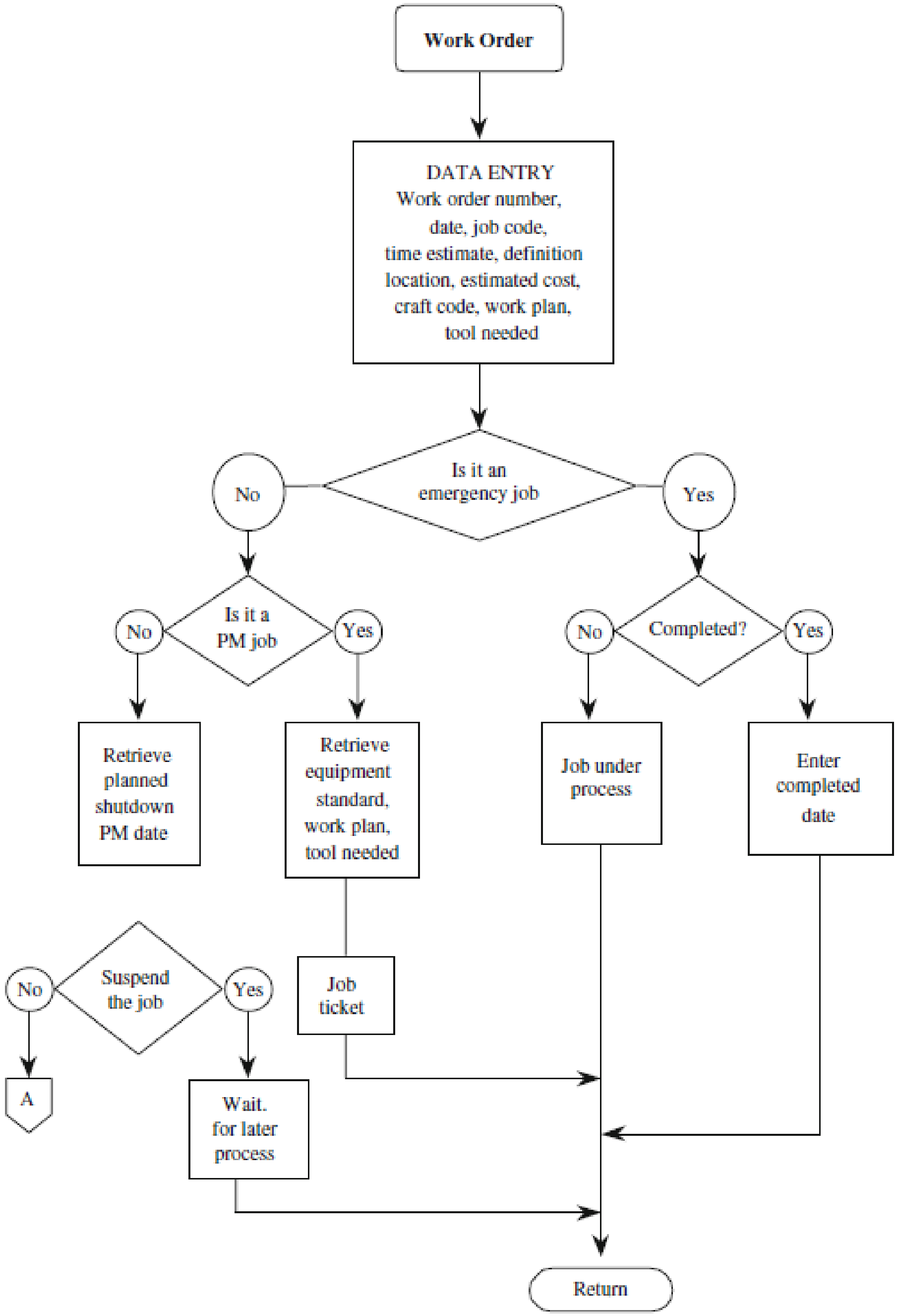

Figure 19: Flow diagram for work order

Source: Duffuaa and Raouf, 2015:228

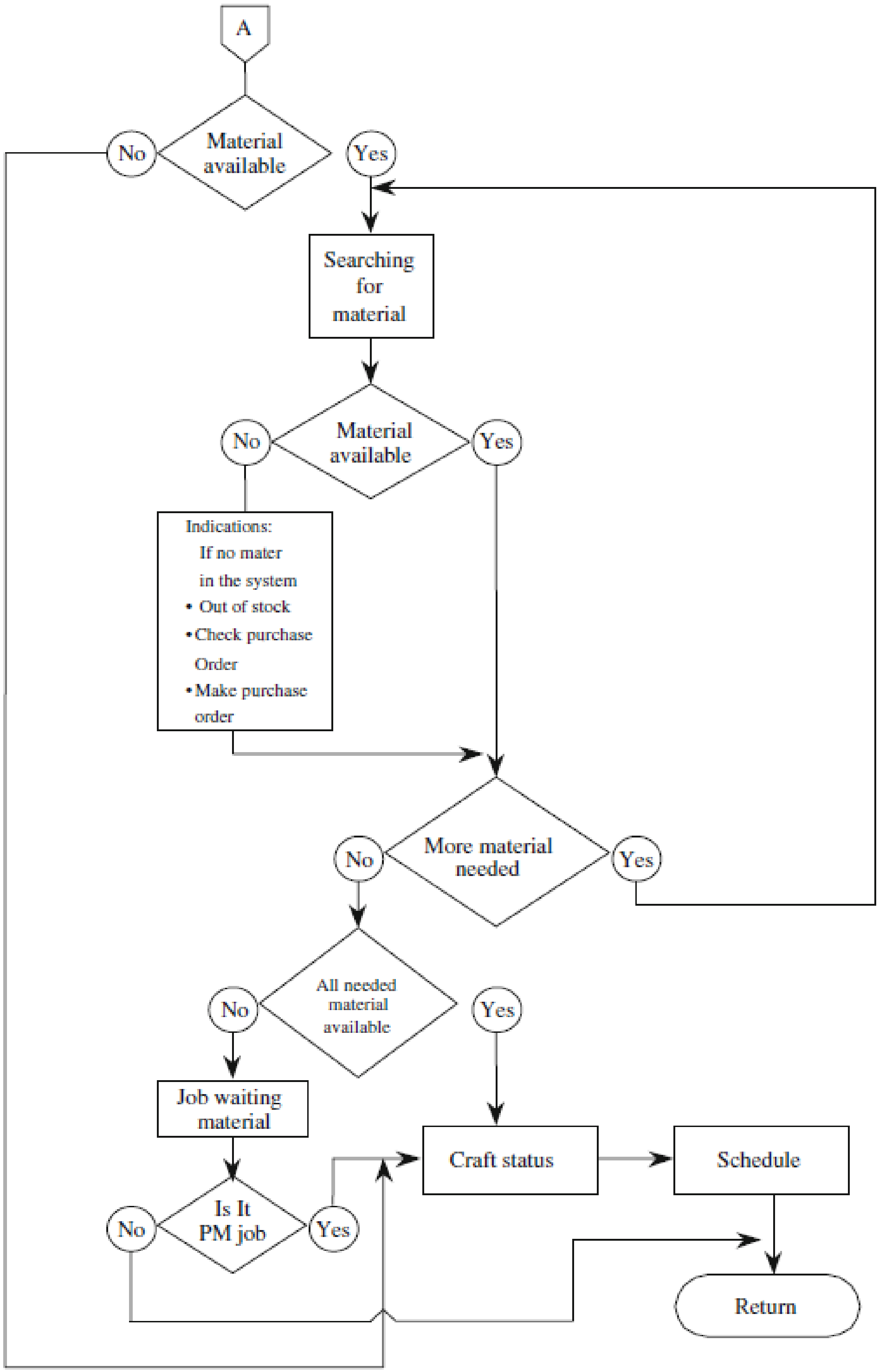

Figure 20: Flow diagram of work order (continued)

Upon completion of the work order, the CMMS should ask if a follow-up work order needed to be created before it is moved to the historical records. An example of a follow-up order is to create a work order to do thermal imaging of an electrical panel to check for hot connections two weeks after a new breaker has been installed.

2.7.4.8 Preventative maintenance

Preventative maintenance (PM) starts by making a master plan and linking it to one or more assets. Sapp (2016) lists the following capabilities that may be provided in a CMMS to manage a preventative maintenance program:

- Supporting multiple criteria for generating PM work orders. If a PM master has both time-based and meter-based frequency information, the program should use whichever becomes due first and then update the other.
- Generating time-based PM work orders based upon last generation or last completion date. Next due date and job plans should be displayed.
- Permitting and tracking PM extensions with adjustments to next due date.
- Triggering meter-based PM by two separate meters.
- Printing sequence job plans when wanted.
- Creating a PM against an item so new parts have PM automatically generated on purchase.
- Specifying the number of days ahead to generate work orders from PM masters that may not yet have met their frequency criteria.
- Consolidating weekly, monthly and quarterly job plans on a single master.
- Assigning sequence numbers to job plans to tell the system which job plan to use when a PM work order is generated from a PM master.
- Permitting overriding of frequency criteria in order to generate PM work orders whenever plant conditions require.
- Routing PM with multiple equipment or locations.
- Generating work orders in batch or individually for only the equipment specified.
- Capability to be used with the system scheduler to forecast resources and budgets.

Some PM orders only call for inspections of assets to be done and have a huge influence on the PM module. Gauge readings, vibrations readings and oil samples will help predict equipment failures before they occur and will help plan further maintenance actions (Duffuaa & Raouf, 2015:78).

Feedback information received from work orders (preventative or requested) is analysed and follow-up work orders are created, if necessary. Duffuaa and Raouf (2015:145-149) state that this course of actions and decisions is aimed at improving the following:

- Work control that monitors statuses of work orders. Reports generated include:
    - Performance according to the standard by the crafts utilised for the job and their productivity, showing what proportion of maintenance work is performed using overtime.
    - Weekly backlog report by craft. A backlog of about two to five weeks must be maintained. If the backlog is too long, you can increase contract maintenance, increase maintenance force or schedule cost-effective maintenance. If the backlog is too short, you can reduce maintenance contracts.
    - The percentage of unplanned maintenance to planned maintenance. This report will show if planned maintenance is effective in minimising or eliminating breakdowns.
- Cost control where maintenance costs by work done is generated monthly. The cost report will indicate where cost reduction programs must be launched. Cost reduction programs include:
    - Modifying inspection procedures.
    - Considering the use of alternative maintenance materials.
    - Redesigning material handling procedures and the workshop layout.
    - Revising maintenance procedures, particularly making adjustments with regard to the size of crew and methods used.
- Quality control is very important, since it has been proven that the condition of a machine is directly related to the quality of the product. A machine in good condition will produce better quality products than a machine that is in poor condition. Daily product rejection reports and repeat work orders will help you identify which machines may be underperforming; you can than investigate causes of quality programs.
- Plant condition control requires an effective system for recording failures and repairs for critical and major equipment in the plant. This monthly report should include downtime of critical and major equipment and their availability. Another report that can be generated is the maintenance cost per animal slaughtered.

Maintenance contracts, service level agreements and legal inspections should be managed by the CMMS. The preventative maintenance module should also incorporate other systems where standard operating procedures is maintained so that it can be linked to PM orders that are created.

2.7.4.8.1 Turnaround maintenance

Turnaround (TA) maintenance forms part of the preventative maintenance module where a yearly shutdown is planned to execute important preventative functions and repairs. In the abattoir environment, one example of where turnaround maintenance is used is at an automatic carton freezer. A machine capable of freezing one hundred and fifty tons of offal from thirty-six degrees Celsius to a core temperature of minus eighteen degrees Celsius within twenty-four hours. Duffuaa and Raouf (2015:177) defines TA maintenance as a periodic shutdown of plants to allow for overhauls, replacements and repairs that can be done only when the plant is taken out of service.

Duffuaa and Raouf (2015:177-178) lists the following work types that will be performed during TA maintenance:

- Work which can be done while equipment is in operation, but which requires a lengthy period of maintenance work and a large number of maintenance personnel;
- Work on equipment which cannot be done unless the whole plant is shutdown, and
- Defects which could not be repaired pointed out during operation.

Duffuaa *et al.* (2019) make the following recommendations for organisations conducting TA maintenance:

- Establish committees or teams to enhance coordination between supply chain partners.
- Develop measures to access the impact of TA maintenance on plant performance and should include the impact on the plant reliability, availability, quality- and process rates.
- Engineer a formal process for documenting information and knowledge obtained from each TA maintenance event.
- Develop a formal process for sharing information and best practices in TA maintenance planning and execution among partners.
- Give feedback to equipment vendors in order to design new generations of equipment with better specifications and performance.

2.7.5 Why does a CMMS fail?

Vendors are very good at developing software programs that will store massive amounts of data, manipulate the data, automate recurring tasks and generate standard reports, but they do not provide the real management tools needed to have an effective maintenance organisation (Cato & Mobley, 2002:125). Partial implementation, poor planning, incorrect training, staff overload, work culture, insufficient data and infrastructure are some of the factors contributing to CMMS failures in many plants and facilities. A short description of each of the factors will be discussed in the following paragraphs. It is discussed in more detail by Cato and Mobley (2002:125-132).

2.7.5.1 Partial implementation

A third of CMMS failures are due to partial implementation. Most companies' in-house personnel lack the expertise and working knowledge of the CMMS being used by them, and they do not recognise all of the tasks required to directly or indirectly support the CMMS (Cato & Mobley, 2002:126). Partial implementation stems from the fact that personnel do not understand the true capabilities of the system.

2.7.5.2 Poor planning

Most CMMS packages and project plans, if developed at all, fail to estimate the level of manpower and financial resources that will be required to fully implement the CMMS, and all of the limiting factors that preclude effective maintenance management (Cato & Mobley, 2002:127). Before you start to implement the CMMS, it is of vital importance that every level - from management down to workshop level - buys into the program. If adequate training of the CMMS is not part of the initial planning, the likelihood of the CMMS failing is very high.

2.7.5.3 Incorrect training

If training is neglected or not done properly, maintenance personnel or users of the CMMS may apply their own methodologies when using the software. Clear instructions and standard operating procedures should be in place on how the CMMS should be used and how data should be captured.

2.7.5.4 Staff overload

Failing to see the amount of man-hours needed to successfully implement a CMMS, normally leads to overloading of staff where companies expect their own employees to implement a CMMS without any outside help. A frequent result is that the CMMS implementation becomes a second priority and the system is never fully implemented (Cato & Mobley, 2002:128).

2.7.5.5 Work culture

Fundamental management, philosophical as well as procedural issues impede the smooth implementation of, or transition to a new CMMS and radical changes are sometimes necessary to break the habits of the past (Cato & Mobley, 2002:132). The relationship between machine operators and maintenance personnel is crucial to a successful CMMS. This relationship may not directly affect the workings of the CMMS, but in the case where machine operators do not take care of their equipment, maintenance personnel may feel it is a waste of time filling in work orders to repair recurring issues on equipment (Cato & Mobley, 2002:132).

2.7.5.6 Insufficient data

Lack of data captured into the CMMS will lead to the failure of the CMMS. The strength of the CMMS lies in its reporting- and analysis of trends ability. Without the proper capturing of data, no reports can be generated to help managers make informed decisions regarding maintenance strategies.

2.7.5.7 Staff turnover

It takes anywhere between two and five years to successfully implement a CMMS. Staff turnover adds directly to implementation failure, as you will constantly lose valuable knowledge when an employee leaves.

2.7.6 List of CMMS

This paragraph will list some of the CMMSs available for the industry. The top ten CMMSs, according to Software World (2020), are:

1. MicroMain
2. eMaint CMMS
3. Fiix
4. Maintenance connection
5. IndySoft
6. EZOfficeInventory
7. UpKeep
8. Tenna
9. Maintenance Care CMMS
10. Tofino

2.7.7 Summary of CMMS

The short history showed in the beginning of this paragraph shows how far maintenance systems have come in a short period of time. The seventh generation of CMMS makes it possible for everyone to implement a CMMS at their company. The paragraph continued to show what the importance of each module is, and what information is to be captured for the successful implementation of a CMMS. The main reasons why CMMSs fail, were briefly discussed. These reasons need to be addressed if the CMMS is to be implemented successfully. The next paragraph will look at the MEGKON maintenance optimisation training course.

2.8 THE MEGKON MAINTENANCE OPTIMISATION TRAINING COURSE

This section will show different sections of the maintenance optimisation training course that will help the researcher in developing a guide for the successful implementation of a CMMS. It will start by explaining baseline information. The section will continue and show the purpose of the hardware breakdown structure, followed by giving an example of how codification can be done for a factory. Systems engineering will be briefly described, followed by an explanation of the maintenance optimisation process, as shown in the MEGKON training course. The paragraph will end by introducing the plant level impact of functional failures for which MEGKON received Technology Top 100 recognition.

2.8.1 Introduction to baseline information

Information is probably the most strategic asset of any company where the value of information should be measured by the cost of obtaining information versus the value of having information available (Wichers, 1996). Information development aims to empower management and technical staff by having information readily available for perusal before making decisions. The first project to undertake when implementing a CMMS is to establish the baseline information of the equipment on site. The following list found in the MEGKON training course highlights what should be part of baseline information:

- Plant breakdown structure/inventory
    - Establishment
    - Control
- Equipment codification & classification
    - Plant numbering
    - Rotable control
    - Stores numbering
    - Critical equipment identification
- Modification, control & management
    - Plant
    - Documents
    - Software
- Documentation, control & management
    - Manuals
    - Drawings
    - Procedures
- Technical writing
    - Manuals
    - Drawings
    - Procedures
- Change control management & software
    - Supply
    - Implementation
    - Customization
    - Support
- Training

The project objective will be to capture as-built info, optimise plant info, obtain all usable manuals - including working procedures - and to gather information on managements systems that includes the following: plant configuration (hardware breakdown structure (HBS) and plant codification), workflow management (change control) and documentation management (master record index (MRI), storage and retrieval) (Wichers, 1996). Figure 21 shows a configuration approach for documentation of baseline information. Links between the MRI and sub assets identified in the HBS should be made for every asset.

Source: Wichers, 1996

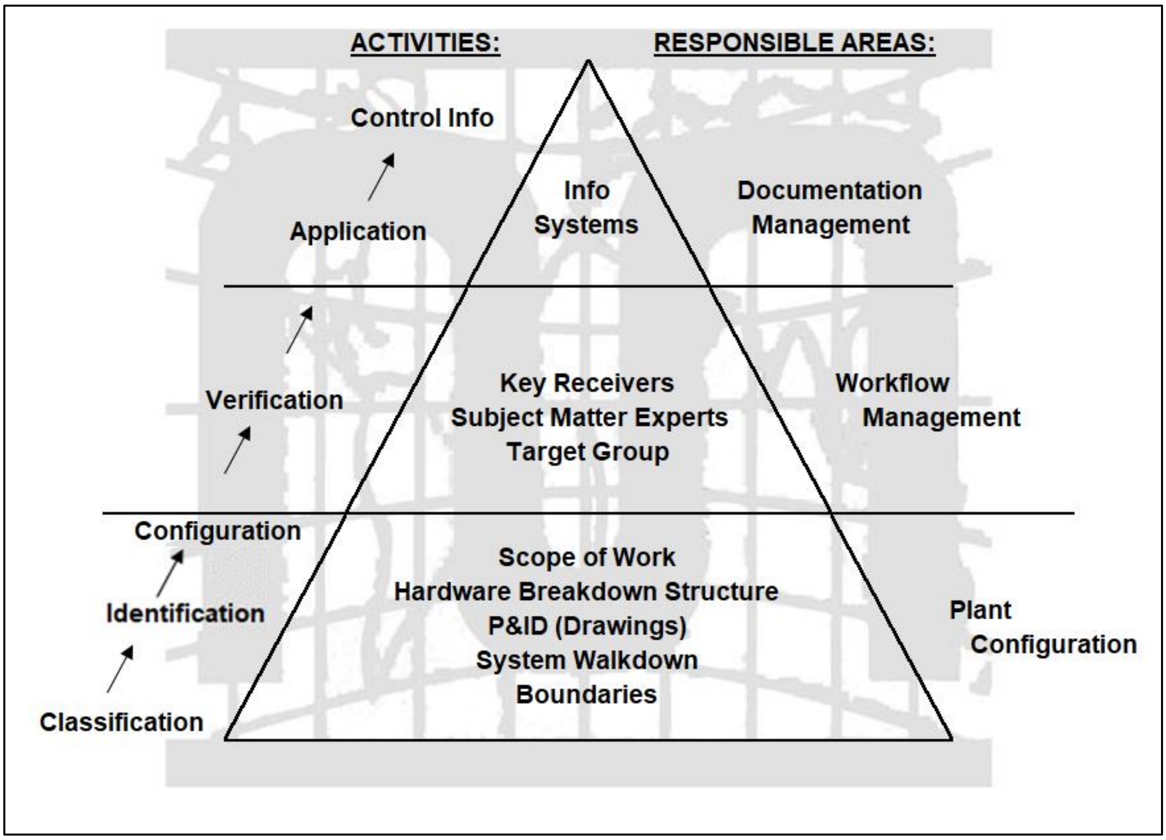

Figure 21: Configuration approach to documentation

Figure 22 gives a good guideline for the optimisation process when acquiring the necessary baseline information for assets.

Source: Wichers, 1996

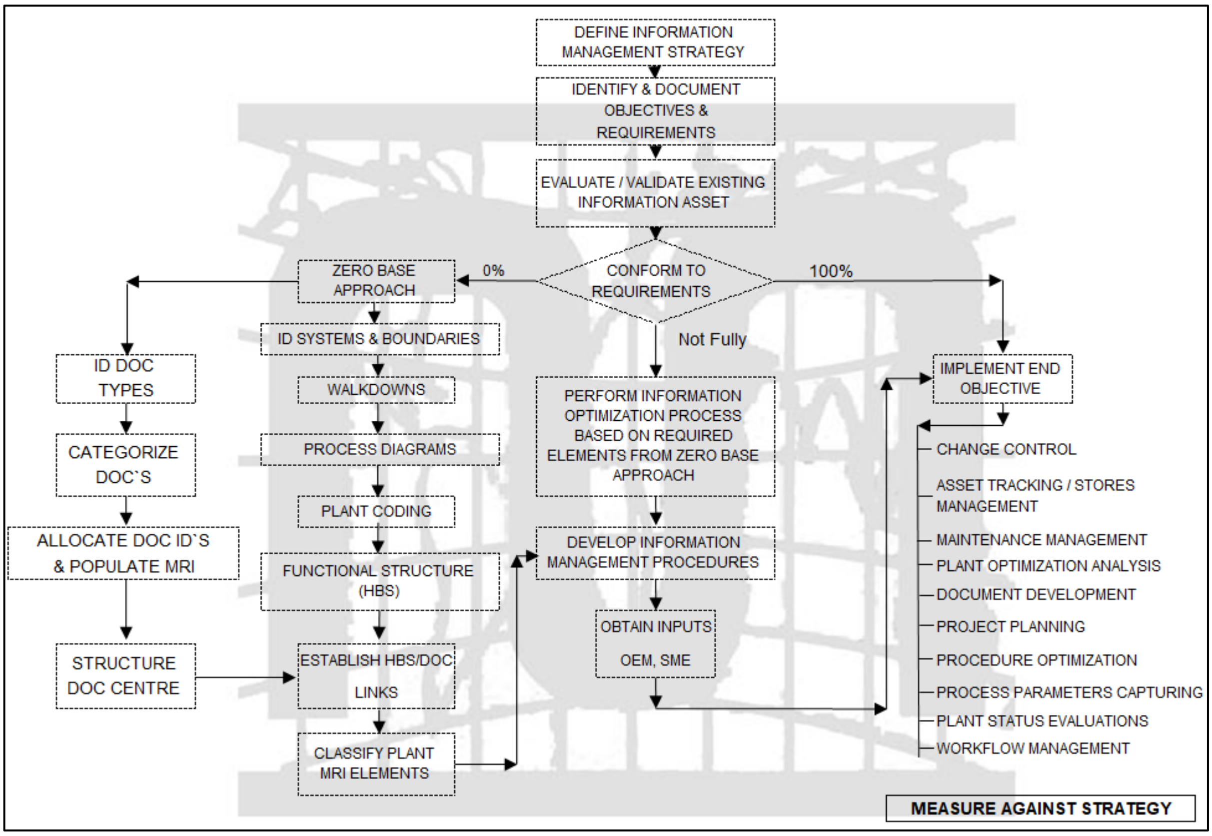

Figure 22: Information back fit/optimisation process

2.8.2 Hardware breakdown structure (HBS)

2.8.2.1 Introduction

Most organisations use hundreds if not thousands of physical assets, ranging from small valves to large expensive equipment. A comprehensive list of these assets needs to be drawn up before you can determine the maintenance requirements for best availability and reliability. Two commonly used lists are the bill of materials by contractors and an asset register kept by the financing department (Wichers, 1996).

2.8.2.2 Purpose of the HBS

During the life cycle of any plant, a large amount of information that is applicable to the equipment or system is gathered. Fixed asset depreciation, drawings, procedures, manuals and process costing are some of the information gathered and where the interest of all departments, from financial to engineering and maintenance, are clearly visible.

In most cases, this requires a structured approach to compile an asset listing that is commonly referred to as the HBS and should be carried through down to component level (Wichers, 1996). Wichers (1996) gives a list of benefits of compiling an HBS:

- Helps you present the plant in a structured way:
    - The bill of material will be available for every asset
    - Failure mode effect and criticality analysis will be done for every asset
    - Boundaries will be defined of functional systems
    - Actual plant audit against structure will be done
- Ensures ability to obtain information per system
- Assists with plant codification:
    - Highlights coding errors
    - Assists with correct coding implementation
    - Ensures consistency in coding philosophy
    - Implements the method, not the personality
- Piping and instrumentation diagrams:
    - Makes you think about your plant
    - Enables some standard on the plant
    - Ensures correct as-built piping and instruments diagrams
- Management information:
    - Maintenance, plant history and change control
- Base info systems and procedures on the HBS:
    - Linking or control of documentation (library documents linked to as-built plant items)
    - Forcing functional descriptions
    - Ensuring consistency of terminology
    - Utilising workflow planning and execution as-built info
    - Keeping track of items removed and modified for future reference
    - Active databases refer to same control data.

Building a structure can only be properly introduced if all terminologies and functionality rules are combined in a single procedure and the management thereof done by a single person (HBS administrator). This will ensure consistency and the proper documentation of all deviations (Wichers, 1996).

2.8.2.3 Basic rules and codification

To ensure that the HBS does not lead to non-functional groupings, make sure that the HBS can fulfil the following functions:

- Component defined to line replaceable level
- System boundaries clearly defined
- Representing the main path through the system
- Creating an understanding of the system
- Having the ability to navigate through the system
- Functionality of groupings clearly visible

Codification systems should be as simplistic as possible not to confuse people. Some basic codification rules, according to Wichers (1996), are to start with the main systems first. After completing this, you can start with the sub systems. The counting rules for codification is to start with the direction of flow, beginning from left to right, front to rear (drive end to non-drive end) and then bottom to top. Use numerals when equipment is used to full capacity, e.g. where pump 1 or pump 2 has 100% demand capacity and letters, when pump A or pump B has only half of the desired capacity.

System boundaries, level of breakdown, functionality of systems, high level systems and the purpose of the HBS should be clarified with all the different departments before you begin, as views may differ from department to department.

2.8.2.3.1 Codification example

This section will show a codification example and will briefly explain the meaning thereof. It is not in the scope of this dissertation to develop a codification system for factories or an abattoir. The example shown below can therefore be expanded to suit your individual needs.

X_0X_1 12345 $Y_0Y_1Y_2$ Z_0Z_1	
X_0	The first character refers to the site and department where the asset will be installed. This should correspond to one the department codes that was created when operating locations of the plant had been established (refer Annexure F).
X_1	The second character refers to the fixed asset codes that were developed for the equipment module (refer Annexure E).

12345	This is a number created and allocated to specific assets. This unique number links to the description of the asset	
Y_0	**This character will represent the process in the department**	
	C	Cooking
	R	Refrigeration
	P	Processing
Y_1	**This character should give the name of the asset.**	
	A	Band saw
	B	Compressor
	C	Condenser
	D	Conveyor
	E	Chiller
	F	Cooker
Y_2	If there is only one asset, the number should be coded as 0, and as1, 2, 3 if there are more than one of the same asset. Refurbishments can be extended from the original numbers.	
Z_0 and Z_1	**Subgroup of the asset**	
	E	Evaporator
	G	Gearbox
	M	Motor
	P	Pump unit
	R	Rails
Z_2	If there is only one asset, the number should be coded as 0; and 1,2,3 if there are more than one of the same asset. Numerals will be used if one unit can handle 100% of the demand, and letters if the unit can only deliver part of the demand. Refurbishments can be extended from the original numbers.	

Table 5: Codification example

ABBP PM 04268 CF1 G0 = Abattoir Bloemfontein By-Products Plant and Machinery Cooking Cooker 1 Gearbox 0.

TKRE PM 52145 RB1 M0 = Technical Kroonstad Refrigeration Plant and Machinery Refrigeration Compressor 1 Motor 0.

The codification above is only an example of how you can standardise your codes for equipment. Before you start with the codification process, it is important to involve all the relevant departments - as different department will have different views on how the codification of assets should be done.

The Key for every character that will be used for codification of assets must be strictly followed. If you allow any deviation from the Key, your system will be of almost no value to you. If you find that the Key does not suit all your needs, you can make amendments to the Key after having consulted all the relevant departments that formed part of the team that developed the Key.

2.8.3 Systems engineering

Systems engineering is a systematic, integrated engineering process constituting speciality functions such as system simulation, life cycle cost analysis, functional analysis and many others. It involves the efforts necessary to achieve two primary objectives. The first objective is the transformation of an operational need into a description of system performance parameters and a preferred system configuration, using an iterative process of functional analysis, synthesis, optimisation, definition, design, test and evaluation. The second objective is integration of related technical parameters and assurance of compatibility of all physical, functional and program interfaces in a manner that optimises the total system definition and design (Wichers, 1996).

Wichers (1996) suggests that the aim of systems engineering is to work smarter, thereby saving cost and increasing performance and profitability where the system engineering process is characterised by:

- a top down analysis process whereby a complex system (or problem) is broken down into manageable elements;
- a bottom up synthesis process whereby element solution concepts are integrated into an effective total system.

Systems engineering comprises of seven systems engineering activities:

- Requirements analysis – Requirements are defined as the criteria by which the system will perform and fulfil its intended purpose.
- Functional analysis – Functions can be defined as discrete operations the system must perform in order to fulfil its intended purpose, where the functions can be performed by equipment, programs, people, documentation or facilities.
- Requirement allocations – A situation where the defined system performance criteria are matched to the functions to be performed.
- Performance analysis – A comparative study of performance requirements against predicted or empiric performance at commissioning, which in turn is compared to the average performance in operation.

- Optimisation and effectiveness analysis – An evaluation that comprises deficiency analysis and identification of alternative solutions.
- Synthesis – Ensure that interfaces are matched and that the whole system is effective within its environment.
- Implementation programme – This involves the generation of definitions, specifications, activity lists and critical path networks. These will now enable the establishment of an implementation plan, which may be completed in terms of:
  - Plant and equipment
  - People and training
  - Documentation and data
  - Programmes, plans and software
  - Support services and facilities.

2.8.4 Maintenance optimisation process

Integrated logistic support is a process for the development of maintenance capability. Maintenance capability consists of the availability of a set of resources to satisfy approved maintenance requirements. Maintenance resources are tangible assets and include facilities, support & test equipment, technical documentation, trained personnel and spare parts (Wichers, 1996). The objective of an integrated logistic support process is to optimise the maintenance capability provided to support the operational requirement.

A maintenance plan is developed from the maintenance support concept and the results of the logistic support. The purpose of a maintenance support concept is to provide a system level description of maintenance and associated support that is properly integrated.

Wichers (1996) states that the maintenance support concept is used for:

- Regulating the maintenance environment;
- Orientating new personnel in the maintenance environment;
- Guiding the project environment when new equipment is purchased and installed to ensure supportability;
- Supporting strategic decision-making by providing a framework for assessing the impact of such decisions on maintenance and associated support.

Wichers (1996) goes on in stating that the maintenance and support policy should consist of the following concepts:

- Management concept, where the management of maintenance and support functions is of prime importance for the effectiveness thereof. The following issues should be discussed:
    - Management structure
    - Rules and responsibilities of each organisational entity
    - Management information systems
    - Management mechanisms and processes
- Maintenance concept that contains:
    - A maintenance approach:
        - Types of maintenance
        - Maintenance functions and flow diagrams
        - Maintenance responsibilities and locations
    - Maintenance engineering:
        - Identifying equipment groups
        - Development of an HBS
        - Executing maintenance analysis
        - Monitoring equipment history
- Manpower and personnel concept that define drives such as:
    - Geographical distribution of maintenance
    - Minimising of down-time
    - Multiskilling
- Training concept:
    - Theoretical training
    - Practical training
    - Continuation training
    - Ad-hoc training
- Supply support concept:
    - Spares distribution
    - Accounting
    - Spares and material determination

Establishing these support plans and concepts are crucial for developing maintenance strategies like RCM and TPM.

2.8.5 Plant level impact of functional failures (PLIOFF) method

PLIOFF is a variation of the well-known RCM II method. There are several good reasons to implement a PLIOFF analysis for your plant, but by far the most important reason is the following: maintenance as put together by the PLIOFF process follows the operational procedures and policies. Your plant`s operational policies and procedures are in some distinct ways different from, for example, a general world fossil or coal terminal procedure and policy. Maintenance optimisation is being done with your plant's specific operating methodology, procedures, policies, training and real-time operator response as the core guidelines. Omitting these inputs will not only result in a sub-optimised maintenance program, but can lead to unnecessary plant forced outages, reduced plant availability, possible high risk maintenance activities and shall not be accepted by plant personnel in general (Wichers, 1996).

Wichers (1996) gives the following brief overview of the PLIOFF process:

- Documenting of system functions:
    - Reviewing of design basis documentation
    - Using flow diagrams to see interfaces with other systems
    - All system functions should be identified
- Compiling sub-system functions:
    - Start by clearly indicating on the flow diagrams the sub-system boundaries, as it corresponds with the HBS.
    - Consider those functions that all or most of the components in the sub-system have in common. A sub-system should be created if components provide a flow path from one point to another, if all components contain the flow and if components work together to accomplish a complicated task.
    - Consider the sub-system boundaries and interfaces with other sub-systems and with other systems. If the interface is necessary to fulfil a system level function, a sub-system will be created.
    - Review system instrumentation and control courses to determine if the sub-system should be added.
    - Considering indication requirements where the loss of signal has an impact on the system function.
- Documenting the sub-system functional failures:
    - Each sub-system is analysed to determine the sub-system functional failures.
    - A function can have more than one functional failure.

- Effect and consequence of sub-system functional failure:
  - During this task, the ramification upon the following parameters should be considered:
    - Immediate and ultimate reactions of the plant automatic systems;
    - Immediate and ultimate plant operator reactions;
    - Limiting operational technical specifications;
    - Direct and indirect effect or damage upon the entire plant hardware, instrumentation and control;
    - Direct and indirect effect upon the probabilistic risk of the plant's core damage frequency;
    - Considerations to personnel safety;
    - Accessibility to component for repair;
    - Detectability of failure, and
    - Historical maintenance philosophy of failure.
- Evaluating the effect and consequence of the sub-system functional failures:
  - The inputs of the operator and system engineer are required. If a sub-system functional failure increases the risk of safety or result in production loss, the sub-system should be considered as a critical functional failure.

The following eight steps are a condensed view of the process described above:

- Step 1: Identify and group all component into functional groups (HBS).
- Step 2: Collect information from international and own databases. Identify and describe all systems and sub-systems functions. Document the impact on plant level of the unavailability of the sub-system functions.
- Step 3: Do an MSI selection process (cost and failure frequency related review).
- Step 4: Document the undesirable failure modes and other related information for each MSI, a process known as failure mode analysis.
- Step 5: Process all probable failure modes of every MSI through either RCM or work sessions with component experts.
- Step 6: Do task analysis whereby the various inputs from step 5 are converted into specific maintenance tasks.
- Step 7: Do a comparative check between proposed maintenance schedules, the current schedules, manufacturer recommendations and best practices from the industry.
- Step 8: Compile required documentation to support the new optimised maintenance task schedules.

The MEGKON training course, as explained in the previous paragraphs, will help the researcher develop a CMMS implementation- and sustainability guide. The next paragraph will briefly explain extra modules that form part of EAM systems.

2.9 EAM SYSTEMS

EAM and CMMS are both maintenance management software with many features that overlap. Since the CMMS - as a work order system - was developed first, many companies have already started using some sort of CMMS when the EAM was developed. Many companies stayed with the CMMS already being used and did not switch over to an EAM system. EAM includes a couple of features that, if possible, should be included into a company’s CMMS. An overview of the modules will be discussed below.

Warranty claim and tracking

Warranty claim and tracking has become a very important part of maintenance management. All the warranty information regarding the asset or sub-asset should be captured in this module when a new asset or sub asset is acquired.

This information includes - if the warranty needs to be registered with the vendor - special requirements for the warranty to be kept intact, as well as a countdown of warranty expiration in days to alert the user of the lapse of the warranty, should they want to apply for an extended warranty.

This module will also assist the user to determine if an asset with a warranty should be placed into production to fully utilise the warranty period. The asset taken out of production can be cleaned and kept as spare.

Energy monitoring

Energy monitoring falls in line with the fourth industrial revolution. With technological advances, many assets are being sold with the option to add monitoring devices directly onto machines. These devices include running-hours monitoring, cycle counters, temperature- and vibration monitoring, amperes-, voltage- and pressure readings and oil level monitoring.

The machines should communicate directly with the CMMS. The CMMS can then create work orders at predetermined running hours, or when a certain value exceeds the prescribed limit determined by the user. This will help the user with optimising its condition-based monitoring.

These two modules of EAM will definitely improve the functionality of any CMMS, but will not be included in the scope of this dissertation.

2.10 FOURTH INDUSTRIAL REVOLUTION

Skilton and Hovsepian (2018:4) state that the first industrial revolution refers to the period from the 1770s to the middle of the 1870s, when technological change enabled humanity to harness mechanical and electrical forces and that - as a result of these changes - many changes was seen in production and manufacturing methods where the first mechanical loom was built in 1784. They continue by stating that the second industrial revolution came at the end of the 19th century with the invention of electricity. Mass production and globalisation, that we recognise today, started in Cincinnati where the first assembly line designed had been installed in a slaughterhouse in 1870. Skilton and Hovsepian (2018:5) go on in saying that the first few decades of the 20th century saw the conflict of the world instigating the third industrial revolution of information systems and the automation of manufacturing and production. The first programmable logic controller was designed in 1969.

Figure 23 illustrates the major trends of change from the first to the fourth industrial revolution.

Source: Skilton and Hovsepian, 2017:6

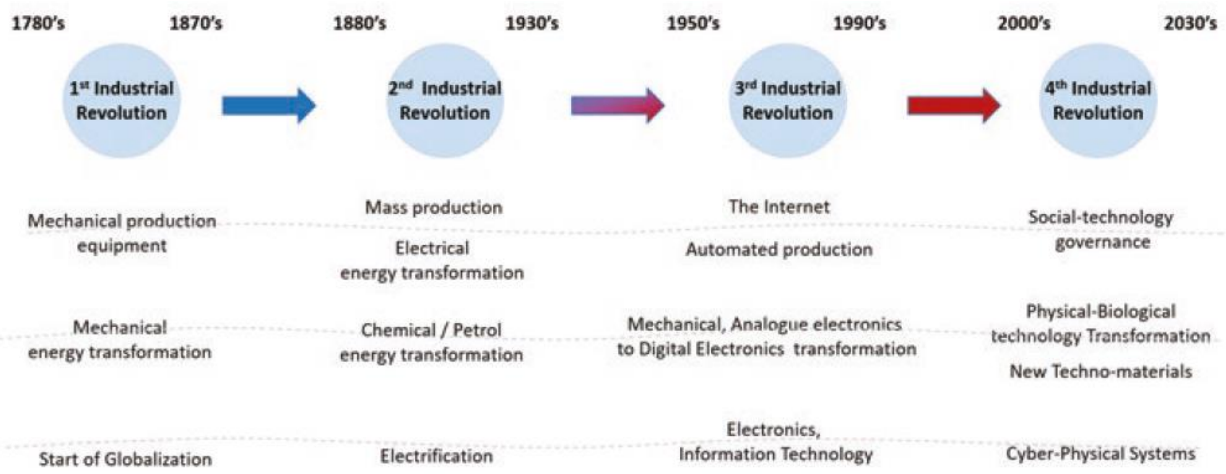

Figure 23: The four industrial revolutions

The fourth industrial revolution is described as a culmination of emerging technologies fusion into the physical and biological worlds the likes of which has not been seen before (Skilton & Hovsepian, 2018:9). IoT, cloud computing, big data and cyber-physical systems all form part of Industry 4.0.

The industrial internet of things (IIOT) includes a vast amount of disciplines such as energy production, manufacturing, agriculture, health care, retail, transportation, logistics, aviation, space travel and many more (Gilchrist, 2016:2).

Skilton and Hovsepian (2018:11) define the IIOT as the automation and communications network of smart embedded and external sensors and machines, representing an intelligent industrial factory and supply chain lifecycle. Sensor technology has improved dramatically over the last couple of decades, and the cost of these sensors has reduced dramatically. This paved the way for the industrial internet of things where sensors can be fitted to every asset to continuously monitor almost every aspect of the asset.

The huge amount of data or 'big data' that is collected from these sensors can only be effectively analysed by computers to reveal patterns or trends. The vast amount of information received from sensors mounted on assets helps predict - with better accuracy - potential failure times of assets.

Cyber-physical systems are defined by Skilton and Hovsepian (2018:12) as follows: It is a system that integrates cyber components (namely, sensing, computing and human users), connecting them to the internet and to each other. It is the tight conjoining of and coordination between computational and physical resources called a digital twin (the physical assets, components, energy, materials, interfaces), and the cyber representation of the physical system (the software, digital data, usage, sensors that enables higher capability, adaptability, scalability, resiliency, safety, security and usability).

The fourth industrial revolution, and more specifically the IIOT, will help maintenance managers to manage equipment more effectively. However, it will not help implementing this when the CMMS in use is not fully implemented and capable to analyse, give reports and create work orders from the information received.

2.11 SUMMARY

Maintenance has been part of our lives for many years. We can now theoretically maintain assets and have no downtime. The three main strategies show how maintenance has evolved over the years. The need for maintenance evolved not only to reduce the number of breakdowns of machines, but also to reduce the maintenance cost of machinery as a whole. The diagnostic techniques explained will, if used correctly, assist with the reduction of maintenance cost. It can however be noted that the wrong use will increase cost and will add no real value to the maintenance program.

The chapter continued to describe different maintenance models that will help the researcher create the implementation guide. The information will guide the researcher as to what is necessary for maintenance in an industrial concern. RCM, as discussed, will reduce the maintenance cost even further by focusing on the most important functions of maintenance and removing the action that are not strictly necessary. The development of TPM, where operators are given more responsibilities to try to solve maintenance issues, was introduced. TPM addresses six major losses that, if minimised, will improve the OEE of the machines.

A CMMS will help you to keep all the data generated by maintenance of equipment in an orderly manner. We are already part of the seventh generation of CMMSs, which make CMMSs even more accessible to companies to incorporate into the maintenance system. The modules inherent to a CMMS were explained. How these modules should use the information required for them to function, will be shown in the implementation guide in Chapter 5. The MEGKON training course gives you a good description of baseline information, HBS and systems engineering. The maintenance optimisation process, discussed in conjunction with the PLIOFF method, will be used to develop the guide in Chapter 5.

EAM is a program that incorporates the functions of a CMMS, ERP, material management and human resources into one complete program. The EAM falls out of the scope of this dissertation, but the two modules that were mentioned will be very useful if they can be added into the company's existing CMMS.

This chapter concluded by looking at the fourth industrial revolution. It is essential to recognise that the fourth industrial revolution will change the way we work forever. The remote monitoring of machinery will help you to plan preventative maintenance more effectively and only when necessary. Managers can also trust the information gathered by a CMMS to a greater extent, since it is not dependent on humans to gather the information.

Chapter 3 will discuss the research methodology of the study.

CHAPTER 3

3 RESEARCH METHODOLOGY

3.1 INTRODUCTION

The purpose of this chapter is to identify and describe the research methods followed to achieve the objectives. The chapter will by defining research. Research is about acquiring knowledge so that we can understand the world around us in a better way. General characteristics of research will be listed and different research paradigms will be explained. By understanding the different paradigms and certain assumptions made towards the dissertation, the chapter will continue to present case study research as the methodology that will be used.

The antepenultimate part of the chapter will discuss the research methodology which will consist of three sub paragraphs, namely philosophical assumptions, case study design as well as concerns about case studies. Case study research will be explained, showing the six activities that are used to conduct case study research. General concerns about case studies and ways to address these concerns will be looked at. This will help to show the relevance of using case study as the methodology for the dissertation.

The penultimate part of the chapter will discuss the data collection techniques used for the dissertation. It will then show four tests to construct validity and reliability that is important in case study research.

The chapter will conclude with a general discussion of ethics and the effect thereof on research. Four principles will be listed to be considered when doing research. Research that is done ethically will ensure trust in the dissertation and in the research profession as a whole.

3.2 RESEARCH DEFINED

Walliman (2011:15) states that research is about acquiring knowledge, developing understanding, collecting facts and interpreting them to build up a picture of the world around us, and even within us. Phophalia (2010:1) further describes it as the intellectual work undertaken with the purpose of advancing the frontiers of human knowledge and abilities. Phophalia (2010:2) further states that research transforms reality into a logical array of information, so that the reality may be comprehended and understood in a better way.

According to Nayak and Singh (2015:3), one approach to gain knowledge is through empiricism, which is the acquisition of knowledge through experience. Some general characteristics of research are as follows:

- It is an exact, systematic and accurate investigation;
- It is logical and objective;
- The researcher resists the temptation to seek only the data that supports his/her hypothesis;
- Conclusions and generalisations are arrived at carefully and cautiously.

Nayak and Singh (2015:4) assert that the main function of research is to improve research procedures through the refinement and extension of knowledge, and that the refinement of existing knowledge is essentially an intermediate step towards the improvement of research. The following three aspects are linked to improvement:

- research encourages scientific and inductive thinking;
- a function of research is to make a decision concerning the refinement or extension of knowledge;
- research also tries to solve various operational and planning problems.

From the above we see that developing an organisational implementation and sustainability guide will not only help Company A to reduce maintenance costs but can, with further studies, help other companies to achieve the same.

3.3 RESEARCH METHODOLOGY

Research starts with how the researcher perceives a specific phenomenon. How the researcher sees the phenomenon, leads to the paradigm that will be used, while the paradigm then leads to the methodology that the researcher will use.

3.3.1 Philosophical assumptions

Johannesson and Perjons (2014:167) state that a research paradigm is a set of commonly held beliefs and assumptions within a research community about ontological, epistemological and methodological concerns. Nayak and Singh (2015:1) continue by saying that the selection of research methodology depends on the paradigm that guides the research activity.

Nayak and Singh (2015:10) state that ontology is concerned with the nature of reality (or being or existence), and that different ontological positions reflect different prescriptions of what can be real and what not.

Johannesson and Perjons (2014:167) state that epistemology addresses questions about the ways in which people can know reality, i.e. how they can gain knowledge about the world. At the risk of oversimplification, ontology is about what can exist or what is real, while epistemology is about knowledge (Nayak & Singh, 2015:11). According to Johannesson and Perjons (2014:167), the two most established research paradigms in the area of information systems are positivism and interpretivism.

Johannesson and Perjons (2014:176-177) sum up positivism and interpretivism as follows:

Positivism is a research paradigm that:

- claims that objective knowledge about the social world is obtainable, but only through observation and experimentation;
- assumes that reality exists, independent of human actions and experiences;
- prefers experiments and surveys as research strategies.

Interpretivism is a research paradigm that:

- claims that researchers can only achieve a deep understanding of a social phenomenon by actively participating in that phenomenon together with the people who actually create it;
- assumes that the social world does not exist ‘out there’, independent of human action and intentions, but instead assumes that the social world is constructed by people who carry out social actions and give meaning to them;
- prefers case studies, action research and ethnography as research strategies.

From the above it can be deduced that positivism is grounded on deductive reasoning, and interpretivism is grounded on inductive reasoning. In the broader sense, Johannesson and Perjons (2014:61) state that quantitative research and qualitative research are two research paradigms, roughly corresponding to positivism and interpretivism respectively.

Venkatesh *et al.* (2013:37) state that “Pragmatism considers practical consequences and real effects to be vital components of meaning and truth. Although a quantitative approach is primarily based on deduction and a qualitative approach is based on induction, a pragmatic approach is based on abduction reasoning that moves back and forth between induction and deduction.” Pragmatism is seen as one of many ’mixed methods designs’ a researcher can use to conduct research.

The aim of this research is to create a CMMS implementation and sustainability guide for Company A for use to improve overall efficiency of the said company's maintenance system. A pragmatic approach will be followed, drawing on the strengths of both positivism and interpretivism.

To develop an implementation guide, quantitative data was collected as follows:

- A questionnaire will be done to understand what people consider the functions of a CMMS to be. It will help the researcher understand why CMMSs fail to be implemented.
- Financials will help the researcher investigate whether implementing the CMMS guide on some selected assets at Company A has helped in reducing the maintenance cost of Company A.
- Going through the company`s archives will help the researcher establish what all the requirements were when the CMMS has initially been implemented.

Qualitative data, collected by means of semi-structured interviews through the use of open questions, will ultimately help to develop a guide.

Finally, a research paradigm answers methodological questions about legitimate ways of investigating reality and how to confirm that the knowledge generated is valid (Johannesson & Perjons, 2014:167).

3.3.2 Case study

A case study approach has been decided on for this dissertation. Different authors have defined case studies differently. Johannesson and Perjons (2014:44) state that a case study focuses on one instance of a phenomenon to be investigated and it offers a rich, in-depth description and insight for that instance. Hays (2004:218) further states that case study research can involve the close examination of people, topics, issues, or programs.

Yin (1981:98) defines a case study as follows: A case study is an empirical inquiry that examines a contemporary phenomenon in its real-life context, especially when the boundaries between phenomenon and context are not evident.

Dooley (2002:338) states that case study research, like all other forms of research, must be concerned with issues such as methodological rigor, validity and reliability. The six activities distinguished by Yin (2009) when doing case study research will be discussed next.

Source: Yin, 2009:1

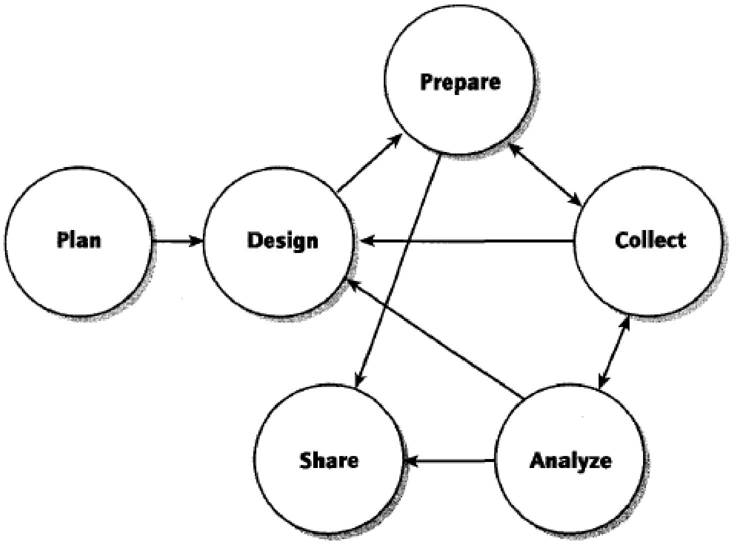

Figure 24: Doing case study research: A linear but iterative process

<u>The first activity is plan:</u> This will help with determining and defining research questions. In general, case studies are the preferred method when asking "how" or "why" questions (Yin, 2009:2). The question that guides this dissertation states: Can a guide be designed and implemented at Company A to ensure that implementation of a CMMS does not fail?

<u>The second activity is design:</u> A research design is the logic that links the data collected to the initial questions of study (Yin, 2009:24). Yin (2009:26-27) suggests five components for case studies research design that is important to help design rigorous and methodological case studies.

<u>Five components:</u>

The first step is to define the research question. According to Yin (2009:27), the case study strategy is most likely to be appropriate for "how" and "why" questions, so your initial task would be to precisely clarify the nature of your study question to be examined.

In the *second place*, study propositions direct attention to something that should be examined within the scope of the study (Yin, 2009:28). This dissertation has three propositions: The first proposition of the dissertation is that 'Old school' technical staff with lack of knowledge of what the proper use of a CMMS can mean for an organisation, is the main reason for failure of the CMMS.

The second proposition is that maintenance staff believes that the CMMS is a maintenance strategy itself and not an instrument to support the company's maintenance strategy. The third proposition of the dissertation is that staff turnover is one of the reasons for failure, as it takes between two to five years to successfully implement a CMMS.

The *third component* is the unit of analysis. Rowley (2002:19) states that the unit of analysis is the basis for the case and that it may be one of the following: (i) an individual person (such as a business leader, or someone who has had an experience of interest); (ii) an event (such as a decision, a programme, an implementation process or organisational change); (iii) or an organisation or team or department within the organisation. The unit of analysis will be the CMMS program of Company A, an implementation guide and the sustainability (organisational change) thereof.

The *fourth component* is the logic linking of data to propositions.

The *fifth component* is the criterion for interpreting the findings. A major and important alternative strategy is to identify and address rival explanations for your findings (Yin, 2009:34).

The third activity is preparing to collect case study evidence: Yin (2009:66) states that investigators need to feel comfortable in addressing procedural uncertainties during the course of the study. The researcher should also be able to ask good questions, to 'listen' and to know how to avoid bias.

The fourth activity is collecting of data: Four of the sources of case study data are documentation, interviews, participant-observation and direct observation. The dissertation will make use of documentation, interviews and direct observation by the researcher. Observational evidence is often useful in providing additional information about the topic being studied (Yin, 2009:110).

The fifth activity is analysing of data: The researcher now evaluates the data, using an array of interpretations to find all relations that may exist with reference to the research questions (Dooley, 2002:342).

The sixth activity is share: The goal of the report is to present the conclusion to the question posed by the research in a way that the reader can understand (Dooley, 2002:343). Regardless of the form of the report, similar steps underlie the case study composition, namely: identifying the audience for the report, developing its compositional structure and having drafts reviewed by other (Yin, 2009:164).

3.3.3 Addressing some of the concerns

Flyvbjerg (2006:219) lists common misunderstandings about case-study research. A couple of these misunderstandings will be discussed in this paragraph.

A common criticism of case studies is that their results only apply to the instance being studied, i.e. that the results cannot be generalised. To address such criticism, a case study researcher needs to clarify the extent to which an instance is representative of a class of similar instances. (Johannesson & Perjons, 2014:45). Hays (2004:219) agrees in saying that generalisation is possible when based on several studies of the same phenomenon. However, generalisation is not the main goal of case study research. Hays (2004:218) agrees and adds that discovering the uniqueness of each case is the main purpose. One can often generalise on the basis of a single case and the case study may be central to scientific development via generalisation as supplement or alternative to other methods. However, formal generalisation is overvalued as a source of scientific development, whereas 'the force of example' is underestimated (Flyvbjerg, 2006:230).

The next misunderstanding is that case studies are most useful for generating hypotheses in the first steps of the research process, and that other methods used later in the process are better for hypothesis-testing and theory-building (Flyvbjerg, 2006:231). With Flyvbjerg's view on the generalisation of case studies, we can now correct this misunderstanding and say that case studies can be useful for generating and testing of hypothesis, but is not limited to these research activities alone (Flyvbjerg, 2006:231).

Testing of hypotheses ultimately relates to case selection. Flyvbjerg (2006:34) identifies four cases for information-orientated selection strategy:

- Extreme cases are used to obtain information on unusual cases and are well suited for getting a point across in a dramatic way.
- Maximum variation cases are used to obtain information about the significance of various circumstances for case process and outcomes.
- Critical cases are used to achieve information that requires logical deductions.
- Paradigmatic cases that aim to develop a metaphor or establish a school for the domain that the case concerns.

Flyvbjerg (2006:235) mentioned that the various strategies of selection are not necessarily mutually exclusive. A case can be simultaneously extreme, critical and paradigmatic.

Another concern is that a case study contains a bias towards verification, that is, a tendency to confirm the researcher`s preconceived notions (Flyvbjerg, 2006:222). Flyvbjerg (2006:239) showed that case studies contain no more bias towards verification than any other method and that case studies have a greater bias towards falsification than towards verification.

The dissertation does not set out to design a guide that will help all companies ensure that the implementation of their CMMS does not fail, but rather an implementation- and sustainability guide for Company A.

3.4 DATA COLLECTION TECHNIQUES

Johannesson and Perjons (2014:55) suggest that collecting data about a phenomenon is the key activity in empirical research. Qualitative and quantitative data can be collected by various collection methods. Six sources of evidence in case studies, according to Yin (2009:99), are documentation, archival records, interviews, direct observation, participant-observation and physical artefacts. Yin (2009:114) notes that not all sources will be relevant for all case studies, but Johannesson and Perjons (2014:55) highlight that employing several methods will improve the accuracy of data and broaden the picture.

As highlighted in Chapter 1, quantitative and qualitative data will be collected for this case study, which is an empirical study. Quantitative data will be collected by means of a questionnaire, financials and archival records, while qualitative data will be collected by means of semi-structured interviews with staff, using the CMMS at Company A.

3.4.1 Quantitative data

3.4.1.1 Archives

Quantitative data will be collected by going through the company`s archives to establish what all the requirements were when the CMMS was initially implemented. The research will also show if all the requirements set out for the CMMS have been met.

3.4.1.2 Questionnaires

A questionnaire is a written document that includes a list of questions to be distributed to a number of respondents (Johannesson & Perjons, 2014:55). The questionnaire will use closed questions to gain background information on the users of the Microsoft Dynamics Navision system. Open questions will be asked about the program being used to help the researcher understand what the respondents' views and opinions are towards the CMMS program at Company A. Open questions about the functions of a CMMS will also be asked.

3.4.1.3 Financial data

The researcher will highlight three case studies within Company A where unnecessary maintenance cost was incurred due to lack of data on the CMMS. The guide will be implemented on some selected assets and financial data will be gathered to help the researcher identify if the implementation of the CMMS guide at Company A helped to reduce their maintenance cost.

3.4.2 Qualitative data

3.4.2.1 Semi-structured interview

One of the most important sources of case study information is the interview (Yin, 2009:106). For this dissertation, the semi-structured interview will be used to give more insight into the quantitative data collected. According to Johannesson and Perjons (2014:57), interviews are also suitable for getting a researcher into contact with people who have access to privileged information. The researcher will conduct semi-structured interviews to help him understand management's view about a CMMS and the application thereof at Company A.

Different authors have different views on the number of types of interviews that can be used. The researcher must ultimately decide which interview approach to use. Yin (2009:106-109) discusses three interview types of case studies that will be subsequently explained.

The first type of interview is an in-depth interview where you can ask respondents questions about facts of a matter, as well as their opinions thereof. Yin further states that the interview can take place over an extended period of time. This is when the respondent gives his or her own opinions about a certain occurrence, which probes different questions on a matter. The interviewee can also suggest other sources of evidence. The more the interviewee assists in this manner, the more that role may be considered one of an 'informant' rather than a respondent.

The second type of interview is the focused interview. This is when a person is interviewed for a short period of time. This interview is open-ended and assumes a conversational manner, while a certain set of questions are still likely to be followed. A focused interview can be viewed as a semi-structured interview. Johannesson and Perjons (2014:57) state that a semi-structured interview is also based on questions, but they can be discussed in a flexible order, and they are open. A major purpose of such an interview could be to corroborate certain facts you consider to have been established already (Yin, 2009:107). Fresh commentary about a topic will be received, with carefully worded questions that make the researcher seem to be genuinely naive about the topic.

The third type of interview entails more structured questions along the lines of a formal survey (Yin, 2009:108). This type takes on the format of a structured interview that follows a predefined protocol and is similar to a questionnaire, as it builds on a fixed list of questions that can be answered by choosing from a predetermined set of allowed responses (Johannesson & Perjons, 2014:57).

The researcher will use semi-structured interviews to help determine management's level of understanding of the CMMS, as well as that of the users thereof. The semi-structured interview will be open-ended, guided only by a set of questions in an attempt to corroborate certain facts obtained by the questionnaire.

3.4.3 Validity and reliability

Yin (2009:45) states that four tests may be relevant to judge the quality of a research design, and that various tactics are available to deal with these tests. These tactics can be used during the formal stage of designing the dissertation, while other tactics will occur during data collection and data analysis.

Four tests have commonly been used to establish the quality of any empirical social research (Yin, 2009:40). Case studies are one form of social research and that is why the four tests are also relevant to case studies. The four tests will be explained briefly.

Construct validity: One of the tactics to construct validity for this case study will be to use multiple sources of evidence. The use of multiple sources of evidence in case studies allows an investigator to address a broader range of historical and behavioural issues (Yin, 2009:115).

Internal validity: Rowley (2002:20) states that internal validity is more for casual or explanatory studies and not for descriptive or exploratory studies.

External validity: According to Rowley (2002:20), external validity is when the researcher establishes the domain to which a study's findings can be generalised.

Reliability: Yin (2009:45) explains that the objective of reliability is to ensure that, if future investigators follow the same procedures as described by the earlier investigator, the later investigators will arrive at the same findings and conclusions. Documentation of procedures followed is crucial for the repeating of the case.

3.4.4 Validity of case study at Company A

To help ensure validity, multiple sources of evidence will be used to help identify if the CMMS at Company A is used to its full potential. The first four activities suggested by Yin (refer paragraph 3.3.2) for case studies will culminate in Chapter 4. The results from the questionnaire and interviews will help to establish whether the propositions made by the researcher are true or false. The quantitative data and results from the semi-interviews will be discussed in Chapter 4.

Analysing the data (fifth activity suggested by Yin) in Chapter 4 will assist the researcher to develop an implementation guide for Company A, helping them to fully utilise their CMMS and to implement RCM and TPM. The guide will be discussed in Chapter 5.

Part of the validity of the dissertation is also the sixth activity proposed by Yin and Dooley (refer paragraph 3.3.2). The guides developed in Chapters 5 and 6 will be presented to the management of Company A. The purpose of the presentation will be to show the implementation guide that has been developed, and what steps from management level to workshop level would be necessary to ensure sustainability of the guide. Any feedback received from management will be incorporated into Chapter 6.

3.5 ETHICS

The awareness of ethical concerns in research is reflected in the growth of relevant literature and in the appearance of regulatory codes of research practice, formulated by various agencies and professional bodies (Cohen *et al.*, 2011:75).

Cohen *et al.* (2011:85) mention that when doing research, first of all no harm should be done, i.e. research should not damage the participants in any way. The following list by Johannesson and Perjons (2014:181-183) shows four principles that put ethical constraints on research:

- Protect the interest of participants;
- Ensure that participation is voluntary and based on informed consent;
- Operate openly and honestly, and
- Comply with laws.

All investigators, from undergraduates pursuing a course-based research project to professional researchers striving at the frontiers of knowledge, must take cognizance of the ethical codes and regulations governing their practice (Cohen *et al.*, 2011:98). Cohen *et al.* (2011:98) go on in stating that failure to meet these responsibilities on the part of researchers is perceived as undermining the entire scientific process and may lead to legal and financial penalties and liabilities for individuals and institutions.

3.6 SUMMARY

Research is about acquiring knowledge to better understand the world around us, and enabling us to improve research procedures through refinement of existing knowledge. All research starts with philosophical assumptions made by the researcher and how he/she sees the phenomenon that has led to the paradigm the researcher will be using. A pragmatic paradigm will be followed, drawing on both the strengths of positivism and of interpretivism. Pragmatism considers practical consequences and real effects to be vital components of meaning and truth (refer paragraph 3.3.1).

Various methods can be used to collect research data. For this dissertation a pragmatic approach, which is a combination of quantitative and qualitative research, will be followed. Quantitative data will be collected by means of a questionnaire and by going through archive records and financial data obtained by implementing the guide on some selected assets. Qualitative data will be collected by means of a semi-structured interview. The semi-structured interview will also help to determine management's and the users' level of understanding of the CMMS.

A case study approach will be followed in the dissertation. The six activities for case study research, distinguished by Yin, were discussed to help the researcher design and execute the case study. More emphases was placed on the design activity with regard to a case study. Three concerns about case studies, and how to address such criticism, were discussed.

The dissertation will be done in the field of development and management engineering. Research loses its value if done without rigor. Methods were discussed to address validity and reliability in case studies. To ensure that the research is valid, multiple sources of evidence will be used to collect data. To ensure reliability of the dissertation, documentation of procedures followed will be done so that repeating of the case might be possible.

Certain ethical standards will be applied in the dissertation to help the dissertation not lose any value. Four basic principles that normally puts ethical constraints on research were listed. All potential participants in the research will be informed before they participate on how the information gathered from them will be used. The slaughtering process of the animals will not be changed or altered in any way by implementing the CMMS guide. There will also be no environmental change by implementing the guide.

Chapter 4 will analyse and discuss the quantitative and qualitative data gathered.

CHAPTER 4

4 ANALYSES OF QUANTITATIVE- AND QUALITITATIVE DATA

4.1 INTRODUCTION

Analysing of data collected is the fifth activity described by Yin and Dooley (refer paragraph 3.3.2). This chapter will analyse and discuss the data collected by the researcher.

The first part will discuss the data collected by the researcher about the history and the implementation of the CMMS of Company A.

The second part will analyse the results of the questionnaire that focused on gathering background information on the users of Microsoft Dynamics Navision and the users' views and opinions about the program. The analysis starts with a formulation of the participant's profile that will be covered in Questions 1 to 4. The analysis continues with the participants' views on the ease of use of the program that they are using (Question 7, 8, 13, 15, 16). The analysis continues by gathering the participants' views and opinions on what they think the function of a CMMS is, and the opinions on the different modules that are used in the CMMS (Question 9, 14, 17-21). Reasons for implementation failure of a CMMS is outlined next (Question 11 and 12) and will be followed by the views on reporting (Question 10 and 22). The section concludes with an overview of training and support received by the participants (Question 5, 6, 23-25).

The questionnaire can be seen in Appendix L and the graphical representation of the feedback received by participants in Appendix M. The researcher took part through direct observation where he took time to observe the user using the functions of the CMMS.

The third part will show three case studies where Company A incurred unnecessary maintenance cost due to lack of data on the CMMS. The third part continues with the analyses and discussion of results obtained by implementing the guide developed in Chapter 5 on some selected assets.

The chapter will continue by discussing the field notes taken during the semi-structured interview.

The summary at the end of the chapter will aim to link the propositions of the dissertation to the data collected by the questionnaire and the semi-structured interview.

4.2 ARCHIVES

Going through the archives at Company A, no evidence could be found that a list of requirements was given to the vendor of the system before it was implemented. The maintenance dashboard had only basic functions and generic reports available for use. Little to no extra development concerning the maintenance has been done on the system. Further investigation revealed that no flow-diagram was available for the CMMS, and that one needed to be developed.

The research showed that the first work order was opened in 2005, and the first PMO in 2008. The gap between the first work order and the first PMO also indicates that the program was only partially implemented. If the system has been fully implemented, the two would have at least been created in the same year.

Taking the above into consideration, the researcher could still not accurately determine if all the requirements have been achieved, as he did not know what the requirements were in the beginning. The requirements can range from only supplying a base package, to supplying a fully functional program and anything in-between.

4.3 QUESTIONNAIRE RESULTS

This paragraph will discuss the results obtained from the questionnaire that was circulated to the participants. The questionnaire results are grouped into six sections that will be discussed separately in the following sub-paragraphs.

4.3.1 Participants

Only six employees within Company A were requested to participate. The participants represent various departments within the company. Three of the participants are an integral part of the engineering and planning team, and the others are part of the financial-, procurement (Stores) and IT departments respectably.

Portfolio questions of the participants show that the participants are between the ages of 30 and 60, where half of them are between 45 and 60. The number of years experience on the program corresponds with this, where only half of the respondents have between 1 and 10 years experience using a CMMS, and the rest between 11 and 20 years. It can be seen that 83% of the participants used the program on a daily basis. This corresponds with the amount of hours per day spent using the program, where 83% of participants used the program for more than half of their normal working day.

From the portfolio it can be seen that the participants had a number of years' experience using the company's CMMS. It can be deduced that the views and opinions by these participants will paint an accurate picture of the company's CMMS.

4.3.2 Ease of use of the program

Question 7: The participants were required to indicate their rating (poor, below average, average, above average, excellent) on how user friendly the program is. The response showed that 67% of the participants indicated that the program is average and the rest rated it as above average.

Question 8: The participants were asked how difficult (very easy, easy, somewhat easy, somewhat difficult, difficult, very difficult) it is to use the program. A third of the participants viewed the program as somewhat difficult to use, while the rest were in agreement that it is easy to use - with half of these saying it is 'somewhat easy' and the other half saying it is 'very easy'. Combining Question 7 and 8, you can see that the program is user friendly and easy to use, but there is still some difficulty in using the program. If a program is difficult to use and only rated average on how user-friendly it is, data that should be captured into the system may get lost as the user does not know where or how to capture the data in the correct field. This will lead to reports that will still be lacking the correct information needed to make proper decisions.

Question 13: The participants were asked what could be added to the existing program to improve its effectiveness. Only two thirds of the participants answered the question. The feedback received is that the reporting of the program needed to be improved in general. The reporting may not improve if the correct data is not captured, as mentioned under the previous question. The next improvement mentioned by the participants is that the system needed to be an in-time system where all the modules are linked in real time and that assets needed to be linked to stock items in the stores. Links between different modules are crucial in using a CMMS to its full potential. One participant made a comment that nothing can be added to the current program. It can be argued that the participant might not be experienced enough to give informed feedback on the question. It could also be argued that the participant felt that the program has everything she or he needs for the part of the program she or he is using.

Question 15: The participants were asked whether they feel that the program is used to its full potential. All the participants agreed that the program was not used to its full potential. This shows that the participants, whether experienced or not, know that the program is not used to its full potential and might not know what is needed from them to fully utilise the program at their disposal.

Question 16: The participants were asked whether a guide explaining the importance of different modules of a CMMS would help with the implementation of the CMMS. 83% of the participants were in agreement that a guide would most likely help with the implementation of a CMMS, while it is recorded that 17% felt it to be ‘extremely likely’, 50% ‘very likely’ and 17% ‘somewhat likely’. The rest of the participants felt that it was not at all likely that a guide would help with the implementation of a CMMS. It might be that the participant felt that, if there was a guide available, it would still not help with implementing the CMMS. Even with the small percentage that believed a guide would not help at all, participants agreed in general that a guide would help with the implementation of a CMMS.

4.3.3 Views and opinions towards the program and modules

Question 9: The participants were asked which sentence best described a CMMS. It can be seen that 83% of participants knew that a CMMS is a tool to support existing maintenance strategies. Only one participant stated that it is a maintenance strategy itself. The participants were in agreement that it is only a tool to support maintenance strategies. However, from direct observation by the researcher, not all the relevant data is captured into the system for the CMMS to be a tool that supports maintenance. The participants might know the purpose of a CMMS, but they did not know what was needed from them as users of a CMMS.

Question 14: This question requested the participants to rate the significance of the modules of a CMMS for the successful use of a CMMS. The questionnaire results indicated that 83% of the participants placed a high significance on the equipment module for listing of assets, where 66% of the participants rated it as very high. It can be seen that, when implementing a CMMS, more time should be spent on how to register an asset - and especially what information should be recorded for the particular asset.

From the results of the questionnaire, it can be argued that 100% of the participants were in agreement that the operation location of assets has a high significance for the successful use of a CMMS. Operating locations help with the logical hierarchy of network systems. The operating locations of assets help with a parent-child link between assets. It can be argued that the participants viewed this as important to help with creating work orders.

With regard to the resources module, it can be seen that 83% of the participants were in agreement by placing a high significance on this module for the successful use of a CMMS. It is important that this module should be used correctly to ensure that all the possible man-hours available for planning of jobs are used, and that no time is wasted or not fully utilised.

This module becomes especially important when specialised jobs need to be planned, and the correct training or skills are necessary for the successful completion of the work order in time.

The respondents' views on inventory control were the same as their views for the resource module, where 83% of participants were in agreement that the module has a high significance on the successful use of a CMMS. This module is responsible for making sure that spares are always available for maintenance of machines. Spares are necessary to keep the machines running at optimum efficiency with no production down-time.

The participants' views and opinion on the safety plan module were evenly spread, with a 33% distribution to significant, high significance and highest significance.

The participants were in agreement that the purchasing module for purchasing of stock items for asset numbers plays a huge role in the successful use of the CMMS. The importance of the purchasing is in line with the importance of the inventory module. These two modules work closely together to have enough spares on hand for maintenance.

The participants were in agreement, by 83%, that the work orders is very important for the success of a CMMS. 50% rated it at the highest significance, while 33% rated it high. An effective work order system is very important for sound asset management. It can be argued that 83% of the participants knew that this module should work flawlessly for a CMMS to be used successfully.

It is clear from the questionnaire results that all participants had the same view on the preventative maintenance module, as 50% of participants rated it at the highest significance and the rest rated it at high significance.

Question 17: This question asked whether the participant felt that the maintenance function gets lost in an ERP system. The response received back is that 83% of the participants did feel that the maintenance function gets lost in an ERP system. It can be argued that the one participant that felt that the functions do not get lost, either does not have enough experience and did not know enough about the maintenance functions to make an informed decision, or that only one participant knew the program well enough to know that the functions do not get lost and the rest of the participants did not.

Question 18 and Question 19: Following Question 14, where the participants were asked to rate the significance of the different modules, Question 18 asked which modules, in the opinion of the participant, is not up to standard. The overall agreement by the participants was that the modules are not up to standard. The views on the different modules will be analysed separately. Question 19 asked what could be added to the different modules. These answers will be incorporated into the analysis.

The views amongst the participants regarding the equipment module were evenly spread out between ‘up to standard’, ‘adequate’ and ‘not up to standard’. It can be argued that participants from the different disciplines had different views on this module and that some might feel it to be adequate, and others not. Participants felt that the layout of reporting on assets should improve in general, and that more data should be included in the original registration of an asset. The researcher is of the same opinion, namely that if more information is captured into the system from the beginning, the equipment module would be of more use to the users.

The second view about the standard of the operation location module is a bit different, where 50% of the participants felt that the module is not up to standard, and 33% felt it to be adequate. Only one participant felt that it is up to standard. It can be argued that the reason for this rating is that the parent-child relationship is not built into the current program and maintenance cost cannot be rolled up from one level to other levels in the hierarchy.

Regarding the third view on the resources module, the participants felt the same about it as about the operation location module. The reason - can be argued – is that not all the relevant information about resources is available for proper planning of work cards.

The fourth view about inventory control shows that 66% of the participants agreed that the module is not up to standard, and 34% regarded it as adequate. Through direct observation by the researcher, he feels that the view about the inventory module is mainly because no links are available between assets and stock items. The participants might have encountered problems where items were bought on special requests, only to find out later that the item is a stock item in the stores.

The fifth view is about the safety plans module. 50% of the participants were in agreement that this module is not up to standard. The rest of the participants were divided into 33%, saying it is adequate, and 17% that it is up to standard. It can be argued that the participants that form part of the engineering team felt that the safety module is not up to standard because they encounter the shortcomings of the module more frequently that the other participants.

The sixth view on the purchasing module reveals that the participants felt more comfortable that the module is up to standard, where only 33% of the participants viewed it as not up to standard; 33% viewed it as adequate, and the rest were in agreement that the module is up to standard. The views of the participants were that the inventory module is not up to standard, and this could give a false sense that the purchasing module is not working correctly. If the inventory module is brought up to standard, it may be seen that the view on the purchasing module could change.

The seventh and eighth view regarding the work order- and preventative maintenance module is the same, where 34% of the participants were in agreement that the modules are up to standard, 33% agreed that the module is adequate and the rest saying it is not up to standard. The reason for the similar views regarding the two different modules could be that the participants viewed these two modules to go hand in hand with each other. If the work order module is not up to standard, the preventative maintenance module will suffer.

Question 20: In this question, participants were asked if external maintenance orders are managed properly. The feedback received back from the participants was 50% ‘yes’ and 50% ‘no’. The participants were asked to give a reason for answering no. Two reasons were received from participants who answered no. One reason was that, up until recently, the external maintenance orders were not used correctly and the other reason was that there is no quality control in place for external maintenance orders.

Question 21: Participants were asked if rotable spares are managed properly. 66% of the participants felt that it is not managed properly, where they felt that there is no traceability of these spares and that satellite stores are not managed properly. Rotable spares are insurance-like assets to keep the plant running at full production without breakdown. The feedback received from the participants warrants a deeper look into rotable spares and how it can be managed properly – by using a CMMS.

4.3.4 Implementation failure

The participants were required to rate the impact that different reasons had on the implementation failure of a CMMS. They were also required to rate the importance that the different reasons had for the successful implementation of a CMMS. Several reasons for implementation failure were mentioned under Question 11, and the reasons were rated by the impact the reasons had: ‘no impact’, ‘smallest impact’, ‘small impact’, ‘big impact’ and ‘biggest impact’.

Question 11: Participants were requested to rate the impact that the following reasons could have on CMMS implementation failure. 83% of the participants were in agreement that *partial implementation* has a big impact on the successful implementation of a CMMS, whereas 17% believed it has the biggest impact and 66% felt it has a big impact. Partial implementation of a CMMS, or anything else for that matter, will never yield good results. Partial implementation will lead to the system only being used less and less, because the user may feel that the information or reports received from the system are not helping as they felt it should. Less data is then captured into the system and the reports will only get worse.

The participants were in 100% agreement that *poor planning* has a big impact on implementation failure of a CMMS. Insufficient manpower, as a result of poor planning, can lead to the system not being implemented fully. Manpower is needed to retrieve information to be captured into the CMMS. Part of the initial planning in implementing a CMMS is to get everyone involved from shop floor level to top management to implement the CMMS.

A large percentage of participants, namely 83%, indicated that *incorrect training* leads to implementation failure. Training on what a CMMS is and how to use the system is very important for correct implementation. If people are not trained on what data needs to be captured into a CMMS or how to use the system, the system will fail to serve its purpose.

Fifty percent (50%) of the participants were of the view that *overloading of staff* when implementing a CMMS has a big impact, while the responses of the rest of the participants are evenly spread out between ‘no impact’, ‘smallest impact’ and ‘small impact’. It can be argued that half of the participants that participated in the questionnaire forms part of the engineering team and will thus be more involved in the CMMS - thus feeling the impact of staff overloading more than the other participants. This is only an assumption made by the researcher.

A split decision was arrived at regarding *work culture* as a reason for implementation failure. 50% of the participants were in agreement that it has little impact, and 50% were in agreement that is has a big impact. 17% and 33% rated work culture having no impact and smallest impact, and 17% and 33% rated the impact as ‘big’ and ‘biggest’ respectively. The participants might feel that - on the one hand - work culture could have a big impact, as people are sometimes reluctant to change, especially people using the program for many years. Even with correct training and planning, the system will still not yield correct results due to the fact that the people using the program is not using it as they should.

It can be seen from the results that the participants were in 83% agreement that *insufficient data* has the biggest impact on implementation failure, where 50% rated it as the biggest impact and 33% as having big impact. In can be argued that one participant was not as involved in the CMMS as the other participants to give an informed opinion.

Eighty-three percent (83%) agreed that *staff turnover* can have a big impact on implementation failure. The reason for such a high rating could be that the participants might have felt that the procedures in place to keep the system working, when one or two people leave the company or retire, can have an adverse effect on using the CMMS correctly or to its full potential.

Question 12: Participants were requested to rate the importance that different reasons have on successful implementation. The scoring system used for Question 12 worked in the way that the reason with the lowest score would be seen as the most important factor, and the reason with the highest score as the least important factor.

The views were as follows:

- Correct implementation is most important, with a score of 7
- Planning is second most important, with a score of 17
- Training and data gathering is tied third, with a score of 18
- Staff needed is fourth with a score of 31
- Work culture is fifth with a score of 35

4.3.5 Reporting

Question 10: Reporting is one of the tools utilised in a maintenance management program. This question asked the participants about the reports currently generated by the CMMS for review by management. The reports mentioned in the question are, in the opinion of the researcher, crucial for effective maintenance management. From the result, it can be argued that the program currently generates at least two reports. The two reports are a report showing the percentage of emergency maintenance to planned maintenance, and a summary of maintenance cost by work performed. Only one participant had knowledge of two other reports, namely a report showing the percentage of repeat jobs and projects rejects, and a monthly report that includes downtime of all critical and major equipment. It can be argued that the reports, as indicated by one participant, do not exist or that only she or he knew about these reports. Hierarchy levels are not present in the current program and assets are not labelled as ‘critical’ or ‘major’ equipment.

Question 22: The question was: Should the CMMS make recommendations to management after reviewing breakdown trends and cost incurred? There was an agreement of 100% that this should be the case, 50% of which ‘strongly agreed’ and 50% ‘agreed’.

4.3.6 Training and support

Question 5: This question asked the participant to rate the training they received on how to use the CMMS. 33% of the participants stated that they received no training on how to use the program. 50% viewed the training as average, and 17% as below average. The reason for not using a CMMS to its full potential can be attributed to the fact that a third of the participants in the questionnaire had not even received training. Training tells you what functions can be used and where all the relevant information should be captured. If the user does not know this, the CMMS will fail and the user will be none the wiser.

Question 6: Responses to Question 6 showed that all the participants agreed that support for the program is always available. This does not correspond with Question 5 for the fact that, if support is always available, why had a third not received training at all.

Question 23: The participants were asked on how often training on the uses of the program should take place. 83% of them were in agreement that the training should be annually. Annual training will certainly help with keeping the CMMS working effectively. It gives the user enough time to use the program, while having support available, and to refresh their knowledge every year.

Question 24: The participants were asked which module, in their opinion training, should be focussed on. A general observation from the answers showed that the participants viewed all the modules as ‘medium’ to ‘high priority’. Not one rating of ‘no priority’ was given to any of the modules by any participant. The equipment module is evenly spread between ‘high priority’, ‘medium priority’ and ‘low priority’.

The participants were, by 67%, in agreement that operating locations should enjoy a medium priority when it comes to training of modules. Half of the participants rated it as a medium priority and one rated it as a high priority. 33% of the participants rated it a low priority.

Eighty-three percent (83%) of the participants were in agreement that resource information should be rated as medium priority, where 50% rated it as ‘high priority’, 33 % as ‘medium priority’ and 17% as ‘low priority’. The reason for the high priority rating by the participants could be that they felt that, if the module is used correctly within the CMMS, planning of jobs would be much easier and that the time to complete jobs would reduce drastically if resources with the correct experience and skills are used for certain jobs.

All the participants were in agreement that training on the inventory control module should have a high priority. 83% of participants rated it as a high priority, and 17% as a medium priority. The reason that the participants felt this module should have a high priority, could be just the basic understanding that maintenance of assets cannot be done without spares. Spares in the inventory module is not only restricted to spares for assets, it can also be for packaging material for finished products, like bags and boxes.

Safety plans and the purchasing module received the same rating from the participants. They were in agreement, by 83%, that the modules should receive a medium priority - with 33% rating it as a high priority, 50% as a medium priority and 17% as a low priority. The safety plan module is there to help management comply with all the relevant health and safety standards and inspections. It makes sense placing such a high priority on the safety module.

Work orders received an overall high priority rating by participants. 66% rated it as a high priority, 17% as a medium priority and 17% as low priority. The high priority could mean that the participants felt that the work order system needs to be managed properly so that the correct data can be captured back into the CMMS. Without the work order system, managing all the tasks will be a daunting job for the planned maintenance office.

The rating of the preventative maintenance order is split into 50% for ‘high priority’ and 50% for ‘medium priority’. The high rating here could be that the participants felt that the correct use of all the functions of this module would help reduce downtime and improve overall equipment efficiency.

Question 25: The participants were asked if regular training would help with the sustainability of the CMMS program. All the participants were in agreement that it would definitely help with the sustainability - 50% ‘strongly agreed’ and 50% ‘agreed’. With such a good response, one can see that training should be made a priority by companies who have a CMMS.

4.4 FINANCIAL DATA

This paragraph will consist of two sections. The first section will show three case studies where unnecessary maintenance costs were incurred by Company A, due to lack of data and partial implementation of the CMMS. The second section will discuss results obtained from implementing the guide developed in Chapter 5 on some selected assets. The results will show whether there was a decrease in maintenance costs.

4.4.1 Case studies

Pre breaker: Company A uses a pre beaker to reduce the size of bones and fat down to a particle size of 50mm. The pre breaker was underperforming as it did not have the throughput stated in the manual and was prone to bearing failure. An investigation into the bearing failures led to the discovery that, although the hammers used for assembling the pre-breaker shaft were marked, they were wrongly marked and thus always assembled in the wrong order. This in turn led to another discovery, namely that there was no assembly drawing of the pre breaker available for perusal by artisans. Two birds were struck with one stone in the sense that, as soon as the artisans assembled the pre-breaker shaft correctly, the throughput of the machine increased dramatically and the bearing life was extended.

Screw press: Company A uses a screw press to extract tallow from rendered bones and fat (cracklings). The screw shaft pushes these rendered cracklings towards a choke, thus increasing the pressure inside the barrel cage. The tallow is then pressed through small openings between the barrel bars in the barrel cage and a dry cake is formed.

In 2014 an investigation into the maintenance cost of the screw press showed that the screw shaft, barrel cage and barrel bars have been changed ten times since 2010. The specifications available in the instruction manual indicated a functional failure of the machine, as the amount of overhauls done on the shaft and barrel cage did not align with the amount of product produced.

At first, the investigation showed nothing out of the ordinary, as the screw shaft and barrel cage were seemingly assembled correctly. However, further investigation into the spares used to assemble the barrel cage showed that not enough information was available for the artisans' perusal regarding the specification of the bolts that must be used when assembling the barrel cage. The lack of data about the ultimate tensile strength of the bolts that must be used when assembling the barrel cage caused the artisans to use any bolt that was available. The correct torque could thus not be applied to the bolts to keep the barrel bars in place - causing the barrel bars to come lose under the pressure inside the barrel cage and prematurely damaging the flights on the screw shaft and barrel bars.

A work instruction that included step-by-step instructions and the exact spares to use when overhauling the barrel cage, was compiled. Training was given to the artisans and artisan aids on the specific work instruction.

In the period 2015 to 2019 the screw shaft, barrel cage and barrel bars have only been changed six times, which is more in line with the product that was produced. The maintenance cost saving of about 40% for this period in relation to the previous period, was noted.

Hammer mill: Company A uses a hammer mill to reduce the size of materials at their onsite rendering facility. Product falls from a receiving hopper directly into the hammer mill chamber, hitting the rotating hammers. The force exerted by the hammers exceeds the rupture force of the particles and is reduced. A perforated screen inside the hammer mill helps in the further reducing of the particles. A hammer has four cutting edges. As the hammers wear, they are rotated to a new cutting edge until they are eventually changed. The process of changing to a new cutting edge or changing the hammers takes nine hours.

Between 2014 and 2016, the hammer mill had an unusual spike in maintenance cost. A breakdown of the financials showed that the hammers were changed 13 times in that period. Further investigation into the spike revealed that the stores changed the vendor of the hammers. Their decision was based on cost alone, as the new vendor supplied hammers at a much better price. The better price was, however, due to the fact that the new vendor supplied standard hammers and not hard-faced hammers.

The datasheet for the hammers was added to the inventory item card, but unnecessary maintenance cost had already been incurred. During the period 2017-2019, the hammers were only changed four times. The maintenance cost saving of about 65%, for this period in relation to the previous period, was noted.

This case study shows that, if the technical information for the hammers had been available on the system, the stores could have sent the correct technical specification through to be quoted on. The process has however been changed so that the maintenance manager will always be involved with any changes regarding the engineering spares of assets in the stores.

From the case studies mentioned above one can clearly deduce that, had there been enough data available on the system, unnecessary maintenance cost would have been avoided.

4.4.2 Guide implemented on some selected assets

This section will analyse and discuss data obtained from implementing the guide, as in Chapter 5, on assets at Company A. Two periods of six months each will be analysed, one from using data prior to implementing the guide and the second after the guide has been implemented.

The guide was implemented on 20 assets in two different departments. Baseline data was collected for the assets and the manuals obtained were used to see if the preventative maintenance orders were in line with the recommendations of the original equipment manufacturer (OEM). It was found that the assets were over-maintained and that the logic behind the preventative maintenance orders was to do as much as can be done every month, and not what was specified in the manual.

The preventative maintenance orders for these twenty assets were revised using the manuals obtained, production data and the little historical data of the asset available on the system. A combined reduction of 54% in the amount of man-hours spent on preventative maintenance orders were noted between the two periods for the 20 assets. This is mainly because of the removal of maintenance actions that were not strictly necessary, but also by incorporating the production data from the first period for the asset. The production data showed that not all machines can be treated equally; for example, one conveyor might not have moved as much product as another. The financial statements also showed a 43% reduction between the two periods. It must, however, be noted that the two periods fell in different financial years and the direct unit cost of the resources was adjusted from the one year to the next. This still gives a 48.5% reduction in the maintenance cost between the two periods.

Machines rarely work 24 hours per day and almost never the same amount of hours per day. Another saving was introduced by capturing the machine hours into the system. This led to preventative maintenance only being done when the hours have actually been reached. The previous method used was to calculate the number of days until the next service by taking the hour interval until the next service, and dividing it by 24.

From the above it can be seen that implementing the guide developed, as described in Chapter 5, will reduce the maintenance cost of Company A.

4.5 INTERVIEWS

A semi-structured interview was conducted with each of the participants of the questionnaire. Field notes taken of the answers given to the researcher will be discussed in the following section. The length of the interviews varied between half an hour to two hours. The following sub-paragraphs will first state the question posed to the participant, followed by the answers provided by the participants.

4.5.1 Questions and answers

Question 1: Please describe the main objective of the company's CMMS.

- To help the company reduce the number of breakdowns
- Help manage cost of asset maintenance
- Keep track of maintenance done on assets
- To see where the problem is
- Improve overall equipment efficiency

The participants had a general idea that the CMMS should assist with the maintenance process. It is important that the users at least know why they are using the CMMS.

Question 2: Please describe the functions of the CMMS modules as you see them.

The answers given by the participants, when asked what every module's specific function is, were very vague, although they rated all the modules very high in the questionnaire. When asked the question in the interviews, it could be seen that the participants did not know the importance of the different modules and what information was needed in the different modules to effectively use the CMMS.

Question 3: What information do you need before registering a new asset at the moment?

The responses received back were as expected. When registering a new asset at the moment at Company A, only the invoice and operating location is needed. The question prompted further questions by the researcher. The question asked was if they were of the opinion that it would be a good idea to make prerequisite fields to be filled in before registering an asset, like serial numbers, power connections of the motor and utilities required for operation of the machine. The participants all agreed that it would make sense to have prerequisite fields to be filled in. If the field is not necessary, only the maintenance manager should be able to approve creating of the asset without these fields being filled in.

Question 4: Please describe the information needed and process followed to bring new stock items into stores.

The participants' answers all corresponded with one another. The process described by them is that someone identifies an item that seems necessary to be made stock. Paperwork is filled out for the critical spare and the quantities needed are determined. The stock number is created and the spare is brought into stores.

Linking of assets to stock items is essential for better planning of maintenance of assets. The amount of spares used for equipment should also be included. This will help with the creation of picking slips and reducing standing time where people do not know whether certain spares are stock or not. It will also help with better control of spares where the artisan will only be allowed to draw the correct amount of spares needed. None of the participants mentioned this as a requirement, but all agreed that it was a good idea that is should be implemented immediately. No technical data or material safety data sheets from the part or lubricants is required to open up a stock item. Company A is classified as a major hazard installation where it is required by regulation that suppliers always supply the safety data sheet for the substance, making it a hazardous installation. This data sheet can then be linked to the substance store number. For this reason, every part in the stores can have technical- or safety data sheets connected to it.

Question 5: What is the process when disposing of assets?

Only three participants had enough knowledge to answer the question. The steps of disposing of an asset currently are:

- Identifying the asset that must be sold.
- Customer buying the asset is invoiced.
- The finance department disposed of the asset once it is sold.

The process is simple. No mention was made of stock items that might remain in the stores. The link between assets and stock items will help in letting the user know that there is stock in stores when an asset is sold. If there is stock that is only used against the asset being sold, the spares should be sold with the machine. Before the asset is disposed, the manager responsible for the equipment must sign it off before being disposed. A standard operating procedure should be created that must be followed when disposing of assets.

Question 6: What is the process for registering work orders?

Registering of work orders originates from four sources. The first one being from the departments that fill in a work request order. If the work order request is approved, it is sent through to the planning office to be opened. The second one originates directly from the engineering office of special work to be completed. The third work order is created by walk-ins from the artisans for breakdowns. The first two are scheduled jobs, and the third one is an unscheduled job. The fourth work order originates from the preventative maintenance orders and is a manual system. The only thing needed to create a work order at the moment is the asset number and a description of the work that needs to be done.

For better planning of the jobs at Company A, more fields should be made a prerequisite before a work order can be opened - although the concept is there that if it is an unscheduled-, a scheduled-, a breakdown or an external work order, it is not captured into the work order module of the CMMS. A report can therefore not be generated to see the ratio of scheduled to unscheduled work. Other fields that should be a prerequisite before opening of a work order include the priority of the job, estimated time to completion, craft code and skills necessary to complete the job. The fields are in most cases there to be used, but is not filled in due to lack of training. A guide explaining the importance and value of information to be added to the CMMS will ultimately help improve planning.

Question 7: Are rotable spares managed effectively, in your opinion?

Three participants felt comfortable in answering the question. They all agreed that it was not managed effectively at the moment. The reasons being that there is no traceability and that there is no procedure in place to handle rotable spares.

Question 8: Is the information received from preventative maintenance orders used effectively?

Five participants agreed that the information received was not used effectively. Two reasons stood out. The first being that they felt that the information received back from workshop level is not accurate enough. The second reason is that the information that they do receive was not accurately captured back into the CMMS.

The way the preventative maintenance orders are currently being used at Company A is to do inspections on assets and to report faulty component or to replace faulty components. This may cause confusion in the workplace, as some artisans will replace the faulty part while others only report the faulty part.

The preventative maintenance orders should give clear instructions on what to do, for example to change oil or to replace bearing, not just to inspect and report. The preventative orders should be revised using user manuals and MTTF as guidelines.

Question 9: What activities do you need to ensure correct use of the program?

Training was the only reason given by participants. Continuous training will help any user to understand the system they are using.

Question 10: What are the pros and cons of the program?

Only one participant gave a list of pros. The list is:

- Pros
    - The program is user friendly.
    - Adaptable and can be changed to suit the user.
    - More than one user can work on the program at the same time.
    - Reports are generated quickly.
    - Navigation is good and fairly easy.
    - The system has a good search function that other programs do not have.

Questions 11 and 12: What are some of the barriers encountered for the successful use of the CMMS, and how did you overcome the barrier(s)?

Work culture was mentioned as one barrier. None of the participants had a way to overcome this barrier, as they felt that the people are too set in their ways and will never change. Computer literacy was another barrier that they felt was still present at the time of the interview and that has not been overcome yet.

If barriers are not dealt with promptly, or if there is no plan to try to overcome these barriers, the CMMS of Company A will never be used to its full potential. The users may then feel demotivated to continue using the program if other users are not on-board.

Question 13: In your opinion: what steps should the company take to ensure that the CMMS is used to its full potential?

The feedback from the participants is listed below.

- Training should be done annually to keep users up to date on the program. Training should include the training of users on other system functions that they do not use daily. It will help them better understand the system.
- The company or management should communicate to all the users on the importance of using the system correctly. Everybody should know why we are using the program and why we need to capture the information accurately.
- The company must include every user or at least the head of every department when upgrades are planned for the program. Constant communication about issues with the program will add more value to the upgrades.
- The management of Company A should all buy into the CMMS program. Management will then guarantee that the necessary steps are taken to use the program effectively.

Question 14: Will a CMMS implementation guide help reduce maintenance cost in your opinion?

All the participants agreed that a guide would definitely help in reducing maintenance cost. A guide will help get every user on the same page. Planning of maintenance will improve and will thus reduce cost of maintenance.

Question 15: What does the term ‘world class maintenance’ mean to you?

The list (below) of answers received shows how different people think regarding maintenance:

- To be very cost effective with no down time.
- To have and accurate, complete and in time system.
- Everything is running smoothly.
- A maintenance system that works for you with an early warning system in place for maintenance.
- Minimal breakdowns.

4.6 SUMMARY

The chapter started by showing the results that were obtained by going through the company's archives. The data revealed that no real requirements were given to the CMMS vendor. This was already an indication that not enough planning was done when the CMMS was first implemented and this led to the CMMS only being partially implemented.

The chapter continued with the analysis and discussion of the feedback received from the questionnaires. A summary of the links between the questionnaire and the three propositions (refer paragraph 3.3.2), and which forms part of the validity of the dissertation, will be made next.

Questions 5 and 11 of the questionnaire link to the first proposition, namely that old school technical staff and lack of knowledge of what the proper use of a CMMS can mean for a company, is the main reason for failure of the CMMS. Question 5 links to the second part of the proposition, where a third of the participants indicated that they did not receive training on the use of the CMMS. The lack of training is directly related to lack of knowledge on how to use the CMMS. The feedback received from the participants in Question 11 also shows that 83% of participants rated incorrect training as one of the biggest impacts on implementation failure of a CMMS. Interview Question 11 links to the first part of the proposition, where the participants felt that the work culture is a barrier that could not be overcome. It is difficult to change the work culture of old school technical staff where they feel that the system is working and does not need to change.

The second proposition, namely that maintenance staff believe that the CMMS is a maintenance strategy itself and not an instrument to support that the company's maintenance strategy, is linked to Questions 9 and 10 of the questionnaire and Question 2 of the interview. Question 9 showed that the participants did know what sentence best describes a CMMS. Question 10 is related to the reports needed for proper management of maintenance, but it can be seen that not all of the reports are generated. Knowing that the CMMS is only an instrument to assist with maintenance decisions, but not capturing the required data, shows that the participants did not fully understand the role of a CMMS.

The third proposition, namely that staff turnover is one of the reasons for failure as it takes anywhere from two to five years to successfully implement a CMMS, is linked to Question 11. Staff turnover is rated by the participants as one of the biggest impacts on implementation failure of a CMMS. Going through the employee list of Company A, it was noted that the company had five CMMS coordinators during the past ten years.

The chapter continued by discussing three case studies at Company A. From the case studies one can clearly see that, if the CMMS had been implemented correctly and baseline documents for equipment and inventory items were a pre-requisite before registering of the assets or items in the stores, unnecessary maintenance costs would have been avoided. The baseline documents will also help with the creation of work instructions and SOP's.

The guide developed in Chapter 5 was implemented on some selected assets and the results have been analysed. It was clear to the researcher that the implementation of the guide on certain assets definitely showed a decrease in the maintenance costs of the assets. Artisans now have more time to do specialised and intricate work and to do more root cause failure analysis.

The chapter concluded by discussing the field notes taken during the semi-structured interviews.

Chapter 5 will now show the implementation guide. It will be a culmination of Chapters 2 and 4.

CHAPTER 5

5 DEVELOPING A GUIDE TO SUCCESSFULLY IMPLEMENT A CMMS AT AN ABATTOIR

5.1 INTRODUCTION

Maintaining of assets is of utmost importance. Chapter 2 described the maintenance strategies you will need to effectively maintain assets. Chapter 2 also discussed different maintenance cycles and models showing what information is needed for effective maintenance in an industrial concern. All the knowledge gained from the previous chapters will now be combined in Chapter 5, creating an implementation guide that can be used by Company A's maintenance team.

Company A has fallen into the trap of thinking the CMMS is a strategy itself and not just an instrument to support the company's maintenance strategy. The CMMS program has been used for more than 10 years, but is still underutilised and the program is only used to print out preventative maintenance orders. Only the time spent on each line-item is captured into the system and no additional work that was done on the order is captured back into the system. Work orders are also created, but no links are available to any of the other modules - making it difficult to plan work orders properly. Controlling the maintenance activities in any facility requires an effective organisation. Also required is an accurate, comprehensive, easily accessible database of relevant information (refer paragraph 1.1.1). Baseline information necessary for each module is crucial to do proper planning and should be available on the system (refer paragraph 2.8.1). This will free up more artisans to do maintenance work, do root cause failure analysis and repair breakdowns faster instead of trying to gather information for spares to be bought when a breakdown occurs.

Master drawings on site will be a universal means of communication. Updating of the master drawing is the first project to be undertaken and will take between one and three months to complete. The master drawing needs to show all the buildings on site, all the equipment or assets in relation to the building, utilities and services on site. This step will help you acquaint yourself with the plant. This step will also help you better understand all the processes and how the machinery in different departments work together, which will enable you to create better hierarchies of assets in the different departments. Red lining of drawings and site walk-downs is the only way to achieve this. The maintenance manager/engineer, CMMS coordinator and the drawing office need to work closely together to complete the first step. Every module has its own set of baseline information that will be discussed separately for each module.

The chapter will present each module separately, showing the baseline information necessary for each module and explaining the different fields that should be filled in. This will be followed by a graphical representation of links to other modules, and will then show how the baseline information is necessary for the one module to be linked to another module. It will continue by giving a list of reports and a flow diagram of the guide.

Figure 25 shows the most important links between modules, but will be explained separately in its relevant section. The links formed between modules will show why certain information is necessary for the successful implementation of a CMMS in abattoirs.

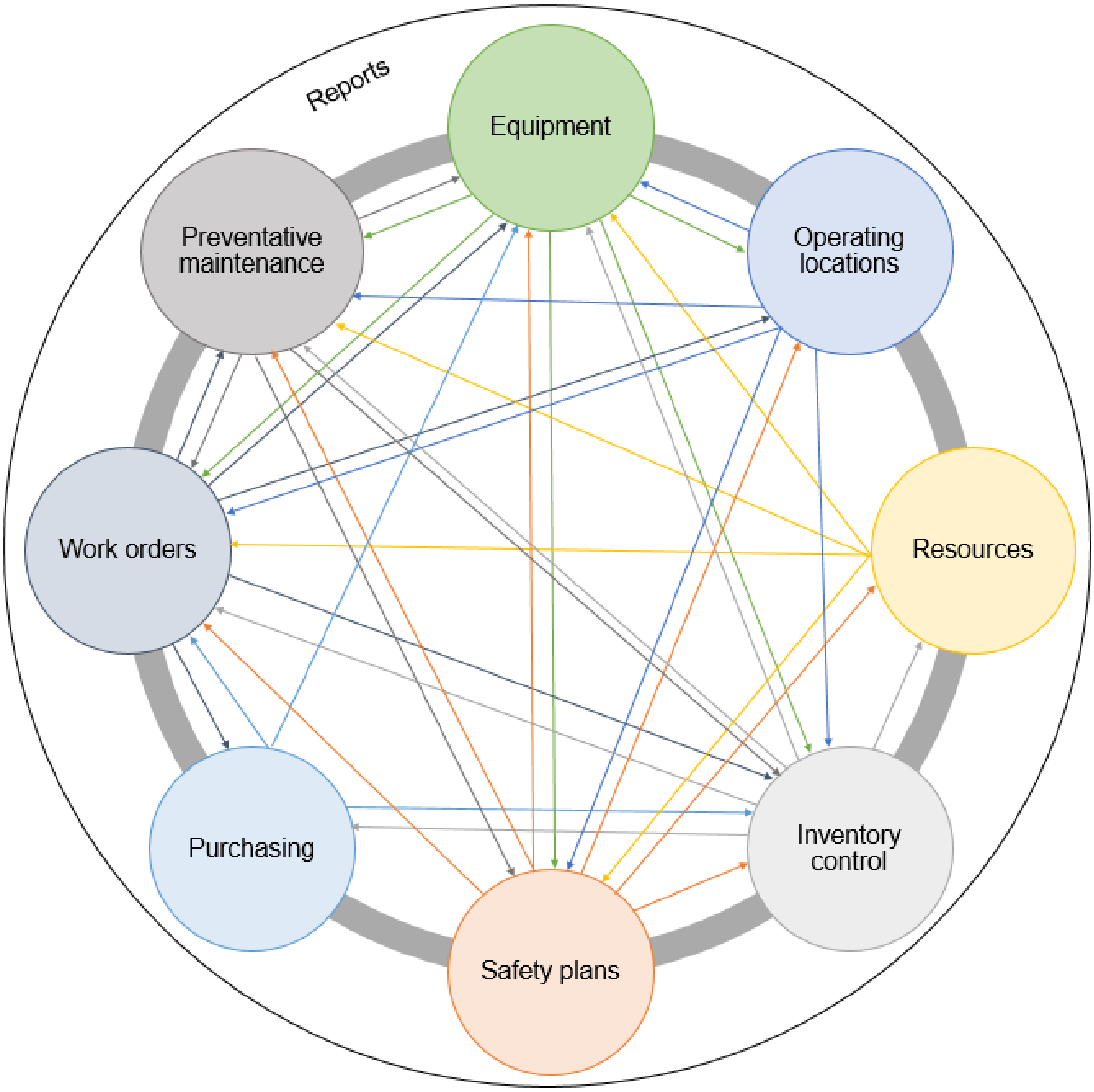

Figure 25: CMMS implementation illustration

The equipment-, work order- and preventative maintenance modules can be seen as the core modules for maintenance and the rest as supplementary modules to assist core modules in improving the total maintenance function at Company A.

5.2 EQUIPMENT

The equipment module is one of the most important modules of any CMMS. Without this module, you will not be able to manage any of your assets properly and maintenance as a whole will not be done effectively.

5.2.1 Baseline information required

Referring to paragraph 2.7.4.1, we see that the equipment module should be used to manage all assets on site whether it is a building or a piece of equipment. Completing the master drawing helps you to know and understand all assets and its inter-relationships you have on site. Keeping in mind that insufficient data is one of the main reasons for failure of a CMMS (refer paragraph 2.7.5) you should now start to gather all the information related to each asset. This will probably be the most difficult part in successfully implementing the CMMS and to ensure sustainability of the implemented CMMS.

Use the master drawing in conjunction with tables in Annexure E to physically go to each asset and gather as much information as you can on each asset. The baseline information (refer paragraph 2.8.1) and Table 1, described in Chapter 2 (refer paragraph 2.5.1.2) will also help you create a list of everything you need to capture. Where no tags or nameplates are on the equipment, you must try to cross-reference the machine with manuals obtained to the best of your abilities and retag said equipment. It is recommended to take as many pictures as you can of the equipment and any data plates so that you can refer back to them when capturing the information into the equipment module of the CMMS. The photo can also be used to orientate new employees and it should be added to the PMO. Taking thermal images of equipment while you are capturing the info will be invaluable, as you will have baseline temperatures of bearings and other processes. All information up to this point can now be used to develop the HBS for all the assets and will assist with the codification process on site. The HBS will help you identify equipment that uses the same spares and sub-assets so you can add these links between assets in the CMMS. This will enable you to only type in a specific motor and the CMMS will show all the machines that use that specific motor. Completing the steps mentioned above will help you obtain all the data necessary for effective maintenance and inadvertently completing an asset verification of all assets on site. Asset verification of the entire facility can now be done on an annual basis, and spot-checks can be done monthly.

Only when all the information has been gathered one can start capturing it into the CMMS. Hard copies of user manuals, working procedures and other technical information should be scanned into the system and links created to the asset numbers. One can contact equipment vendors and ask for electronic copies, which will make the tedious work of scanning all the manuals into the CMMS faster, as one can then link the electronic copy to the asset. After capturing all the information on the CMMS, the hard copies of manuals and drawings collected should be indexed and stored away for safekeeping and referencing. When creating a fixed asset card currently, one requires almost no additional fields other than the information required by the finance department. The finance department only needs an invoice and the physical location of the asset. When looking at the fixed item card one can see that there are many fields that should be captured. Almost all of these fields will be used when correctly completed.

5.2.2 Fields to be filled in for the module

The fixed asset code of the asset is the number everything will be linked to. The fixed asset code will also be used to create work orders and PMO's. The description is the name that will be chosen by you for the specific asset. Spend some time on choosing the description, as it will be linked to the fixed asset code and will be used by everyone. Description 2 can be used to add additional search descriptions as a prefix to different assets, sub-assets and components. When searching with this function you will only need to type in the main asset and the CMMS will show you all the sub assets and component. Using the fixed asset code of the asset will still be the most effective way to search assets with all the sub assets or components linked to it. The price captured will be used by the financial department and added to their depreciation books. The serial number captured is vital for tracing of fixed assets when rotable spares will be used.

The maintenance section of the fixed item card allows you to capture vendor information for the asset. Capturing the vendor information will allow you to search assets by vendors. Licence- and certificate-of-fitness renewal dates must be captured when you register an asset, if applicable. A pressure vessel is a great example of where these two fields must be captured. The meter reading will be zero when new assets are acquired, but must be updated for assets already on site and working when gathering all the information for correct implementation of the CMMS.

5.2.3 Links between modules

Figure 26: Equipment module

The following paragraph will show how the information captured in the equipment module should help the other modules with their own functions.

<u>Equipment module:</u>

- **Operating location**
  - The master drawing shows every asset in each department. This will help you to establish hierarchies between equipment, which will have numerous benefits (refer paragraph 2.7.4.2).
- **Inventory control**
  - The bill of materials generated by the HBS (refer paragraph 2.8.2.2) will help determine maximum stock levels, keeping it as low as possible to keep cost down. Each item in the store should be connected to the relevant assets.
  - Asset and item specific information captured into the CMMS will help the stores with the replenishment of stock. Stock is normally received from one vendor, except for some cases. If the item code from the vendor is captured into the system, it will ensure that the correct spare is acquired. If a wrong item is received into stock and only drawn in two months' time, the vendor is unlikely to trade or replace the wrong item that was delivered.

- **Safety plans**
  - Operational manuals is an excellent source of information regarding the safety of personnel when operating machinery. Although it may not cover every possible precaution, it will be adequate for baseline information. The information available in an operational manual will help with the development of SOP's and work instructions for equipment.
  - The CMMS will be able to generate reminders or work orders, reminding the user of expiry dates on licences relevant to the OHSA.
  - The licence- and certificate-of-fitness renewal dates will help the CMMS remind the user of upcoming renewals on a monthly basis. These dates will also help with budgeting for three-yearly legal inspections that might occur in a year.
- **Work orders**
  - The fixed asset code used by the financial department is linked to all the work orders created. You will be able to search the fixed asset code and get all work order and PMO information captured against it.
  - The bill of materials that will be generated by doing an HBS will assist with issuing of the spares to work orders, where picking lists can be created and sent to the stores. This will help eliminate wrong spares issued to jobs, or too many spares issued to jobs, and will eliminate time wasted by artisans waiting for spares.
  - The baseline information should include all special tools that are necessary to work on specific equipment. The link will let the CMMS coordinator know to add the special tool to the picking slip that must be issued to the artisans for timeous completion of the work order. This link will also be useful for the preventative maintenance module (refer paragraph 2.7.4.8).
  - Different permits are necessary to work on different assets. The relevant permits should be captured as part of the baseline information. This will then enable the CMMS to print the permits automatically when work orders are created against these assets. The same will count for preventative maintenance orders.

- Assembly drawings captured (refer paragraph 2.5.1.2) will always be available for the perusal by artisans and maintenance supervisors. This will eliminate unnecessary assembling errors and ensure minimal time wasted by artisans trying to figure out how the asset should be assembled. The assembly drawings will also be available for the preventative maintenance module.

- **Preventative maintenance**
  - The information gathered as part of the baseline information will already be available for perusal when you start to implement RCM or PLIOFF on all of the assets.
  - Design specific requirements captured into the system will help identify whether the equipment is running at capacity. The data received back from inspections can now be measured against design specification and if it is not within specification, preventative maintenance needs to be done to address the problem before it is accepted as the norm. This will help Company A manage its equipment more efficiently and assist with moving towards TPM and will minimise hidden maintenance cost.
  - The HBS will help identify MSI's for equipment. The engineering management will decide on the importance of the MSI. FMEA can now be done on the MSI's, which will help with the improvement of the preventative maintenance orders for each asset.
  - All the data gathered will be easily accessible for the creation of SOP's for all activities regarding assets.
  - The meter reading will help plan preventative maintenance orders that are time dependent. The meter reading will also be used to schedule rebuilds for the asset and major overhauls of critical equipment.

5.3 OPERATING LOCATIONS

The main function of the operating locations module is to create a location/equipment/asset hierarchy for equipment. This module is very useful when maintenance costs needs to be determined for certain areas or departments for budgeting purposes.

5.3.1 Baseline information required

Once the master drawing for the site has been updated, you can start to create functional block diagrams and process flow diagrams for each department. Start by creating a functional block diagram of the department as a separate drawing, as it will help you understand the interrelationships between the equipment and will assist you to clearly identify the parent-child relationships between machines and where bottlenecks will be created if certain machinery has a breakdown.

You should now start to create a product or process flow diagram for each department. It will help you to assign priorities to the equipment and determine crucial equipment that will stop production completely in the event of a breakdown. The next step is creating a piping and instrumentation diagram (P&ID) for the department. The process should be repeated for each department on site. Upon completion of the process flow- and P&ID diagrams, you can now add each diagram as a separate layer to your existing master drawing. You can then choose if you want to view the complete master drawing or switch between layers and view each department's process flows and P&ID's separately. A separate layer should be created, showing all the square metres of departments for budgeting purposes.

The 5S's of TPM should now be done for each department (refer paragraph 2.6.1). Upon completion of this task, the standards decided on by employees for keeping the workplace clean, as well as the processes that are put in place to sustain this, must be communicated to all the employees.

5.3.2 Fields to be filled in for the module

Looking at the CMMS, only the department or operating location can be captured into the CMMS. This is by no means an indication of the importance of the module. The information gathered plays an important role for effective maintenance management. The priority determined by using the block diagrams of the asset must be updated on the asset registration card.

5.3.3 Links between modules

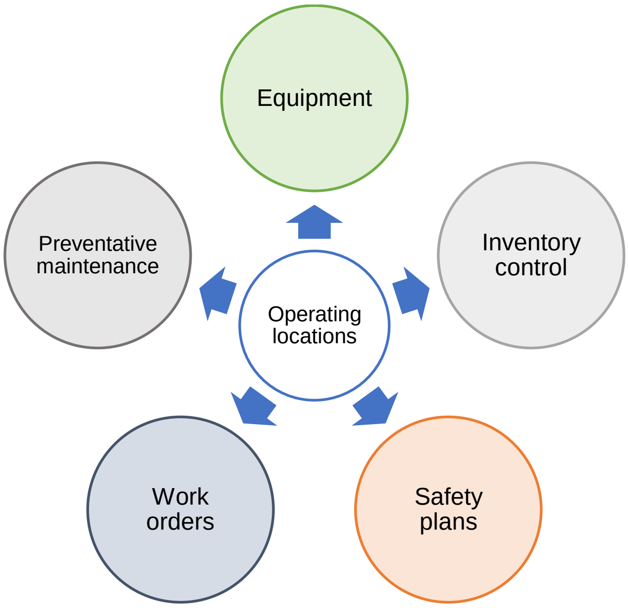

Figure 27: Operating locations module

The following paragraph will show how the information captured in the operating locations module should help the other modules with their own functions.

<u>**Operating location module:**</u>

- **Equipment**
    - The baseline information collected on all of the equipment/assets will help with the creation of a functional block diagram. The functional block diagram will help describe functions and relationships of the equipment in the different departments.
    - System schematics for equipment will show the interconnection of parts. The system schematics will form part of the functional block diagram.
    - P&ID created and captured into the system will assist artisans to do fault finding on complicated systems.
- **Inventory control**
    - The priorities of equipment determined by using the block flow diagrams for each department will help you determine the quantities of spare parts to keep in stock and to determine the safety stock needed.

- **Safety plans**
  - Certain hazards will be identified for different locations. It will help create different permits that must be issued when work orders or preventative maintenance orders are created on equipment in certain departments.
  - The process flow diagram created can be easily transformed to create an evacuation diagram that must be displayed in every department.
- **Work orders**
  - The operating location module will help the CMMS coordinator quickly determine if work orders are created for the correct assets by seeing the relationship between items.
  - By using all the failure data and work orders on assets, this link will allow you to determine if an asset is failing at a specific location or in different locations.
- **Preventative maintenance**
  - The priorities of the equipment determined will help you identify which equipment preventative maintenance orders should be refined first, using the RCM and PLIOFF methods to minimise breakdowns.

5.4 RESOURCES

Like with the equipment module, no maintenance can be properly planned if this module is not properly utilised and managed. The main purpose of the module is to help you determine the internal and external capacity that you have on site to complete work orders and PMO's. The information necessary (refer paragraph 2.7.4.3) will subsequently be explained in more detail.

5.4.1 Baseline information required

The basic information captured into the system (refer Annexure G) will be the employee's name, company number, craft code, medicals and direct unit cost. The company number will be used to link resources to work orders and PMO's. The craft code added to the CMMS will help the CMMS calculate how many hours are available for each craft code. When work orders and PMO's are created using the craft code, the CMMS will automatically deduct the hours and only show the available hours for other work orders. The hours are updated as work orders and PMO's are closed and created. This list of available hours will assist the CMMS coordinator with the allocation of work orders to different craft codes and will help to eliminate wasted resources. The direct unit cost linked to the company number will help determine the cost of labour on work orders and PMO's.

Every employee will, at some time while working at the abattoir, come into contact with fresh meat. It is important to send employees for medicals (list of medicals shown in Annexure G). These medicals done when you employ an employee must be captured into the CMMS, as this will be your baseline for the health of the employee. Yearly medicals will be compared to the baseline to see if the health of the employee has deteriorated or not. When you set up the craft codes in the CMMS, you should add pre-requisite medicals that must be done for each craft code. The list helps you ensure that all the relevant medicals are done before an employee starts working.

The CMMS should allow you to keep track of PPE issued to employees. A list of PPE that is required for each craft code should be drawn up by the health and safety committee and added to the CMMS. The PPE and the date it was issued must be captured into the CMMS. PPE must be checked monthly to monitor misuse and to inspect if is still in good condition, and should be replaced if it is damaged. The maintenance managers should create a list of tools needed for different craft codes. The tools on the list can either be issued to employees or they can buy the tools themselves. Special tools to complete work orders should be issued to employees where they sign acceptance of the tools that are in good condition.

All the tools must be subjected to an annual check to make sure the tools are still in good condition. It is wasteful to have resources but not the correct tools to complete work orders timeously.

The resource module is also used to track the skill levels, training of resources and regulatory appointments. Training of resources is crucial for safe and effective maintenance. The health and safety committee must create a list of toolbox talks and SOP's that an employee must complete and sign before starting to work. The training given to the employee by the employer will be linked to the employee's company number. Certain machinery and equipment requires from resources to have certificates or special licences before they can operate said equipment or machinery. External training given to resources should be captured into the CMMS, along with the expiry date of the licence or certificate. The courses attended by the employee must be added to the system to give a complete view of the training of an employee. Regulatory appointments for employees must be captured into the CMMS.

5.4.2 Fields to be filled in for the module

The employee's company number assigned by the human resources department is the first thing to be captured on the card. This number will then be linked to work orders and PMO's. The name and surname must be filled in, as it will be printed on work orders and PMO's. The department code and resource group is selected in drop-down menus. The financial department fills in the direct unit cost, which is the hourly rate of the resource that will be charged against work orders and PMO's. The personal data is necessary, as some of the fields will be used to let the user of the CMMS know if annual medicals are due. Medicals done, promotion history and accident history should be updated as soon as new information is available. The education data will, first of all, create a baseline of the skill and training of the employee. Extra courses attended and training received should be updated regularly. The CMMS must create a table of training received and courses attended with the date it was attended.

5.4.3 Links between modules

Figure 28: Resource module

The following paragraph will show how the information captured in the resource module should help the other modules with their own functions.

<u>Resources Module:</u>

- **Equipment**
  - This link will help you keep track of the skills level of operators. Operator skills must be developed to help free up artisans for more specialised work.
  - This link will also enable you to keep track of the internal capacity of the artisans and where training on different machines are still necessary. This forms part of the training and education pillar of TPM where you develop all employees and aim to bridge the skills and knowledge gap (refer paragraph 2.6.2).
- **Safety plans**
  - Medicals that are done yearly will help establish whether engineering control measures that have been put in place are still effective. One example is personal hearing protectors issued to employees. If the audiogram shows a drastic decline in the hearing of an employee, the noise-rating limit assessment needs to be revised and control measures to be checked. The CMMS will remind the user to send the employee for yearly medicals.

- The training linked to the company number of the employee when he started working needs to be done periodically in order to keep the employee vigilant. The link will help the CMMS to remind you of which employees need to go for refresher training on an annual basis.

- The training given to the employee by external contractors that issue a licence of competence for equipment and machinery normally expires within one to three years. The CMMS will remind the user to send these employees for refresher training before their licences expire and extra costs are incurred to obtain the licence again.

- PPE is checked on a monthly basis to monitor misuse of PPE. The employment date captured into the CMMS and when the PPE was issued, will let the CMMS remind you when retraining on the use of the PPE has to be done. The correct use of PPE is vital for protecting employees, and retraining on the correct use of PPE should thus be done annually.

- Regulatory appointments for resources expire every three years and employees have to be reappointed. If it is correctly captured on the CMMS, it will allow the CMMS to reissue appointment letters when they have expired to be signed again.

- **Work orders**

  - Work orders may require special training. The link will help the CMMS only show which resources that have all the relevant training that can do the work order. Training can include safe handling of ammonia, height training and breathing apparatus training. The work order may also require the resource to have a back actor or forklift licence. This point is also valid for the link between resources and preventative maintenance.

  - Work orders created for high risk (hypoxic and height) areas require extra medicals. The link will be used by the CMMS to only show the employees that have done all the relevant medicals for selection when allocating work orders and PMO’s.

- **Preventative maintenance**
    - The step-by-step work instruction that is created for every PMO should be communicated to every employee. Every employee should know exactly what is expected or required from him or her when doing a PMO. The same standard can thus be expected from every employee and it will help eliminate inferior maintenance. The failure data will also be much more reliable if every artisan works according to the work instruction.

5.5 INVENTORY CONTROL

As mentioned in Chapter 2, the inventory control module is for the control of spares related to all asset numbers. Whether the spares are stock, non-stock or a special order item, spare part control and rotable spare control plays a big role in the complete general maintenance cycle (refer Figure 2). The inventory items in the stores must all be numbered and allocated to a specific place in the stores. This forms part of 5S's of TPM where each item should be numbered and with only one place of storage (refer paragraph 2.6.1).

The procurement manager and stores personnel will primarily use the inventory control module. The module will work best in a current or live system. When parts are issued, it must reflect on the system in real time.

The inventory will constantly change due to new machines being bought and old machines either being decommissioned or sold. SOP's for increasing of stock, lowering of stock, changing vendors of items and the process of adding new items to the inventory should be created. The SOP's will guide the employees and is a way of ensuring that the correct process is always followed.

Requisitions will be used to get spares from the stores manually. You will, however, still need a job number created by the system when work orders are created to get the spares. This function should be replaced by the picking slip created with work orders. Using the picking slip will make sure the system is current and that spares will be issued to the correct assets.

The module will also allow you to create external gate passes for assets and items to be repaired. You will need a job number created by the repair work order to link it to the gate pass. The asset or item can now be sent out to the vendor specified for quotes. When the quote is received and accepted, the CMMS allows you to convert the external gate pass to an order without the need of filling out extra paperwork.

The inventory control module is also used to keep track of stock that the company has for resale, like bulk-deboned meat and sides in chillers.

5.5.1 Baseline information required

Like with the equipment module where lack of data is directly related to implementation failure, lack of data for inventory items will have the same outcome. If it is possible, start by printing out an inventory list of the spares you currently have in stock. This will be a great start as you can now take the list and allocate all the inventory items to asset numbers with the exception of items used for packaging.

Take a picture of every item on the list and add it to the CMMS; link it to the item - therefore linking it to the asset. A photo is sometimes the best way of identifying items. The CMMS should allow you to allocate inventory items to more than one asset and it must include the number of spares used by different assets.

After all the items on the list have been allocated to their respective assets, you will now start with the collection of the baseline information of all these items. The baseline information will include the technical datasheet, instruction manuals and detail drawings. The information should then be captured into the CMMS for perusal by personnel when necessary. Every piece of information captured into the CMMS must be indexed and stored away for safe keeping. The same index number should be used to save the data on the CMMS.

5.5.2 Fields to be filled in for the module

The inventory code is a code created by the financing department using the inventory code layout in Annexure H. The description must be an accurate description of the part. Base unit of measure should be the smallest unit available for the item and will be available in a drop-down box. The CMMS must allow you to choose your own shelf number when you want to put all the spares of one machine in a certain location, or it can create a shelf number for you.

The location code is used to determine on which of the sites the spare is in the store. The CMMS might show that stock is available but it might not necessarily be available on your site. Statistic Group 1 and 2 must be filled in for every item so that you will be able to search spares by these groups.

The purchasing system can be selected from drop-down menus (refer Annexure H). The lead time calculation depends on many factors. Consult with the vendor of the item to help you determine average lead times for the item. Lead times depend on local availability, whether the part is shipped or flown in from overseas, or if the part is ex-stock or needs to be manufactured.

The vendor number captured should link to the vendor item card created in the CMMS (refer Annexure I). The vendor item number will be the unique number given to you by the vendor to ensure that you buy the correct item every time. You need to consult with the vendor and ensure that he will only use one unique number and that you will be notified if the number is changed for any reason. The system must also allow you to add more item numbers if the item is acquired from more than one vendor. When you have a fleet of trucks or many of the same assets, you can approach your vendor and arrange for them to keep consignment stock in your stores. A list of spares used weekly can then be sent to them to be replenished, and they should invoice you accordingly.

The reordering points of items must be determined using the categories as set out in Duffuaa and Raouf (refer paragraph 2.7.4.4). The HBS created with the selection of MSI's must also be used to determine reordering points. Cycle counting should be practised, as it will help you keep more control and accurate records of all the spares in the stores. The procurement manager together with the CMMS coordinator and maintenance manager/engineer must review the inventory list on an annual basis. Their primary objective will be to review stock holdings and movement of items in the previous year and adjust levels accordingly. Some items will be bought and kept in stock for very long periods. These spares will not break under normal circumstances but the extremely long lead times make them high priority items. When such a spare is bought, you will need to contact the vendor with the request to send you special instructions for long-term storage of the item. This must be captured into the CMMS and should be done to keep the spare in perfect condition.

5.5.3 Links between modules

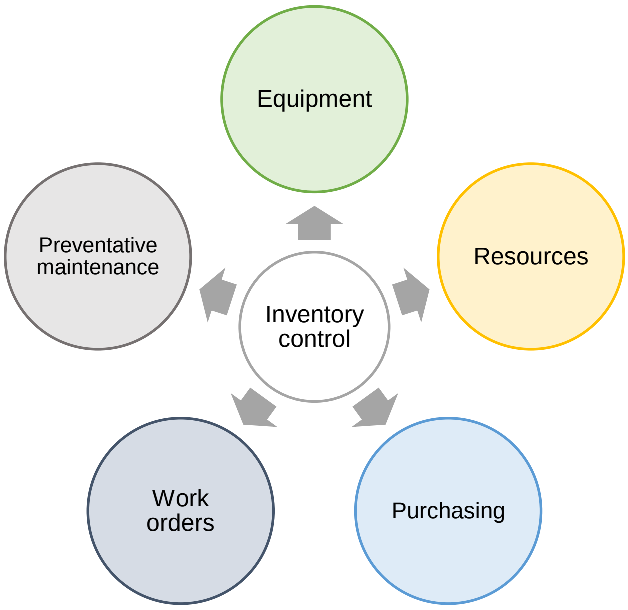

Figure 29: Inventory control module

The following paragraph will show how the information captured in the inventory control module should help the other modules with their own functions.

Inventory control module:

- **Equipment**
  - The HBS together with FMEA for each asset will help determine how critical a spare is. This will help you determine safe stock required for items.
  - Inventory control should manage the rotable spares or equipment. The rotable spares must always be fully functional and ready to use.
  - You will be able to search all the different machines that use the same spare if the baseline information is captured correctly.
  - This link will show what spares are linked to assets you want to dispose of. You can then sell the spares with the asset.
- **Resources**
  - Maintenance supervisors will have more time to do their own work if spares bought regularly from vendors are made stock items. It will reduce the amount of paperwork and the store personnel will be responsible to follow up on spares, allowing the maintenance supervisors to focus more on training and assisting artisans.
- **Purchasing**
  - This link will allow the CMMS to automatically adjust inventory upon receiving an item. The item number will be captured into the system where the system should automatically adjust the level of the item and indicate to the stores clerk where the item should be stored.
  - Better purchase planning is made possible by cycle counting.
  - The link to the vendor card will enable the CMMS to remind the procurement manager of vendors that will be closed over festive periods. You will now be able to buy extra stock from this vendor before they close. This will ensure that you do not have prolonged breakdowns due to no stock in the stores.

- External gate passes converted to work orders electronically will ensure the cost to be allocated to the correct work order, as no extra paperwork is needed. It will improve the traceability of items send out and reduce the paperwork for the maintenance supervisors.

- **Work orders**
  - If spares were issued against a work order but not used, the inventory control function should allow items to be booked back into the stores. This will help eliminate spares lying around and eventually being thrown away. The link should also allow items issued for preventative maintenance to be booked back into the stores if not used.
  - The quantities of items that each asset uses will help the system automatically let the stores know if an artisan wants to draw more bearings or other items that can actually be used on a specific asset. This will eliminate wastage of items and help with allocating the correct costs to assets. This link will also help the inventory control module to control the spares issued to PMO's.

- **Preventative maintenance**
  - The CMMS coordinator will be able to use the CMMS to create picking slips for work orders and PMO's. The picking slip will be sent to the stores automatically, to be picked prior to the artisan arriving at the store. This will help reduce standing time waiting for spares.
  - A current or live inventory system will allow the CMMS to show current inventory stock to the CMMS coordinator when creating picking slips for work orders and PMO's. This will minimise hidden cost where time is spent planning a job but which cannot be done because no spares are available.

5.6 SAFETY PLANS

In Chapter 2 we have seen that SHE is one of the eight pillars of TPM, where the main function of this pillar is to create a safe working environment that is free of accidents. Other functions also include the identification and elimination of work place hazards and doing activities that preserve the environment (refer paragraph 2.6.2). The baseline documents gathered for this module can be done concurrently when you are collecting the equipment- and inventory modules information. The information gathered here will be incorporated into the SOP's.

The module will help you reduce the hidden cost associated with safety risks and environmental issues, as shown in the iceberg model in Chapter 1 (refer paragraph 1.1). Having a safe workplace where you have identified all the potential hazards and trained all the employees on said hazards, will reduce the number of injuries on site and the cost that goes with it. The module will also ensure that the footprint you leave on the environment is as small as possible. The cost for paying penalties on effluent discharge will be avoided.

Extensive historical tracking of safety compliance and the ability to drill down into the details for each procedure, using the CMMS, can be used for internal and external audits and will be invaluable for establishing the track record for safety compliance (refer paragraph 2.7.4.5). Tracking of safety include showing what safety talks have been done, if a PPE has been issued, if lock-out books have been filled in, over-inspections on risk assessments done and quarterly review of contractors' safety files.

5.6.1 Baseline information required

Baseline information is required to update the master drawing created in the equipment module. Information includes fire hydrant positions, hose reel positions, fire extinguishers' positions, aspirated smoke detectors, emergency buttons, emergency escape routes, earthing points of buildings, underground electrical and information technology (IT) cables, location of all electrical panels, hypoxic pipe work, utilities and roll call positions. Each of the items mentioned above should be drawn on a different layer on the master drawing and saved.

Baseline information for the safety module also includes creating and/or updating of the relevant registers mentioned in Chapter 2 (refer Table 3). Once the registers are up to date, it should be updated regularly.

To comply with national and municipal laws, you will be required to submit quarterly and yearly reports. While gathering baseline information, you must gather all the requirements imposed on you by the municipality so that you can use the preventative maintenance module to create reminders and checks for you.

One example is the atmospheric emission licence (AEL) for which you are required to give quarterly reports. The OHSA regulations also require you to do certain checks. These checks must also be researched as part of the baseline information so that it can be added to the CMMS.

The different levels of risk assessments form part of the baseline information and should be done when you have finished collecting the baseline information for this module. You need three different risk assessments:

- A baseline risk assessment for the entire site
- Location specific risk assessment
- Job/work order/PMO specific risk assessment.

5.6.2 Fields to be filled in for the module

There are no specific fields for this module. The information gathered will be added to assets in the equipment- and inventory module and will be used to create checks controlled by the preventative maintenance module.

5.6.3 Links between modules

Figure 30: Safety plans module

The following paragraph will show how the information captured in the safety plans module should help the other modules with their own functions.

Safety Plans module:

- **Equipment**
  - Some equipment has specific requirements that must be complied with to ensure the safety of employees. One example is an X-Ray machine that requires a special radiation certificate when installed or moved.
  - Any precautionary measures pertaining to certain equipment should also be captured into the CMMS to ultimately help create SOP's. These SOP's will be used in work- and preventative maintenance orders.
- **Operating locations**
  - The information gathered by this module will help with the creation of SHE inspections for each department. These inspections must be done monthly. You can use the preventative maintenance module to print these inspections every month.
  - Major hazard installation (MHI) assessments for the site need to be done periodically and the checks imposed on the company being classified as an MHI must be added to the preventative maintenance module.
- **Resources**
  - The baseline information of equipment together with the MSDS will help the health and safety officer identify all the potential hazards that may arise from doing work orders or preventative maintenance orders. This will help with the creation of toolbox talks and SOP's. The relevant information must be communicated to every employee so that they can work in a safe manner and avoid injuries in performing their duties.
  - The relevant toolbox talks and SOP's created can now be communicated to different employees before entering the workplace. Refresher training on the toolbox talks and SOP's should be scheduled yearly. Training on SOP's for sensitive or critical equipment can be reduced to six-monthly cycles.

    - The training record saved on the system will help with audits and prove a track record of safety compliance.

- **Inventory control**

    - Baseline information and especially the MSDS of items will be used in the SOP's for safe handling of dangerous substances or items. It will help you identify safety precautions when working with certain items and what PPE should be worn when handling certain items. The MSDS of items and substances will give storage instructions of items, as some items should never be stored together.

- **Work orders**

    - This link will help management comply with the OHSA where mandatory inspections on certain assets will also be added to the CMMS. The work order module will create orders for AIA's to do inspections on equipment. Inspections include vessel-, lifting equipment-, firefighting equipment- and breathing apparatus inspections (refer paragraph 2.7.4.5).

- **Preventative maintenance**

    - PMO's should be done monthly on equipment that has been installed in the interest of health and safety, for example safety devices and lockout switches.

    - Checks and tasks that must be done to comply with all the relevant municipal and national laws can be added to the module to remind you of what must be done.

5.7 PURCHASING

The purchasing module relies on the information captured into the CMMS in the inventory module. It will use the information to create orders to buy the parts or items from vendors. The module is also used to create manual orders by the user for the acquisition of extra special parts or capex buyouts.

5.7.1 Baseline information required

For inventory items to be purchased, the module depends on the information on the inventory- and vendor item card that is captured at the inventory control module. If an item in the stores reaches the reordering point, the CMMS must automatically send a ‘request for quote’ e-mail to the vendor/s specified on the item card, using the vendor item no. Replies received must be sent to all the e-mails added in the purchaser field. The quotes will be reviewed and the best one chosen. The item will be bought after approval by the respective managers. If there is a preferred supplier specified for an item (this will normally be suppliers of OEM parts), the system will notify the procurement manager when 50 successful purchases were made from this vendor. The procurement manager must then get counter quotes from at least two other vendors and compare prices for the item.

RTO is the process of manually adding a purchase order to the CMMS for the acquisition of spares. This will be explained in the next paragraph, as extra information is needed before an order can be placed. The normal process is to create an RTO to buy spares before a job can be completed; it is however possible that breakdown spares will be needed over a holiday or weekend. The spare may then be acquired and the paperwork completed first thing the next business day. Manual RTO’s need to be approved twice. Pre-approval will allow the buyer to obtain quotes. The buyer will review all the quotes and select the best quote to be added to the order (with technical data sheets of items). The order must then be reviewed and approved if everything is in order.

Any of these methods can be used to obtain parts, spares or new machinery. All items must be received by the stores, where the invoice and item number will be checked against the parts that was delivered. If all the parts on the invoice have been received, the invoice can be sent to management to authorise payment.

5.7.2 Fields to be filled in for the module

If you want to create an RTO, you should have a job number already created on the system. The job number is created when work orders are created for assets. The CMMS should be set up in such a way that nothing could be bought without a job number on the system. This will ensure that spares are not bought unnecessarily and that the cost of the spares will be allocated to the correct asset. Other fields that will need to be captured when manually creating an RTO are the fixed asset code (it will already be linked to the job number), description of spares needed, quantity of spares needed and the name of the machine - for easy reference.

The lead times entered on the item card will allow the CMMS to automatically follow up on outstanding orders. Late deliveries are one of the hidden maintenance costs on the iceberg model.

5.7.3 Links between modules

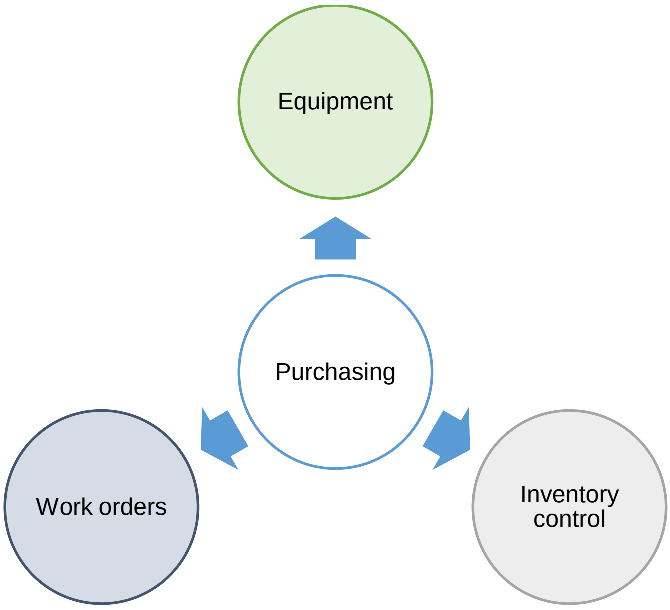

Figure 31: Purchasing module

The following paragraph will show how the information captured in the purchasing module should help the other modules with their own functions.

<u>Purchasing module:</u>

- **Equipment**
  - All spares will be linked to the correct asset number, using the job numbers created for work orders.
- **Inventory control**
  - The link between the purchase and inventory module will allow for timeous reordering of stock. When the item reaches its reorder point, a purchase requisition will be created automatically.
  - The purchasing module will ensure that all parts or items bought comply with the prerequisites programmed into the CMMS for the specific item. Prerequisites should include specification- and technical data sheets for items. When special parts are made specifically for the abattoir, a drawing with all the dimensions, material used and any special instructions for manufacturing of the part and material used must be submitted.
  - The lead times captured on the item card will allow the purchasing module to automatically send out an e-mail to the vendor if the part is not received on time - asking for an explanation. The date must then be updated for the specific order so that it can be followed up again when the date arrives.
- **Work orders**
  - This link will help the CMMS coordinator reprioritise work orders if the material ordered to do the work orders has a long lead time. The lead time indicated will give a good indication of when the work order can be started. The CMMS will automatically send an e-mail to vendors to ask for reasons why the item or part has not been delivered on the specified date. At the same time, the CMMS will also send an e-mail to the CMMS coordinator and the engineering management, saying that the part has not been delivered.

5.8 WORK ORDERS

There are three different types of work orders, namely blanket-, special- and preventative maintenance orders. This paragraph will focus on special work orders and what is needed as input form the user. Preventative maintenance orders are mainly used by the preventative maintenance module and will be discussed in the next paragraph.

Company A is currently using five different methods for creating work orders, four of which was identified during the interviews. The five methods are as follows:

- The first method is when an artisan or maintenance supervisor identifies something that needs immediate attention to prevent a breakdown. A work order is created and is attended to immediately and is classified as minor repairs.
- The second method is when work orders are created on the system after a breakdown has occurred and has a negative effect on SHE. This will be classified as a breakdown.
- The third method is the opening of work orders for work identified by the maintenance manager/engineer for the continuous improvement of the plant, repairs and projects that need to be completed. The maintenance manager/engineer will discuss the work identified in their department meeting and the work order will be created afterwards. This work order will be classified as either modification, damage to property, repairs or capital/abnormal.
- This fourth method of work order is for work identified by department heads to increase production, improve efficiency and for minor repairs needed that they have identified in their operating location. This increases the eyes you have in the plant for identifying of minor issues before they become major issues. The work orders for departments follows a slightly different route where the department head needs to fill out a job request. The job request will be reviewed and will only be captured into the CMMS after the maintenance manager/engineer has approved it. The work order will be classified as modification, minor repair, repair or maintenance.
- The fifth method is work orders for preventative maintenance and will be discussed in the next paragraph. These work orders will be classified as planned maintenance or external orders. External orders refer to assets sent out for repairs by OEM's. Holding points must be added to external work orders where the maintenance supervisor or maintenance manager/engineer can then go and inspect the asset at the holding points specified. This will help will the quality control of external maintenance orders.

The job designations are not set in stone and the CMMS coordinator can choose any job designation for any work order as he pleases. The job designation allocated to different work orders must, however, be constantly applied to improve reporting of work orders. This will ensure that the failure and modification history of all the assets is a true reflection of the situation. RCM and PLIOFF rely on this history to be accurate and you will be able to optimise the maintenance of asset.

Work orders status will give an indication of the stage in which the work order is. If the work order is closed, the CMMS must automatically block any further capturing of maintenance cost to the order.

5.8.1 Baseline information required

The baseline information required by this module will be the information captured when creating work orders. When creating work orders, it is important to remember that work orders need to be specific for each job. You cannot create a work order and state “replace valve”. The artisan assigned to the work order might know what asset the work order is for, but if there are four valves on the machine he will not know what valve needs replacing. You have to write “replace inlet valve to refiner”, so that the artisan knows exactly what is expected to be done.

The job designation and code-numbering table must be available for perusal to anyone who fills out a work order request. This will enable them to choose the correct designation.

5.8.2 Fields to be filled in for this module

The work order request and the work order itself will now be discussed. The work order request is done before work can commence. The work order issued to the workshops will be partially filled in with the information received from work order requests.

Department heads must be able to create work order requests electronically as it will be faster and more accurate. All the fields should be pop-up menu types and only the description of the work that needs to be carried out, as well as the date required, needs to be filled in. Manually filled out work orders must also be available for people that do not have access to a computer. The date and time will be the same as the system that is being used. The ‘requested by field’ will also be automatically filled in by the user logged into the system. If you choose the asset number or equipment description, the CMMS must automatically fill in the other one as well as the cost centre. You can see that manual work requests, filled out on paper, will be much more tedious.

When ‘external’ is chosen as a job designation, it is important to write down any holding points and special instructions or prerequisites for complete payment in the ‘please carry out the following section’. The holding points specified by the engineering team will help with quality control of repaired parts as you cannot test every spare received back from the OEM. Repair parts need to be ready for use and will only be used when needed.

The payment terms specified on the work order will be used when placing the order at the vendor. You need to specify what percentage of the invoice will be withheld until the relevant document has been received. Documents include pressure test certificates for vessels, certificates of repair of vessels, reports, data books or any certificates or documents relevant to the repairs being carried out.

The work order issued to the respective departments must now be completed and sent back to the planning office. All the information on the work order request will be shown on the work order. The CMMS coordinator will have estimated how long the work order will take to complete. The fields to be completed by the artisans include the amount of time spent on the work order, the details of the job done and the amount and description of spares used. The signature of the requester after completion of the job is very important, as it will close the loop of the work order.

5.8.3 Links between modules

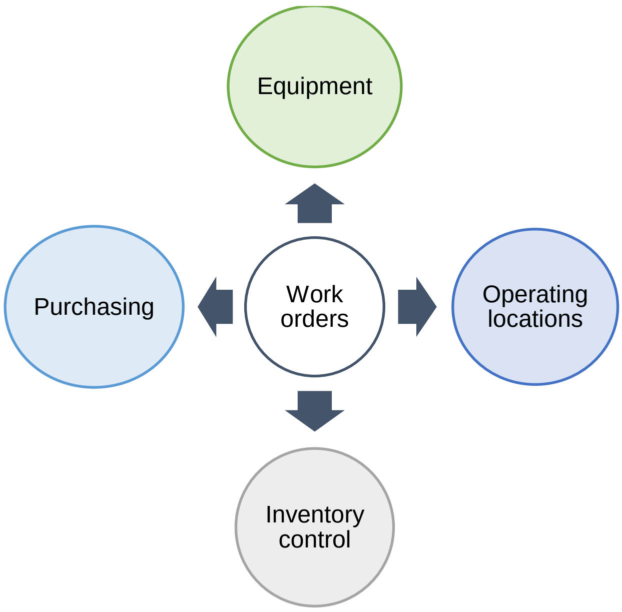

Figure 32: Work orders module

The following paragraph will show how the information captured in the work orders module should help the other modules with their own functions.

Work orders module:

- **Equipment**
    - This link is important as it will give you the best record of the modification history of the asset.
    - This module will link the failure data for every asset correctly. The job designation for the work order will allow for better reporting, as you will be able to generate a report for breakdown, minor repairs or major repairs for each asset. The information will also help with the implementation of RCM.
    - The link will also enable the CMMS coordinator to print relevant documentation needed for timeous completion of the work order. If you require any permits or special instructions to work on a piece of equipment, this link should allow the CMMS to print the documentation automatically. The manual will also be readily available for perusal together with assembly drawings.
- **Operating locations**
    - When work orders for assets are created, it should be linked to a cost centre that is linked to a specific operating location. The baseline information for an operating location must include any special PPE that must be worn and all the hazards identified for the specific location. When a work order is created, the CMMS should automatically indicate if special training or PPE is required to complete the order. One example is a hypoxic storage area where the O_2 is on average 14.4%, with temperatures below minus 30°C. The system will also be able to check which artisan fulfils all the prerequisites.
- **Inventory control**
    - The link between these two modules will make planning of work orders easier. You will be able to see if spares or material required to do the work order is available or if it needs to be purchased.
- **Purchasing**
    - When work orders require special parts or items to be bought, the work order number is linked to the RTO created. This will ensure cost is allocated to the correct work order.

5.9 PREVENTATIVE MAINTENANCE

As mentioned in the work order module, the information gathered by work order module and captured into the CMMS play a significant role in moving towards RCM and TPM. As stated in Chapter 2, explaining RCM will not be done in this dissertation nor will it focus on implementing RCM. It is however important to state that, after the preventative maintenance module is operational and the CMMS is fully utilised, you need to start implementing the RCM and PLIOFF method on all assets to help you reduce maintenance costs. This will help you reduce the hidden maintenance costs shown in the iceberg model, for example: reducing over-maintenance on equipment will reduce low quality products and reduce energy consumption and will extend asset life.

The preventative maintenance module must at least have the capabilities as mentioned in paragraph 2.7.4.8.

TA maintenance forms part of the preventative maintenance module. For proper planning of TA maintenance, you will need information from each of the other modules. The recommendations set out in paragraph 2.7.4.8.1 will help you improve TA maintenance of assets. After each year's TA maintenance has been done, the process must be reviewed and improved upon, if necessary.

5.9.1 Baseline information required

The baseline information is already captured into the CMMS by the other modules. It is important for links to be created to all the information that was scanned into the system. It will be useful to get a developer involved to enable you to capture running hours, bearing temperatures, vibration monitoring measurements and oil analysis directly into the CMMS. It does not help scanning these documents into the system as you will not be able to do analysis and reporting on it.

You now have all the relevant baseline information necessary to set up a maintenance plan for assets. When creating a maintenance plan, you need to develop a PMO and SOP's that include guidelines to do the PMO, a list of spares needed, precautionary measures to be taken and special equipment or tools required. Job shadowing should be programmed into the master PMO, where if the same task is listed on the monthly, three-monthly or yearly PMO, only the last task will print. If it is captured as 'done', all the other PMO's must be updated simultaneously.

PMO's must be created for autonomous maintenance where the operator will be responsible to complete the PMO. The seven steps mentioned in Chapter 2 will be incorporated into these PMO's (refer paragraph 2.7.4.3). The steps can also be used in all PMO's and not just the ones issued to operators.

5.9.2 Fields to be filled in for this module

The fields to be captured when creating a PMO must be pop-up type inputs. You will be able to choose only the fixed asset code or description and the CMMS will fill in all the other fields related to the asset. You will be able to attach documents to the PMO that can be printed on demand. The main asset components created when you did the bill of materials for each asset will also be available. The priority when creating a report will be low.

The priority of the PMO will escalate to medium and then critical if monthly PMO's are skipped. Three-monthly, six-monthly and yearly PMO's will however go straight to critical if not done in the month it was scheduled.

Each task added to a PMO will need an interval that it needs to be checked. It could be weekly, two-weekly, monthly, three-monthly, six-monthly, yearly, two-yearly, three-yearly or it can be based on running hours. The PMO will print whichever comes first of the two. The description of the task must be added. It is useful to create the task lines in such a manner that it follows a flow through the machine. If tasks are added erroneously, it will only confuse the artisan tasked with completing the PMO. If a task line is to inspect the v-belts of the machine, the CMMS must allow you to link the part number in the stores to the task line. It will then print with the PMO so you will know exactly what part to draw from the stores, if necessary. If the task line is to replace the v-belt, it will use the same link to create a picking list that will be printed with the PMO.

The information or comments captured on the PMO's by artisans must be captured back into the system. Some of the orders will only be to inspect or check assets and to report any faults. If any faults are noted on the PMO, it must be brought to the attention of the maintenance manager to be reviewed. If necessary, the maintenance manager will then instruct the planning office to open up a follow-up work order after assigning a priority to the work order (refer paragraph 2.7.4.8).

5.9.3 Links between modules

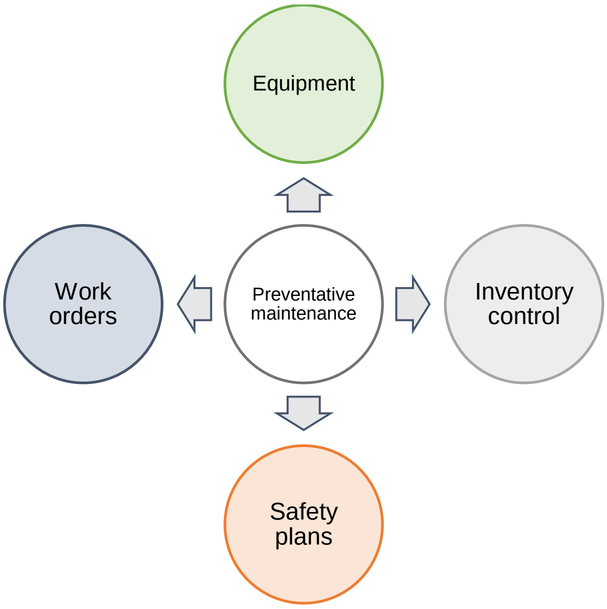

Figure 33: Preventative maintenance module

The following paragraph will show how the information captured in the preventative maintenance module should help the other modules with their own functions.

<u>**Preventative maintenance module:**</u>

- **Equipment**
    - Adding the maintenance manual as part of the baseline information from the beginning will help the engineering- and planning department develop PMO's for assets. The information available in maintenance manuals comes from years of experience of the OEM's and an enormous amount of tests. Although the information is based on data generated from controlled environment tests, it will be a good starting point and should then be revised according to plant specific requirements and the environmental conditions.
    - The maintenance manual added to the baseline information will help create a work instruction. The work instructions will show step-by-step instructions on how to complete preventative maintenance orders. The information will also be available for the work orders module.
    - Part of TPM is "Shine" (refer paragraph 2.6.1) that should be built in with preventative maintenance. Regular cleaning of equipment will help identify issues before they can cause breakdowns.

- **Inventory control**

    - The bill of materials will help with the creation of picking lists for preventative maintenance orders. PMO's require that spares are available for the job to be correctly planned and executed. When the PMO is generated, the CMMS should automatically check if all the necessary spares are available before printing and releasing the order. This will improve the planning overall, as jobs will not be planned that cannot be completed timeously.

- **Safety plans**

    - The preventative maintenance module can not only be used to periodically print out preventative maintenance orders, but you can utilised it to print out periodic reminders of safety compliances that include monthly checks of the registers, SHE representative inspections, noise levels and lux levels. You can also use it to create annual checks required by insurance companies.

- **Work orders**

    - This link will help to create follow up work orders on PMO's or asset inspections. If the PMO was to change bearings, the follow up work order can be to do vibration monitoring every day for a week to monitor the asset. After the initial period, you can revert back to the original vibration monitor schedule (refer paragraph 2.3.3.1). Thermal imaging is also used as follow-up work orders (refer paragraph 2.3.3.2). Oil analysis and acoustic analysis can both create follow up work orders (refer paragraph 2.3.3.3 and 2.3.3.4).

5.10 REPORTS

The power of the CMMS lies in the ability of analysis and reporting. In the previous chapters, and in Chapter 5 specifically, we have seen that all the information captured will help the CMMS create reports for the user. The CMMS only have basic reports programmed in as standard and is not sufficient for companies' specific needs. The CMMS must be adaptable and capable to enable the user thereof to create additional reports using all the information captured into the CMMS by the different modules. The reports generated must be easily accessible and easy to understand. If reports are not user friendly, easy to understand, it will not be utilised.

From the managerial cycle we see that reports should be generated by the CMMS to help with maintenance planning and budgeting processes (refer paragraph 2.4.3.1).

The next paragraph will list reports that should be created by the CMMS to be reviewed by management. The list will show a large amount of reports that can be used, but is by no means all the reports that can be generated and used. The list will focus on important reports relevant to engineering that should help you to manage the maintenance more effectively and efficiently. Only a few production and inventory reports will be mentioned.

5.10.1 List of reports

- Maintenance cost per animal slaughtered.
- Maintenance cost per asset per animal slaughtered.
- Water- and electrical usage per animal slaughtered.
- Effluent discharge per animal slaughtered.
- Report of the utilisation of different crafts showing the percentage of unplanned and planned hours.
- Report showing the amount of overtime worked per department or craft code.
- Backlog report of work orders and preventative maintenance orders by craft and departments.
- Cost per asset per animal slaughtered, de-boned or rendered (depending on department) to help see if further optimisation of the maintenance plan in necessary.
- Catastrophic failure reports on critical assets.
- Amount of product produced to the amount of defects that will help you with improving the quality maintenance.
- Report showing amount of product over conveyors between failures (not all conveyors do the same so it will be different strategies for different equipment).
- Percentage of planned maintenance versus breakdowns (emergency maintenance).

- Percentage of repeat jobs and product rejects.
- Report showing the amount of recurring work orders for assets. (You can then investigate why there are so many recurring work orders. The reverse can also be monitored if work orders become fewer and fewer.)
- Where possible, a report of all the asset errors on a daily basis.
- Percentage of repair work orders from PMO's versus unplanned repairs. (This will help you see if your preventative maintenance is effective.)
- Report of all production stoppages that were due to equipment failure.
- Production reports of departments to monitor idling and minor stoppages and yield.
- Report showing the assets disposed and acquired for each month,
- Report showing the overdue work orders and PMO's,
- Report showing the PMO's that have reached critical level. (This is monthly orders that have been skipped twice. Three-monthly, six-monthly and annual PMO's must show as critical if skipped once. This report should be generated immediately for the attention of the maintenance manager/engineer.)
- Report showing what permits and lock-outs were issued to the different assets.
- Cycle counting reporting to monitor the spares movement more frequently.
- Report showing the date RTO's are expected on site for better scheduling of work orders and PMO's.
- Report showing the progress of external maintenance orders and the expected return date of the asset.
- Report showing the outstanding external gate passes. (The date must also be added when the gate pass was issued.)

The CMMS must follow up on overdue dates of RTO's and external maintenance orders automatically by sending out an e-mail to the vendor, asking for the reason for late delivery. Late deliveries are one of the hidden maintenance costs of the iceberg model and must be monitored on a weekly basis.

Extra reports that will help you to monitor assets more effectively include:

- Weekly vibration reports on critical equipment.
- Daily water usage per asset.
- Daily chemical use at condensers, cooling towers and pressure vessels.
- Daily temperature and humidity readings of critical cold rooms and freezers.
- Daily bearing temperature readings of critical equipment.
- Hourly hot well and condensate readings that is reviewed daily.

When developing new reports for the CMMS to generate automatically, you must involve all the different departments in the designing phase of the report. By doing this you will ensure that the different departments use the report.

5.11 LIST OF LAYERS FOR MASTER DRAWINGS

This section will give a list of layers for easy referencing that can be added to the master drawing:

- Square meters of every department.
- Steam-, water-, storm water-, sewage-, hypoxic- and air piping of the plant.
- Electrical reticulation (Included all cables, earthing points and panels).
- IT cables.
- Assets in each department.
- Process flow for each department.
- P&ID for each department.
- Fire hydrant positions, hose reel positions, fire extinguishers positions, aspirated smoke detectors, emergency buttons, emergency escape routes and roll call positions.
- Emergency escape routes.

5.12 FLOW DIAGRAM OF DEVELOPED GUIDE

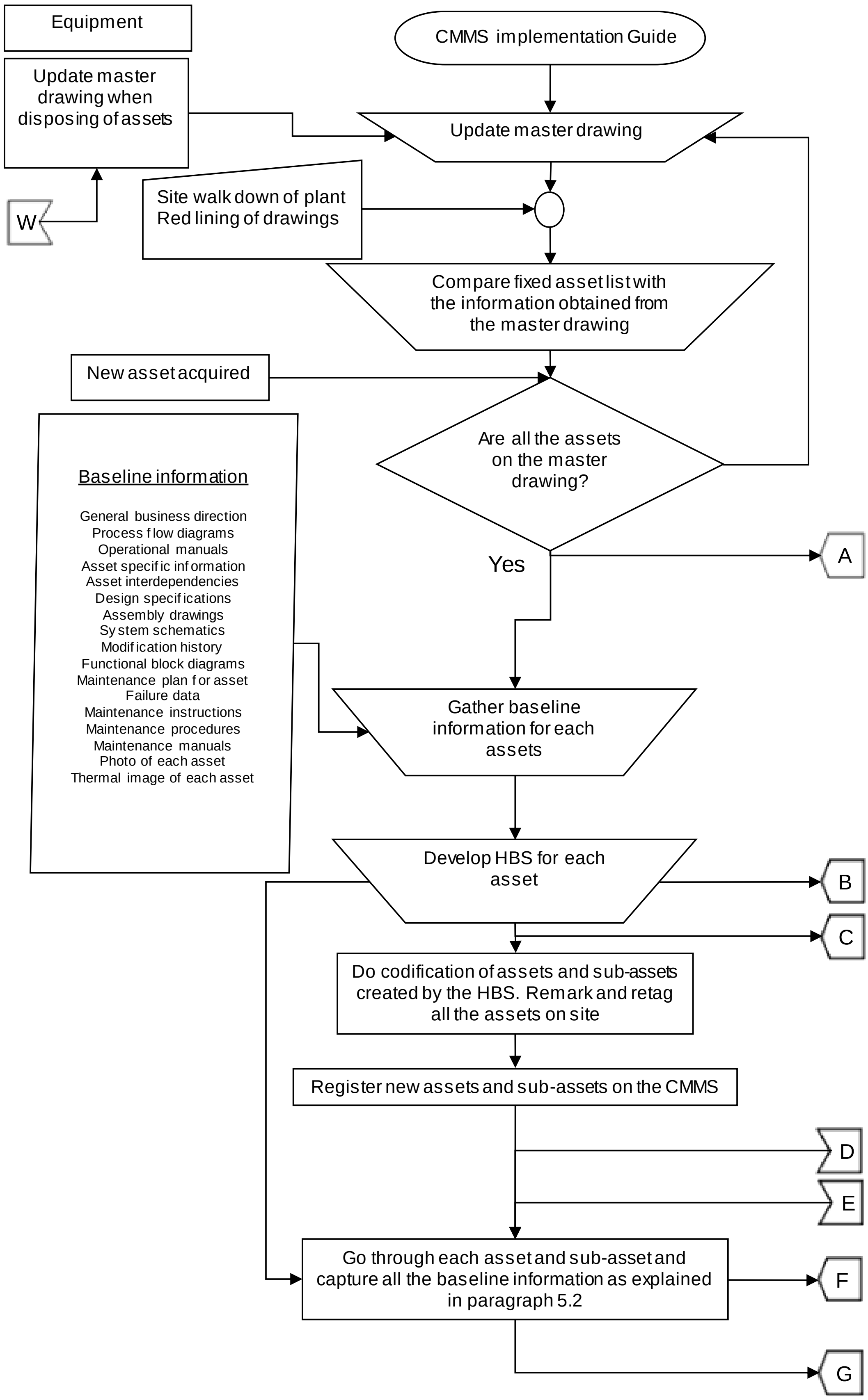

Figure 34: Equipment flow diagram

Safety Plans

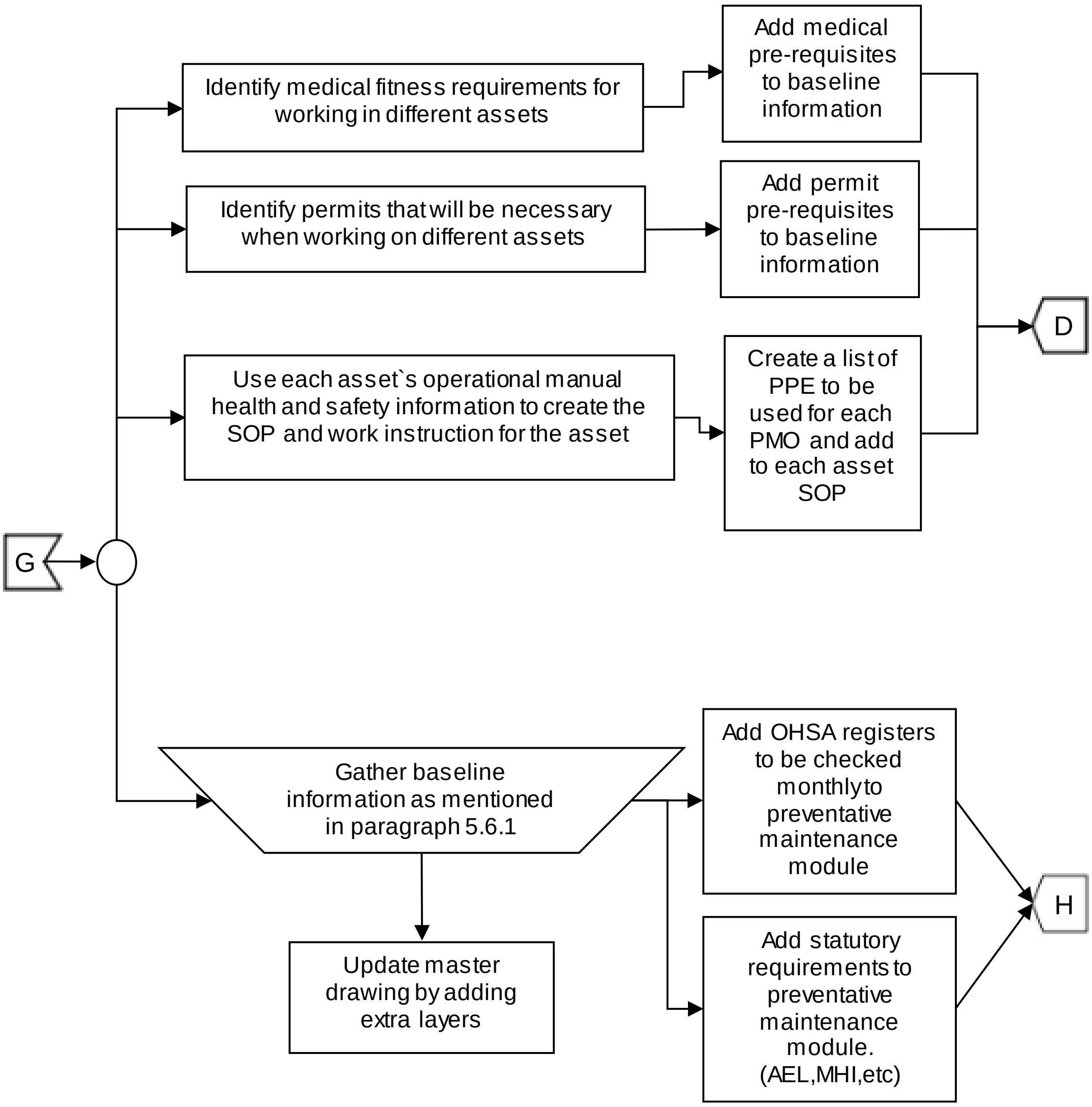

Figure 35: Safety plans flow diagram

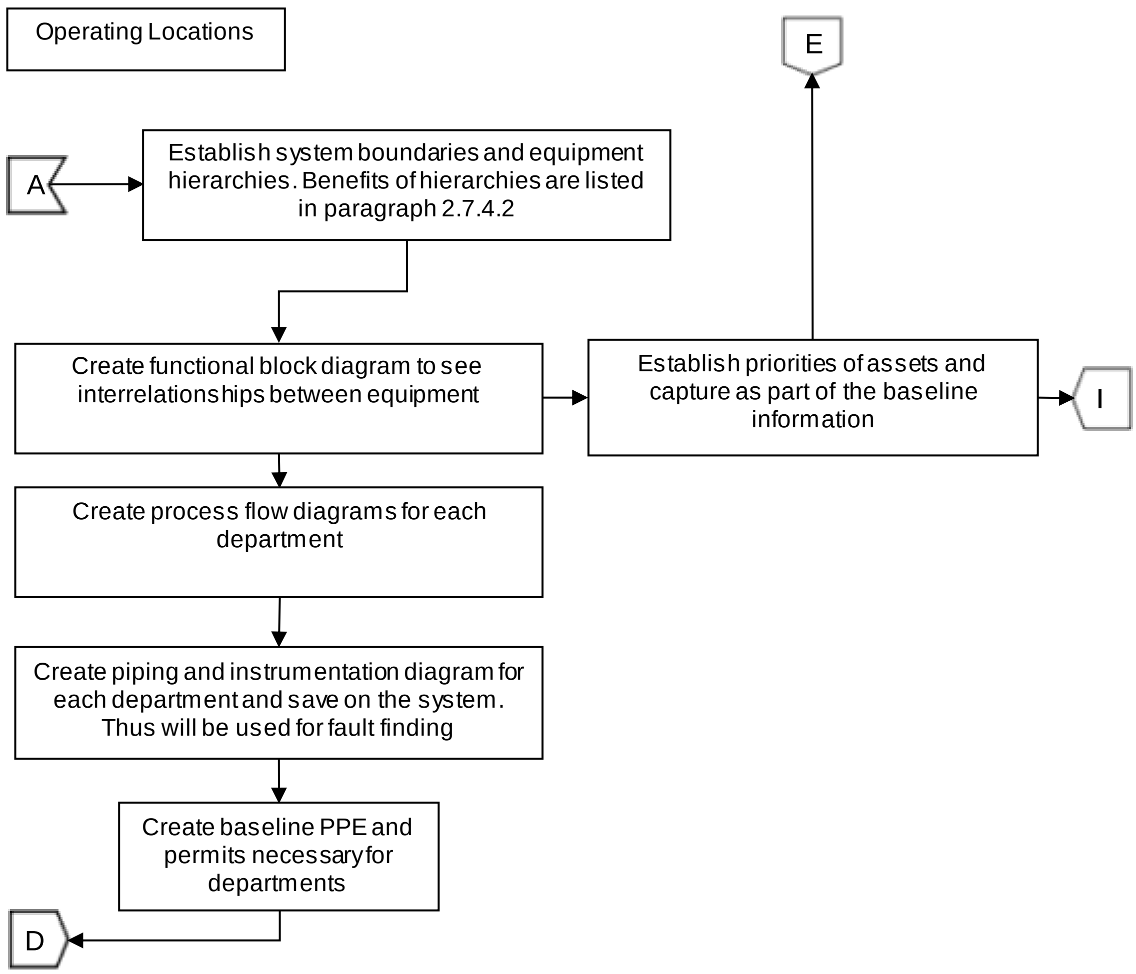

Figure 36: Operating locations flow diagram

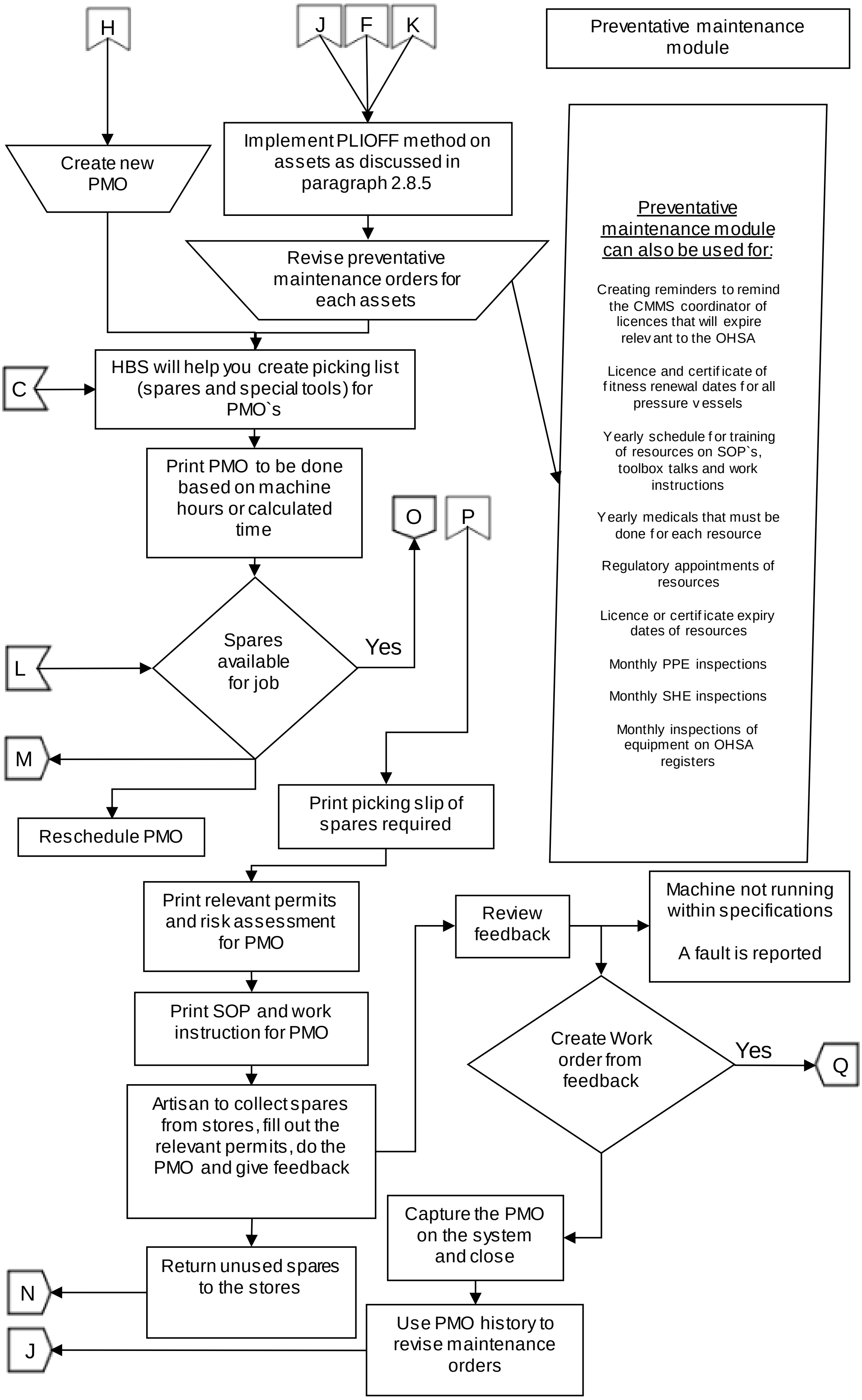

Figure 37: Preventative maintenance flow diagram

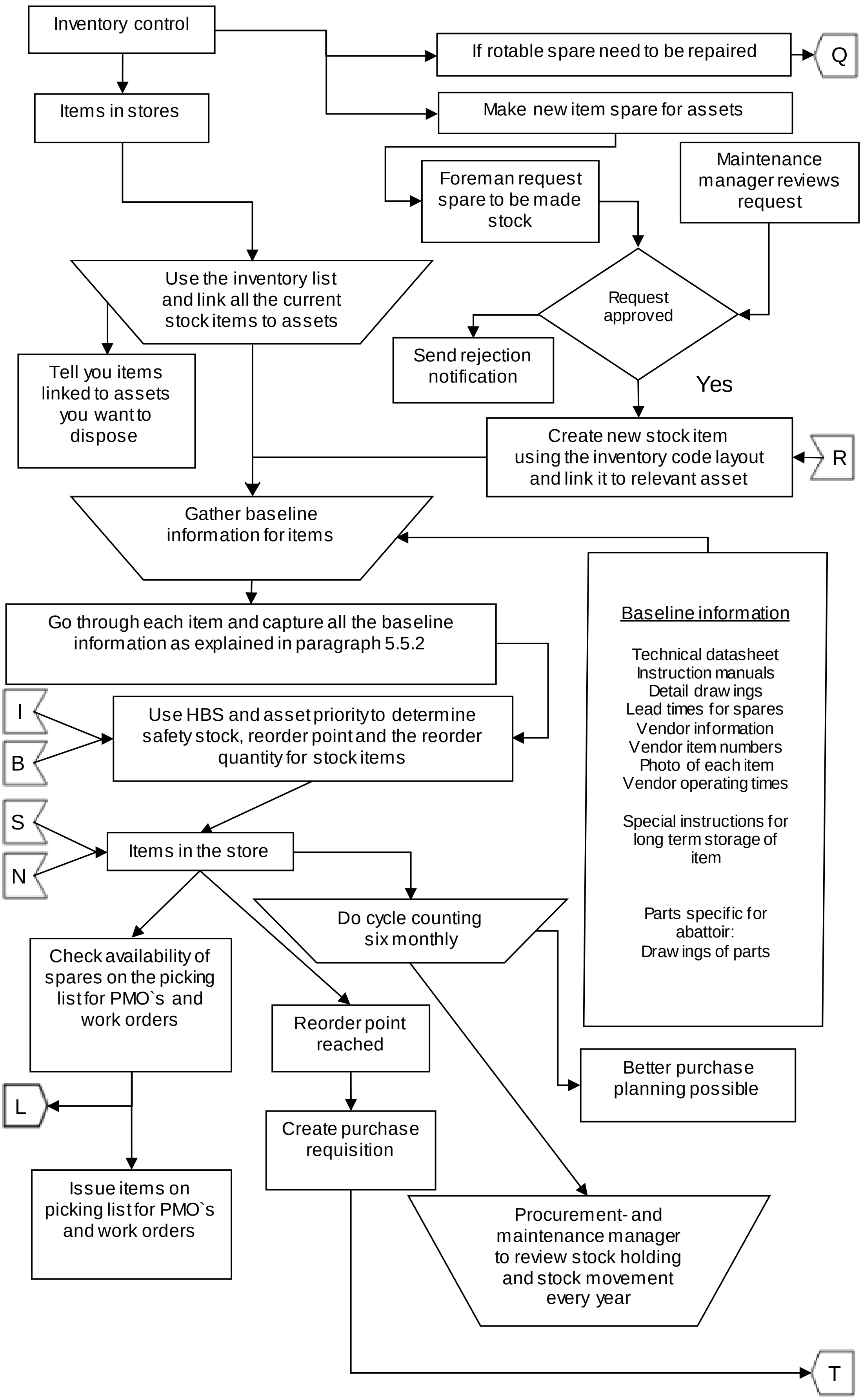

Figure 38: Inventory control flow diagram

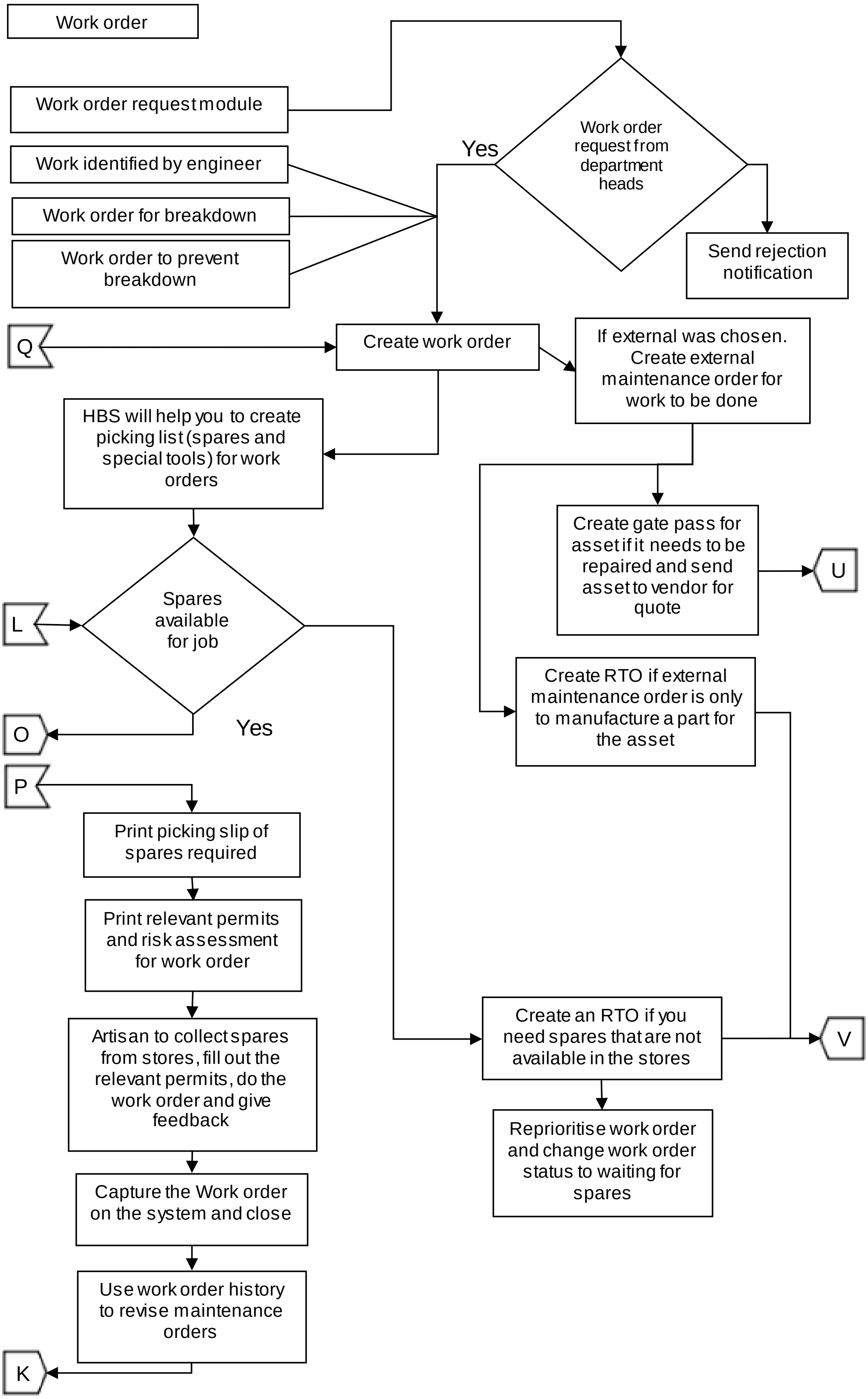

Figure 39: Work order flow diagram

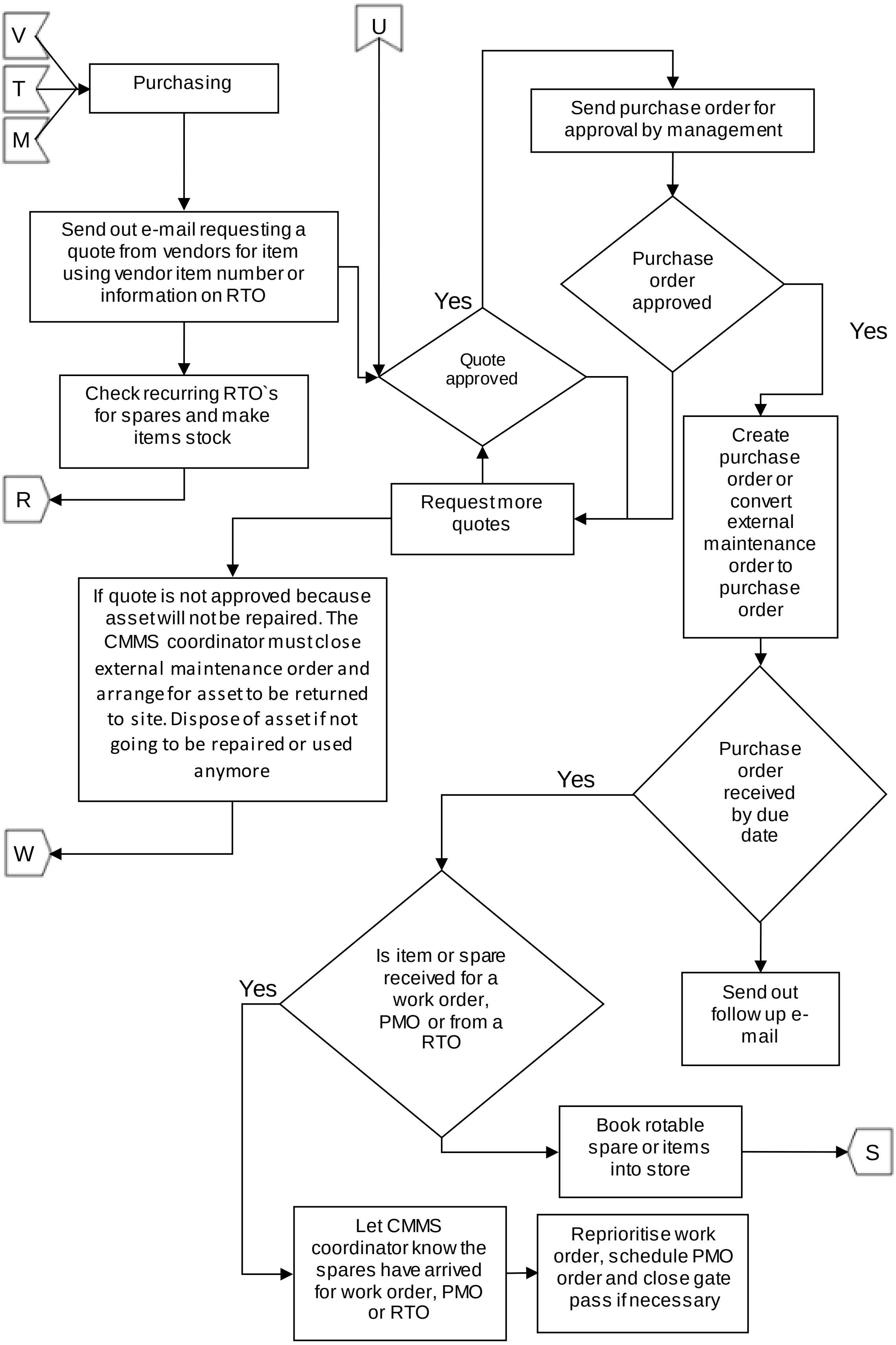

Figure 40: Purchasing flow diagram

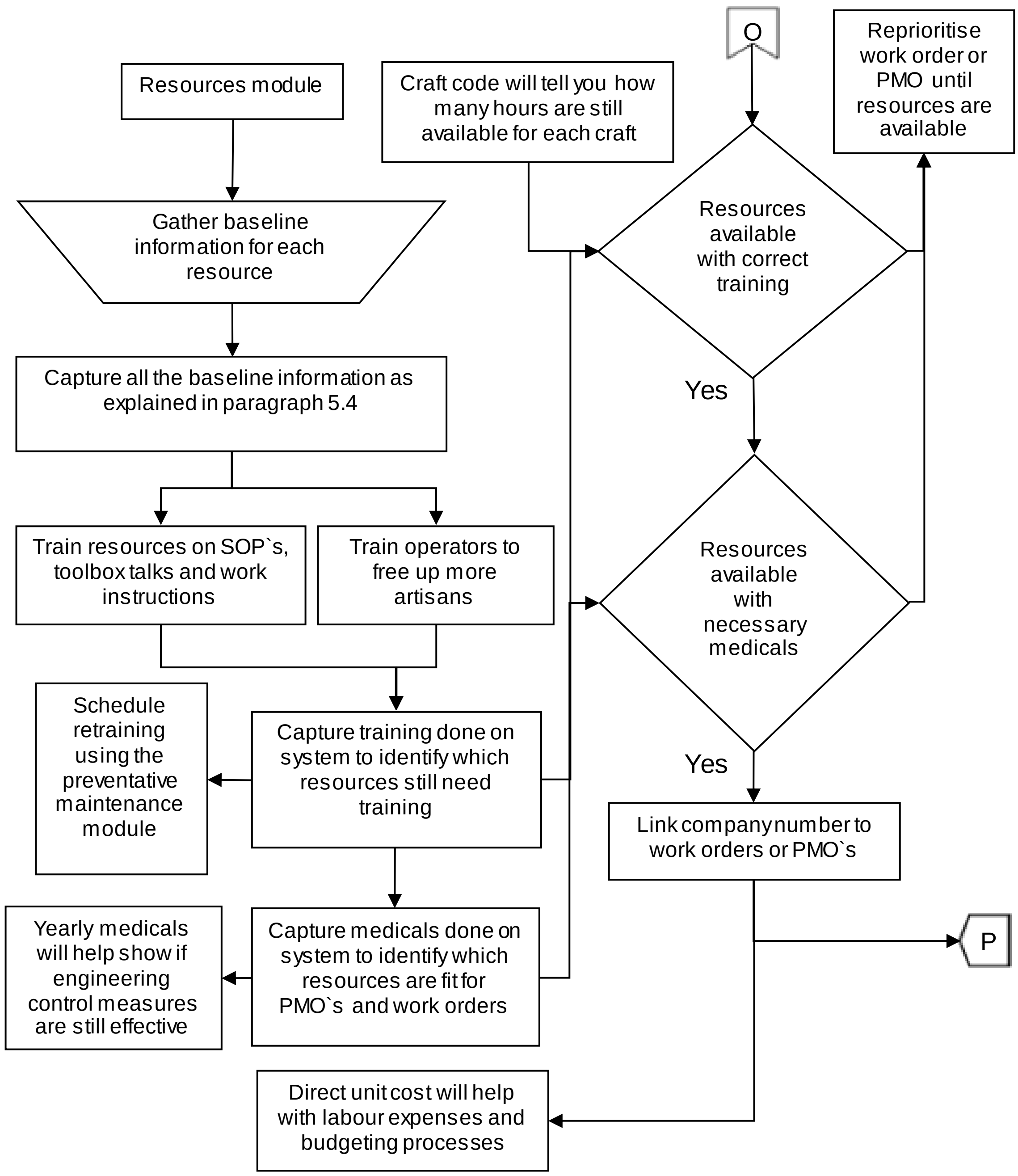

Figure 41: Resources flow diagram

5.13 SUMMARY

Maintenance of assets is of utmost importance to reduce Company A's maintenance cost. Utilising the company's CMMS to the fullest is the first step in achieving this. The introduction gave a brief overview of how the CMMS is currently being used at Company A. The CMMS is currently only used to create work orders, which means that the company is stuck in the second generation of CMMS. It briefly discussed the importance of baseline information and master drawings. A graphical representation showing the links between the modules discussed can be seen.

Every module that is necessary for the successful implementation of the company's CMMS was discussed in detail. Every paragraph discussed a new module, briefly describing the function of the module, followed by the baseline information necessary for each module, fields to be filled in on the CMMS and finally showing important links between modules.

The baseline information, as discussed for each module, explained in detail what information should be gathered and captured into the system. It is advisable not to just dive in and start gathering the information. Meet with all the relevant parties and make a list of the information that needs to be gathered for each module. This way everyone will be on the same page and working towards a common goal. The entire CMMS depends on the baseline information captured into the system.

The fields to be filled in for each module identify the fields that need to be captured into the CMMS. All these fields that were discussed will be used when the CMMS is utilised completely. The fields themselves also help with the links formed between modules, where different modules use the information captured into these fields.

The links between modules illustrate how the information captured by one module is utilised by other modules. The system needs to be current or live so that information on the system always reflects actual data.

The chapter continued by showing a list of reports that can be created to assist maintenance managers to effectively manage maintenance cost. The list shown is by no means the entire list that can be used. You can consult with the developer or programmer to create any report you want. As long as the information is captured into the system it can be reported on, keeping in mind that garbage in will give you garbage out. It is recommended that you meet with all the relevant parties that will make use of the reports, and to make a list of reports needed and what information should be on the reports.

A list of layers that can be added to the master drawing was given for easy reference. The list only gives the most basic layers that can be added and it is recommended that you compile your own list.

The chapter concluded by showing the flow diagram of the developed guide.

Chapter 6 will now develop a sustainability guide to be used by management.

CHAPTER 6

6 ENSURING SUSTAINABILITY

This chapter will start by giving a short introduction on sustainability and why it is important to sustain the CMMS. It will be followed by demonstrating what infrastructure, whether people or hardware, will be necessary for CMMS sustainability. The chapter will continue by explaining the importance of training and will give training guidelines. The antepenultimate paragraph will discuss steps that need to be taken from management down to workshop level. The penultimate paragraph will list the feedback received from management from the guide presented to them. The ultimate paragraph of this chapter will give a summary of the chapter.

6.1 INTRODUCTION

Chapter 1 stated that maintenance does not only aim to keep the equipment in a state of working order, but also plays a decisive role in achieving production goals with optimum cost of ownership and maximum productivity (refer paragraph 1.1). Sustainability is defined as the ability to be maintained at a certain rate or level. We do preventative maintenance on assets to maintain certain levels of operation. If we look at synonyms for ‘maintain’, we see that one is ‘sustain’. This tells you that sustain and maintain can be used interchangeably; and it can be presumed that maintainability and sustainability are also closely related. The previous chapter focussed on eight modules that need to be used correctly for an effective CMMS, the baseline information required and the fields that must be captured on the CMMS.

If you have gathered all the baseline information and captured the information onto the CMMS, you will have an accurate reflection of all the equipment you currently have on site, with all the relevant information. Keeping the information on the CMMS up to date should then become one of the objectives of the company.

This chapter will discuss three points that need to be addressed. The first point will be to show what needs to be put in place in certain departments - whether it is people or hardware. The second point will be to discuss the training that must be given to employees. The third point will be to show what the steps that should be taken, from management down to workshop level, to ensure the sustainability of the implemented CMMS.

By sustaining the information levels of the CMMS you will increase the productivity of the plant and the effectiveness of maintenance strategies.

6.2 WHAT NEEDS TO BE PUT IN PLACE

This paragraph will discuss four points that need to be put in place to ensure CMMS sustainability.

The first point in ensuring sustainability will be to appoint a champion for the CMMS. Duffuaa and Raouf (2015:67) confirm this by saying that a single person should be appointed to head the task group. Wichers (1996) continues by saying that building a structure can only be properly introduced if all terminology and functionality rules are combined in a single procedure and the management thereof done by a single person. The champion must be naturally curious with a desire to improve continuously. He/she must also have a sound knowledge of the company's assets and asset hierarchies, the ability to adapt to a changing environment, strong leadership skills and should also be socially well connected in the company with a good understanding of the different maintenance strategies and activities.

The champion for Company A's CMMS will be responsible for:

- Developing the CMMS implementation plan specific for the company.
- Creating a flow diagram for the CMMS.
- Creating SOP's for each process indicated on the flow diagram.
- Coordinating the update of all the master drawings, doing site walk-downs and making a list of information needed for assets.
- Coordinating with the CMMS coordinator for the capturing of all the information gathered on assets and noting down any deviations.
- Coordinating with the CMMS coordinator for the asset codification of all the assets to ensure consistency.
- Coordinating with the CMMS coordinator for the development of the HBS and establishing of MSI's for the company's assets.
- Coordinating with the IT department to create mandatory fields that must be filled in before an asset can be registered on the CMMS.
- Handling of change management within the maintenance department.
- Auditing information captured into the system to ensure it is complete and accurate.
- Collaborating with IT and the CMMS provider to improve the company's CMMS.
- Developing key performance indicators for the system.
- Creating an asset management policy using international organisation for standardisation (ISO) 55001:2014 as a guideline.
- Developing and optimising of maintenance strategies.
- Training co-champions.

- Developing a knowledge transfer program for the CMMS.
- Developing a training program for maintenance personnel.
- Reviewing asset acquired- and assets disposed accounts on a monthly basis.

The CMMS champion is essential for using the system to its full potential. He/she will use maintenance reports to improve maintenance strategies for assets with the help of the CMMS coordinator, maintenance supervisors and maintenance manager/engineer. The champion will also ensure that indices that measure the performance of maintenance are put in place. A list of indices is explained in Duffuaa and Raouf (2015:288 -292). For the purposes of the sustainability guide, the CMMS coordinator is the lead maintenance planner in the planned maintenance office.

The second point to ensuring sustainability is to give all the relevant stakeholders access to the CMMS. With the eye on the fourth industrial revolution, it does not make sense to have maintenance personnel that do not have access to computers. Giving access to all relevant stakeholders will also enable department heads to create electronic work requests, as discussed in paragraph 5.8.2.

A personal computer with a printer must be made available in each workshop. This will enable the CMMS coordinator to send preventative maintenance orders and work orders to the respective workshops where they can print it out together with any additional information available on the system. The picking slip for the preventative maintenance order will also be already available for printing. The maintenance supervisors can create their own picking slips for work orders from the inventory module and in turn reduce the workload of the CMMS coordinator.

A personal computer with printer must also be made available at the issuing counter of the stores. The store clerk can then access picking slips on the system, thus enabling a paperless picking slip system. This will also make the system as current as possible, as items that are booked out against an order will immediately reflect on the system. The CMMS coordinator can thus not create work orders or preventative maintenance orders under the pretence that stock is available. The purchase order module will also receive immediate notification if inventory items are at their ordering points. With a paper system, this process can take up to two days to reflect on the system.

Having all these things in place will enable you to establish a system in which - if no work order is created - no work may be done.

The third point is to develop procedures for different processes so that anyone who is capable of reading instructions will be able to do certain tasks. The previous chapter focussed on the updating of all the information of the assets and inventory items on site. To ensure the sustainability of the CMMS, you must create certain procedures that must be followed. The CMMS champion must coordinate the development of these procedures. The following list will show some of the critical SOP's to develop to ensure sustainability of the system. The SOP's will also help create a standard for the different sites.

<u>List of SOP's:</u>

- SOP that needs to be followed when a new asset is acquired. (Part of this SOP will be to establish an HBS for the asset, marking the asset and ensuring that the master drawing is updated. The SOP will also explain the necessary fields that need to be captured into the CMMS. The SOP will also explain the process that must be followed when not all the fields on the system can be captured; if there are open fields on the system that cannot be filled in, the maintenance manager/engineer must sign off that the asset can be registered without these fields being captured.)
- SOP showing how to create a PMO.
- SOP showing artisan how to give written feedback on PMO's and work orders; together with spares used and labour hours utilised.
- SOP for capturing information received from PMO's into the system and what steps need to be taken when additional information is received from the PMO.
- SOP for the creation and capturing of work requests and work orders to ensure that one standard is used.
- SOP for disposal of assets and requirements from each department.
- SOP for requesting and creating of inventory codes. The SOP will include instructions for each department to follow to ensure that the correct information is captured on the system.
- SOP that needs to be followed when changes to the plant is done. It includes updating of master drawings.

The mentioned SOP's must be created to sustain the information captured into the CMMS. The SOP is a way of ensuring that all employees know what is expected of them and to create a standard for everyone to use.

The fourth point will be to develop a disaster recovery program for the CMMS. You have already spent countless hours gathering equipment baseline information and capturing it onto the system, creating functional block diagrams, capturing resources information and linking all the assets in the stores to relevant assets. You have created PMO's for each asset and hundreds of work orders. The modification- and failure history has never been so detailed. The last thing that you need is for the CMMS server to fail and lose all the data. The maintenance department normally does not have the capacity to re-enter all the information that will be lost.

The CMMS champion needs to work with the IT department to develop a backup system that will not let the company down. The IT infrastructure should be arranged in such a manner that there are always two backups of the system at any given time and it should not be older than one day. One server can be on site, but the second server should ideally be located off site in a fireproof room. Cloud backups of the CMMS system should also be investigated, as this will dramatically decrease downtime should there be any server failures.

The server should be checked daily to ensure that the backup system is working and that backups are created constantly. Some server rooms create an enormous amount of heat in fireproof rooms so you must ensure that you have adequate climate control and a means of monitoring the climate remotely.

The four points mentioned above are a great starting point to ensure a sustainable CMMS. A sustainable CMMS will allow the said CMMS to be used to its full effectiveness, even if a key maintenance employee or champion leaves the company.

6.3 TRAINING NECESSARY

Many of the maintenance ineffectiveness can be traced to the lack of skilled technical staff (Duffuaa & Raouf, 2015:152). This is also true for the CMMS, where many CMMS features may be underutilised due to the lack of skills and training of CMMS users. The questionnaire results showed that a third of the participants did not even receive training on how to use the CMMS, and they agreed that annual training would help with the sustainability of the CMMS program. The questionnaire showed that incorrect training, partial implementation and staff turnover are three of the main reasons for CMMS implementation failure.

Duffuaa and Raouf (2015:215) state that a training program should be developed to improve existing conditions and issues. Developing multi-skilled workers, by imparting specialist skills through a combination of lectures and on the job training, has to be clearly stated in the basic policy.

They continue by stating that developing equipment-competent maintenance and to nurture human resources must be stated in the training program goals. Before we can start training, we must first evaluate the effectiveness of the current training program by determining the skill level and the level of understanding of the users of the CMMS.

Determining the level of understanding should be done by interviewing the CMMS users. This will highlight any shortcomings in the training program that should be addressed. The interviewer can also be the champion of the system, as he/she will have the best knowledge on all the functions inherent to the system functioning at its best.

The first thing to be addressed by training should be the training of all the users of the CMMS on the SOP's developed for the system. Spend some time ensuring that everybody understands the SOP's developed for the training program, as the information captured by them will be used for many years to generate reports. The SOP's will guarantee that every user of the CMMS is on the same page, thus ensuring accuracy and consistency within the CMMS and the CMMS system not losing its efficacy in case of employee turnover. Training will also assist with the multi-skilling of the CMMS users on all the modules. Multi-skilling will improve the sustainability of the CMMS, as users will know what is necessary for other modules from the module that they use often.

It is important to remember that training must constantly be given to employees in order to prevent users of the CMMS creating their own methodologies when using the CMMS. Internal training courses must be evaluated annually to ensure that any shortcomings are addressed. The preventative maintenance module can be used to create reminders for retraining of CMMS users on the SOP`s for the system. This will prevent the users from doing things differently as stipulated in the SOP`s.

6.4 RESPONSIBILITIES FROM MANAGAMENT DOWN TO WORKSHOP LEVEL

This paragraph will show the different levels from management to workshop level. It will show the different responsibilities in each of the levels with regard to the CMMS of Company A.

Company A has six levels - from management to work shop level - that have to buy into the CMMS for it to be successful. Management involvement will not be confined to the few items listed. Management involvement must, however, be seen all the way through, right down to workshop level. The involvement of management will definitely increase the level of employee involvement. The following section will show the six levels separately and will list the responsibilities of each level. The list will draw from all the information in the previous chapters.

Management of company

Management is responsible for:

- setting out the management structure, showing the rules and responsibilities of each organisational entity;
- all regulatory appointments;
- ensuring that SOP's are developed for each module of the CMMS to ensure that correct data is collected and captured;
- ensuring the flow diagram for the CMMS is updated when changes are made;
- ensuring that adequate training is given to all the users of the CMMS;
- taking charge of the knowledge transfer management in the company;
- giving annual reports to the board of directors on the overall status of the CMMS;
- developing, together with the maintenance manager, the maintenance policy for the company that describes, in broad terms, the direction in which the maintenance management team wants to steer the maintenance organisation (refer paragraph 2.4.3.1);
- working with the maintenance manager and determine the objectives for the maintenance department. These objectives should be updated annually and be specific in terms of both the end results that must be achieved and the dates for achieving such results (refer paragraph 2.4.3.1);
- creating a new awareness of the company`s CMMS and develop in-house expertise for the CMMS;
- involving the head of each department when the company`s ERP and CMMS is upgraded. This normally happens every five years and all the shortcomings or improvements can then be added to the system.

Maintenance manager

The manager will be responsible for:

- communicating the maintenance policy of the company to every employee in the maintenance department - this will create a sense of involvement and the success rate of the CMMS will improve dramatically (refer paragraph 2.4.3.1);
- guiding the project environment when new equipment is purchased and installed to ensure supportability;
- reviewing the maintenance approach that include the type of maintenance, maintenance functions and diagrams;

- developing the maintenance strategy that will be used to maintain different assets (strategy optimisation for assets must be done annually by reviewing the maintenance plan and data received back from PMO's);
- coordinating soft audits of the department`s management and technical systems;
- recommending changes and improvements to the system;
- developing a continuous training program for the maintenance supervisor, CMMS coordinator and the artisans;
- creating, together with the maintenance supervisor and the CMMS coordinator, spare lists for assets, using the HBS and ensuring that stock codes are created in the stores;
- developing TA maintenance programs for assets.

Maintenance supervisors

Maintenance supervisors will be responsible for:

- orientating new personnel in the maintenance environment;
- working with the maintenance manager to constantly create and update work instructions and SOP's;
- working with the CMMS coordinator to conduct hard audits of the plant - with proper inspections of the plant - using a well-defined check list and scoring system;
- quality control of work orders and PMO's executed, giving expert advice to artisans and operators, requisitioning of spares, general safety and housekeeping;
- working with the maintenance manager and CMMS coordinator in prioritising work orders and PMO's;
- explaining why work orders and PMO's are not completed and work with both the maintenance manager and CMMS coordinator to manage backlog of work orders and PMO's;
- monitoring the six losses of TPM on a daily basis.

CMMS coordinator

The CMMS coordinator is responsible for:

- creating work instructions for the processing of work order, work requests, external maintenance orders and PMO's;
- developing the HBS together with the maintenance manager, maintenance supervisor and champion of the CMMS, if not done already;
- arranging continuous asset verification with other departments - taking charge of a complete asset verification once a year;

- assigning work orders and PMO’s to trained, medically fit and qualified resources;
- taking charge of the maintenance administration that includes work orders and PMO’s scheduling, prioritising of work orders and PMO’s, creating picking slips for spares, work order and PMO planning, issuing of work orders and PMO’s, documentation and capturing of feedback of work orders and PMO’s;
- creating external maintenance orders with suitable holding points;
- creating work orders relevant to the OHSA;
- working with the maintenance manager and use feedback from PMO’s and work orders to prioritise and create additional work orders;
- doing monthly updates on running hours of machines;
- reviewing, together with the procurement manager, maintenance manager and maintenance supervisors, the store’s inventory list on an annual basis;
- doing monthly reviews of the finance disposal- and new asset accounts. This will ensure that a maintenance strategy is developed for each asset and if an asset is disposed, the correct processes are followed.

Artisans

Artisans are responsible for:

- maintaining assets at the level expected by the maintenance manager, by performing PMO tasks documented (which will be their main responsibility);
- providing accurate feedback on work orders and PMO’s - with the feedback including work done, inventory items used, parts used and time spent completing the work order or PMO;
- feedback on breakdown work orders, which also include giving a short description of the problem, cause of the problem and what was done to repair the asset;
- doing root-cause analyses of breakdown that occurred.

Machine operators

Machine operators are responsible for:

- performing autonomous maintenance on machines allocated to them, which will include cleaning, lubrication and inspection of machines, making minor adjustments and doing small component change outs;
- reporting functional failures on machines allocated to them.

6.5 FEEDBACK RECEIVED

Part of the validation of the dissertation is to present the implementation- and sustainability guide to the management of Company A and to note down the feedback received. To achieve this, the researcher has developed slides that give a short background of the CMMS at Company A, stating the problem researched, showing the flow diagram of the implementation guide and presenting the sustainability guide. The presentation was presented individually to selected management personnel at Company A. Notes were taken of feedback received during the discussion.

The implementation and sustainability guide presentation was well received by the management team and constructive feedback was received. The feedback received is given in the following condensed paragraphs.

<u>The MTTF should be added to the equipment module:</u> Although the MTTF is not explicitly shown in the implementation guide, it will form part of the baseline information and falls under the 'failure data' mentioned in the baseline information.

<u>The guide must extend past the fourth industrial revolution:</u> The impact that the fourth industrial revolution has on assets does not form part of the dissertation. The researcher agrees that the fourth industrial revolution should form an integral part of the maintenance plan. The researcher explained that the guide would help to implement the CMMS, and thus paving the way for it to receive, analyse and report on the information received from the machines. A decision was made that, when quotes are obtained for new machines, the remote monitoring of that machine must be added to each quote for consideration by management.

<u>Knowledge transfer needs to be improve immediately:</u> Management felt that knowledge transfer is currently completely absent. The researcher agrees that the knowledge transfer is lacking and should start immediately within the maintenance department. The maintenance supervisors are nearing retirement age and valuable knowledge will thus be lost. A possible plan was discussed, namely that interviewing for replacements should start in the near future. The current maintenance supervisors will then exclusively be used for the creation of WI, SOP's, developing the training program for the maintenance department and developing a quality control plan for PMO's and work orders with the CMMS coordinator and maintenance manager. It was also decided that computer literacy would be added to the list of pre-requisites when hiring new artisans and maintenance supervisors.

Appointing of a CMMS champion for sustainability: Appointing a CMMS champion, or even two, was discussed in length. The conclusion was made that appointing a suitably qualified CMMS champion will ensure sustainability of any CMMS and if a CMMS is appointed at Company A, it will ensure better utilisation of their current system.

Training to ensure sustainability: To ensure sustainability of the implemented guide, it was proposed that training must be done on a monthly basis for at least six months to ensure that the users do not create their own methodologies.

Involving more users with the upgrade of the ERP's or CMMSs: Part of the responsibilities of management is to include the head of each department when upgrades to the system is planned. It was suggested that, when upgrades are planned, questionnaires must be sent out to each user of the ERP and CMMS to obtain more information on the issues experienced. Interviews must be held with key users of the system and not only with the head of each department.

Keeping management invested in the CMMS: Many CMMSs fail because the management of the company is not invested in the success thereof. To ensure that management stays invested in the program, the implementation guide must first be done on some selected assets. The feedback of the results must then be given to management. If the maintenance cost has been reduced, the guide must then be implemented in the department. Each department should then be done separately and feedback given to management. The researcher agrees that a pilot program for the guide will help keep management invested in the CMMS, as they will constantly see results from the guide and not only after it has been fully implemented. It will show management that, although they are spending money, they are saving even more.

6.6 SUMMARY

The chapter discussed four points for the consideration of management for the successful implementation and sustainability of the company's CMMS. The training necessary for a sustainable CMMS was discussed. Developing a training program firstly requires that it should be established what employees know and what they do not know. Using the information will help in creating SOP's for the system that will address all the training shortcomings of the past.

The responsibilities of all levels, from management down to workshop level, were discussed. Every level was shown separately, with activities listed for each level. The list for each level must, however, constantly be updated to address any shortcomings and thus ensuring a sustainable CMMS.

The chapter concluded by giving the feedback received from management.

Chapter 7 will make recommendations and conclude the dissertation.

CHAPTER 7

7 CONCLUSIONS

7.1 INTRODUCTION

This chapter will conclude the study by addressing the research objectives as set in Chapter 1 and will make some practical recommendations to ensure sustainability of the implemented CMMS guide. The chapter will continue by making recommendations and discuss limitations of the dissertation. The penultimate paragraph will discuss future research possibilities. The ultimate paragraph will give a summary of the chapter.

7.2 RESEARCH OBJECTIVES

The research question, as stated in Chapter 1, “Can an implementation and sustainability guide be designed and implemented at Company A to ensure that the CMMS is used to its full potential?” was divided into two objectives, namely a main objective and a secondary objective. A literature review of maintenance strategies, maintenance models and CMMS modules was conducted in Chapter 2. Both qualitative and quantitative data was collected and analysed to support the research.

7.2.1 Main objective

The main objective of the dissertation was to develop a CMMS implementation guide for abattoirs, and specifically for Company A, to follow to successfully implement and utilise a CMMS. The interviews, together with the questionnaire circulated to the users of the CMMS, showed that there is a need for a practical, understandable guide to implement a CMMS. It was established that, although users know how to use the CMMS, they do not necessarily know how all the modules work together and why it is important for them to accurately and constantly capture information into the CMMS. It was also established that the users felt that partial implementation, incorrect training, poor planning and staff turnover are currently the biggest contributors to CMMS implementation failure.

To achieve the main objective, Chapter 5 was dedicated to developing an implementation guide for Company A. A graphical representation was given, showing the links between all the modules. Not only was the information necessary for each module discussed, but also the fields that need to be completed for each module. A graphical representation for each module was given again, followed by a list showing the links formed between modules by the information captured for the said modules.

The researcher showed that implementing the guide on some cases reduced maintenance cost. The reduction in maintenance cost on some selected assets chosen by the researcher lead the researcher to believe that, if the implementation- and sustainability guide (as set out in Chapter 5 and 6) is used at Company A; the CMMS will be used to its full potential and maintenance costs will be significantly reduced.

7.2.2 Secondary objective

The secondary objective of the dissertation is to develop a guideline for management to follow to ensure the sustainability of the implemented CMMS. The interviews and questionnaires showed that not enough training is currently given to new employees, and that little or no refreshment training is given to existing employees. From the questionnaire and semi-structured interviews, it became clear that annual training on the CMMS would help to ensure sustainability of the implemented CMMS. The reasons for implementation failure of the CMMS guided the development of the implementation guide and also formed the basis for the sustainability guide.

To achieve the secondary objective, Chapter 6 was dedicated to developing a sustainability guide for Company A. The guide provided the reader with four points that need to be put in place to ensure the sustainability of the CMMS. Each point was discussed and lists were made for ease of use by the reader.

The necessity of training was addressed to ensure that the implemented guide does not lose its effectiveness. Continuous improvement of employees should be the underlying goal of the training program. Sending employees on training courses and classes will increase the morale and self-confidence of the workers.

The guide created a list for each of the six levels of management, listing the responsibilities of every level to ensure the sustainability of the program. The researcher is of the opinion that, if every level does at least the activities listed in Chapter 6, the company’s CMMS will be sustainable for years to come. The guide will ensure that the money spent to implement the CMMS is not in vain and in turn brings down maintenance costs.

Most importantly, the validation of the dissertation was achieved by presenting the implementation- and sustainability guide to the management of Company A. The guide was well received and constructive feedback was obtained. The feedback was used to improve the guide in order to ensure that sustainability of the CMMS will be achieved.

7.3 RECOMMENDATIONS

The training program that must be created for the CMMS users, mentioned in Chapter 6, can also be used as a guide for the development of a training program for the maintenance personnel. You must create detailed work instructions for each asset's PMO and incorporate it into the induction training of the plant. The training program must be designed in such a way as to ensure knowledge transfer between workers. Asking staff members at different levels of management to assist in the creation of work instructions and SOP's will ensure that their knowledge will not be lost when they leave or retire. Knowledge is often overlooked as an asset to the company and is only realised when key personnel leave or retire.

The resource module discussed focused only on the maintenance personnel. The resource module can be expanded to include all the employees on site. You can then list all the training given to all the employees and use the preventative module to create training reminders until the system is able to send out reminders from the resource module itself. This will help the production department choose a suitable replacement, that has all the correct training, for an absent employee.

The inventory module can be improved by developing and implementing store control procedures. Better methods for determining stock levels can be investigated and incorporated into the inventory module.

Improving the preventative maintenance module can be done by incorporating the production figures into the module. Each plant has specific requirements when it comes to maintenance of equipment. OEM specifications might be a good indication of when to do preventative maintenance, but site conditions may drastically change the intervals at which preventative maintenance should be done on assets.

The dissertation briefly discussed RCM, the PLIOFF method and TPM. After the implementation guide has been successfully implemented and the sustainability of the CMMS has been achieved, the PLIOFF method will optimise the maintenance of the plant, using the plant's specific operating methodology, procedures, policies, training and real time operator response as core guidelines (refer paragraph 2.8.5).

Warranty-claim tracking, as well as energy monitoring, normally forms part of an EAM system and both have already been programmed and ready to use. It will be beneficial for the company to invest in adding these modules to the existing CMMS. Adding the energy-monitoring module, together with small modifications to assets, will allow the company to eliminate manual capturing of machine hours, as the hours will always be current on the CMMS.

7.4 LIMITATIONS OF THE DISSERTATION

The dissertation only looked at the CMMS functions of the modules and did not consider any financial or other functions. These functions are important for the overall working of the ERP.

The possibility arises that not enough employees were interviewed or requested to fill out the questionnaire. This can create a false sense of management's understanding of the CMMS and can also lead to the generalisation of the views and opinions of the users of Company A's CMMS - based on the views and opinions of a few users.

Fully testing the implementation and sustainability guide cannot be done in the timeframe set out for this dissertation. It may be necessary to implement radical personnel changes to utilise the CMMS. Changing the work culture in a workplace also requires time. The implementation and sustainability guide can be used and training programs developed, but the full effect of these changes might only be seen when older employees retire and new employees are orientated with the new programs. The guide can also be implemented in stages, as suggested by the feedback received in Chapter 6.

7.5 FUTURE RESEARCH

The implementation and sustainability guide was developed for small companies, specifically for Company A. Further research can be done by implementing the guide at bigger factories to see if the guides reduces the maintenance cost and improve the training program of such factories.

Another study can be done by using the guide and incorporate the ISO 55001 asset management standards into it. The standards show the customers that the company understands how to manage their assets and to consistently deliver quality products. It will be beneficial to manufacturing companies that already comply with ISO 9000 and 14000.

The last recommendation is for a study to be done, incorporating the fourth industrial revolution's concepts, and the benefits associated with it, into a successfully implemented CMMS. A study can be done to see how much a CMMS need to change to accept data directly from machines. The study can include using the internet, video calling and the cloud to improve maintenance of the plant. Where QR stickers on machines allow artisans to download all the data linked to it to their phones, and video calls directly to the maintenance supervisors or maintenance managers/engineers, turnaround time on repairs and fault finding will be improved.

7.6 SUMMARY

The chapter presented the two objectives and showed how the two objectives have been achieved.

Recommendations were made on how different modules of the company's CMMS can be improved; that was not discussed in the dissertation, as it fell outside the scope of the dissertation.

The final part of the chapter identified possible limitations to the dissertation and made suggestions for possible future research topics that build on this dissertation.

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9 ANNEXURES

ANNEXURE A: VIBRATION IDENTIFICATION

Source: Mobley, 2014

Vibration Identification

Cause	Amplitude	Frequency	Phase	Remarks
Unbalance	Proportional to unbalance. Largest in radial direction.	1 × RPM	Single reference mark.	Most common cause of vibration.
Misalignment Couplings or bearings and bent shaft	Large in axial direction 50% or more of radial vibration	1 × RPM usual 2 & 3 × RPM sometimes	Single double or triple	Best found by appearance of large axial vibration. Use dial indicators or other method for positive diagnosis. If sleeve bearing machine and no coupling misalignment balance the rotor.
Bad bearings anti-friction type	Unsteady-use velocity measurement if possible	Very high several times RPM	Erratic	Bearing responsible most likely the one nearest point of largest high-frequency vibration.
Eccentric journals	Usually not large	1 × RPM	Single mark	If on gears largest vibration in line with gear centers. If on motor or generator vibration disappears when power is turned off. If on pump or blower attempt to balance.
Bad gears or gear noise	Low-use velocity measure if possible	Very high gear teeth times RPM	Erratic	
Mechanical looseness		2 × RPM	Two reference marks. Slightly erratic.	Usually accompanied by unbalance and/or misalignment.
Bad drive belts	Erratic or pulsing	1, 2 ,3 & 4 × RPM of belts	One or two depending on frequency. Usually unsteady.	Strobe light best tool to freeze faulty belt.
Electrical	Disappears when power is turned off.	1 × RPM or 1 or 2 × synchronous frequency.	Single or rotating double mark.	If vibration amplitude drops off instantly when power is turned off cause is electrical.
Aerodynamic hydraulic forces		1 × RPM or number of blades on fan or impeller × RPM		Rare as a cause of trouble except in cases of resonance.
Reciprocating forces		1, 2 & higher orders × RPM		Inherent in reciprocating machines can only be reduced by design changes or isolation.

Figure 42: Vibration-identification chart

ANNEXURE B: RCM - FMEA

Reliability Centred Maintenance Analysis - FMEA

System:
Reference:
System Function:

Analyst: **Date:**

Reviewer: **Rev No:**

Approved: **Page of**

XRef	Item	Function	Functional Failure	Failure Mode	FC	Comments	FRef

Failure Effects	
FRef	
Local	
System	
Unit	

Figure 43: RCM FMEA analysis sheet

- Item – Refers to the MSI.
- Functions – Each item has primary and secondary functions that describe the functionality of equipment in its plant context.
- Functional failure – Each function will have one or more functional failures, which is the inability of an item to function at a specified level of performance.
    - Coetzee and Claasen (2002:107) define three concepts *failure, functional failure* and *potential failure* as follows:
        - A failure is any condition which results in unsatisfactory performance or points to the fact that the instant of such unsatisfactory performance is near.
        - A functional failure is the inability of an item (or the system/sub-system in which it is installed) to meet a specific functional performance standard.
        - A potential failure is the imminence of the instant of functional failure. The presence of such potential failure is normally found through measurement of some physical parameter (detecting a deviation from its normal 'healthy' value).
- Failure mode – Each functional failure will have one or more failure modes.
    - Analysis must be performed at the level at which maintenance is executed
    - Only valid failures must be listed
    - It must be descriptive of the failure
    - Identify the cause
- Functional check (FC) – This check implies that the failure mode has an adverse effect on the system function.
- Failure mode reference (FRef) – this column carries a special reference number identifying the failure mode uniquely within the system.
    - The failure effects column carries the failure mode as heading and each has three spaces for local, system and unit effects:
        - Local effects are those that the failure mode has on its own function.
        - System effect is the effect of the failure mode at system level.
        - Unit effect is the effect on the total production unit.

This appendix shows the work done by Coetzee and Claasen (2002:106-107).

ANNEXURE C: RCM – TASK ANALYSIS

Reliability Centred Maintenance Analysis - Task Analysis

System:
Reference:
System Function:

Analyst:
Date:

Reviewer:
Rev No:

Approved:
Page of

Legend
TO: Trade-off Study Number
TC: Task Combination Check
F: Frequency Group
T: Trade
ST: Setup Type
P: Production Indicator
SG: Schedule Group

FRef	Failure Mode	RR	RC	Conseq Type	Task Type	TO	Task	Task Detail	TC	F	T	ST	P	SG

Figure 44: RCM - Task Analysis sheet

The first two columns have already been explained.

- Relative Risk (RR) – This calculated value is used to select the “20%” of failure modes, which has “80%” of the risk impact, for further analysis
- Risk Check (RC) – The failure modes that will be analysed further should be ticked here
- Conseq type – Indicates the failure mode classification
    - H – Hidden safety and environment consequence
    - HO – Hidden operational consequence
    - S – Safety and environment consequence
    - O – Operational consequence
    - NO – Non-operational consequence
- Task type – Filled in with the following abbreviations
    - LSA – Lubrication, Servicing or Adjustment task
    - FF – Failure finding task
    - QI – Quality improvement task
    - OC – On-Condition task
    - Rec – Reconditioning task
    - Rep – Replacement task
    - CM – Corrective maintenance task
    - DO – Design-out task
- Trade-off (TO) – Used to document a cross-reference to the trade-off study, if applicable
- Task and Task detail – Self-explanatory
- TC – Task combination
- F – Frequency of task
- T – Trade involved in the task
- Set-up (ST) – Activity that precede execution of the maintenance task
    - P – Work can be done during production
    - O – Opportunistic – minor work, to be done during production stoppages
    - SD – Major work to be done during shutdowns
- Production indicator (P) – Indicates when work can be performed

This appendix shows the work done by Coetzee and Claasen (2002:122-123).

ANNEXURE D: CALCULATION OF OEE

OEE calculation according to Duffuaa and Raouf (2015:264-265) is as follows:

$$OEE = Availability \times Performance\ efficiency \times Quality\ rate$$

Where

$$Availability\ = \frac{Loading\ time\ - Downtime}{Loading\ time}$$

$$Loading\ time\ = Available\ time - Planned\ downtime$$

Planned downtime refers to downtime officially scheduled I the production plan, such as scheduled maintenance and management activities

$$Performance\ efficiency = \frac{Theoretical\ cycle\ time\ \times Amount\ processed}{Operating\ time}$$

$$Quality\ rate\ = \frac{Amount\ processed - Defective\ amount}{Amount\ processed}$$

Overall equipment efficiency can thus be reduced to the following:

$$OEE\ = \frac{Theoretical\ cycle\ time\ \times Amount\ processed\ \times Quality\ rate}{Loading\ time}$$

ANNEXURE E: EQUIPMENT MODULE FORMS AND SHEETS

Asset registration form:

General:

Description: ____________________________

Serial number: ________________________

Description 2: ___________________________

Vendor Name: ________________________

Price: _________________________________

Department Code: _____________________

Fixed asset code: ________________________

Fixed asset location: ___________________

Maintenance:

Vendor No.: ____________________________

Warranty date: _______________________

Insured: _______________________________

Licence renewal: ______________________

Certificate of fitness Renewal: _____________

Meter reading: ________________________

Meter Type: ___________________________

Priority of asset in system: _____________

Information to be submitted with asset registration:

Relevant specific data for asset

Architect plans if asset is building

Photograph of asset

Signed plans from municipality

Operation manual

Signed plans from department of agriculture

Maintenance manual

Updated master drawing with new building on

Safety data sheets for lubricants

Safety date sheets of dangerous substances

Assembly drawings

Special tools required for asset

Special training needed to work in asset

Maintenance Manager Signature……………

Date……….…..

- Description – Description of asset
- Description 2 – Additional search description
- Price –The price of the asset
- Fixed asset code – The allocated code to the asset

Example of fixed asset codes			
BO	Building office block	CH	Computer hardware
EE	Electronic equipment	EM	Earth moving machines
LE	Laboratory equipment	LT	Loose tools and equipment
PM	Plant and machinery	WE	Workshop equipment

Table 6: Example of fixed asset codes

- Serial number – Serial number of asset
- Vendor Name – Name of vendor or OEM of equipment
- Department code – Refer Annexure F
- Fixed asset location – Refer Annexure F
- Vendor No. – Number allocated to the OEM for the asset
- Insured – Yes or no answer
- Certificate of fitness renewal – This can be for assets that need to be calibrated yearly to government inspection on pressure vessels.
- Meter type – Hours or kilometres
- Warranty date – Date the warranty expires
- Licence renewal – Date when licence of equipment expires
- Meter reading – Will be zero except if second hand asset is acquired
- Priority of asset in system – The rating will by between high, moderate and low
  - High: Has an impact on production
  - Moderate: Might have an impact on production
  - Low: No impact on production

Asset disposal form:

Description: ______________________________ Serial number: _________________________

Fixed asset code: ___________________________ Fixed asset location: ____________________

Department code: _________________________ Estimated value of asset: _______________

Replacement asset number: ________________ Value of asset on Navision: _____________

Condition of asset:

☐ Excellent ☐ Good ☐ Fair ☐ Poor ☐ N/A

Recommended method of disposal:

☐ Sale ☐ Auction ☐ Trade - in ☐ Scrap/Junk ☐Lost ☐ Stolen

Reason for Sale/Auction/Trade-in: ____?

Items linked to asset in inventory:

____

____

____

Will the inventory assets be disposed or sold with asset? _________________________________

Invoice number if asset is sold, auctioned or traded in: ___________________________________

Weighbridge slip if asset is sold as scrap with invoice: ____________________________________

Planned maintenance officer: Signature _______________ Date______________

Maintenance Manager: Signature _______________ Date______________

Financial Manager: Signature _______________ Date______________

Procurement manager: Signature _______________ Date______________

Operation Manager: Signature _______________ Date______________

Data sheet for motors:

Frame design:		Model:	
Output:	kW	Frequency:	Hz
Voltage:	V	DE Bearings:	
Ampere:	A	NDE Bearings:	
Number of poles:		Insulation class:	
Ingress protection:	IP	Phases:	
Service factor:		Serial number:	
Duty:		Cos φ:	
Weight:	kg	Seal:	

Table 7: Data sheet for motors

Data sheet for gearboxes:

Type:		Serial number:	
Rotational speeds:	RPM	Gear ratio:	
Oil type:		Oil quantity:	L
Mounting position:		Service factor:	
Weight:	kg	List of oil seals:	
Bearing in gearbox:			

Table 8: Data sheet for gearboxes

Data sheet for pumps:

Type:		Serial number:	
Rated Flow (Q):	l/min	Head max:	m
Speed:	RPM	Max fluid temp:	°C
Ingress protection:	IP	Number of stages:	
Bearings:		Weight:	kg
Oil seal:		Mechanical seal:	
Add the following if it is a submersible pump			
Phases:		Frequency:	Hz
Speed:	RPM	Volts:	V
Ampere:	A	Cos φ:	
Output:	kW		

Table 9: Data sheet for pumps

Data sheet for hydraulic pumps:

Pump:	cc/rev	Maximum pressure:	bar
Motor:	kW	Type:	

Table 10: Data sheet for hydraulic pumps

Data sheet for evaporative coils:

Coil Thermal Rating			
Latent heat capacity:		Sensible heat capacity:	
Total heat capacity:			
Coil Data			
Finned length:		Rows high:	
Rows deep:		Fin spacing:	
Overall length:		Overall height:	
Face area:		Air face area:	
Total surface area:		Coil internal volume:	
Fluid Connection sizes:			
Fluid conditions			
Refrigerant		Refrigerant Temp:	
Recirculation ratio:		Refrigerant flowrate:	
Air conditions			
On coil conditions			
Altitude:		Dry bulb Temp:	
Wet bulb Temp:		Relative humidity:	
Airflow rate			
Off coil conditions			
Dry bulb Temp:		Wet Bulb Temp:	
Relative humidity:			

Table 11: Data sheet for evaporative coils

Data sheet for ammonia screw compressors:

Type:		Serial number:	
Year of manufacture:		Weight:	kg
Max allowable working pressure:	bar	Temp at max allowable working pressure:	°C
Refrigerant:		Rotation	
Swept volume:	cfm		
Thermosiphon			
Shell side			
Max allowable working pressure:	bar	Temp at max allowable working pressure:	°C
Max design metal temperature	°C	Pressure at max design metal temperature:	bar
Tube side			
Max allowable working pressure:	bar	Temp at max allowable working pressure:	°C
Max design metal temperature	°C	Pressure at max design metal temperature:	bar
Serial number:		Year built:	

Table 12: Data sheet for screw compressors

Data sheet for air compressors:

Type:		Serial number:	
Max working pressure:	bar	Input power:	kW
Rotational speed:	RPM	Free air delivery	l/s or m³/min
Weight:	kg	Volts	V
Phase		Frequency	Hz
Ampere:	A		

Table 13: Data sheet for air compressors

Data sheet for vacuum pumps:

Type:		Serial number:	
Pressure abs:	mbar	Volume:	m³/min
Rotational speed:	RPM	Oil type:	
Weight:	kg	Oil quantity:	L

Table 14: Data sheet for vacuum pumps

Data sheet for Pressure vessels (Boilers):

Manufacturer:		Serial number:	
Type of boiler:		Year of manufacture	
Government #		Working pressure:	kPa
Design pressure:	kPa	Design temperature:	°C
Operating temp:	°C	Test pressure:	kPa
AIA:		Design code:	

Table 15: Data sheet for pressure vessels (Boilers)

Data sheet for pressure vessels:

Manufacturer:		Serial number:	
Code of manufacturer:		Hazard category for SANS 347	
Design pressure:	kPa	Test pressure:	kPa
Design temperature:	min/max	Cubic capacity	m³
AIA:		Year of manufacture	
Stress relieved:		Corrosion allowance	mm

Table 16: Data sheet for pressure vessels

Data sheets for transformers:

Manufacturer:		Serial number:	
Type cooling:		Phases:	
Frequency:	Hz	kVA	
Impedance:	%	Core & Windings:	kg
Date manufactured:		Total mass:	kg
High voltage amps:	A	Oil quantity:	L
Low voltage amps:	A	Max altitude:	m
Connection symbol:		Temp rise over amb:	°C

High voltage Side			Low voltage Side
Position	Connect	Volts	Volts

Table 17: Data sheet for transformers

Data sheets for power factors:

Manufacturer:		System rating	vAC
Continuous rating:	vAC	Steps each (Qn)	kVAr
Temperature rating:		Total steps:	
Connection:		Frequency:	Hz

Table 18: Data sheet for power factors

Data sheets for mechanical power transmission:

For chain drive:			
Drive end sprocket:		Non drive end sprocket:	
Drive end taper lock if applicable:		Non drive end taper lock if applicable:	
Chain size:		Chain length:	mm
For V-belt drive:			
Drive end pulley:		Non drive end pulley:	
Drive end taper lock if applicable		Non drive end taper lock if applicable:	
Number of v-belts:		Size of V-belt	

Table 19: Data sheet for mechanical power transmission

Data sheet for conveyors:

Belt type:		Wear strip material:	
Belt sprocket size:		Belt sprocket material:	
Flight thickness:	mm	Screw orientation:	

Table 20: Data sheet for conveyors

It is impracticable to list all the different data sheets in this dissertation. The data sheets shown are the most common data sheets that are used in an abattoir environment. It will be a good idea to develop all the relevant data sheets for your organisation when you gather all the baseline information for your factory. You will again need to consult with all the relevant parties when developing the data sheets.

ANNEXURE F: OPERATING LOCATIONS

- Fixed asset location – This refers to the town/site where the equipment is installed. This is useful when one program is used for multiple sites.
    - Department code – The department code is used to show where the asset will be installed on site.

Table 21 shows an example of how you can determine department codes:

1234					
1		2		34	
A	Abattoir	B	Bloemfontein	BP	By-Products
C	Carcass	C	Ceres	SF	Slaughter Floor
D	De boning	H	Howick	CH	Carcass Handling
E	Export	N	Nelspruit	BH	Box handling
L	Loading	K	Kroonstad	DC	Deboning cutting
O	Offal			WB	Warehouse boxing
S	Site			GO	Green offal
T	Technical			EN	Engineering
				RE	Refrigeration
				BL	Boilers
				PT	Pre Treatment

Example of department codes			
ABBP	By-Products	ABSF	Slaughter floor
OBGO	Green offal	OBRO	Red offal
DBDC	Deboning Cutting	DBDB	Deboning boxing
TBEL	Electrical department	TBMC	Mechanical department
TCRE	Refrigeration	LBWB	Warehousing Boxing
AKBH	Box handling	TKBL	Boilers

Table 21: Department codes

Explanation of department code:

AKBH = Abattoir Kroonstad Box handling

ANNEXURE G: RESOURCES

General			
Company Number:		Department code:	
Name:		Surname:	
Use time sheet:	Yes / No	Resource group:	
Invoicing			
Direct unit cost:	R		
Personal data			
Job Title:		ID Number:	
Drivers licence:		Employment date:	
Address:		Medicals done:	
		Promotion history:	
		Craft Code:	
		Accident history:	
Education			
Secondary Education:		Tertiary Education:	
Courses attended:		Training received:	
Date of course:		Date of training:	

Table 22: Data sheet for resources

- Department code – The department to which the resource cost will be allocated.
- Resource Group – Groups that can be chosen for engineering will be MECH, ELEC, WORKSHOP and CIVIL.
- Direct unit cost – Hourly rate that will be charged to work orders and jobs.
- Employment date – Date employee started at company.
- Medicals done – All the medicals that the employee has done are available here. Medicals include a spirometry, chest X-ray, audiogram, electrocardiogram, diabetes test, vision and colour vision test, epilepsy, previous operations. The CMMS should be updated every time the employee is sent for any medical whatsoever.
- Craft code – Trade of the employee or if he will be an operator.
- Courses attended – Special courses attended for further development of employee.
- Training received – Training include training on SOP's, breathing apparatus training and height training.
- Date of course and training – The date that a course was attended or training was received by an employee.

ANNEXURE H: INVENTORY CONTROL

The inventory item card table will show the fields that (at least) needs to be captured into the CMMS.

Inventory item card					
General					
Inventory code:			Description:		
Base unit of measure:			Shelf number:		
Stock out warning:			Technical datasheet:		
Invoicing					
Unit cost:			Location code:		
Statistic group 1:			Statistic group 2:		
Replenishment					
Purchasing System:			Lead time calculations:		
Vendor No.:			Vendor item No.:		
Purchase unit of measure:			Safety stock quantity:		
Priority of item:			Preferred supplier:		
Reorder point parameter					
Reorder Point		Reorder		Max Inventory:	
Maintenance Checks					
Use for maintenance:			Fixed asset numbers:		

Table 23: Inventory item card

- Inventory code – The inventory code selected for the item upon registration of the item.
- Description – The item description that will mainly be used to search the item.
- Base unit of measure – The unit measure of the item (each, gram, case, litre, roll, etc.).
- Shelf number – This will be the location of the item in the store.
- Technical data sheet – The reference number and link must be added here to the technical data- or material safety data sheet for the item.
- Stock out warning – The default setting is normally yes, but No can be selected. This is more for production inventory.
- Unit cost – The price the unit is at the time of purchase.

- Location code – This refers to the site where the spare is kept.
- Purchasing system – This is the system that will be used to replenish stock (purchase, production order or assembly).
- Statistic group 1 and 2 – The statistic group that the spare belongs to must be selected from a list. It is common for different people to misspell when capturing information. The statistic group will help you search spares according to groups and not description alone.
- Lead time calculation – The lead time for the spare will be entered here that will be used to determine quantities and safe stock.
- Vendor No. – The vendor number of the vendor suppling the item will be selected here from a list of vendors.
- Vendor item No. – The vendor item number must be entered here. This will help ensure that the correct item is ordered.
- Safety stock – Extra stock that is maintained in the store. Works in unison with minimum stock levels.
- Use for maintenance – You must indicate if the spare will be used for maintenance of machines.
- Reorder point parameter – The reorder point is the point when a purchase order must be created. Reorder is how many items must be ordered.
- Fixed asset numbers – The list of fixed asset numbers that the item is used on must be selected from a list form the equipment module.
- Preferred supplier – If there is a preferred supplier for the item the vendor no. must be captured in this field.

Inventory code layout					
ABCDEF1234					
A		B		CDEF	1234
Z	Consumable stock	C	Cleaning, Computer stationary, Construction, Consumables	Short description	Numerical codes
C	Consignment stock	E	Electrical		
		F	Food		
		L	Loose tools		
		M	Mechanical, Maintenance		
		P	Packaging, Protective clothing		
		R	Returnable		
		S	Stationary, Spices		
		W	Workshop		
Example of inventory codes					
ZMDROP1135	Drop finger carcass chain 458				
ZPGUMB1200	Gumboot Green Size 7				

Table 24: Inventory code layout

ANNEXURE I: VENDOR ITEM CARD

Vendor item card			
General			
Vendor number:		Vendor Name:	
Address:		Address 2:	
Postal code:		Country/Region:	
Communication			
Contact person:		Contact number:	
Fax number:		E-mail:	
Website:		Work number:	
Invoicing			
VAT Registration number:		Payment method:	
Price including VAT:		Payment terms:	
Closed over holiday seasons:		Purchaser	

Table 25: Vendor item card

- Vendor number – The vendor number allocated to the vendor by the financing department.
- Vendor Name – Trading name of vendor.
- Address, Address 2, postal code, country/region – Address of vendor. The country will automatically select the currency in which the vendor must be paid.
- Contact person – Sales representative or main contact.
- Contact number – Cell phone number of main contact or sales representative.
- Fax number – Fax number for communication.
- E-mail – E-mail of company and sales representative and main contact.
- Website – Website of company for online trading or shopping.
- Work number – Company`s head office number.
- VAT registration number – Self-explanatory.
- Payment method – Method vendor prefers to be paid.
- Payment terms – Account or cash on delivery.
- Closed over the holiday season – ‘Yes’ or ‘no’ required.
- Purchaser – E-mails of all the relevant store staff that will review quotes to be added here.

ANNEXURE J: DESIGN OF A WORK ORDER REQUEST

WORK ORDER REQUEST					
Date:		Requested by:			
Time:		Job Designation			
Cost Centre:		Minor repair		Breakdown	
Asset Number:		Modification		External	
Equipment description:		Damage to property		Capital / Abnormal	
When required:		Planned Maintenance		Repair	
PLEASE CARRY OUT THE FOLLOWING WORK:					
…… …… ……					
Received by:		Department responsible:			

Table 26: Work order request

- Date – Date department head requested work to be done
- Time – Time department head requested work to be done
- Cost centre – Department cost centre that requested the work to be done
- Asset number – Asset number of equipment for which work needs to be done
- Equipment description – Asset description
- When required – Date when work should be completed
- Requested by – Supervisor’s name of relevant department requesting work order
- Job designation – Supervisor selects job designation for work order
- Please carry out the following work – Description of work that the supervisor is requesting
- Received by – The CMMS coordinator’s name
- Department responsible – Department to which the work order is allocated.

ANNEXURE K: DESIGN OF A WORK ORDER

WORK ORDER:...

Work order number:		Requested By:		Time Spent:	
Date:		Job designation:		Date:	Time:
Time:		Craft required:			
Cost Centre:		Estimated time in hours			
Asset number:					
Equipment		Special tools and technical information required:			
When Required:					
Carried out by:					
				Total:	

DETAILS OF WORK DONE:

....
....
....
....
....
....
....

IMPORTANT SPARES USED

Quantity	Description	Stores part number

Signature of artisan	Signature of Maintenance supervisor	Signature of requestor

Table 27: Work order

- Work order – Description of work that needs to be done.
- Work order number – Unique work order number created by the planning office.
- Date – Date the work orders was created.
- Time – Time the work order was created.
- Cost centre – Department cost centre that requested the work to be done.
- Asset number – Asset number of equipment that work need to be done for.
- Equipment description – Asset description.
- When Required – Date when work should be completed.
- Carried out by – Resource name that will carry out the work.
- Requested by – Supervisors name of relevant department.
- Job designation – Job designation and code numbering will be shown here.
- Craft required – The craft can be either a single craft i.e. mechanical, electrical, civil, handyman, welder, plumber, painter, carpenter, or can be a combination thereof.
- Estimated time in hours – Estimated hours to complete work order.
- Special tools or technical information required – Will show what tools or technical data may be required (Manuals, drawings, SOP's, Work instructions, etc.).
- Time spent – The date and time spent on completion of the work order.
- Details of work done – Notes are made here on what was actually done to complete the work order.
- Important spares used – The quantities, description and stores part number of spare parts used to complete the work order.
- Signatures – The work order will be signed here upon completion of the work order.

ANNEXURE L: QUESTIONNAIRE

1. How old are you?

20 – 30		30 – 45		45 – 60	

2. Do you use the CMMS (ERP Add-on) on a daily basis?

Yes		No	

3. How long have you been using the program (Years)?

1 – 5		5 – 10		11 – 15		15 – 20	
Select here if answered no in Question 2							

4. How many hours a day do you spend using the program?

1 – 2		2 – 4		4 – 6		6 – 9	
Select here if answered no in Question 2							

5. Rate the training you received on how to use the CMMS

Poor		Below Average		Average		Above Average		Excellent		Did not receive training	

6. Is help and support for the program readily available?

Always available		Sometimes available		Not available	

7. How user-friendly is the program?

Poor		Below average		Average		Above average		Excellent	

8. How difficult is it to use the program?

Very easy		Easy		Somewhat easy		Somewhat difficult		Difficult		Very difficult	

9. What sentence best describes a CMMS?

It is a maintenance strategy itself	
It is a tool to support existing maintenance strategies	
It is a good work order system	

10. Which of the following reports are currently generated by the CMMS for review by management? There can be multiple answers.

Report showing performance according to the standard by the crafts utilised	
Weekly backlog report by craft	
Report showing the percentage of emergency maintenance to planned maintenance	
Report showing the percentage of repair jobs originated as a result of PM inspections	
Summary of maintenance costs by work	
Percentage of repeat jobs and product rejects	
Monthly report that includes downtime of critical and major equipment and their availability	

11. In your opinion, rate the impact that the following reasons have on CMMS implementation failure.

Extent / Reason	No Impact	Smallest Impact	Small Impact	Big Impact	Biggest impact
Partial Implementation					
Poor Planning					
Incorrect Training					
Staff Overload					
Work Culture					
Insufficient Data					
Staff turnover					

12. Rate the importance of the following, in your opinion, for the successful implementation of a CMMS.

Importance / Requirement	Use a scale of 1 to 6. Where 1 is most important and 6 least important.				
Correct Implementation					
Planning					
Training					
Staff Needed					
Work Culture					
Data gathering					

13. What can be added to the existing program to improve its effectiveness?

14. Rate the significance of the following modules, in your opinion, for the successful use of a CMMS.

Significance / Module	No significance	Least significant	Significant	High significance	Highest significance
Equipment : For listing of assets and data					
Operation locations : Location where asset is utilised					
Resources : Information and skills of resources					
Inventory Control : Control of spares related to asset numbers					
Safety Plans					

Purchasing Module : Purchasing of stock items for asset numbers					
Work orders : For scheduled and unscheduled work					
Preventative Maintenance : For maintenance of assets					

15. Do you feel that the program you are currently using is used to its full potential?

Yes		No	

16. Will a guide explaining the importance of the different modules of a CMMS help with the implementation of the CMMS?

Not at all likely		Not so likely		Somewhat likely		Very likely		Extremely likely	

17. Do you feel, in your opinion, that the maintenance functions get lost in an Enterprise resource planning program?

Yes		No	

18. What modules of the current program, in your opinion, are not up to standard?

Standard / Module	Highly up to standard	Up to standard	Adequate	Not up to standard	Not at all up to standard
Equipment : For listing of assets and data					
Operation locations : Location where asset is utilised					
Resources : Information and skills of resources					
Inventory Control : Control of spares related to asset numbers					

Safety Plans					
Purchasing Module : Purchasing of stock items for asset numbers					
Work orders : For scheduled and unscheduled work					
Preventative Maintenance : For maintenance of assets					

19. What can be added or changed in the following modules to improve the CMMS in your opinion?

Equipment : For listing of assets and data	
Resources : Information and skills of resources	
Inventory Control : Control of spares related to asset numbers	
Purchasing Module : Purchasing of stock items for asset numbers	
Work orders : For scheduled and unscheduled work	
Preventative Maintenance : For maintenance of assets	

20. Do you feel, in your opinion, that external maintenance orders are managed properly? If you answer no, please provide reasons for your answer.

Yes		No	
Reason if answer is no :			

21. Do you feel, in your opinion, that Rotable spare items are managed properly? If you answer no, please provide reasons for your answer.

Yes		No	
Reason if answer is no :			

22. Should the CMMS make recommendations to management after reviewing breakdown trends and costs incurred?

Strongly agree		Agree		Disagree		Strongly disagree	

23. How regular should training be given on the different functions of the program?

Three monthly		Six Monthly		Annually		Bi-Annually	

24. On which module, in your opinion, should retraining focus?

Priority / Module	High Priority	Medium Priority	Low priority	No Priority
Equipment : For listing of assets and data				
Operation locations : Location where asset is utilised				
Resources : Information and skills of resources				
Inventory Control : Control of spares related to asset numbers				
Safety Plans				
Purchasing Module : Purchasing of stock items for asset numbers				
Work orders : For scheduled and unscheduled work				
Preventative Maintenance : For maintenance of assets				

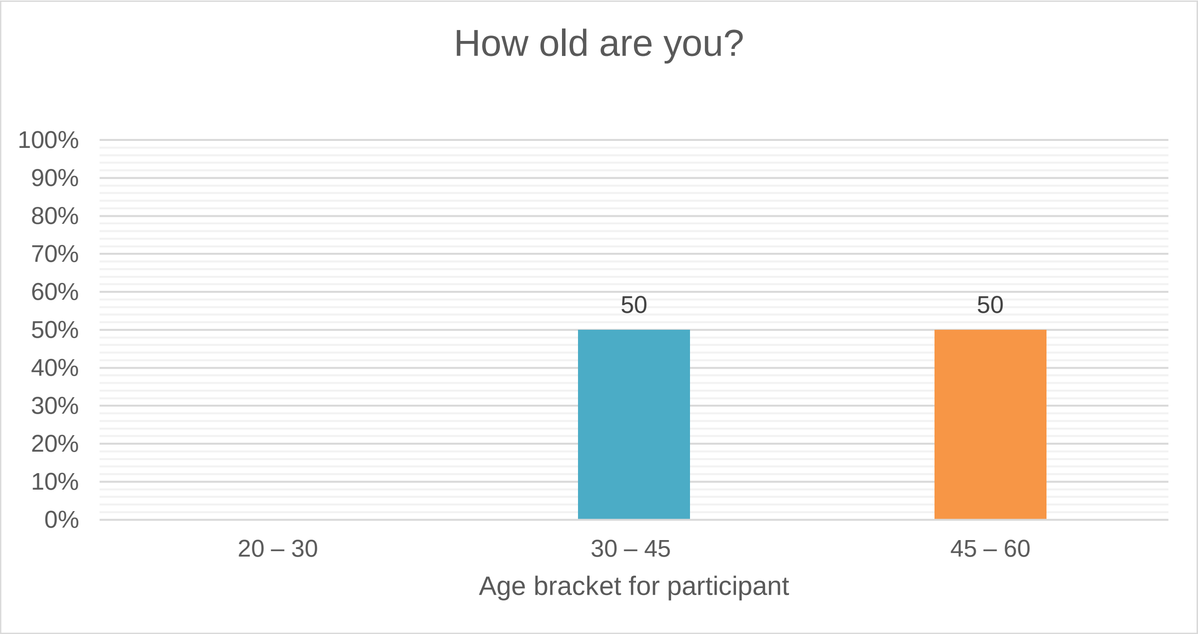
25. Will regular training help with sustainability of the CMMS program?

Strongly agree		Agree		Disagree		Strongly disagree	

ANNEXURE M: QUESTIONNAIRE FEEDBACK

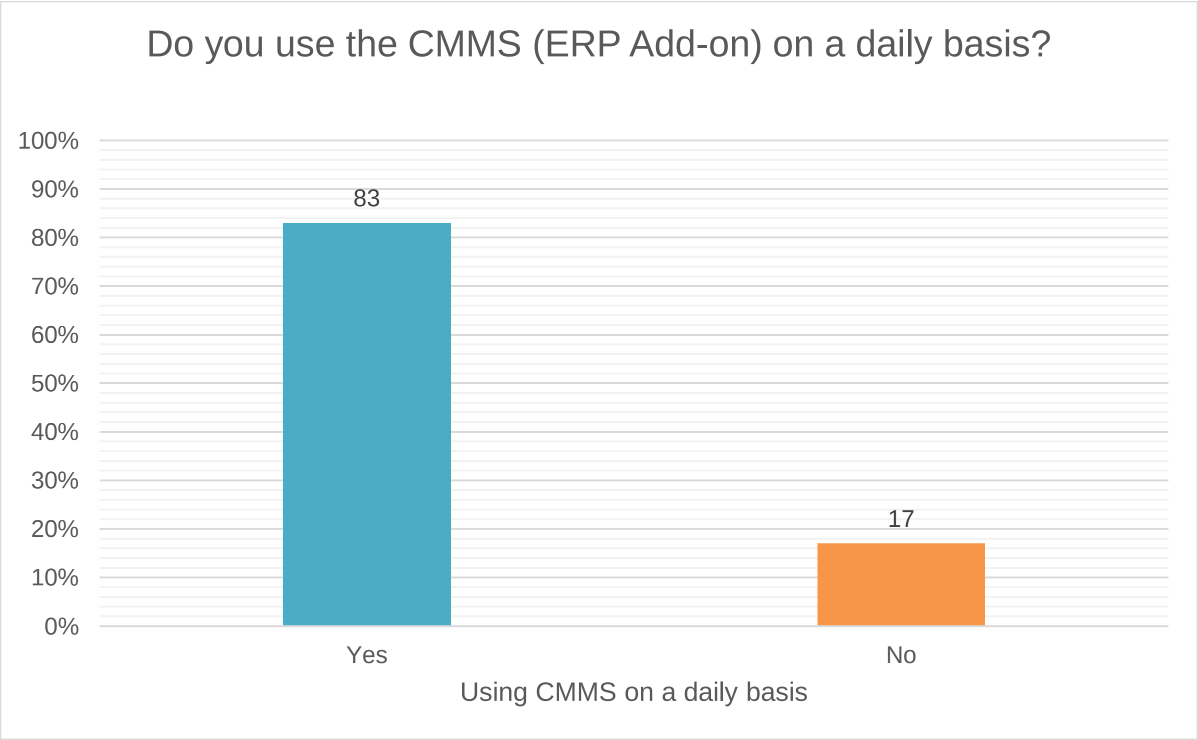
Question 1: How old are you?

Answered: 6 Skipped: 0



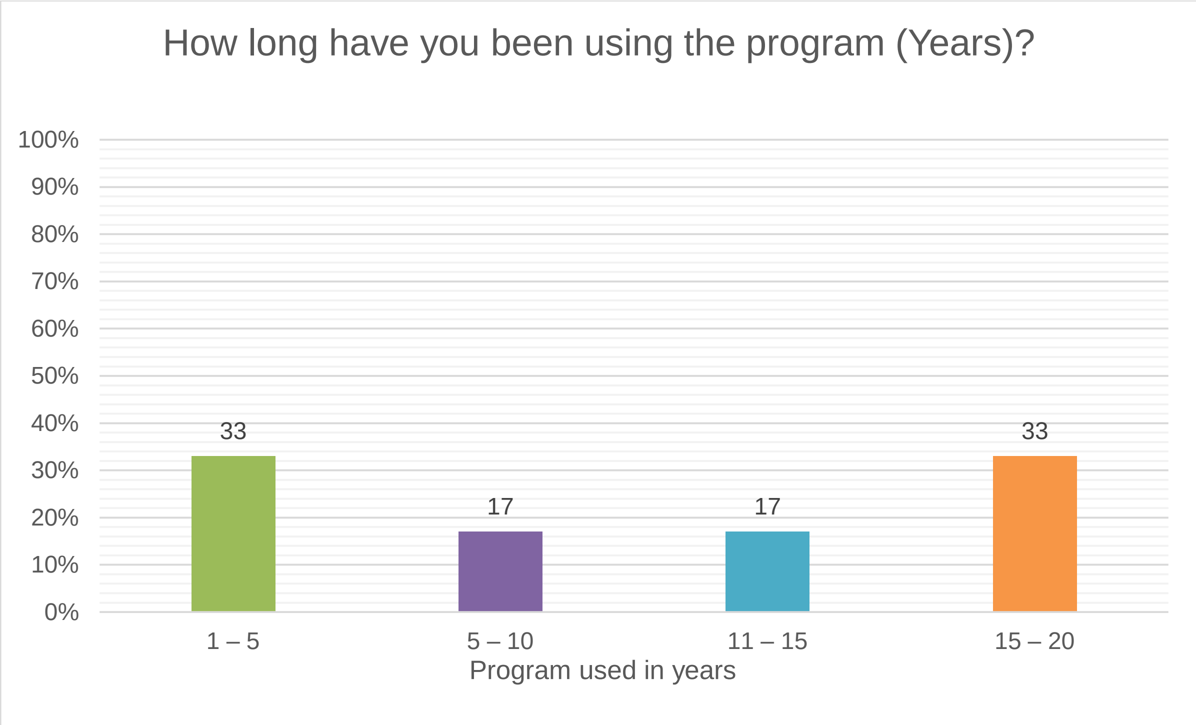
Question 2: Do you use the CMMS (ERP Add-on) on a daily basis?

Answered: 6 Skipped: 0



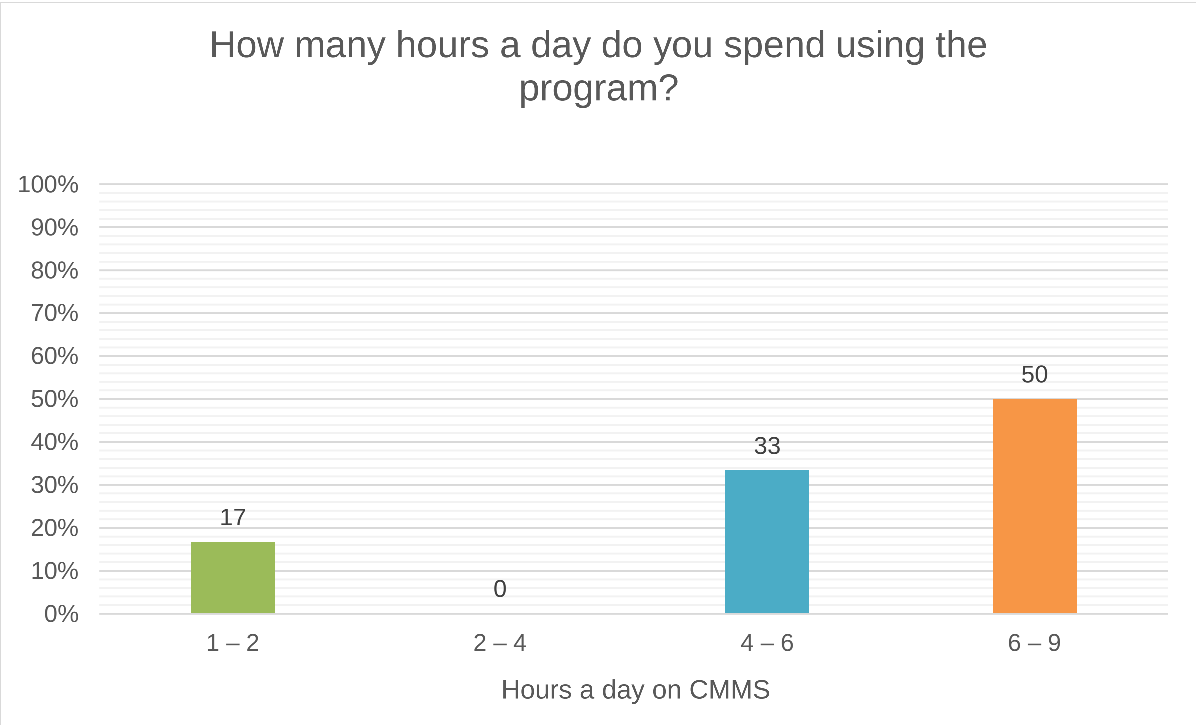
Question 3: How long have you been using the program (Years)?

Answered: 6 Skipped: 0



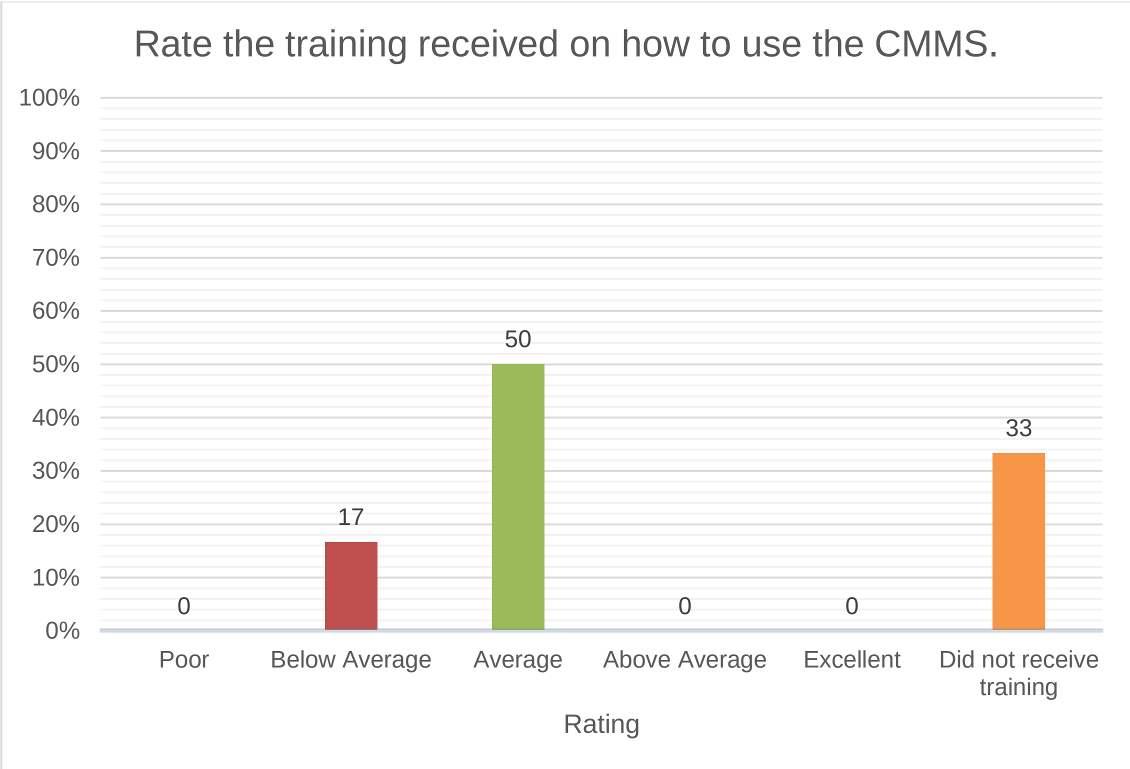
Question 4: How many hours a day do you spend using the program?

Answered: 6 Skipped: 0



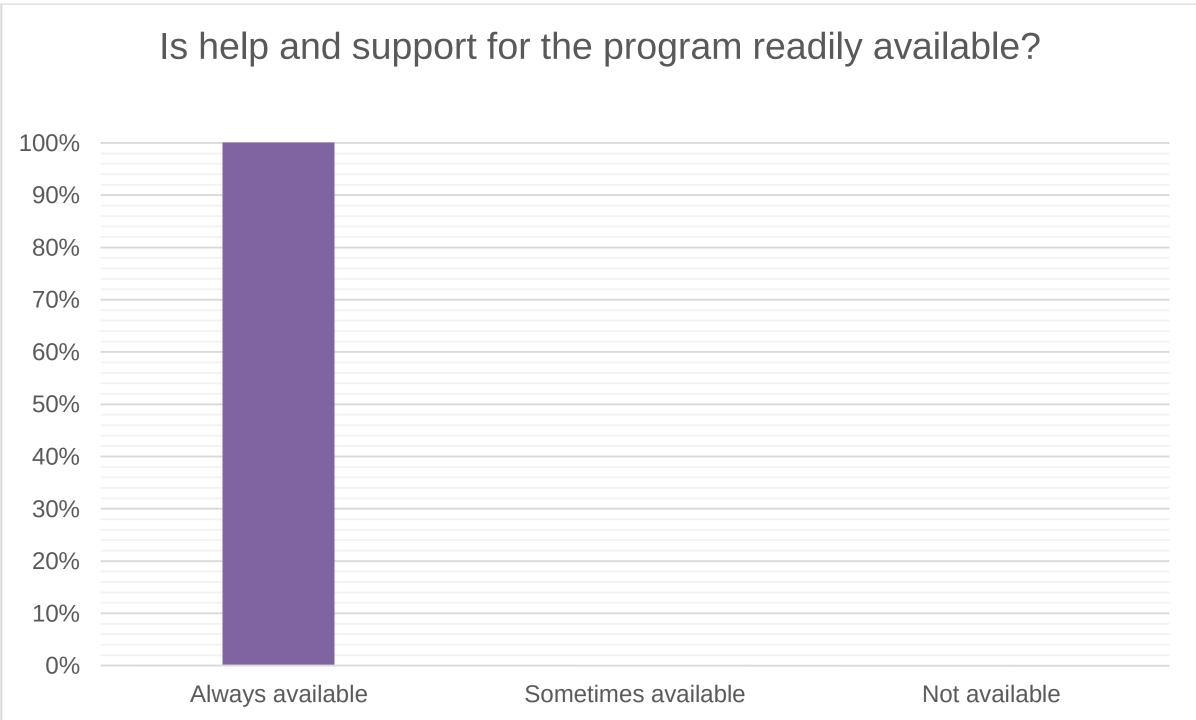
Question 5: Rate the training you received on how to use the CMMS

Answered: 6 Skipped: 0



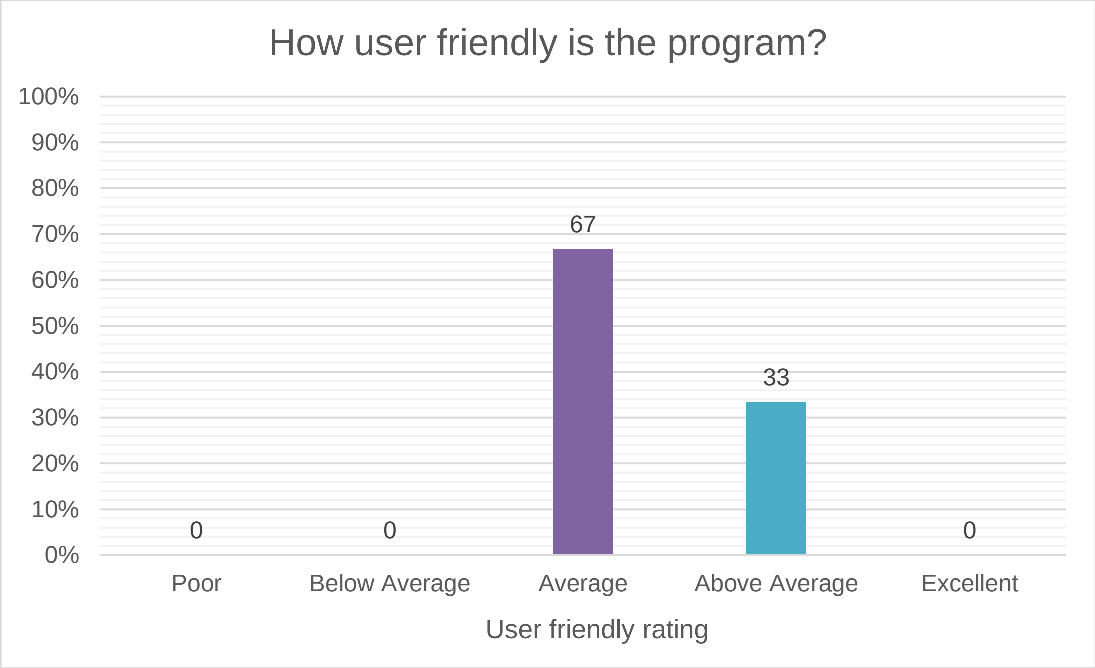
Question 6: Is help and support for the program readily available?

Answered: 6 Skipped: 0



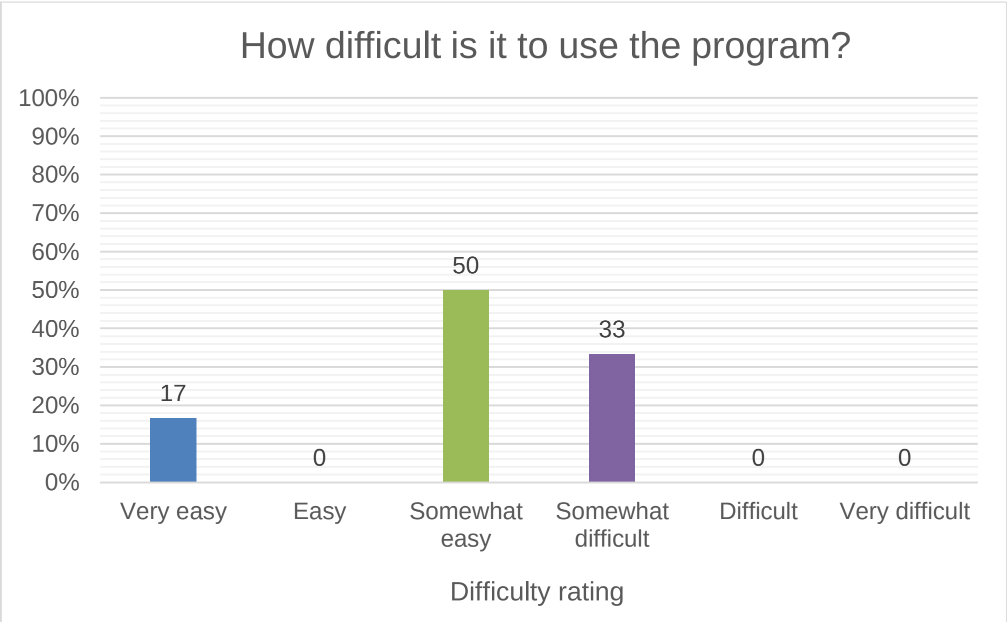
Question 7: How user friendly is the program?

Answered: 6 Skipped: 0



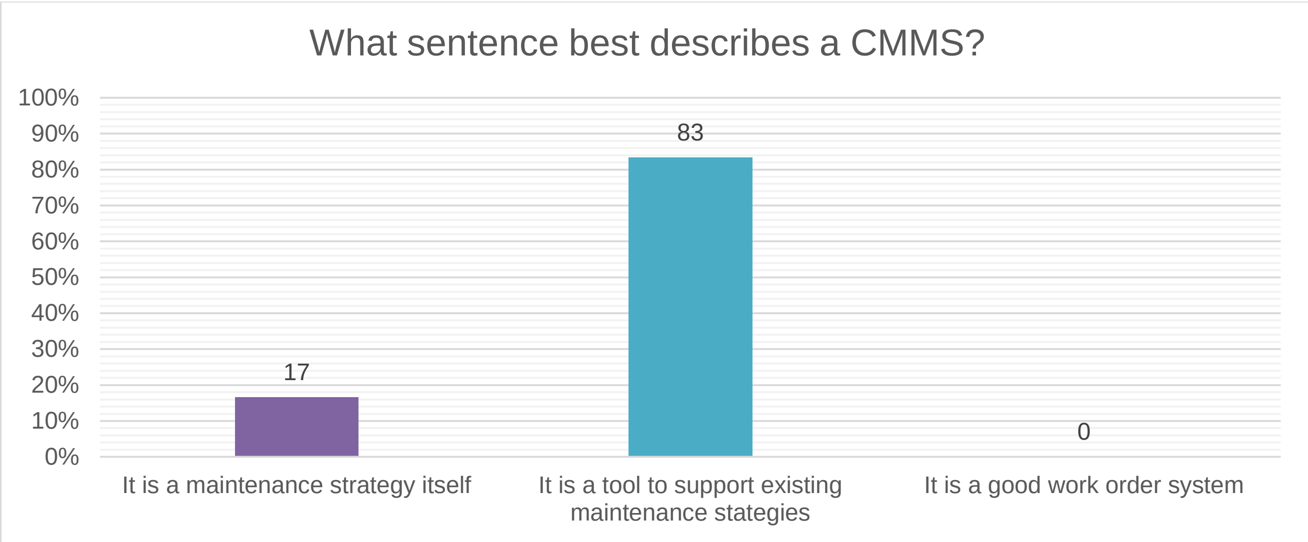
Question 8: How difficult is it to use the program?

Answered: 6 Skipped: 0



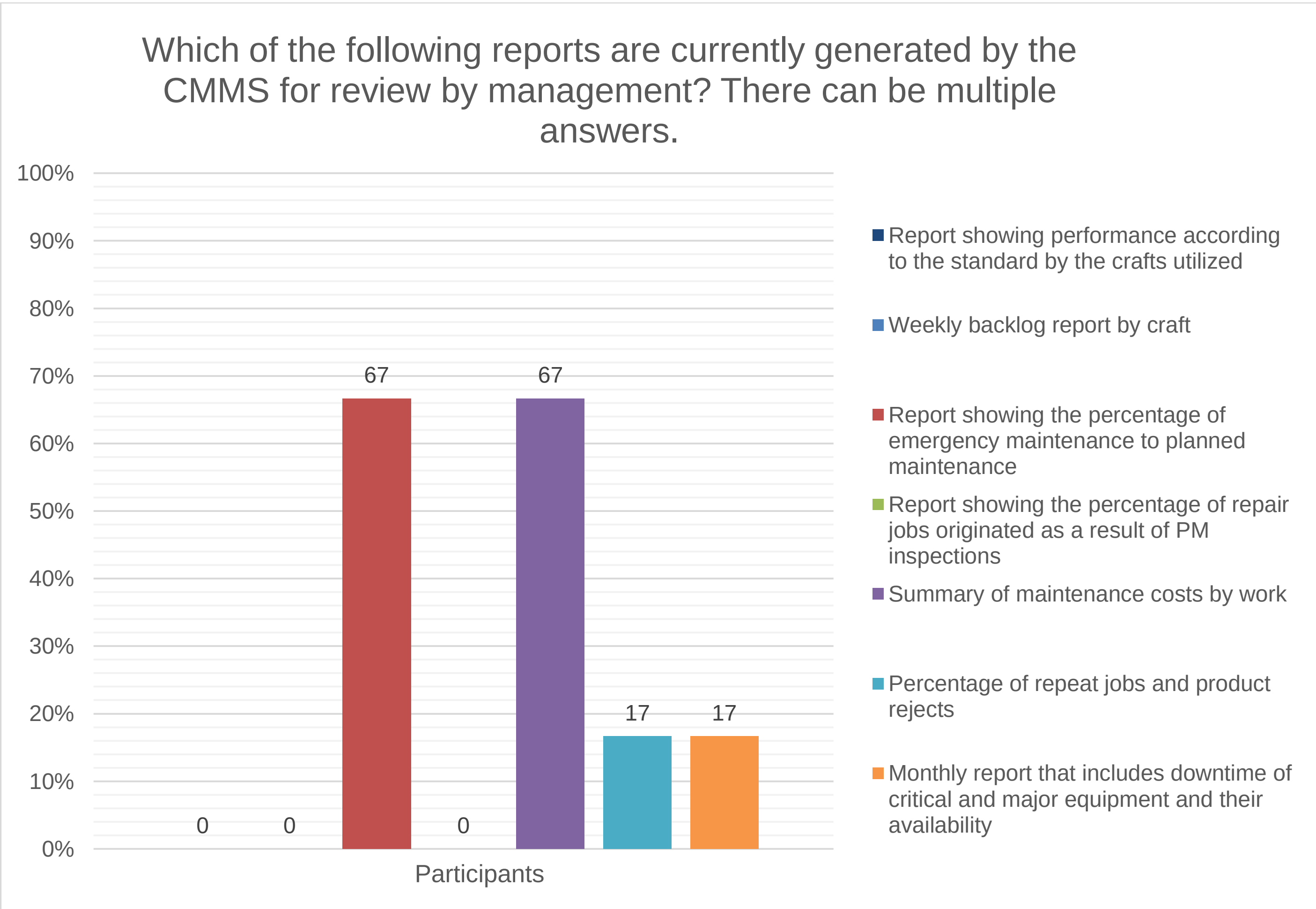
Question 9: What sentence best describes a CMMS?

Answered: 6 Skipped: 0



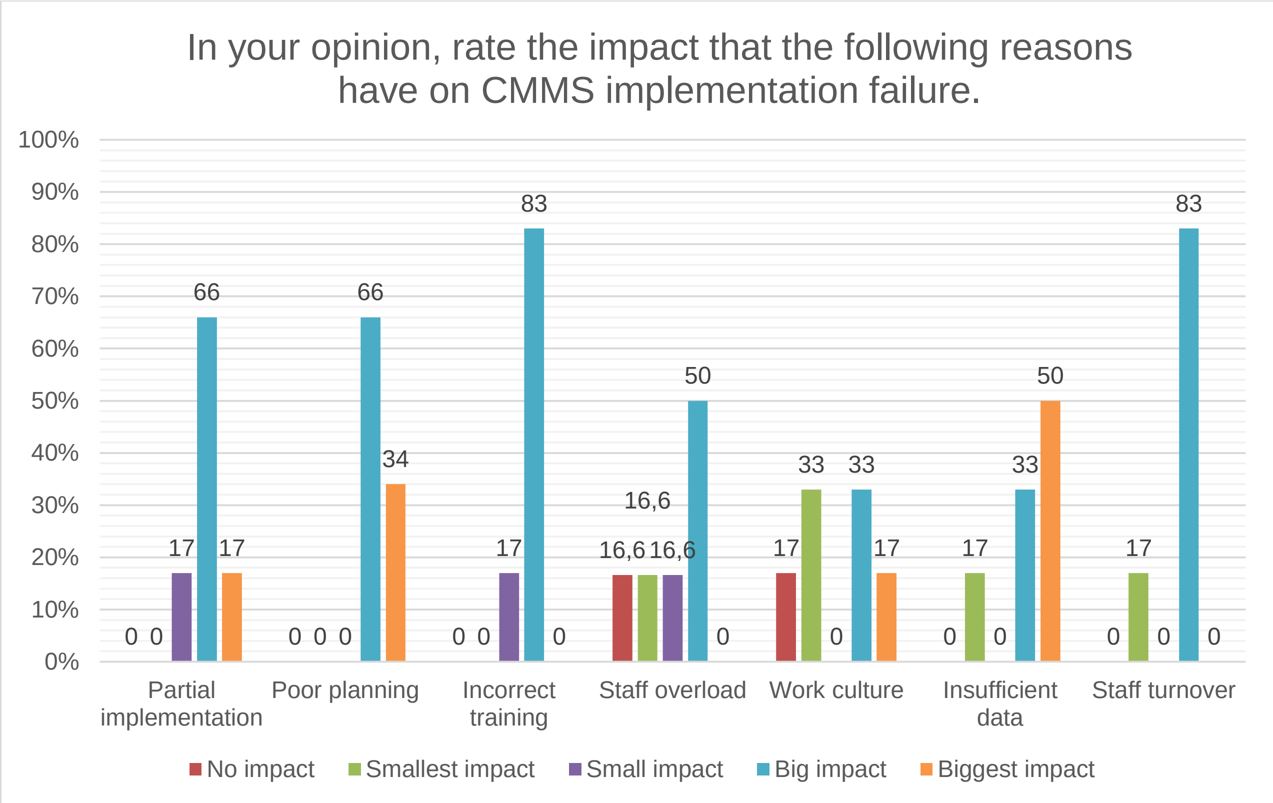
Question 10: Which of the following reports are currently generated by the CMMS for review by management? There can be multiple answers.

Answered: 6 Skipped: 0



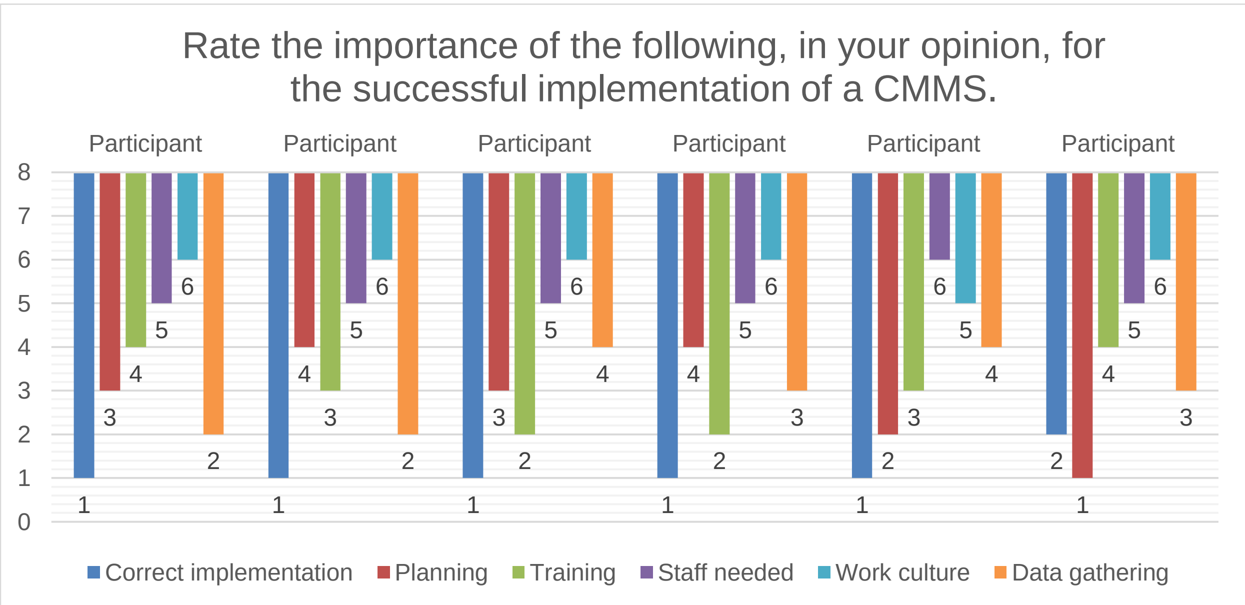
Question 11: In your opinion, rate the impact that the following reasons have on CMMS implementation failure.

Answered: 6 Skipped: 0



Question 12: Rate the importance of the following, in your opinion, for the successful implementation of a CMMS - where 1 is the most important and 6 the least important.

Answered: 6 Skipped: 0



Question 13: What can be added to the existing program to improve its effectiveness.

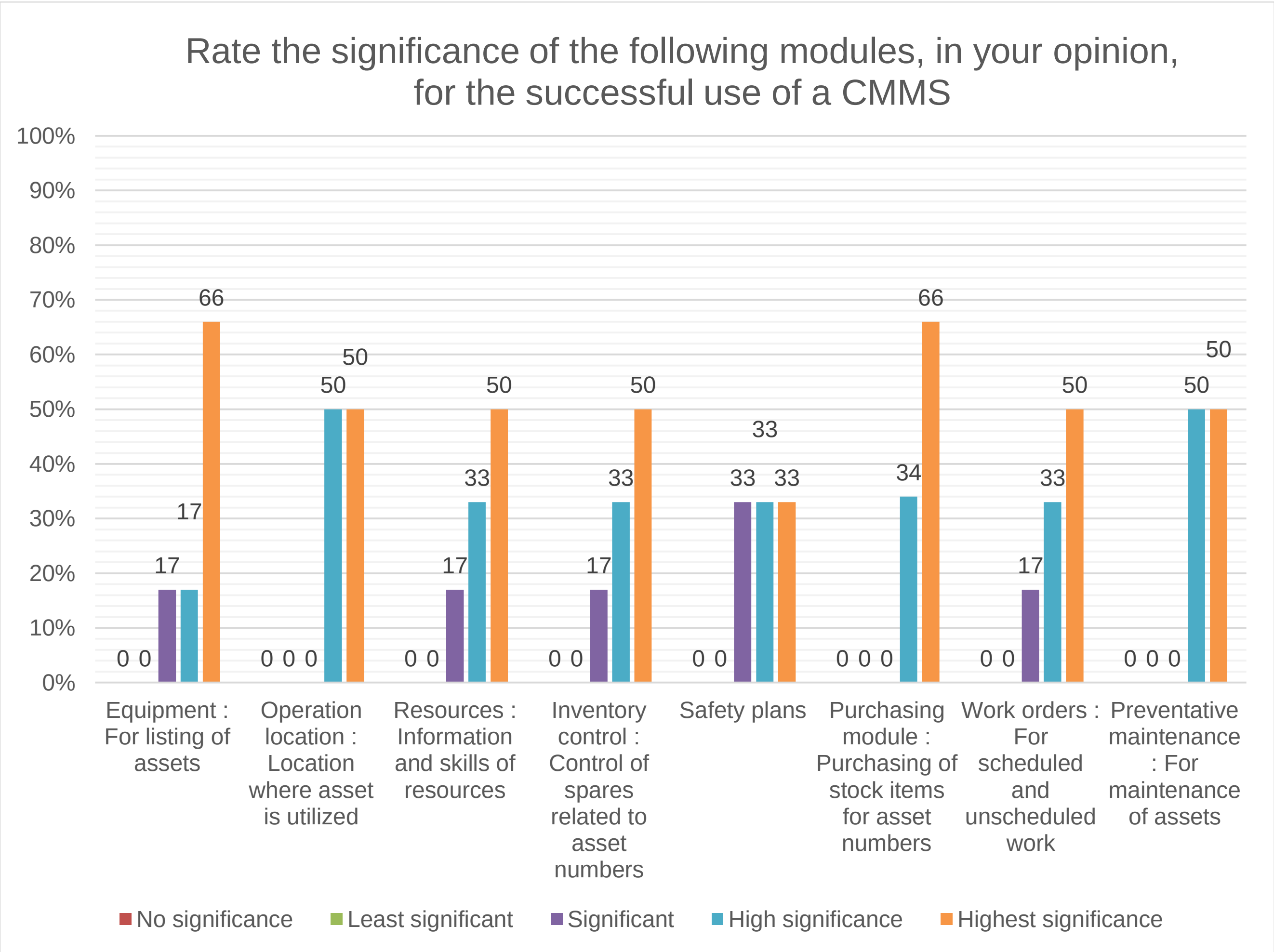
Answered: 4 Skipped: 2

Feedback from participants:

- There is not enough feedback from information that was given. Better reporting needs to be implemented.
- The system must be an in time system between al different modules.
- Nothing – Everything is there.
- The reporting system needs to be improved – Availability of report should be more accessible.
- Links must be created or implemented between different modules such as fixed assets and store's inventory, stock issuing.

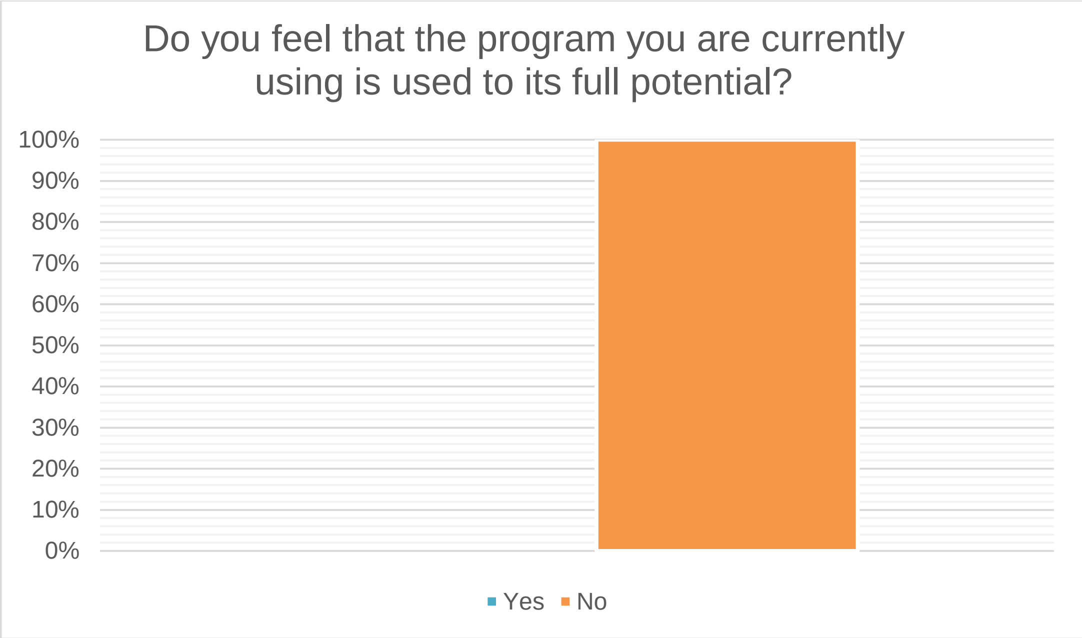
Question 14: Rate the significance of the following modules, in your opinion, for the successful use of a CMMS.

Answered: 6 Skipped: 0



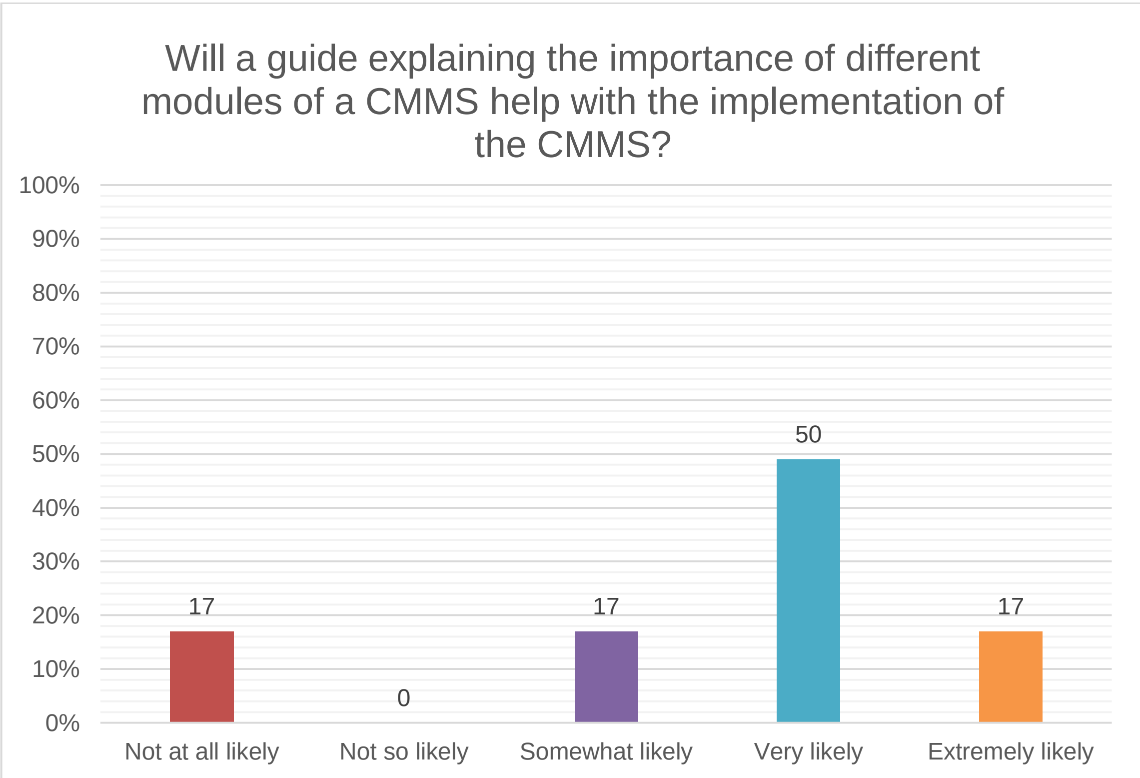
Question 15: Do you feel that the program you are currently using is used to its full potential?

Answered: 6 Skipped: 0



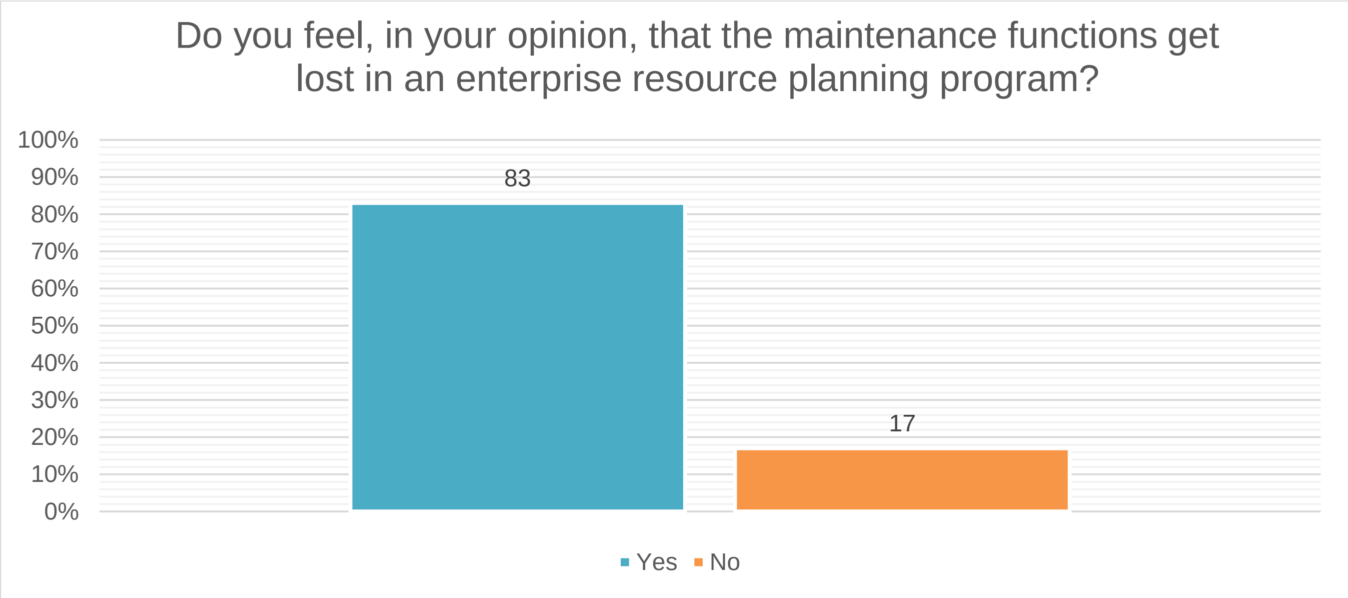
Question 16: Will a guide explaining the importance of different modules of a CMMS help with the implementation of the CMMS?

Answered: 6 Skipped: 0



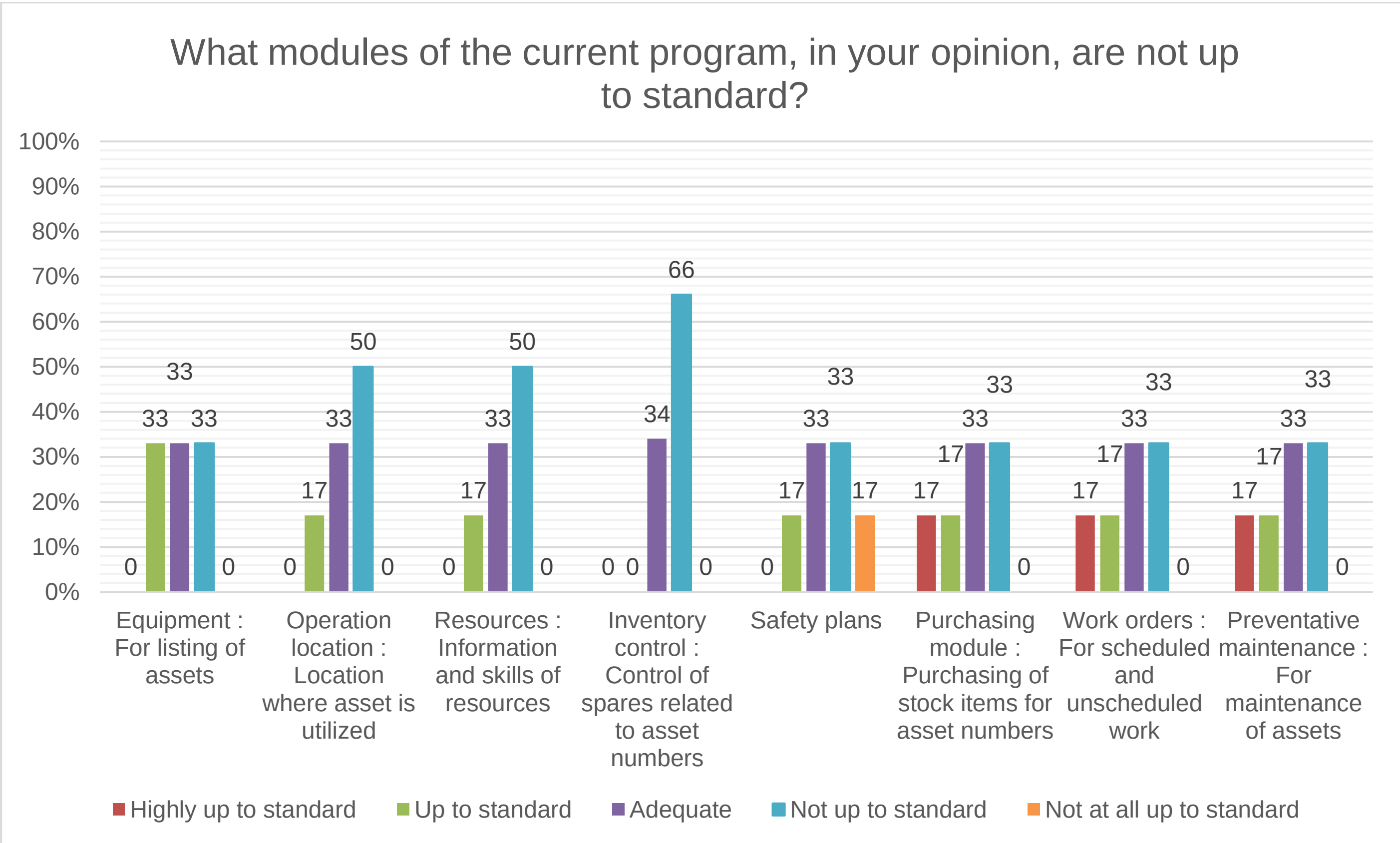
Question 17: Do you feel, in your opinion, that the maintenance functions get lost in an enterprise resource planning program?

Answered: 6 Skipped: 0



Question 18: What modules of the current program, in your opinion, are not up to standard?

Answered: 6 Skipped: 0



Question 19: What can be added or changed in the following modules to improve the CMMS in your opinion?

Answered: 4 Skipped: 2

Equipment: For listing of assets and data

- Layout of reports. Reports in general of different information on assets.
- A better description of assets and relevant data needs to be filled in from the beginning.
- Picking list should be available for equipment maintenance.
- Better control, verification and management of assets.

Resources: Information and skills of resources

- Column should be added to include name of artisan doing the job and who is responsible for the completion of the job.
- Better control, verification and management of resources.

Inventory Control: Control of spares related to asset numbers

- All stock items or spares on site should be linked to asset numbers.

Work orders: For scheduled and unscheduled work

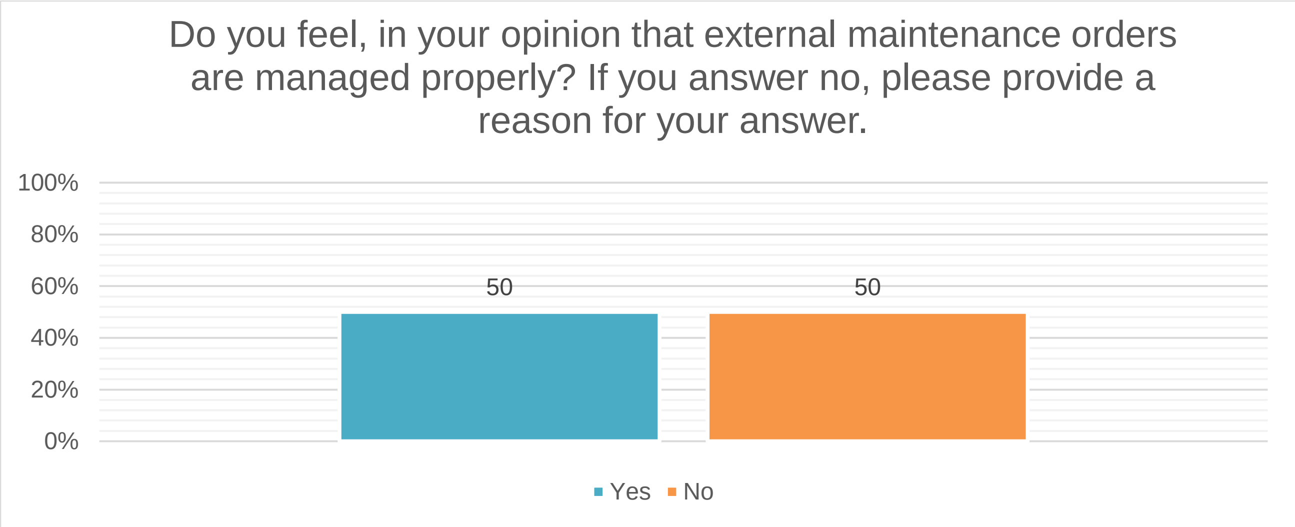
- Work orders should be made digital.
- There should be clear lines to indicate which jobs are scheduled, unscheduled and breakdowns.

Preventative Maintenance: For maintenance of assets

- Standard operating procedures should be added to the system and printed out when preventative maintenance orders are printed.
- More information should be available on the system to better plan preventative maintenance. More fields should be available for information to be added.
- The system must flag when an asset is due for maintenance and should give a list to the planning office before printing is done.

Question 20: Do you feel, in your opinion, that external maintenance orders are managed properly? If you answer no, please provide a reason for your answer.

Answered: 6 Skipped: 0

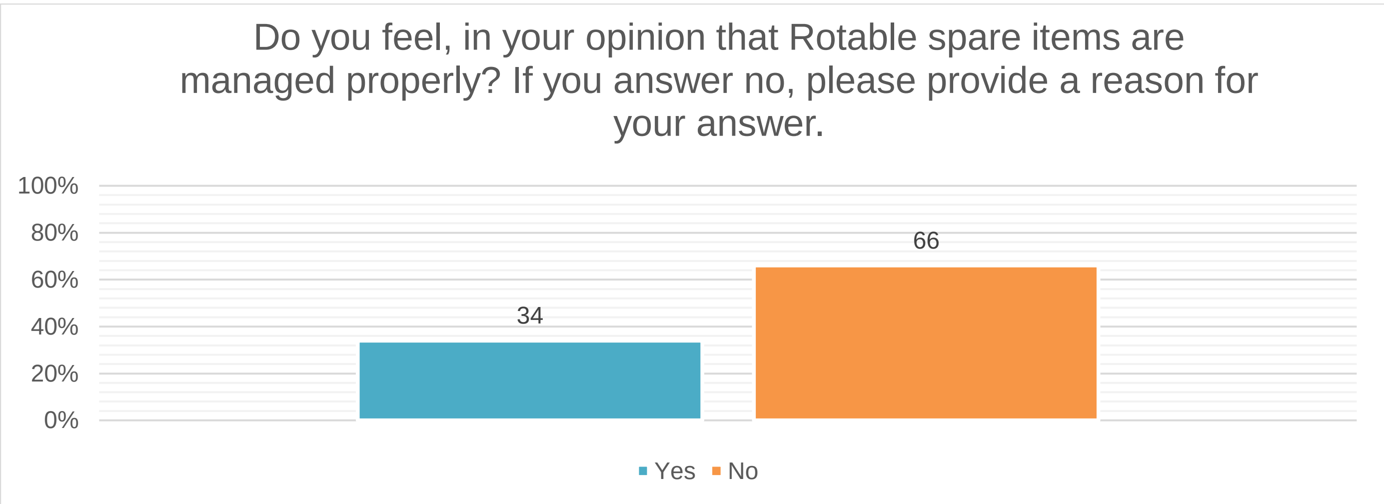


Reasons when answer was no:

- No standard procedure was used until recently.
- There is no quality control procedure in place for external maintenance orders.

Question 21: Do you feel, in your opinion, that Rotable spare items are managed properly? If you answer no, please provide a reason for your answer.

Answered: 6 Skipped: 0

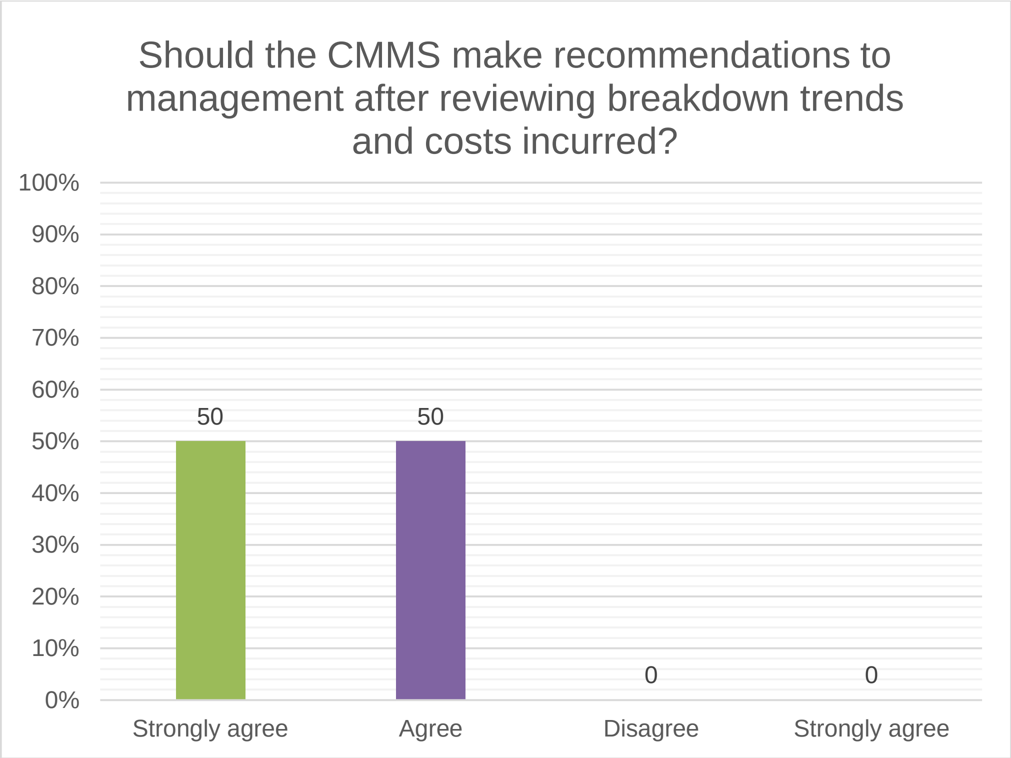


Reasons when answer was no:

- Satellite stores and processes are not standardised.
- The traceability of Rotable spares are not up to standard.

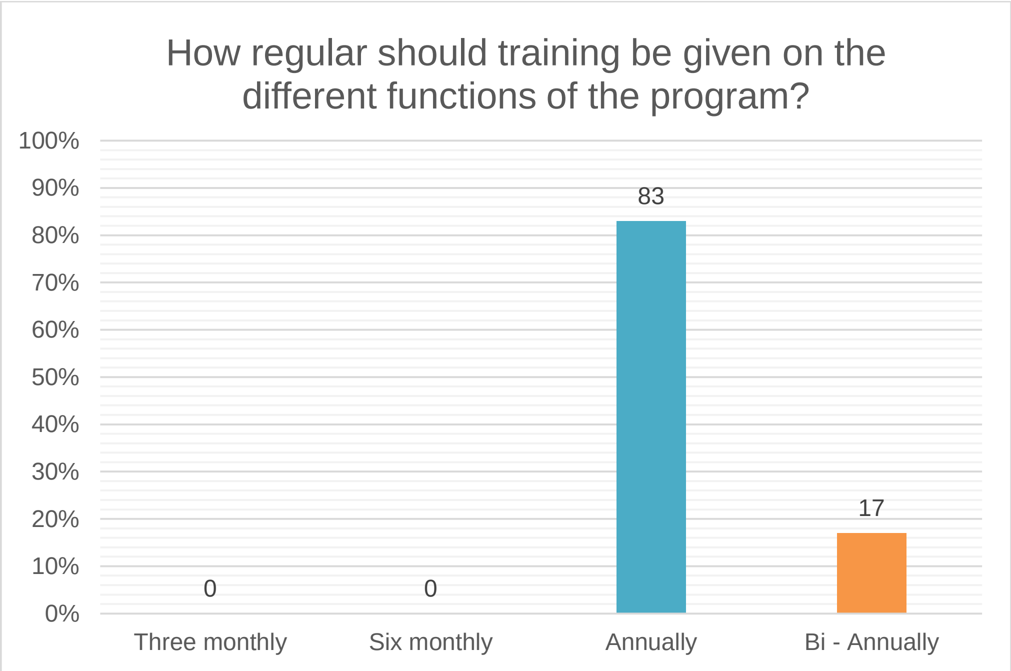
Question 22: Should the CMMS make recommendations to management after reviewing breakdown trends and costs incurred?

Answered: 6 Skipped: 0



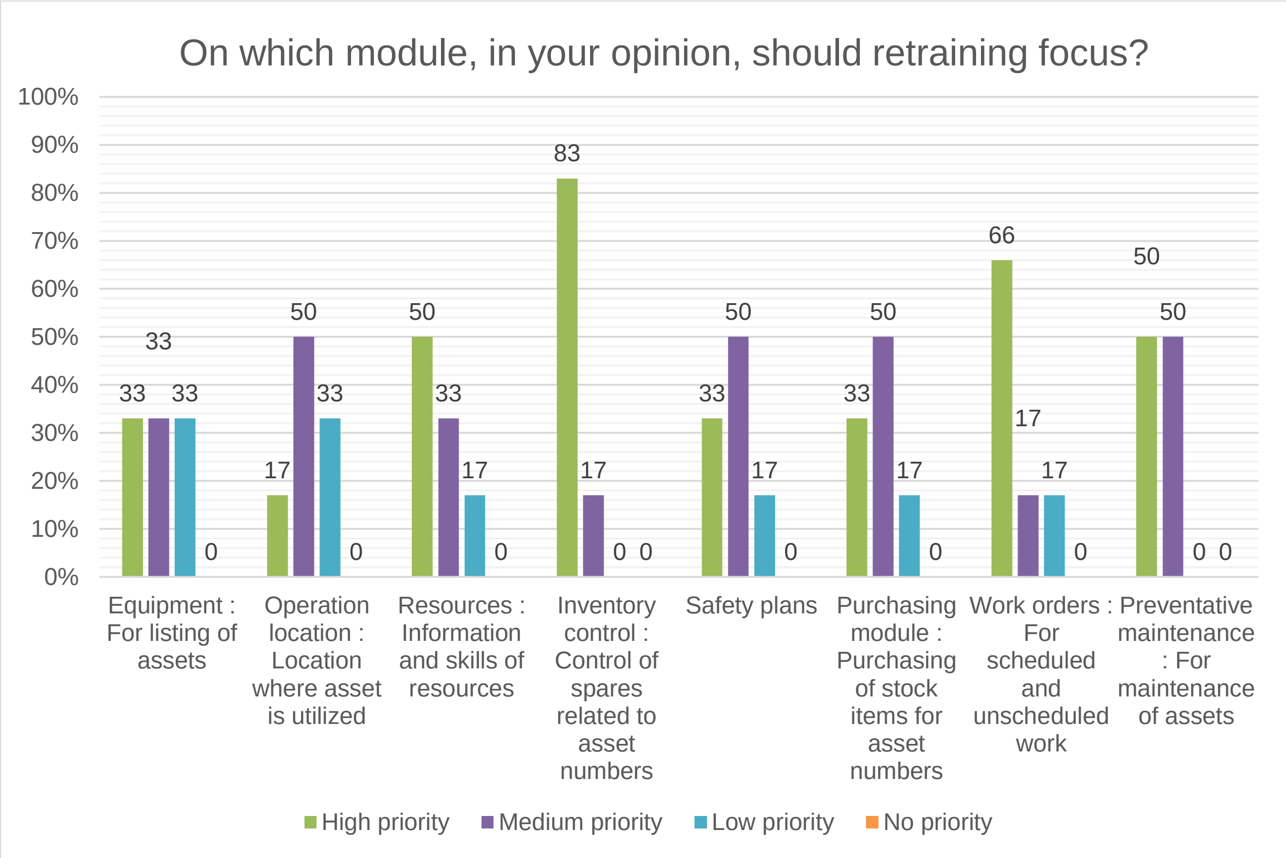
Question 23: How regular should training be given on the different functions of the program?

Answered: 6 Skipped: 0



Question 24: On which module, in your opinion, should retraining focus?

Answered: 6 Skipped: 0



Question 25: Will regular training help with sustainability of the CMMS program?

Answered: 6 Skipped: 0