A study of electrical motor management: Engineering services department within a large steel manufacturer as case study

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Dissertation submitted in partial fulfilment of the requirements for the degree *Master of Engineering* in Development and Management Engineering at the North-West University

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Graduation: May 2018

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DECLARATION

I declare that this dissertation, submitted in partial fulfilment of the requirements for the degree Master of Engineering in Development and Management Engineering at the North-West University, is my own work. It has not been submitted before towards any degree or examination to any other university.

Shaun van Staden November 2017

ABSTRACT

Electrical motors are the true work horses within industry and these electrical motors have to be managed. This study focuses on a large steel manufacturer's motor population within the engineering service department (ESD) where the status quo for electrical motor management (EMM) activities need to be established (if at all existing) and how it compares to what is proposed in literature. This research seeks to establish whether there is a need for developing/improving EMM and to uncover aspects requiring improvement or development to extract full beneficiation of such an approach. This research further seeks to establish a tool to easily identify and interpret critical shortcomings in current EMM activities (in the case where shortcomings exist) and to provide insight on what aspects are critical for advancing EMM. An EMM maturity model was developed and utilised to measure the effectiveness of the ESD with the large steel manufacturer as it acquires, uses, and disposes of the equipment necessary to the functioning its production processes. The researched EMM maturity model would be used for analysing and tracking electrical motor management activities within the engineering services department at the large steel manufacturer to improve/instigate aspects to advance the maturity level of EMM. This research made use of questionnaires distributed to stakeholders and subsequently an EMM maturity level analysis was conducted to produce the maturity levels allocated by a review panel. The EMM-maturity model developed in this dissertation provides the basis for establishing a new EMM-approach and ensures that the EMM-approach to be deployed is comprehensive, safeguarding the best chance for success. This research is envisaged to aid leadership at the ESD within the large steel manufacturer to establish an implementation plan in accordance with the developed EMM-maturity model to advance the level of maturity for the specific conditions (SCs) within the various process areas (PAs) covered in this dissertation.

KEYWORDS

Electrical motor management, motor management, induction motor management, asset management, analysing a management plan, maturity model, electrical motor maturity model, maturity level assessment, induction motor maturity model, induction motor maturity model assessment, electrical motor maturity model assessment, managing electrical motors, managing motors, managing induction motor, manufacturing industry, steel industry, engineering service department, infrastructure department, maturity evaluation matrix, life cycle management, study of electrical motor management.

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List of Abbreviations

ANSI - American National Standards Institute

CEE - Consortium for Energy Efficiency

CM - configuration management

CMM - Capability Maturity Model

ECM - engineering change management

EMM - electrical motor management

EMMM - electrical motor management maturity

ESD - engineering services department

ISO - International Organisation for Standardisation

LCP – Life cycle phase

MM - maturity model

PA - process area

RCM - Reliability Centred Maintenance

SCs - specific conditions (also known as specific goals (SGs)

1 INTRODUCTION

This study deals with the existing electrical motor management (EMM) practices at the engineering services department within a large steel manufacturer. The study will uncover whether such a management approach exists by assessing the level of maturity of the electrical motor management activities and it will also provide insight as to which aspects require possible further development and how it could be developed to reach the next level of maturity.

1.1 BACKGROUND

Production plants and processes within them consist of many forms of energy conversion; the most common form of energy conversion is electrical- to mechanical-energy, this can be achieved with an electrical motor. Electrical motors form an integral part of any plant or process and are subject to wear and aging. The motors will vitiate as time goes by due to the deterioration of the various materials and components that constitutes a motor. If no proactive measures are put in place, they will eventually fail. Failing equipment reduces plant reliability, leading to higher production costs and lower yield; ultimately failures can affect the safety of the plant (Joshy & Narayanan Namboothiri, 2011).

Maintenance is known to be one of the key components when looking at possible ways to improve the management of equipment (and specifically managing electrical motors in this dissertation), however this only constitutes one of many aspects that need to be attended to ensure comprehensive motor management.

At the time of writing this dissertation it was perceived by the author that much was lacking in all aspects pertaining to managing the electrical motor population at the engineering services department within a large steel manufacturer. This perception was also confirmed during a short unstructured interview (consisting of open ended questions) with the supervisor responsible for the electrical motor population at the engineering services department within the large steel manufacturer (Strydom, 2016). The author's perception was again confirmed during an additional unstructured interview (consisting of open ended questions) with one of the production managers at the engineering services department within a large steel manufacturer, who stated that mismanaged motor populations, in the past, have had deleterious effects on availability, profitability and ultimately affected customer confidence in on-time delivery and product quality (Sokolov, 2016).

Case studies have shown (U.S. Department of Energy, 2012; MotorsMatter.org, 2015) that the implementation of EMM resulted in improved availability and curtailing costs, which provide the foundations for improving quality, safety and utilisation of maintenance resources. EMM also improves the emphasis placed on the need for a total life cycle aspects be studied prior to making finalised decisions. If it is determined that the need for developing EMM exists (or that existing EMM-activities are in need of improvement) at the engineering services department within a large steel manufacturer, EMM can potentially hold likewise improvements.

After scrutinising the engineering services department within a large steel manufacturer, it is postulated **that a need exists to develop an engineered electrical motor management (EMM) outline** to identify and improve on mismanaged aspects that ultimately exacerbate inefficiencies and reliability issues which affects the total cost of ownership. Developing/improving EMM will realise opportunities for improved equipment reliability, increased plant profitability and bring about improvements of the maintenance specialist's status quo on work execution due to processes supporting the aforementioned (U.S. Department of Energy, 2012; MotorsMatter.org, 2015; U.S. Department of Energy, 2014).

Most types of failures can be prevented by developing an optimised maintenance approach for equipment. During a preliminary literature survey it transpired that even if maintenance is performed, it only addresses reliability issues and that only constitutes one of the many elements in EMM, thus it only addresses one element towards managing electrical motors. This statement is further supported when interpreting the definitions put forward as found in literature which will be elaborated in Chapter 2.

The aforementioned aspects will be investigated, established and elaborated in the remainder of this dissertation in an attempt to uncover the existing approaches and possible available improvements that can be brought about.

1.2 PROBLEM STATEMENT

Crisis description at the large steel manufacturer

During the period of the year 2000 to 2003, the large steel manufacturer acquired the services of a contractor specializing in maintenance programs and processes to develop and implement maintenance strategies for the various plants and the pertaining equipment. Up to this point in time the large steel manufacturer’s staff have attempted to execute the

maintenance plans and follow the processes developed by these contractors for the equipment.

The dynamics for executing the developed maintenance program and relating processes have however, changed dramatically, posing several challenges owing to the fact that the workforce has downsized from ± 18,000 employees to ± 4,500 employees (still on the decrease evident by recent submissions of a legal document to government for initiating retrenchments (Section-189 notice)). This means that the various maintenance teams (for each plant within the company) have implemented maintenance plans on a biased and selective basis. At present, the maintenance at the engineering services department within the large steel manufacturer gets performed on equipment that has not been maintained for the longest period (fire-fighting due to random selectivity of maintenance carried out in the first place) despite the functional criticality of other equipment left unattended. At the parliamentary gathering on the 3rd of September 2014, the Department of Trade and Industry's minister, *Rob Davies, mentioned that* the large steel manufacturer had not invested sufficiently in maintenance, resulting in the unexpected breakdown of plants (Ensor, 2014). These unexpected breakdowns are ultimately affecting the reliability and quality of production, resulting in deleterious effects upon profitability posing direct threats to safety and customer confidence in on-time delivery and product quality (Copper Development Association Inc., 2012).

Reliability is not the only challenge, at present, the South African industry and commerce are facing energy shortages and demand for energy is constantly on the rise. At the same time, pressure to reduce energy consumption and to lower carbon dioxide (CO_2) emissions are becoming ever more predominant.

Optimising energy use and managing equipment throughout the lifecycle in industry is essential to improve industrial competitiveness and achieve wider societal goals such as energy security, economic recovery, economic development, climate change mitigation and environmental protection.

In lieu with the aforementioned, it ***is imperative that*** **an optimised, comprehensive and engineered electrical motor management (EMM) be analysed for deployment/development for the engineering services department within a large steel manufacturer** to identify and improve mismanaged aspects that ultimately exacerbate

inefficiencies and reliability issues which affects the total cost of ownership. Analysing and improving EMM will realise opportunities for improved equipment management practices, increased plant profitability and improvements of the maintenance specialist's status quo on work execution (U.S. Department of Energy, 2012; MotorsMatter.org, 2015; U.S. Department of Energy, 2014).

It is known that the quality and quantity of EMM activities have decreased with a large contributing factor being the evil necessity of frequent corporate re-engineering (Consortium for Energy Efficiency (CEE), 2012). It is for this reason that the author deems it necessary that EMM be analysed and developed/improved where all aspects can be considered and what the nett consequence of such changes could hold in for efforts towards managing electrical motors, prior to big corporate changes being implemented.

The aim of this dissertation is to study electrical motor management (EMM) at the engineering services department within a large steel manufacturer, which will be utilised as a management tool to establish the status quo on electrical motor management and to identify areas within the program that require improvement/development.

1.3 RESEARCH GOAL AND OBJECTIVE

The research aims to uncover areas for development/improvement in the existing EMM activities within the engineering services department at the large steel manufacturer, as such the following research objectives have been defined to support the research question:

Primary research objective:

1. Investigate the status quo of existing EMM-activities within the engineering services department at a large steel manufacturer and then conduct a comparative analysis of how the status quo compares with EMM proposed in literature.

   Substantiation: A better understanding needs to be obtained of the status quo pertaining to EMM-activities (if at all existing) and how it compares to what literature proposes. This research objective will establish whether the postulated need for developing/improving EMM exists. The objective will uncover aspects requiring improvement or development (where the aspects pertaining to the EMM are not adequately addressed) as to extract full beneficiation of such an approach.

Secondary research objective:

2. Deploy a researched EMM maturity model for the engineering services department within a large steel manufacturer as means for identifying levels of maturity for EMM-activities serving as a tool for continuous tracking and improvement.

Substantiation: Pending the outcome of the first research objective (whether the need exists), the second research objective will aid the need to easily identify and interpret critical shortcomings in current EMM activities (in the case where shortcomings exist) and to provide insight on what aspects are critical for advancing the level of maturity of EMM. In the case where no EMM exists, this objective was set in order *to provide a researched EMM maturity model for analysing and tracking electrical motor management activities within the engineering services department at the large steel manufacturer to improve/instigate aspects to advance the maturity level of EMM.* It is important to gain an accurate representation of the status quo and to establish what aspects need attention to provide a defined means of improving on key process areas and to ensure that improvements follow the natural order of progression allowing the best chance for success. The significance of an assessment of the electrical motor management maturity (EMMM), can be visualised as being three-fold:

1. A comparison of existing EMM-activities within the engineering services department at a large steel manufacturer can be drawn with EMM-activities proposed in literature.
2. Internal - The assessment would provide results that are easily understood and communicated. Aligning with Raber et al. (2013), the improvements can be tracked, to allow distinction and recognition between areas of exceptional maturity and areas requiring changes or resources (or both) to bring about improvements.
3. External – Comparisons can be with made between different departments in a large steel manufacturer as well as higher level comparisons between different operating units within the large steel manufacturer or between national and international industries as part of benchmarking.

1.4 BENEFICIARIES

The primary beneficiary is the engineering services department within a large steel manufacturer and a sub-beneficiary to this study would be other departments within a large steel company aiding in its endeavour towards reliable, efficient and sustainable plants.

Secondary beneficiaries, could possibly be international large scale manufacturing industries (mining, municipalities, utility companies etc.). Upon completion of this study, a further point of instigation could be collaboration with the government to investigate how they can derive from the positive impact such management approach could hold for South Africa and develop a tax incentives programs for successful implementation of electrical motor management to encourage roll-out of such initiatives across industry in South Africa.

1.5 RESEARCH OUTLINE

This paragraph of the dissertation is intended to provide an overview of the research methodology deployed.

Initially, a comprehensive understanding had to be obtained to all aspects pertaining to EMM. This was done in order to gain insight as to what EMM is; why it's needed; and what aspects are perceived to be conventional within EMM. Furthermore, relevant literature was studied and this afforded valuable insight to ensure the highest possibility of success for improving/implementing EMM-activities at the engineering services department at a large steel manufacturer. The literature study provided insight to maturity models and how they are will be deployed in analysing the maturity level of electrical motor management. The literature review also provided insight to aspects that need to be explored as part of the experimental design in Chapter 3. The researcher then explored research design aspects that need to be considered to allow data collection for enabling data interpretation and analyses. The research instrument for study was chosen to be a survey combined with a maturity model analysis. Questions were answered by conducting interviewer administered surveys and also email surveys which consisted of close-ended questions, multiple choice and a scaled questions.

Though small, the sample group was a full representation of the actual population of the engineering services department within a large steel manufacturer. The engineering services department consisted of thirty-two technical staff members who are stakeholders of electrical motor systems in some or other way (electricians, supervisors, procurement clerks, technicians, engineers and process managers).

From a demographics aspect, the sample group was chosen to include all stakeholders within the engineering service department irrespective of their age, experience or educational attributes. Exact details of the survey development can be found in Chapter 3

and the answers to the surveys were analysed and a comparison drawn between the existing electrical motor management activities and how it matched up to what is prescribed in literature. The analysis (and comparison) of the survey (which includes elements such as demographics) are presented and discussed in Chapter 4. Chapter 5 contains the conclusions and recommendations pertaining to this dissertation.

1.6 DISSERTATION LAYOUT

Chapter 2 of this dissertation contains relevant literature of existing work that aids to understand the topic of EMM, its constituents and how one would go about analysing this management plan.

Chapter 3 provides a detailed explanation of the research design and methodology to provide information as to how the research was conducted.

Chapter 4 analyses the results and findings of the research and subsequently interpretations in line with relevant theory were presented.

Chapter 5 summarises the research study and resulting conclusions pertaining to the research objectives are derived from the findings of the experimental design and recommendations for future research are presented.

2 LITERATURE REVIEW

2.1 LARGE STEEL MANUFACTURER BACKGROUND

Working within the large steel manufacturer the researcher gained exposure within the engineering services department by working in the engineering services department. The engineering services department, in the context of the large steel manufacturer, serves as the backbone of the company and its production plants/processes. The engineering services department is responsible for maintaining all infrastructure equipment and infrastructure related processes. The processes are essentially utility services which encompass the distribution and supply of cardinal infrastructure services including electricity, water, steam, air and gas and also include power generation. The steel manufacturing plant's infrastructure is quite dated (in excess of 45-years), but the company has still managed to obtain mining and metals ISO9001:2008-certification. With the aforementioned in mind, the technical personnel within the company are often tasked with undertaking various tasks within the lifecycle stages of the equipment and these activities can be either process management activities or operations management activities. These activities more often than not have no documented processes, which results in activity outcomes being inconsistent with little to no evidence of the decisions made during the process (only a financial trail is available). Principles pertaining to quality management in accordance with ISO9001 (ISO, 2015), on a very high level, entails:

"the development of a culture that influences the behaviour, attitudes, activities and processes that deliver value through fulfilling the needs and expectations of customers and other relevant interested parties."

The ISO9001 further establishes that quality management principles within organisations shall constitute of:

- process-based approaches;
- leadership;
- continuous improvement;
- a customer focused approach;
- engagement of people;
- evidence-based decisions;
- relationship management.

At the large steel manufacturer's engineering services department, the staff do not distinguish between life cycle stages, nor do they distinguish between process management and operation management activities pertaining to EMM.

The ASTM E2452-12 standard is applicable to equipment management in general, this dissertation will be focusing on one a specific scenario of interest, electrical motors (specific piece of equipment). As mentioned in Chapter 1 of this dissertation, the large steel manufacturer's engineering services department has in the past, experienced deleterious effects on availability, profitability and ultimately affected customer confidence in on-time delivery and product quality as a direct result of electrical motor populations being mismanaged (Sokolov, 2016). Sokolov's (2016) notion on motor populations being mismanaged is also shared by the author of this dissertation.

Another element forming part of EMM is record keeping, which typically encompasses record keeping of repairs/changes/maintenance. These records are not always traceable and in the instances where record keeping was conducted, there was no standard practice specified, the onus was thus on each individual responsible for compiling and storing of records. This aspect also forms part of the ISO9001 requirements which is not being complied with by the large steel manufacturer in all respects. This observation is also supported by Du Toit (2014), who found that information was, more often than not, kept in hard copy files or some instances stored digitally on computers of the employees (which is in direct contradiction with the requirements as set out in ISO9001). This shortcoming has, and still makes knowledge retention specifically difficult and consequentially the identification of trends, sub-standard suppliers (of equipment/service), bad internal workmanship and identifying motors no longer utilised has been superfluously difficult and furthermore makes tracking total cost of ownership a challenge and inaccurate.

The EMM-approaches deployed in the U.S.A. industry has shown tremendous benefit toward decreasing total cost of ownership (Whefan, et al., 2004). Manufacturing plants (such as the large steel manufacturer) have hundreds, or even thousands of motors operating within the facility; it is postulated that implementing EMM can hold likewise benefits to the large steel manufacturer and to the reliability of various plants and processes contained therein. Developing/advancing EMM can be a massive undertaking, so, as the old saying goes "take it one step at a time" – and this is exactly the initial approach that will be undertaken in developing/advancing EMM at the engineering services department at the

large steel manufacturer. EMM has to be deployed to follow a natural maturity progression (step-wise approach) which implies, starting at an initial maturity level and progressing towards a higher level maturity (Raber, et al., 2013). If the activities pertaining to EMM do not follow this natural maturity progression and starts of at a very high level of maturity the probability for success will diminish as one first has to get the fundamentals in place for each EMM-activity before progressing at a pace that could increase the existence of confusion and pitfalls. Improving process management will aid the need toward reducing weaknesses in the EMM and boost the chances of success (Object Management Group, 2008)

The concept of an EMM is not new to industry, however developing/improving EMM and analysing the levels of maturity of EMM constituents would provide direction and clarity and in turn would highlight opportunities to bring about vast improvements to electrical motor systems throughout the entire life cycle and all pertaining management activities. An electrical motor management maturity analysis will be utilised as a tool to provide the necessary insight into the effectiveness of EMM-activities at the engineering service department within the large steel manufacturer as it acquires, uses, and disposes of the electrical motors necessary to the functioning of containing processes and infrastructure. Maturity models enable a holistic approach and vision for achieving cost-effective, responsive electrical motor acquisition, use, and disposition. It further, clarifies and illuminates functional responsibilities and associated functional areas (ASTM, 2012). Maturity models are deployed as an analysis tool for identifying areas excellence and requiring improvements. Implementing/improving EMM-activities at the engineering service department within a large steel manufacturer can provide an opportunity of significantly improving their financial bottom line (Consortium for Energy Efficiency (CEE), 2012).

All the aforementioned aspects will be further elaborated in this literature review to gain the necessary understanding of concepts for deployment/improvement.

2.2 GENERIC MATURITY MODEL

Paragraph 2 made it clear that this dissertation needs to establish the status quo of the EMM at engineering services department at a large steel manufacturer and that it is postulated that the existing EMM-activities might need further development. As such, an analysis tool needs to be deployed to provide a clear analysis of the current levels of maturity for all the constituents within the EMM. This analysis would provide necessary descriptive insight for identifying shortcomings and to provide a step-wise approach for each EMM constituent to

bring about development/improvements to advance each EMM-activity to the next level of maturity.

Prior to developing a maturity model (MM) specifically for analysing EMM, it becomes important to understand maturity models in general and how maturity models (MMs) can be applied in the context of this dissertation. The starting point for obtaining such an understanding is obtaining definitions for "maturity". Definitions for maturity according to dictionaries:

- "*being perfect, complete, or ready"* (Anon., 2010)
- *"the state or quality of being mature; full development"* (Anon., 2012)

The International Organisation for Standardisation (ISO) has defined **maturity** as (International Organisation for Standardisation, 2012): *"The creation of characteristics and behaviour in an organisation, as a result of transformation and adoption that permits it to operate better in accordance with its business goals".*

Paulk et al. (1993) generalised the maturity concept and reduced it to be *"a displined process consistently followed because all the participants understand the value of doing so, and an infrastructure to support the process."*

Maturity in the context of the ability of an organisation to manage development and manage activities is dependent on:

- Management's ability to accurately communicate processes to any employee and work activities are executed in accordance with the planned process.
- How actual work gets done and whether it ties up with the mandatory and formalised processes.
- Whether updates to defined processes are brought about if and when required, as and when improvements are identified, which stem from pilot projects.
- Clearly defined roles and responsibilities within projects across an organisation.
- Management's monitoring activities pertaining to program/process/product quality, where objectives exist on a quantitative basis for judging quality and analysing product and process related problems (Paulk, et al., 1993).

The focus in this dissertation is gaining an understanding of the level of maturity/perfection/readiness in terms of EMM at the engineering services department at the

large steel manufacturer and what improvements/development can be brought about to improve the overall EMM-maturity.

The ISO has defined a **maturity model** as (International Organisation for Standardisation, 2012): *"A means of and scale for evaluating and assessing the current state of maturity"* and further elaborates: *"A maturity model also provides a means for developing a transformation roadmap to achieve a target state of maturity from a given current state of maturity. It quantifies the relative growth of certain salient aspects within various dimensions typically within, but not limited to, organizational boundaries".*

The EMM approach deployed at the large steel manufacturer needs to provide opportunity for continuous improvement (transform in accordance with a plan), as such the approach applied to electrical motors needs to be a success and not just "another failed program". During a study undertaken by Dr Penrose, "Motor Diagnostics and Motor Health Study" (Penrose & O'Hanlon, 2003), it was found that 68% of the population surveyed felt they have a motor management program in place, for ease they will be named "the perceivers". The study further showed that "the perceivers" experienced a 72% failure rate in their attempts of deploying a motor management program, with only 28% showing to be "active". 66% of the "active" programs' recommendations were never implemented. The net outcome of the study showed that a mere 7% of the total motor management programs attempted were successful (Penrose & O'Hanlon, 2003). The "Motor Diagnostics and Motor Health Study" (Penrose & O'Hanlon, 2003) was based on the premise of the interpretation and definitions put forward by Dr Penrose as presented in the paragraphs to follow, which indicated that he was actually inferring to only the hardware pertaining to the motor system. There also exists supporting views that if an entity improves process management it will aid the need toward reducing weaknesses in the EMM and boost the chances of success (Object Management Group, 2008).

An investigation into the origins of the maturity model revealed that some of the underlying concepts found its inception from the quality management field where Philip Crosby published the maturity grid model concept in the form of a quality management maturity grid (QMMG) in his text book (Crosby, 1979).

Crosby's maturity grid model (1979) identifies five levels of process maturity for an organisation:

- **Level 1 - Initial** (chaotic, ad hoc, heroic) the starting point for use of a new process. At this level there is an ongoing struggle to make commitments which the employees should meet through applying an orderly engineered process, this struggle results in a series of crises with the consequence of procedures being abandoned (Paulk, et al., 1993).

- **Level 2 - Repeatable** (project management, process discipline) the process is used repeatedly, procedures exist to implement policies. Program managers have instigated basic management controls for example – cost tracking, timeline tracking and functionality where problems to meet commitments are identified as and when they arise as program standards are defined and enforced. The minimum requirement for this level is that companies must have established policies to aid management in establishing appropriate management processes to enable repeatability of earlier successes (Paulk, et al., 1993; Paulk, 95).

- **Level 3 - Defined** (institutionalized) the processes for both management and engineering are documented, standardised and integrated as a standard business process (Paulk, 95).

- **Level 4 - Managed** (quantified) process management and measurement takes place, where process and equipment are quantitatively understood and controlled (Paulk, 95).

- **Level 5 - Optimising** (process improvement) process management includes deliberate process optimization/improvement gained through piloting new ideas and technology (Paulk, 95).

These levels of maturity have been directly adopted as the generic maturity levels and are applicable to any maturity model, hence Phillip Crosby is deemed as one of the key contributors to the maturity model concept, and likewise the research done by Walter Shewhart, Edwards Deming, Joseph Juran (Object Management Group, 2008); Kazanjian and Drazin (1989) as well as other similar studies (Greiner, 1998; Normann, 1977; Quinn & Cameron, 1983) made key contributions toward establishing and standardising the maturity model concept. More recent contributions in this field were made by Lasrado; Ravi; Normann (Lasrado, et al., 2015).

In general maturity models are applied to various scenarios, but all these models share the commonalty in the applied logic that is, stages of growth/maturity emerge in a defined sequence, where solving one set of problems consequentially brings about a new set of problems that require new corrective actions to move forward, evolving towards a new level of maturity (Kazanjian & Drazin, 1989). The study by Kazanjian and Drazin (1989) as well as other similar studies (Greiner, 1998; Normann, 1977; Quinn & Cameron, 1983), combined with the concepts initially put forward by Crosby (1979), have laid the foundations to a generalised approach for developing a maturity model and have enabled researches to utilise an established tool for strength and weakness analysis in various domains (as is the intention of this dissertation).

Upon investigation it was noted that design maturity model (MM) structures have been re-utilised in an extensive manner where these structures included models such as Nolan's Stage of Growth Model, Crosby's Grid, and Capability Maturity Model (CMM). It is clear that maturity models have inherently different purposes and different hybrids exist (De Bruin, et al., 2005). As such, it is of great importance to establish which world view is applicable in this dissertation. All-encompassing observations made by Lasrado et al. (2015) stated that there are three dominant world views in existence with regards to maturity models:

1. Maturity models are perceived as normative theories (mainly process theories) that contain a story, with events taking place around a main entity in a certain order over time that become mature towards improvements.
2. Maturity models are perceived as best practice guides or a certification mechanisms (stemming from capability maturity models (CMMs)).
3. Maturity models are perceived as a practical benchmarking tool where objects (e.g. organisations, programs) are classified and compared against each other using a scale of low to high maturity.

The research conducted by De Bruin et al. (2005) also emphasised that maturity models can vary in their intended purpose as these models can be: **(1) descriptive**; **(2) prescriptive** or; **(3) comparative**. De Bruin et al. (2005) further elaborates the details of each of these maturity model purposes and pronounces a purely **descriptive maturity model** to be applicable in scenarios where it might be of interest to assess the status quo. Initially the author perceived the nature of the maturity model in this dissertation as descriptive, but further reading made it clear that a purely descriptive maturity models, do not facilitate

bringing about improvements on the maturity level status quo, neither does it provide any relationships in performance (De Bruin, et al., 2005).

A **prescriptive maturity model** provides insight into how maturity levels can be advanced, as such an approach to systematically impose improvements and positive change toward advancing the EMM-maturity (De Bruin, et al., 2005).

The last variant of purpose in a maturity model is where it is utilised as a **comparative** tool, comparing equivalent practices across businesses in different industries (or departments within an organisation), a process better known as benchmarking (De Bruin, et al., 2005).

Irrespective of the nature of the maturity model purpose, all maturity models are known to evolve as time passes. Any maturity model starts of as being descriptive in purpose and once a better understanding of the status quo has been obtained, the maturity models evolves to become prescriptive in nature, establishing the way-forward. Once the maturity model has assisted in identifying the required improvements and the roadmap to these improvements have been applied, the maturity level needs to be benchmarked to understand competitive edges and possible shortcomings that in turn lays the foundation for further improvements or if the maturity level is very high, it becomes the new industry maturity benchmark (De Bruin, et al., 2005).

In a general context **MMs define an outline for planned, typical, logical, and desired evolution directives for moving from an initial maturity level towards a higher level maturity** (Raber, et al., 2013), through systematically documenting and guiding the development and transformation trajectory. When developing a MM, it is of cardinal importance to document the construction process and to explain what exactly is intended to be measured and the exact purpose of the MM (Raber, et al., 2016).

With the aforementioned in mind, **in the context of this dissertation MMs will be applied as a prescriptive tool.** The question that might spring to mind, “how can the author just skip through the descriptive life-cycle phase of the maturity model?” The answer lies in how to develop an objective maturity model. De Bruin et al. (2005) has developed a generic framework describing the various maturity model development phases (see Figure 2.2-1) and has described in a great extent how to inclusively develop and expand the constituents of models in the development phase.

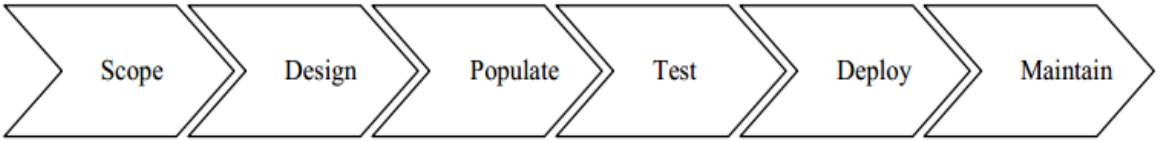


Figure 2.2-1: Model Development Phases (De Bruin, et al., 2005)

De Bruin et al. (2005) has pointed out that no matter how comprehensive the literature review might be, it is unlikely that it will enable all-encompassing information to adequately populate the layers of detail in each of the phases. As such De Bruin et al. (2005) recommends that exploratory research methods be deployed (Delphi technique, Nominal Group technique, case study interviews and utilising focus groups for domains and the sub-domains). These methods are deemed appropriate due to the fact that the development process:

a) Deals with complex issues;
b) Seeks to improve decision making by combining different views;
c) Aims to make contributions to incomplete states of knowledge;
d) Lacks empirical evidence.

The author chose to consult industry accepted norms and standards relating to the field of equipment management maturity models. Standards are inherently industry accepted documents that have already undergone (and still continues) the model development phases as prescribed by De Bruin et al. (2005). Moreover, standards are maintained and updated based on feedback from experts on the relating topics as well as feedback from end-users applying the standards. As such the author has taken full advantage of the continuous improvement nature of maintained standards.

The starting point for obtaining such a standard was consulting the International Organisation for Standardisation (ISO), which provided guidelines relating to “Process assessment — Requirements for process reference, process assessment and maturity models” (International Organisation for Standardisation, 2015).

As mentioned earlier in this chapter, a deeper search revealed that an industry accepted standard pertaining to equipment management maturity models existed in the form of the ASTM E2452-12 standard (ASTM, 2012). The American Society for Testing and Materials (ASTM) is an American National Standards Institute (ANSI)-accredited standards developer (ANSI, 2016) and in turn, ANSI is the United States’ member body to ISO (ISO, 2017). This

relationship is of key importance as it qualifies the ASTM as an internationally recognised standards developer and by default has to follow the international guidelines for standard development, which are also followed by the ISO. ANSI, in cooperation with the ASTM identified the need for the ASTM E2452-12 standard's scope and thereafter ANSI together with the ASTM set priorities for the standard's completion, then assured that all impacted stakeholders had an opportunity to participate. Audits ensured the integrity of the ANSI-process (which complies and aligns with the ISO requirements), regularly ensuring adherence to the ANSI standard development procedures (ANSI, 2017). This important relation to the ISO ensures that the standards produced by the ASTM are recognised by the ISO as valid standards and that the ASTM standard took existing ISO-standards (amongst others) into consideration during the development phase, prior to being published.

The existence of the ASTM E2452-12 standard combined with the important link to the ISO thus implies that the author can skip through the maturity model development phases which aid the descriptive life-cycle phase for the development of a **descriptive** equipment management maturity model. This in turn implies the maturity model immediately progresses from a **descriptive purpose** to a **prescriptive purpose**.

2.3 ELECTRICAL MOTOR MANAGEMENT REQUIREMENTS

In this dissertation the specific case study focuses on a specific piece of equipment in the form of electrical motors. As elaborated and substantiated in the preceding paragraphs, a **prescriptive maturity model** (ASTM, 2012) **will be utilised as a tool to measure the maturity level of the existing EMM** (if at all existing) and further serves as an approach to develop a visible and documented outline to impose improvements and positive change in an effort toward advancing (or initiating) the EMM-maturity at the engineering services department at the large steel manufacturer at the time of writing this dissertation.

2.3.1 DEFINING TERMS AND CONCEPTS

An understanding of the terms "equipment" and "equipment management", in the context of ASTM E2452-12 standard, are important so that the author and whoever might want to execute continuous improvement in context of this study do not wander off on a tangent:

> *"**Equipment** - non-expendable, tangible, moveable property needed for the performance of task or useful in effecting an obligation"* (ASTM, 2012).

This definition for equipment put forward by the ASTM E2452-12 standard (2012) implies that the equipment in the context of a process could be, for example in an instance of a water pumping system, be the incoming power and distribution; motor controls (process logic controller (PLC) and motor control centre (MCC)); electrical motor; coupling; pump/load; piping; valves and the process to which parameters are defined for fulfilling the "obligation". The aforementioned equipment forms a system required to effect a useful obligation i.e. a water pumping system to distribute a certain volume of water from a defined starting destination to defined end destination at a defined rate.

To further elaborate, the ASTM E2452-12 standard (2012) defines the concept, "equipment management" as:

> *"**Equipment management** - systematic planning and control of equipment to optimize its service delivery potential and the management of associated risks and costs throughout its life-cycle in support of organizational objectives. This includes the process management and operations of acquisition or construction of the equipment; its operation, maintenance, and modification while in use; and its disposal when no longer required"* (ASTM, 2012).

The applicability of this dissertation is explicitly to a subset of equipment namely, electrical motors. The author of this dissertation thus puts forward a new definition for electrical motor management (EMM) to align with the ASTM E2452-12 standard (ASTM, 2012), which is as follow:

> *"**Electrical motor management** - systematic planning and control of electrical motors to optimize its service delivery potential and the management of associated risks and costs throughout its life-cycle in support of organizational objectives. This includes the process management and operations of acquisition or construction of the electrical motors; its operation, maintenance, and modification while in use; and its disposal when no longer required.*

Before delving too deep into the ASTM concept for EMM, it would only be deemed diligent and unbiased to explore additional views and definitions in this regard.

A definition put forward by the United States' Department of Energy (Consortium for Energy Efficiency (CEE), 2012) for EMM:

> "*a set of **on-going policies and procedures** that can aid large industrial facilities effectively manage their motor populations based on **life-cycle costing and proactive planning**. Sound motor management helps **reduce downtime**, **decrease costs** and **improve productivity** of the plants."*

Deducing from the aforementioned definition put forward by the CEE (in collaboration with the U.S. DoE), it is clear that an EMM includes various aspects other than only maintenance. Dr Penrose (Penrose, 2005) argued that modern management practices often neglect the importance of **motor system** management requirements and wrongfully perceived motor management as energy management; in some cases, it is viewed as motor testing, storage- or greasing-programs. These views are often the pitfalls to the success of such implemented programs, as is evident by the Motor Diagnostics and Motor Health Study conducted by O'Hanlon and Penrose, where only 7% of perceived motor management programs implemented actually qualify as effective motor management programs (Penrose & O'Hanlon, 2003).

In lieu with the aforementioned, Dr Penrose established that the definition for an EMM put forward by the CEE, focused only on some aspects pertaining to motor management and a more comprehensive definition was put forward (Penrose, 2005):

> *"Motor system maintenance and management is the philosophy of continuous improvement of all aspects of the motor system from incoming power to the driven load. It involves all components of energy, maintenance and reliability from system cradle to grave."*

The author makes four distinct observations in lieu with the definitions put forward by the CEE (2012) and Dr Penrose (2005) respectively.

1. The CEE-definition is vague and only focuses on one aspect within the two levels of equipment management activities i.e. one activity within process management and operation management in the form of "*on-going (continuous improvement) policies and procedures*".
2. The Dr Penrose-definition clearly only considers the hardware aspects once in the use life-cycle phase i.e. focuses on the electrical motor system itself and does not consider process management activities.
3. Neither the CEE-definition, nor the Dr Penrose-definition are industry accepted definitions. These definitions have been presented as academic papers and were

published, implying that these definitions have been academically presented and tested. As such the author has proposed, as part of this dissertation, a "new definition for electrical motor management as it aligns to the industry accepted definition for equipment management. An electrical motor is in fact a specific instance of equipment, but still needs to adhere to the norms of equipment management as presented in the ASTM E2452-12 standard (2012). The ASTM-definition for equipment management is also the most recent industry accepted norm in terms of date.

4. Dr Penrose does however encapsulate an important observation i.e. motor management does not work in isolation, in order to obtain a more reliable motor one needs to take into account the **motor system**. This concept has been proven extensively through the Motor Diagnostics and Motor Health Study conducted by O'Hanlon and Penrose (2003).

As stated in the observations above, it is of great importance to note that Dr Penrose utilises the term "motor system" (2005) in his EMM-definition, which brings the methodology to a systems engineering approach, where the motor system, according to Dr Penrose (2005), includes sub-systems, comprising of:

1. Incoming power and distribution;
2. Motor controls;
3. Electrical Motor;
4. Coupling;
5. Load and;
6. Process (best efficiency point for pumps etc.)

The concept of applying a systems approach to motor driven systems is also supported by the U.S. Department of Energy (U.S. Department of Energy, 2014), as this approach accounts for the interaction of components and the possible changes of variables during these component interactions. The systems approach also allows analysis of the holistic system to ensure the most effective and efficient solution is achieved. As such, a critical review of the definitions put forward by United States' Department of Energy and Dr Penrose respectively revealed that a complete systems approach has still not been deployed to manage the motor systems holistically. As such the author will present a proposed means of comprehensive motor management and substantiate the reasoning in the subsequent paragraphs.

2.3.2 EMM DOMAIN OUTLINE

The aforementioned view (that existing definitions of EMM were falling short of comprehensively managing electrical motors) was also supported during an interview conducted with Professor Wichers (2016), who stated that there are multiple interfaces inherent to a management plans (which would be the case for motor management). These interfaces relate to human factors, control of information and aspects pertaining to logistics. Management plans applied in the context of industry (such as mining and manufacturing industries for example) are subject to five basic sub-systems which determine success of the said management plan for implementation. These five sub-systems of management plans include (Wichers, 2016):

1. Plant and equipment.
2. Documentation and data.
3. People and training.
4. Programs and software.
5. Logistics and support.

However, upon revising the aforementioned the author found supporting evidence from another industry expert that additional domain components and domain sub-components are required. The industry expert (Jooma, 2016) pointed out that a management plan would not boast continuous improvement with a lack of introspection (in the form of audits) on frequent basis, as it will be difficult to gain a comprehensive understanding of detracting performance areas (requiring management intervention) which could be the downfall of the program.

Jooma's (2016) view is also supported by Dr Penrose's (2005) motor management definition presented earlier in this chapter, as the definition calls on continuous improvement. The author has also personally experienced that auditing systems are in place for advancing the level of maturity for other management systems at the large steel manufacturer. A typical example is annual audits for safety management system compliance, but not the same can be said for auditing systems on technical and other management system functions. This notion is further supported by the requirements stipulated in ISO9001 (2015) to achieve ISO9001-accreditation as mentioned in paragraph-2.1. As such the author adapted the five domain components of management plans as proposed by Prof Wichers (2016), by adding an additional sub-domain component namely, audit and improve. Thus the initial sub-domain components for the EMM-domain are as presented in Figure 2.3-1.

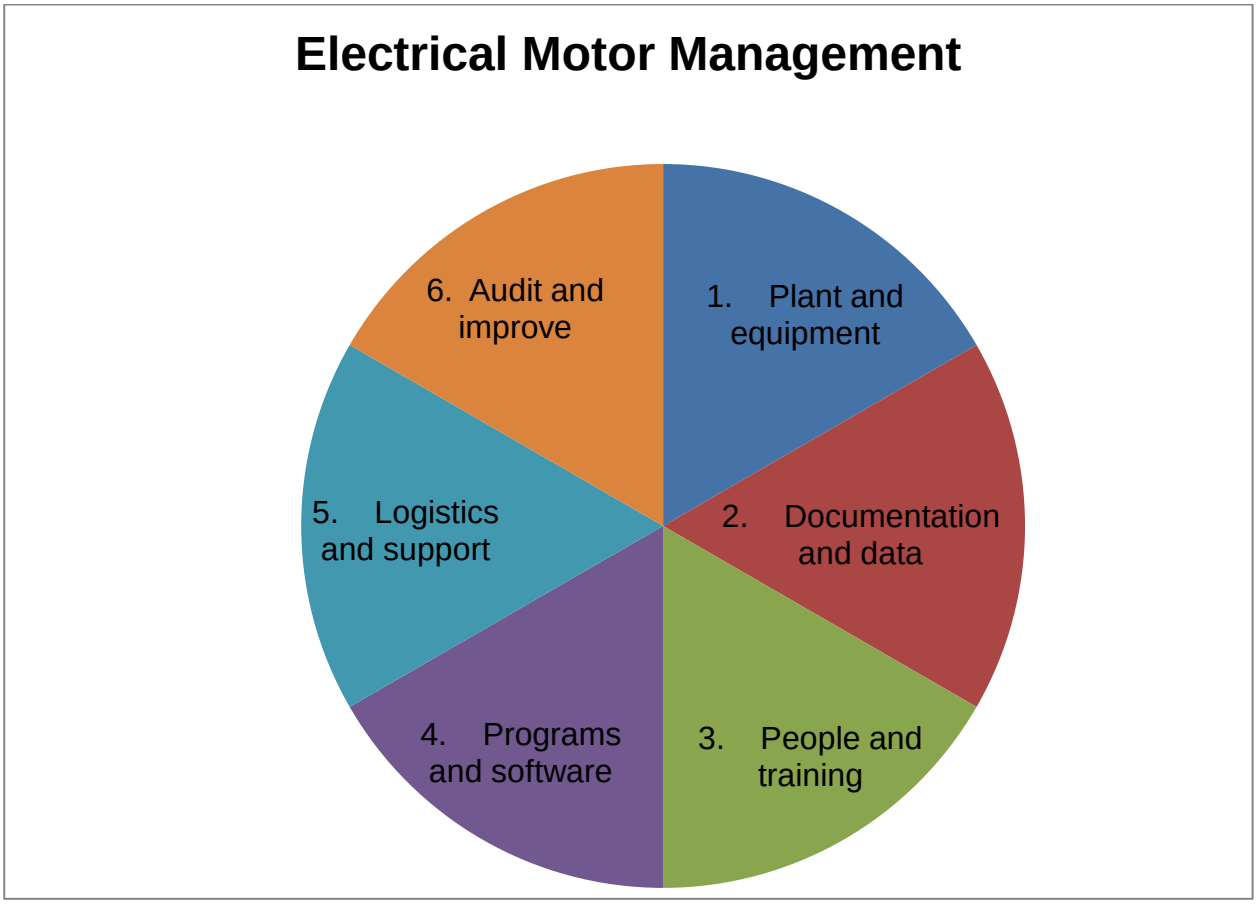


Figure 2.3-1: EMM sub-domain components adapted from Wichers (2016) and Jooma (2016)

Prior to accepting the aforementioned EMM sub-domain components, additional research uncovered industry accepted requirements as put forward in the ASTM E2452-12 standard (2012). The ASTM (2012) identifies that various life cycle phases exist for equipment and in each of these life cycle phases (which aligns with the definition put forward by the United States' Department of Energy (Consortium for Energy Efficiency (CEE), 2012), fundamental levels of equipment management activities exist, namely:

1. Process management.
2. Operation management.

The ASTM E2452-12 standard (ASTM, 2012) defined ***process management*** as:

> *"Process management - a management activity pertaining to the* ***criteria for the people, processes, and systems involved in equipment management for each life-cycle phase"***.

The key observation in the process management definition (ASTM, 2012) is the recognition that a **systems approach** forms part of management activities in equipment management. This aligns and supports Dr Penrose's (2005) view that a **systems-approach** is required to holistically manage the motors. The shortcoming in Dr Penrose's (2005) view however, was that he was actually inferring to the hardware pertaining to the motor system. There also exists supporting views that if an entity improves process management it will aid the need toward reducing weaknesses in the EMM and boost the chances of success (Object Management Group, 2008).

Operation management on the other hand, is defined as:

> ***"****Operation management - the second management activity and it relates to* ***processes that directly impact individual equipment*** *and are* ***specific to the life-cycle phase****."*

The ASTM E2452-12 standard (2012) in the context of this study provides the means necessary for understanding the efficacy and extensiveness (if at all existing) of EMM deployed at the engineering service department within the large steel manufacturer as it acquires, uses, and disposes of electrical motors (the specific equipment case study in the context of this dissertation). The equipment life-cycle phases as addressed in the ASTM E2452-12 standard (2012), typically includes three main life cycle phases which are:

1. Acquisition life cycle phase.
2. Usage life cycle phase.
3. Disposal life cycle phase.

The important aspect to take note of is that each life cycle phase comprises of process- and-operation management activities, i.e.:

1. Acquisition life cycle phase = (Process management) + (Operation management)
2. Usage life cycle phase = (Process management) + (Operation management)
3. Disposal life cycle phase = (Process management) + (Operation management)

Figure 2.3-2, presents all the domain components and domain sub-components of EMM in accordance with the ASTM E2452-12 standard (2012).

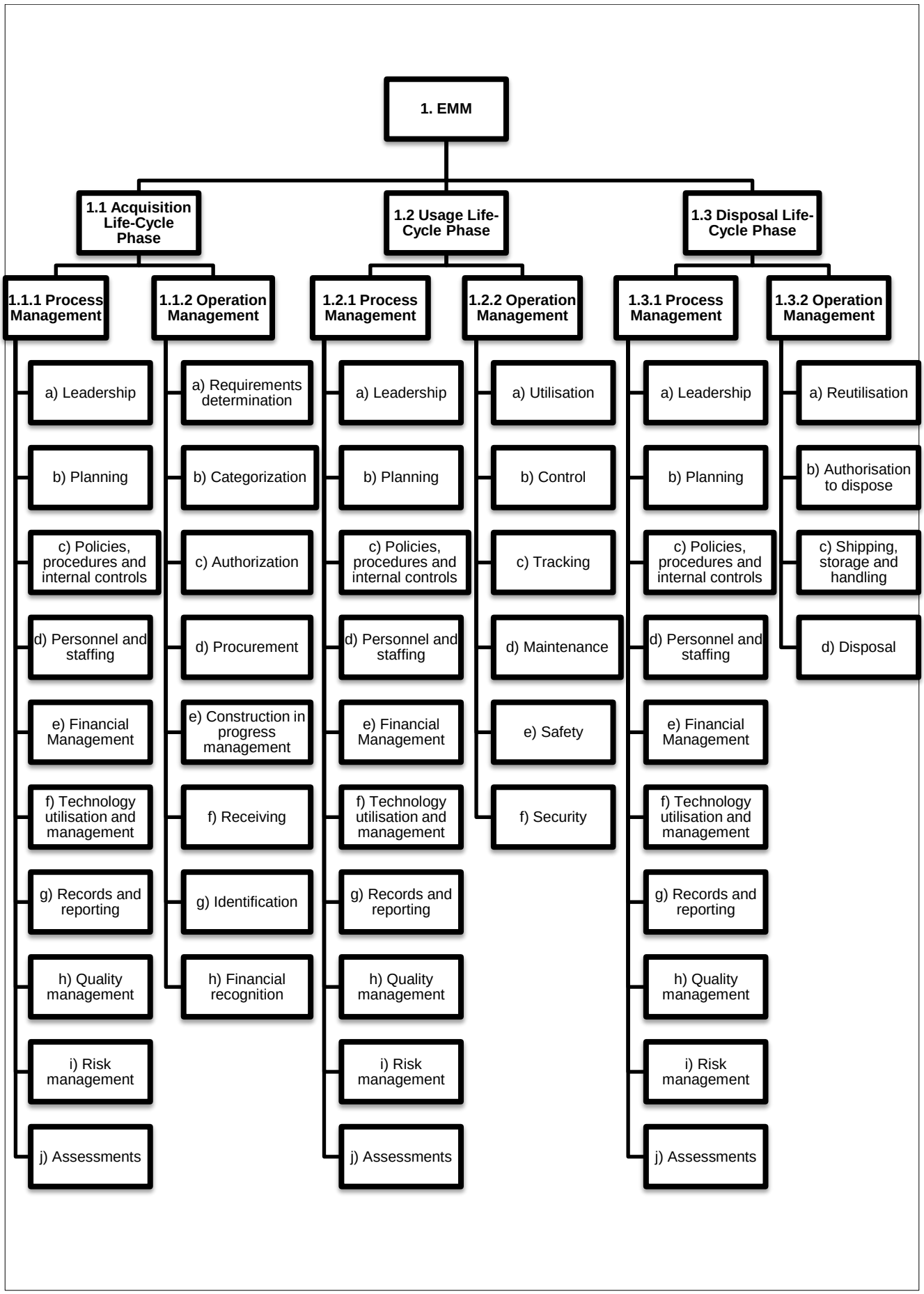


Figure 2.3-2: EMM constituents (ASTM, 2012)

The author makes a key observation with regards to the EMM domain components and domain sub-components (also known as process areas) presented in Figure 2.3-2: one crucial domain sub-component (process area) is omitted in the process management activities within each life cycle phase this domain sub-component (process area) is configuration management (CM) (also known as change management; also known as engineering change management). Though beyond the scope of this study, the importance of CM has been established by Curkovic & Pagell (1999) who have determined that configuration management leads to:

a) reduced time to develop and implement the change;
b) reduced start-up time;
c) overall reduction in cost.

Du Toit (2014) has undertaken an extensive literature review in the field of CM and has concluded from supporting literature that a lack of CM can result in:

- Equipment damage; additional changes and reworks; rescheduling; unavailability of maintenance parts and missing critical information and critical documentation;
- Poor service delivery and a general deterioration of performance in downstream processes, equipment and equipment capabilities – affecting quality, maintainability and operability.

Du Toit (2014) also stated that CM is in fact integrated within the full life-cycle of a product, which supports the author's observation and notion to include CM in the sub-domains presented in Figure 2.3-2. This view is further supported by the process maturity model proposed by the Object Management Group (2008) and by Prof. Wichers (2016).

As such the author will utilise an adapted version of the EMM domain and domain sub-domains (process areas) as presented in Figure 2.3-2. Each domain sub-component (process area), presented Figure 2.3-3, for the entire EMM will be elaborated in the subsequent paragraph in order to obtain an understanding to enable deployment/improvement of EMM activities at the engineering services department at the large steel manufacturer.

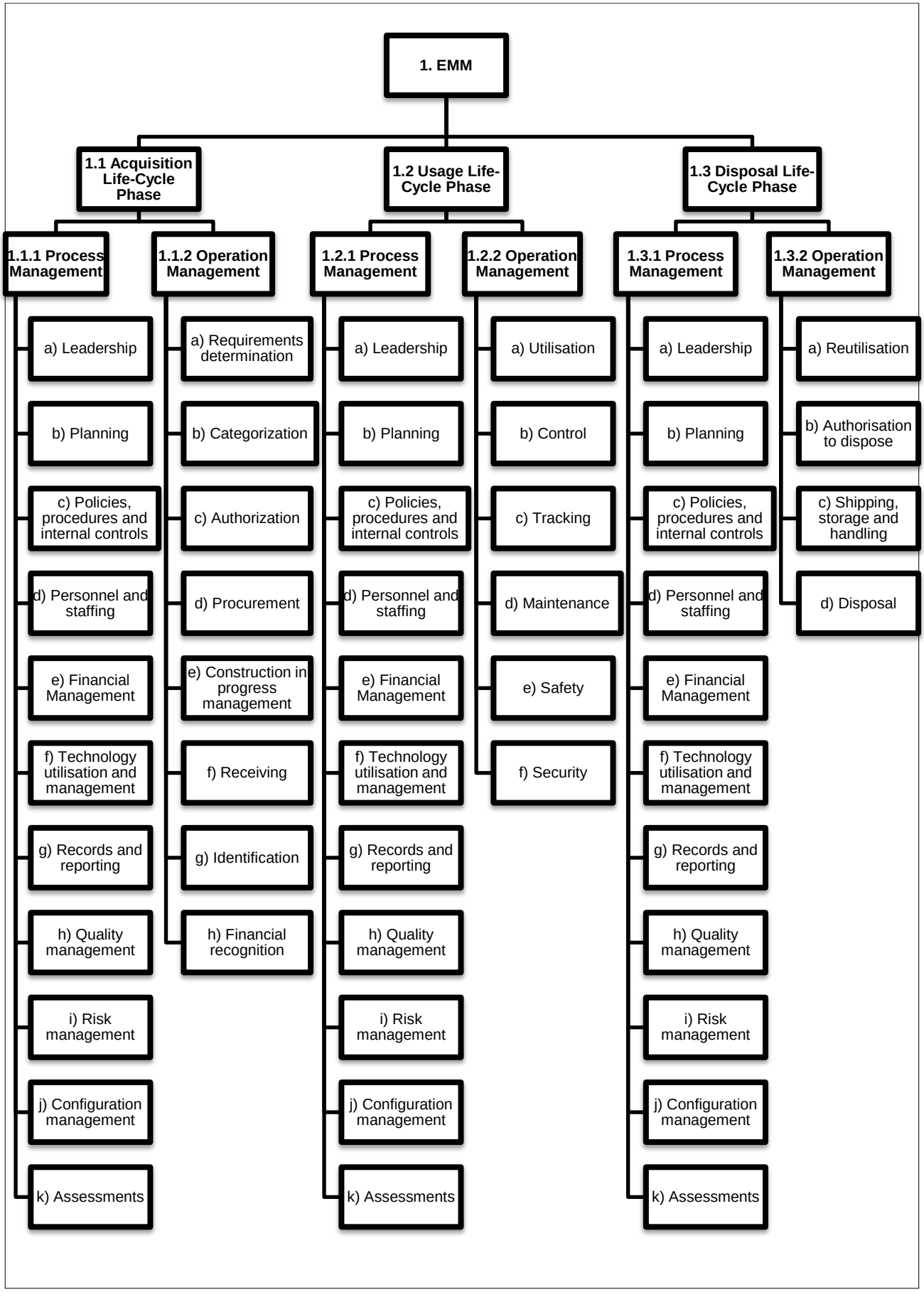


Figure 2.3-3 EMM constituents adapted from (ASTM, 2012)

2.3.3 EMM DOMAIN COMPONENT AND SUB-DOMAIN COMPONENT ELABORATION

The focus for this maturity model, as established in the preceding paragraphs, is on electrical motor management (EMM), i.e. **the domain is electrical motor management**. With the focus of the model now defined the next step would be to develop the model with the input from domain and sub-domain/process area specific stakeholders which typically include stakeholders such as academic institutions, industry experts, government and non-profit organisations (De Bruin, et al., 2005). The EMM domain components and domain sub-components need to be mutually exclusive and collectively exhaustive. The domain components can be defined by means of an extensive literature review. De Bruin et al. (2005) stated that no matter how extensive the literature review might be, it will never allow adequate information to identify required domain components and domain sub-components/process areas. More elaborate research methods such as the Delphi technique, Nominal Group technique, case study interviews and domain focus groups should be utilised to identify domain components and domain sub-components/process areas. Through utilising the maturity model as presented in the industry accepted ASTM E2452-12 standard (ASTM, 2012), the author is ensured that that all EMM domain components and domain sub-components/process areas have been subject to an extensive literature survey combined with Delphi technique and focus groups as proposed by De Bruin et al. (2005).

As such the author will present sub-domain/process areas (PAs) which will be followed by the specific criteria/conditions constituents. Specific criteria describe what needs to be done and does not stipulate requirements for how the specific goals need to be met. In an attempt to an overview structure for the electrical motor management maturity model, one should envisage as follow:

1. Domain (Electrical Motor Management) > Management activities > process areas/sub-domains > specific conditions (as presented hierarchy format in Figure 2.3-4)

or, alternatively

2. Domain (Electrical Motor Management) > process areas/sub-domains > specific conditions (as presented hierarchy format in Figure 2.3-4)

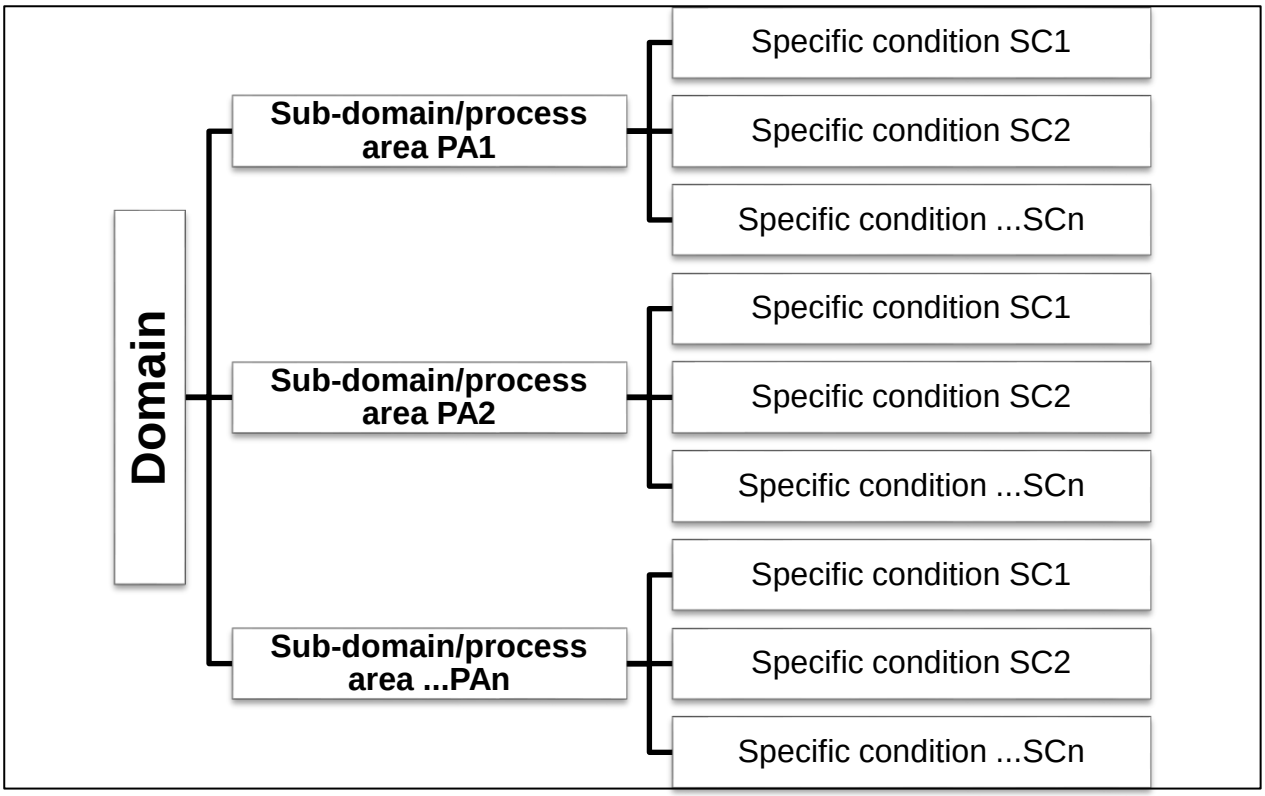


Figure 2.3-4 EMM maturity model hierarchy

After establishing the EMM sub-domain components/key process areas, the final step is to elaborate on the method for determining maturity measurements for the domain and domain sub-components. This can be done by means of determining and defining the inclusion of appropriate questions and measures within this instrument (the instrument being the MM), this will be done in paragraph 3.

The reader might have deduced from the outline presented in
Figure 2.3-3 , the process management activities throughout all of the life cycle phases of the equipment remains the same. As such, the subsequent paragraphs will exclude elaborating the process management sub-components/process areas for each life cycle phase and will only elaborate on these process management process areas/sub-domains in one communal paragraph, as presented in the paragraph to follow.

2.3.3.1 Process management (communal to each life cycle phase)

Processes that are deemed effective integrates the likes of human resources, equipment and methods to work together to achieve a collective objective. The quality of the processes used to develop, deliver, and support services and products are directly proportional i.e. bad quality processes will deliver bad quality services and products. Long term vision and

strategy together with the management support forms the premise of process improvement, as such the culture and infrastructure developed at the large steel manufacturer needs to be supported and enforced through procedures, standard operating practices and methods that will continue even when after the authors have moved on. Each process area (PA) identifies a cluster of specific conditions (SCs) (also known as specific goals (SGs)) that, when performed collectively, achieve a set of goals considered important for enhancing process maturity (Object Management Group, 2008).

Process management activities consist of several process areas/sub-domains that deals with conditions relating to people, processes, and systems involved in electrical motor management for each life-cycle phase (ASTM, 2012), which aligns with the observation made by the Object Management Group (2008). The process management process areas will firstly be presented as a whole, followed by the specific conditions (SCs) for each process area. The process areas are in accordance with the ASTM (2012) and are as follow: *Leadership (PA1); planning (PA2); policies, procedures and internal controls (PA3); personnel and staffing (PA4); financial management (PA5); technology utilisation and management (PA6); records and reporting (PA7); quality management (PA8); risk management (PA9); configuration management (PA10) and assessments (P11).*

Now that the process areas have been presented the ASTM (2012) will be utilised as the premise for defining the specific conditions for each process area.

2.3.3.1.1 Leadership (Process Area 1 (PA1))

2.3.3.1.1.1 Outcome/Process orientation (Specific Condition 1 (SC1))

Outcome or process related metrics based on management and control systems are institutionalised, promoting performance and effective management.

2.3.3.1.1.2 Best value products (SC2)

Best value products are ensured to the large steel manufacturer and its processes and in turn preserves confidence in all internal and external stakeholders due repeated timely best value end user products as a result of the supporting management.

2.3.3.1.1.3 Personal initiative (SC3)

Staff exercise personal initiative and comprehensive business judgement to align with the large steel manufacturer's needs through "best value" services.

2.3.3.1.1.4 Lines of authority/accountability (SC4)

Clear organisational accountability through definite lines of authority for all management and control systems to drive performance and custodial care. In this sub-domain specific condition the lines of authority should be divided:

- to have clear escalation communication channels available; and to
- ensure that the users of the EMM-improvement activities are separated to the resources who audit the compliance and the level of maturity on a continuous basis. In other words the implementation team cannot be responsible for measuring conformance and maturity levels (to prevent conflict of interest) as an auditing authority (the implementation team can however measure conformance and maturity levels as in internal reporting and tracking tool to gauge continuous growth). As such the compliance- and improvement-evaluation team should be an organisational support function.
- To provide control on releases for repairs/procurement, as without consent from EMM custodians are eliminated.

2.3.3.1.1.5 Best-in-class management (SC5)

The large steel manufacturer recognises, identifies and adopts best-in-class management practices and incorporated management systems.

2.3.3.1.1.6 External interface (SC6)

Operative service is provided by establishing partnerships with external departmental customers and with the end-user of products and services rendered.

2.3.3.1.2 Planning (PA2)

2.3.3.1.2.1 Strategic plan (SC1)

The large steel manufacturer's plans and objectives form the premise for undertaking continuous processes of strategic planning relating to electrical motor management which result in strategic plans being followed containing clear goals, objectives and structured programs.

2.3.3.1.2.2 Metrics (SC2)

Specific metrics are identified and institutionalised, where samples of such metrics may include but are not limited to:

- time taken to label and insert data into an enterprise resource planning (ERP) database upon goods receipt;
- time taken for the electrical motor management custodian to recognize data accuracy and physical control upon initial receipt;
- accuracy of physical inventory and the accuracy of the inventory recorded in the system;
- time taken to dispose of an item once it is declared excess.

2.3.3.1.2.3 Financial plan (SC3)

The large steel manufacturer's need for electrical motor management resources is viewed as a whole, and financially planned.

2.3.3.1.3 Policies, procedures and internal controls (PA3)

2.3.3.1.3.1 Exercise of responsibility (SC1)

Where a specific strategy, practice, policy, standard, or procedure is identified as non-existing by electrical motor management officials, it is deemed that implementing actions in accordance with the newly identified strategy, practice, policy, or procedure, as an acceptable exercise of responsibility and authority. The percussive condition is that it has to be in the best interest of the large steel manufacturer and its stakeholders and that implementing the action is not prohibited by law, executive order or other regulation.

2.3.3.1.3.2 Sound policies and procedures (SC2)

Policies and procedures for tasks relating to electrical motor management at the large steel manufacturer are established.

For example establish and enforce minimum energy efficiency performance policies:

- which clearly defines applicable standards for all (low voltage <1000V) 3-phase induction motors 0.12kW – 1000kW (distinctions need to be made for loads running direct on line (DOL) vs. those driven by variable speed drives as some DOL loads will actually consume more power due to reduced slip (higher shaft speed) as is the case for pumps).

For example specifications for new/repair/replace shall follow the adopted company policy:

- All (low voltage <1000V) 3-phase induction motors 7.5kW - 150kW (driven directly on line with no speed control for load variations), shall carry a minimum of IE3 efficiency class (as per defined efficiency classes in the IEC60034-30-1). Once

again, distinctions need to be made for loads running direct on line (DOL) vs. those driven by variable speed drives (VSDs) as some DOL loads will actually consume more power due to reduced slip (higher shaft speed) as is the case for centrifugal pumps.

2.3.3.1.3.3 Reutilisation (SC3)

The large steel manufacturer reutilises electrical motors amongst the various departments when such electrical motors are deemed to be no longer needed for the current purpose and is guided by documented programs to encourage and facilitate the reassignment of electrical motors as such.

2.3.3.1.3.4 Consensus standards (SC4)

Electrical motor management activities are performed in accordance with existing applicable standards.

2.3.3.1.3.5 Available, implemented, and enforced (SC5)

The large steel manufacturer develops and maintains a system of internal management controls sufficient to provide reasonable assurances that:

- management's authorisation is obtained prior to transactions being executed;
- conformance with accepted accounting principles provide the necessary guidelines for recording transactions;
- limitation to access;
- and frequent interval comparisons are drawn for recorded accountability allocations for electrical motors vs. existing electrical motors, where any differences are actioned appropriately.

2.3.3.1.4 Personnel and staffing (PA4)

2.3.3.1.4.1 Adequate staffing (SC1)

Adequate staffing allocations are implemented to function in the electrical motor management process management and operations roles to ensure the large steel manufacturer's electrical motor management goals are achieved and that compliance with applicable internal- and external-standards, laws, regulations, and applicable agreements, contractual obligations, work instructions, policies are controlled, monitored and appropriate actions are taken.

2.3.3.1.4.2 Requisite skills and knowledge (SC2)

The staff executing, providing supporting roles, or affected by the activities for electrical motor management activities are equipped with the required knowledge and proficiency to complete their jobs effectively.

- Relevant education and proficiency development activities are instigated to staff that perform the work.
- Stakeholders are provided with orientation training if they are deemed to interact with staff that performs practices relating to electrical motor management to align and develop a comprehension of the importance of the program and their role as a stakeholder.

2.3.3.1.4.3 Trained staff (SC3)

Continuous development and training for employees who work within the electrical motor management process management and operations which provides the means for continuous improvement and growth.

2.3.3.1.5 Financial management (PA5)

2.3.3.1.5.1 Funding mechanism information provided (SC1)

Procured electrical motors shall be classified in terms of accounting as either being capital expenses or operating expenses or as spares (held for future use spares).

2.3.3.1.5.2 Financial accuracy (SC2)

Transactions and dispositions relating to electrical motor management shall be tracked by means of accounting books and detailed electrical motor management records shall be kept to allow assurance of system accuracy.

2.3.3.1.5.3 Balances costs and risks (SC3)

Trade-off based on risk and cost need to be exercised so that balanced and comprehensive decisions can be made as to cost control vs. the process risk which are determined by the process criticality of the electrical motor. In other words what would the cost impact be to the large steel manufacturer as consequence of shortage (non-availability of inventory) or as consequence of the electrical motor's failure.

2.3.3.1.5.4 Best value (SC4)

The large steel manufacturer pursues best value from electrical motors and factors the use and maintenance of electrical motors aspects in as part of obtaining best value for the long term.

2.3.3.1.5.5 Loss/Overage controls (SC5)

Control measures have been put in place to provide clear guidance to the large steel manufacturer in making economic decisions based on these established controlled measures and applied to the electrical motor inventory as opposed to using only acquisition cost for making economical decisions.

2.3.3.1.5.6 Materiality (SC6)

As part of the established control measures, decisions are also made based on the contextual importance for the large steel manufacturer which will allow matters arising to be placed in a relevant context to comprehend the significance.

2.3.3.1.5.7 Minimize loss consequences (SC7)

To aid the electrical motor management activities' economic factors in measuring its success, continuous condition monitoring practices are deployed to cast projections and minimise the probability of an event relating to electrical motors for being exposed to possible loss, damage, or destruction, an example of tools that can be utilised in such an undertaking is failure modes and effects analyses (FMEA) as presented by John Moubray (Moubray, 1997, pp. 53-80). Functional criticality is also taken into account as part of FMEA, where all the functional failure related risks posed to the plant process; workers and environment are taken into consideration (Moubray, 1997).

2.3.3.1.6 Technology utilisation and management (PA6)

2.3.3.1.6.1 Technology innovation (SC1)

Addition of new technologies such as condition monitoring; motor efficiency; motor control (variable frequency drives) etc. is consistently considered for deployment at the large steel manufacturer whilst keeping a focus on accurate life-cycle cost vs. the full benefits that could be achieved by deploying the considered technology.

2.3.3.1.6.2 Technology implementation (SC2)

The large steel manufacturer implements electrical-motor-related-technologies holding substantial financial benefit.

2.3.3.1.6.3 Technology management (SC3)

Continuous process-improvement is an objective in technology management and the technology within the large steel manufacturer is correctly managed.

2.3.3.1.7 Records and reporting (PA7)

2.3.3.1.7.1 Access to information (SC1)

Key performance indicators (KPIs) are defined to measure electrical motor management activities, these KPIs are communicated on a frequent basis to stakeholders.

2.3.3.1.7.2 Records maintenance (SC2)

Transactions and dispositions relating to electrical motor management within the various departments at the large steel manufacturer shall keep detailed records (accounting books and functional/technical/maintenance related records).

2.3.3.1.7.3 Electrical motor identification (SC3)

The large steel manufacture deploys electrical motor inventory and tracking and the inventory has control systems in place to identify both the economic and physical parameters for the entire electrical motor population. The inventory system should also allow recording the criticality rating (stemming from FMEA-studies). Lastly the large steel manufacturer has predefined a motor reliability strategy in the case where the materiality and functional criticality where substantiated.

2.3.3.1.7.4 Summary report information (SC4)

Responsible overview reports are supplied within the large steel manufacturer to aid decision makers in any managerial related decisions and for organisational reasons.

2.3.3.1.7.5 Records retention (SC5)

The large steel manufacturer complies with the relevant standards; customer specific contractual requirements and organisational policies pertaining to records retention.

2.3.3.1.7.6 Cross-functional integration (SC6)

Departments within a large steel manufacturer (the various production processes) are satisfied with the electrical motor management activities deployed within their departments by the engineering services department.

2.3.3.1.7.7 Cost and performance data (SC7)

Major cost driving processes are trended for determining cost efficiency pertaining to major motor management activities.

2.3.3.1.8 Quality management (PA8)

2.3.3.1.8.1 Monitoring and measurement of processes (SC1)

Processes are implemented to achieve a set of planned outcomes/results, as such the large steel manufacture shall deploy suitable methods for monitoring the process' ability to achieve these outcomes/results and, where applicable, these deployed methods need to measure the quality management system processes. In the instances where the methods indicate failure in achieving the planned outcomes/results, corrective and preventative actions are implemented to contain (as corrective) and prevent reoccurrence (preventative), thereby ensuring future conformity.

2.3.3.1.8.2 Continuous improvement (SC2)

The key objective of electrical motor management is to pave the way for continuous improvement (progressive maturity).

2.3.3.1.8.3 Outcome measures (SC3)

Defined KPIs are based on process outcomes.

2.3.3.1.9 Risk management (PA9)

2.3.3.1.9.1 Establish liability (SC1)

Records relating to the financial liability are established for every electrical motor.

2.3.3.1.9.2 Insurance (SC2)

The large steel manufacturer's policies; procedures and accounting principles define the requirements for liability cover and the large steel manufacturer's electrical motors are covered accordingly.

2.3.3.1.9.3Mitigation (SC3)

The large steel manufacturer takes appropriate action to eliminate/reduce the identified risks and this risk reduction/elimination forms an integral part of the electrical motor management system.

2.3.3.1.9.4 Security (SC4)

The electrical motor management program takes into account factors that pose risks of misuse and theft to the electrical motor population and these risks are in turn addressed by implementing preventative and mitigation strategies.

2.3.3.1.10 Configuration management (PA10)

2.3.3.1.10.1 Configurations are identified (SC1)

Items that will be controlled under the large steel manufacturer's configuration management system are identified.

2.3.3.1.10.2 Contents of configurations are controlled (SC2)

The content of the items that will be controlled under the large steel manufacturer's configuration management system are managed and controlled (prevention of incorrect change requests with inadequate information ensuring compliance of a standard template defining the user input fields).

2.3.3.1.10.3 Configuration management information is reported (SC3)

Content and status information together with the descriptions for configuration items are maintained and reported to accountable parties.

2.3.3.1.11 Assessments (PA11)

2.3.3.1.11.1 Self-Assessment (SC1)

Internal audits and continuous reporting relating to the process management activities and operation management activities are conducted in accordance with the large steel manufacturer's policies and in accordance with the electrical motor management maturity model's domain, sub-domain, process areas and specific conditions (as set out in this document).

2.3.3.1.11.2 Physical Inventory (SC2)

Inventory is planned for and conducted in accordance with the large steel manufacturer's policies and work instructions.

2.3.3.1.11.3 Metrics (SC3)

Processes are improved by means of the established, tracked and reported KPIs and thereby the large steel manufacturer achieves the process objectives.

2.3.3.1.11.4 Third-Party Audits (SC4)

The large steel manufacturer utilises third-party auditors to obtain certification of the applied electrical motor management program. In the case where certification has already been obtained, external audits are conducted to drive continuous improvement and ensuring compliance to the certification obtained.

This concludes process management and the containing sub-domains/process areas. The paragraph to follow will look at the accompanying operation management sub-domains/process areas throughout the acquisition-, use- and disposition life cycle phases respectively.

2.3.3.2 Acquisition Life-Cycle Phase

The *acquisition life-cycle phase (LCP)*, as previously mentioned, consists of *process management activities* and *operation management activities*. In the sub-sequent paragraphs the specific conditions (also known as specific goals) for the operation management activities will be presented and elaborated (the process management activities have already been presented in 2.3.3.1 and will not be repeated in this section).

2.3.3.2.1 Process Management

As presented in paragraph 2.3.3.1

2.3.3.2.2 Operation Management

In this paragraph, the operation management process areas (PAs) during the acquisition life-cycle phase will firstly be presented as a whole, followed by the specific conditions (SCs) for each process area. The operation management process areas (PAs) during the acquisition life-cycle phase are in accordance with the ASTM (2012) and are as follow:
Requirements determination (PA1); categorisation (PA2); authorisation (PA3); procurement (PA4); construction in progress management (PA5); receiving (PA6); identification (PA7); financial recognition (PA8).

Now that the process areas have been presented the ASTM (2012) will be utilised as the premise for defining the specific conditions (SCs) for each process area.

2.3.3.2.2.1 Requirements determination (PA1)

a) Define the functional specification of the equipment required.
b) Document how the equipment would contribute in aligning with the large steel manufacturer's goals.
c) Execute a cost versus benefit analysis.
d) Consider the applicable national adopted standards (SABS) (if none exist refer to international standards e.g. IEC, ANSI, IEEE, ISO etc.) for use during acquisition phase of electrical motors. This would enable interdepartmental swapping of electrical motors that are alike during failures/emergencies. Standardising on electrical motors would also ensure a minimum level of quality and that suppliers don't offer inferior electrical motors during tenders, which make evaluation of electrical motors challenging especially in a price sensitive economic environment.

e) Identify/utilise alternative sourcing and funding mechanisms, which could include, but not limited to e.g. bulk/batch supply and service and agreements; sole supplier and service contacts at reduced rates; guarantees and warrantees relating to electrical motors and related service respectively.
f) Execute a return on investment (ROI) analysis.
g) Calculate the total life-cycle cost, which typically include energy costs; service/maintenance costs acquisition costs.
h) Eliminate/minimise integration issues e.g. by conducting a hazard to operations analysis (HAZOP-study).

2.3.3.2.2.2 Categorisation (PA2)

a) Establish the cost goals and cost accounting treatments,
b) Establish the tax categorisation (e.g. moveable asset; immovable asset whether there are any applicable tax rebates or additional taxes such as import taxes), and
c) Determine other categorisation requirements, and assign proper category.

2.3.3.2.2.3 Authorisation (PA3)

a) Record financial authorisation,
b) Record management authorisation,
c) Record configuration manager (CM) authorisation,
d) Record contractual and/or program authorisation (custodian authorisation), and
e) Exercise financial prioritisation i.e. compare, and document competing electrical motor priorities based on risk, ROI, and plan procurement based on available funding.

2.3.3.2.2.4 Procurement (PA4)

a) Determine the reutilisation possibilities prior to the acquisition,
b) Enquire on possible alternatives in the forms of electrical motor loan and electrical motor sharing options,
c) Conduct a trade-off study for procure vs. lease,
d) Analyse and renegotiate purchase-, license- or lease-terms,
e) Plan and manage delivery,
f) The large steel manufacturer verifies conformance with applicable importing restrictions,

2.3.3.2.2.5 Construction in progress management (PA5)

a) The large steel manufacturer builds-up payments to suppliers on depreciable items under construction and also extends this practice to in-house related labour costs, and
b) When depreciable items are in a status where it is deemed as significantly complete and ready for use, the account is monitored and containing items are initialised to depreciate.

2.3.3.2.2.6 Receiving (PA6)

a) The large steel manufacturer critically analyses inconsistencies in shipping and deliveries and implements solutions accordingly,
b) Records and documents receipts,
c) Storage of electrical motors are executed in accordance with equipment manufacturer's requirements and relevant best practices
d) After goods receiving of electrical motors they are sent to the relevant departments within the large steel manufacturer.

2.3.3.2.2.7 Identification (PA7)

a) Verify that categorisation has been applied,
b) Apply identification plates and markings, and
c) Conduct quality assurance by verifying accuracy and ensuring continued compliance (e.g. annual visual inspection for clarity of identification plates, markings and accuracy against system records.

2.3.3.2.2.8 Financial recognition (PA8)

a) The large steel manufacturer makes use of their subsidiary asset and general ledger to record depreciable items, and
b) Statements are maintained to accurately reflect the large steel manufacturer's assets, liabilities, and operating results.

2.3.3.3 Usage Life-Cycle Phase

In this paragraph, the operation management process areas (PAs) during the usage life-cycle phase (LCP) will firstly be presented as a whole, followed by the specific conditions (SCs) for each process area. The operation management process areas (PAs) during the usage life-cycle phase are in accordance with the ASTM (2012) and are as follow:
Utilisation (PA1); control (PA2); tracking (PA3); maintenance (PA4); safety (PA5); security (PA6).

Now that the process areas have been presented the ASTM (2012) will be utilised as the premise for defining the specific conditions (SCs) for each process area.

2.3.3.3.1 Process Management

As presented in paragraph 2.3.3.1

2.3.3.3.2 Operation Management

2.3.3.3.2.1 Utilisation (PA1)

a) Authorisation for use of electrical motors is verified and recorded,
b) During the usage LCP financial associations are assured (e.g. power usage as a function of running hours, load and efficiency).
c) Electrical motor availability is tracked, deviations reported and corrective and preventative measures applied to achieve the objective of maximising electrical motor availability
d) Identify electrical motor related issues (e.g. condition monitoring techniques and reliability strategies),
e) Deploy electrical motor usage optimisation (e.g. reliability strategies, variable speed drives, soft starters and process related control).
f) Deploy reliability strategies to aid in recognition and to minimise loss and damages relating to electrical motors.
g) Identify surplus electrical motors.

2.3.3.3.2.2 Control (PA2)

a) Follow original equipment manufacturer (OEM) instructions to prevent storage related failures/damage to electrical motors
b) Where *contractors* are utilised for running processes/maintenance within the engineering services department at the large steel manufacturer, electrical motors

utilised by the subcontractors are controlled (registers, loan-database, working instructions for handling and use of electrical motors are understood, communicated and audited for compliance).

c) Where electrical motors are *utilised by departments external to the engineering services department at the large steel manufacturer*, the electrical motors are controlled (registers, loan-database, working instructions for handling and use of electrical motors are understood, communicated and audited for compliance).

2.3.3.3.2.3 Tracking (PA3)

a) Electrical motor's movements are controlled.
b) Electrical motor's physical (geographical) location database is verified continuously for assurance of accuracy.
c) Records pertaining to electrical motors are verified continuously for assurance of accuracy and the stakeholder accountability defined and maintained.
d) The large steel manufacturer's logistical management effectively and efficiently supports the department requirements pertaining to electrical motors.

2.3.3.3.2.4 Maintenance (PA4)

a) Documented reliability strategies exist for electrical motors within the engineering services department at the large steel manufacturer.
b) Electrical motor maintenance is executed in accordance to the documented reliability strategies.
c) Where applicable, the OEM-warrantees are utilised for warrantee related maintenance.
d) Conduct replace vs. refurbish trade-offs based on cost, risk, future support and turn-around time upon failure.
e) Define a breakpoint based on electrical motor kilowatt rating, where costs of maintenance and refurbishment are justified against life-cycle cost of replacing the electrical motors with newer and more efficient electrical motors (to aid in reducing turnaround time after failures).

2.3.3.3.2.5 Safety (PA5)

a) The use of standard operating procedures and documented working instructions form the premise for promoting safe handling practices to protect electrical motors during acquisition, use and disposal phases, and to protect personnel injury or both.

2.3.3.3.2.6 Security (PA6)

a) Electrical motors are in access controlled environments during all the life cycle phases, to ensure that only staff who interact and use the said electrical motor gain access to these secured areas.
b) The electrical motor management program complies with the large steel manufacturer's procedures and policies.

2.3.3.4 Disposal Life-Cycle Phase

In this paragraph, the operation management process areas (PAs) during the disposal life-cycle phase (LCP) will firstly be presented as a whole, followed by the specific conditions (SCs) for each process area. The operation management process areas (PAs) during the disposal life-cycle phase are in accordance with the ASTM (2012) and are as follow:
Reutilisation (PA1); authorisation to dispose (PA2); transport, storage, and handling (PA3); disposal (PA4).

Now that the process areas have been presented the ASTM (2012) will be utilised as the premise for defining the specific conditions (SCs) for each process area.

2.3.3.4.1 Process Management

As presented in paragraph 2.3.3.1

2.3.3.4.2 Operation Management

2.3.3.4.2.1 Reutilisation (PA1)

a) Electrical motors that are in excess are identified,
b) Electrical motors that are in excess are evaluated in terms of electrical motor age to take into consideration the conditional probability of failure to determine usability (taking into consideration the age at which other electrical motors survive, i.e. cut-off age), and
c) Electrical motors that are in usable excess are recorded and reported.

2.3.3.4.2.2 Authorisation to dispose

a) Electrical motor disposals are authorised,
b) Electrical motors that are identified for disposal are recorded and reported in financial books.

2.3.3.4.2.3 Transport, storage and handling

a) Electrical motors are traceable throughout transport, storage, and handling,
b) Electrical motors are packed, transported, stored, and handled in accordance with best practice and OEM recommendations

2.3.3.4.2.4 Disposal

a) Electrical motors are feasibly disposed of,
b) Electrical motors are disposed of in a corporate responsible fashion,
c) Electrical motors are timeously disposed of,
d) Electrical motors that donated are considered as disposed, and
e) Compliance to company policies, laws and regulation are ensured during the disposal of electrical motors.

All the aforementioned aspects presented in paragraph 2.3.3 need to be analysed to gain an understanding of the domain maturity (the domain being electrical motor management at engineering services department at the large steel manufacturer). The maturity level for the domain can be calculated when evaluating the maturity levels for each of the sub-domains/key process areas and the respective specific conditions (SCs) within each of the sub-domains/key process areas.

The levels of maturity for each specific condition can be scored on a scale of zero to five (which aligns with Crosby's maturity grid model (1979)), where the scoring allocation is a direct indication of the maturity score allocation stemming from the following scoring criteria:

- **A score of 0 – Non-existent**

  A score of zero is allocated in instances where the activity has not been conceptualised nor applied.

  Descriptions

  It is usually the where processes haven't been introduced as such no framework exists, duties are unassigned and no task performers are identified.

- **A score of 1 – Basic**

  A score of one is allocated in instances where processes are chaotic, undocumented, and inconsistent, typically the starting point of a process.

Descriptions

It is usually the inception of a process where processes consist of basic framework, duties are assigned and task performers are identified.

- **A score of 2 – Structured**

  A score of two is allocated in instances where processes have been defined and understandable, documented and carry the capability of being repeated.

  Descriptions

  The processes are defined, documented, capable of being repeated, understandable.

- **A score of 3 – Consistent**

  A score of three is allocated for processes that are prescribed and consistently performed at the engineering services department within the large steel manufacturer with consistent results.

  Descriptions

  Established and prescribed, consistently performed, consistent results obtained.

- **A score of 4 – Managed**

  A score of four is allocated in for processes that are systematic, have process performance established, and are predictable.

  Descriptions

  Systematic, calculated, regulated, metrics are applied, objectives are established and continuous improvement established.

- **A score of 5 – Optimising**

  A score of five is allocated in for processes that are embedded at the engineering services department within a large steel manufacturer and are supported through all levels of management.

  Descriptions

Habitual, perpetual, inherent quality, recurrent, culturally embedded, supported throughout all levels of the engineering services department within the large steel manufacturer.

The EMM-maturity evaluation matrix contained in APPENDIX C: EMM-MATURITY EVALUATION MATRIX has been developed in accordance with the preceding paragraphs taking into account the maturity score criteria (maturity levels 0-5) and will be used in Chapter 3 and Chapter 4 as part of the experimental design.

As highlighted earlier in this chapter, it is important to note that EMM is a system of a system (system of systems) and it becomes important to understand the larger system and how the EMM system fits into in the context of the large steel manufacturer.

The large steel manufacturer has already recognised that reliability ensures the best return on investment, as well as less downtime and as a result yielding more sustainable manufacturing. The aforementioned has resulted in the acceptance of Reliability Centred Maintenance (RCM), yet the implementation of this concept on motor systems (the core of any manufacturing plant) has not been implemented. The main reason for not having started the implementation of this program is everyone is scared off by the daunting task and no clear, researched and outlined EMM is currently in place to support this one sub-domain/process area (as defined paragraph 2.3) as part of EMM. EMM forms part of a bigger picture approach, in the form of an equipment management system and in turn the equipment management system forms part of the asset management system (International Organization for Standardization, 2014). As such the author will, on a very high level, present asset management in general and look at asset management and how it is deployed at the large steel manufacturer in paragraph to follow.

2.4 ASSET MANAGEMENT SYSTEMS

2.4.1 INTRODUCTION

Any company needs to realize its objectives, these objectives can only be achieved through the utilisation of assets but ultimately there are factors which influence the type of assets that are utilised and how they managed, the factors as detailed in the asset management standard (International Organization for Standardization, 2014) include the following:

1. the company's purpose and nature;
2. operating framework;

3. constraints on both the regulatory and financial fronts;
4. the company and stakeholder needs and prospects.

The asset management standard further stipulates that the management of assets should extrapolate the company's objectives into asset-related judgements, preparations and executions with a risk-centred approach. Value realisation is recognised to be supplemented through the application of asset management whilst also providing balance to financial, environmental and social costs, risk, quality of service and performance related to assets. Asset management brings about several benefits which include but are not limited to:

- improved financial performance;
- informed asset investment decisions;
- managed risk
- improved services and outputs;
- demonstrated social responsibility;
- demonstrated compliance;
- enhanced reputation;
- improved organizational sustainability and
- improved efficiency and effectiveness.

The author has noted one key observation, the shortcoming where the large steel manufacturer's current asset management system is deployed in such a fashion where assets are being managed individually (per motor, per gearbox, per pump etc.). Instead the large steel manufacturer opted to group the assets by process. This approach goes against the ISO recommended practice of managing assets as a group, these groupings may be asset types, asset systems or asset portfolios. The prudent decision in this case study on EMM would be ability to group assets by equipment type (motors), which will give the added value of redeploying motors of the same characteristics to critical processes which have experienced some unexpected failure. These potential cross collaborations between different plants and processes can improve the sustainability of the company and ensure maximum uptime of critical bottleneck processes. Figure 2.4-1 represents one such interpretation where the different levels are grouped as proposed in the asset management standard. The author also has to point out that the Asset Management System constituents can take on various structures (systems within the system). For example, it is very common to group the asset management structure according to the various plants and the processes

within them. An asset management system that could combine the two preceding groupings (as filters within the software) would be beneficial and a logical approach.

The topic of asset management is a vast field, one which is beyond the scope of this study, but is important to take cognisance of the overarching importance of system integration and that EMM forms part of a larger system in the form equipment management which in turn forms part of an asset management system currently deployed at the large steel manufacturer. As additional information, other systems within asset management include but are not limited to:

> *data management; condition monitoring; risk management; quality management; environmental management; systems and software engineering; life cycle costing; dependability (availability, reliability, maintainability, maintenance support); configuration management; tero-technology; sustainable development; inspection; non-destructive testing; pressure equipment; financial management; value management; shock and vibration; acoustics; qualification and assessment of personnel; project management; property management; facilities management;* ***equipment management****; commissioning process; energy management* (International Organization for Standardization, 2014).

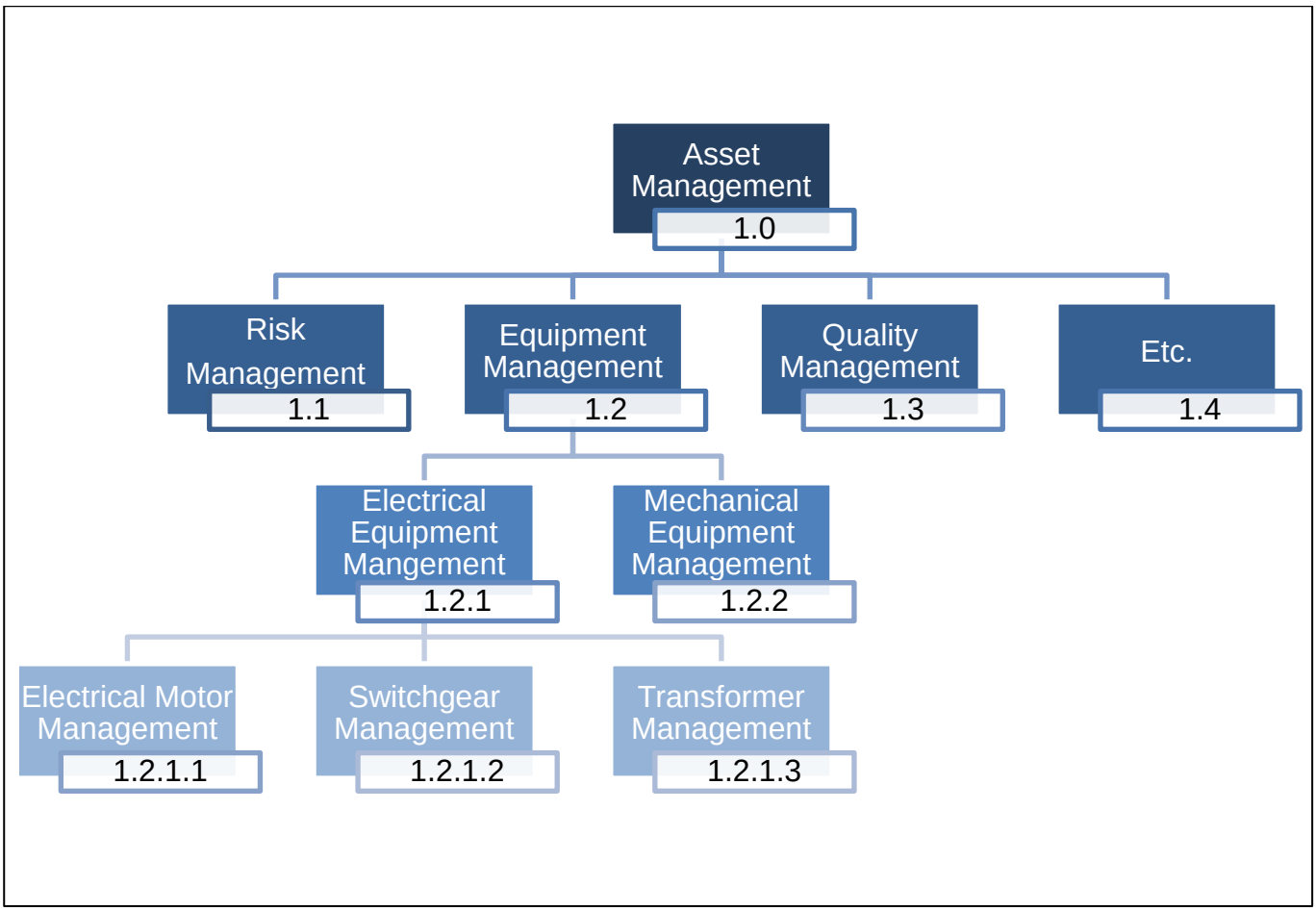


Figure 2.4-1: Asset management and constituent grouping (example)

2.4.2 ASSET MANAGEMENT AT THE LARGE STEEL MANUFACTURER

As mentioned earlier in this dissertation, the topic of asset management is a vast field and beyond the scope of this study. The author has however observed that in addition to the requirements set out in the asset management standard (International Organization for Standardization, 2014), Moubray (1997, pp. 327-334) stated that functional hierarchies and functional block diagrams are key supplementary diagrams to perceive an asset hierarchy fully defined. The functional hierarchies and functional block diagrams are also utilised in defining metrics for performance management and continuous improvement. The functional hierarchies and functional block diagrams are further utilised in the configuration management process to ensure functional parameters are not adversely affected by implementation of configuration requests.

The key observation in terms of the current asset management deployed at the large steel manufacturer is that there exists no functional hierarchies nor functional block diagrams to supplement the existing asset hierarchy.

The asset management policy at the large steel manufacturer aligns with the organisation's current vision, mission, value and legislation framework. The contemporary asset management policy signed off by the large steel manufacturer's Chief Operating Officer (COO) reads as follow (Asset management committee , 2015):

*"**Asset Management Policy Statement***

We manage and control the company's assets and systems in a sustainable, co-ordinated and systematic manner. This includes achieving and sustaining the highest levels of equipment reliability by doing the right maintenance work at the right time at the lowest possible cost with no injuries and minimal impact on the environment.

Strategy

- *We develop and retain a competent, disciplined and motivated workforce*
- *We apply Professional Maintenance on assets*
- *The asset management activities will be consistent with:*
    - *Other organisational policies and legislation;*
    - *The organisation's overall risk management framework.*
- *We communicate to all relevant stakeholders, including contracted service providers, on their obligations to our Asset Management Policy.*
- *We improve asset performance and reduce losses through continuous improvement.*
- *We restore the basic conditions of our assets by means of a Back-to-Basics program*
- *We manage the total life cycle of our assets and reduce the total cost of ownership."*

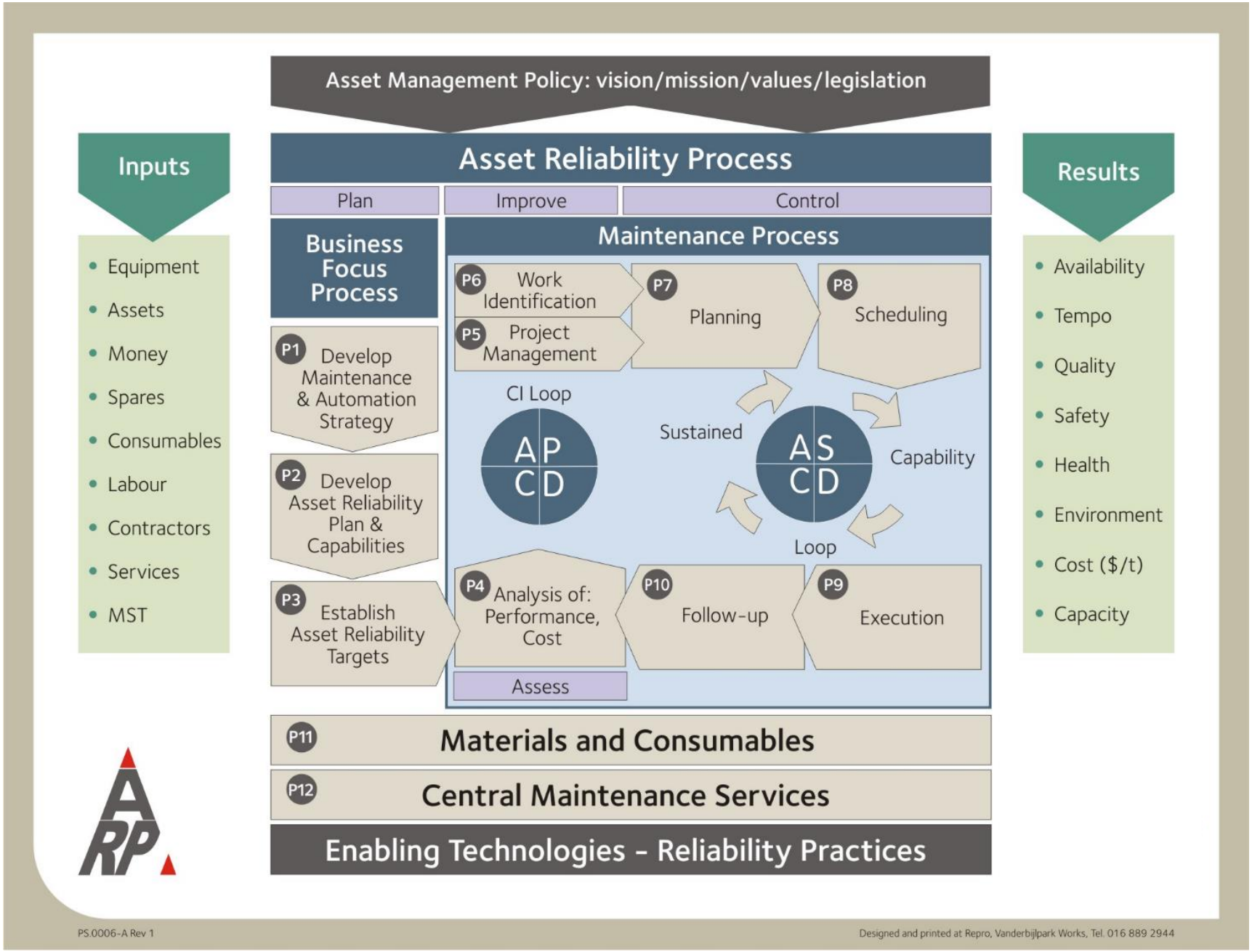


Figure 2.4-2 High-level asset reliability process

Asset Reliability Process Flow Chart

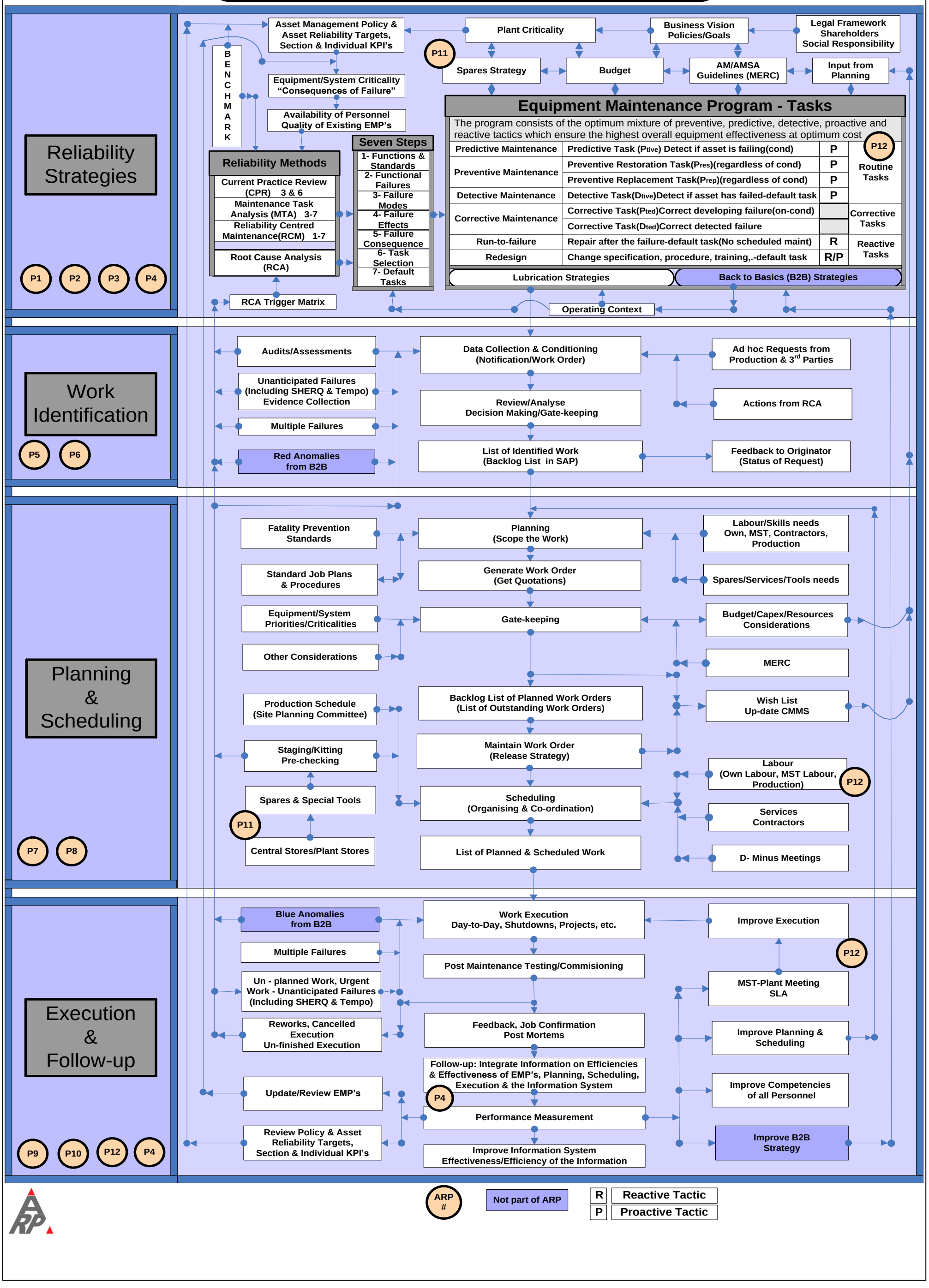


Figure 2.4-3: Detailed asset reliability process

At present, the large steel manufacturer recognises that at the heart of asset management are equipment maintenance programs (EMPs) that have to manage the inherent failure modes of all the organisation's physical assets. The sub-domain/process area for maintenance at the large steel manufacturer is well defined and well managed and is this process is portrayed in Figure 2.4-2 and Figure 2.4-3. The policy statement combined with the approach deployed by the large steel manufacturer (Figure 2.4-2 & Figure 2.4-3) aligns to what is proposed in Figure 2.4-1. Furthermore, the large steel manufacturer recognises that maintenance programs must be developed by identifying the optimum mixture of preventive, predictive, pro-active and reactive approaches, though as elaborated in the preceding paragraphs, maintenance only constitutes one of the key process areas/sub-domains for complete electrical motor management.

The large steel manufacturer needs to shift focus to ensure the entire scope of EMM is deployed/progressed which will ensure the highest equipment effectiveness at optimum cost as this will turn the EMM function into the organisation's competitive advantage in achieving world class competiveness (Consortium for Energy Efficiency (CEE), 2012). Recognising and addressing the aforementioned is prudent in the steel market conditions in the year of 2016/2017 where steel product demands are at declines with all-time lows and in contrast energy costs at an all-time high and continuously on the rise.

2.5 LITERATURE REVIEW OBSERVATIONS

1. The large steel manufacturer's engineering services department staff do not distinguish between life cycle stages, nor do they distinguish between process management and operation management.
2. Electrical motor management (EMM) has to be deployed/improved to follow a natural maturity progression which implies starting at an initial maturity level and progressing towards a higher level maturity (Raber, et al., 2013). If the constituents of EMM do not follow this natural maturity progression and start of at a very high level of maturity the probability for success will diminish as one first has to get the fundamentals in place for each constituent within EMM before progressing at a pace that could increase the existence of confusion and pitfalls.
3. Maturity models define an outline for **planned, typical, logical, and desired evolution directives for moving from an initial maturity level towards a higher level maturity** (Raber, et al., 2013). In maturity models, stages of growth/maturity emerge in a defined sequence, where solving one set of problems consequentially

brings about a new set of problems that require new corrective actions to move forward, evolving towards a new level of maturity (Kazanjian & Drazin, 1989). Success is directly dependant on following the natural maturity level progression to avoid critical pitfalls which would've been solved in the preceding maturity level (Raber, et al., 2013). This observation is evident when analysing the finding by Dr Penrose that a mere 7% of the total motor management programs attempted were successful, though his study did not attribute this to any direct cause. The observation is key as the existing electrical motor approach doesn't provide any guidance for **planned, typical, logical, and desired evolution directives for moving from an initial maturity level towards higher levels of maturity.**

4. The existence of the ASTM E2452-12 standard, combined with the important link to the ISO allows the author to skip through the maturity model development phases which aid the descriptive life-cycle phase for the development of a **descriptive** equipment management maturity model. This in turn implies the maturity model immediately progresses from a **descriptive purpose** to a **prescriptive purpose. Due to the prescriptive nature being established, the EMM-maturity model can be deemed as the "ideal EMM-approach".**
5. The CEE-definition for electrical motor management is vague and only focuses on one aspect within the two levels of equipment management activities i.e. one aspect within process management activities and one activity in operation management in the form of "*on-going policies and procedures*".
6. The Dr Penrose-definition for electrical motor management clearly only considers the hardware aspects once in the use life-cycle phase i.e. focuses on the electrical motor system itself and does not consider process management activities to support the operation management activities.
7. Neither the CEE-definition, nor the Dr Penrose-definition are industry accepted definitions. The closest to industry accepted definitions is the one proposed in this dissertation as it aligns to the industry accepted definition for equipment management. An electrical motor is in fact a specific piece of equipment, but still needs to adhere to the norms of equipment management as presented in the ASTM E2452-12 standard (2012). The ASTM-definition for equipment management is also the most recent industry accepted norm (and academia accepted definition) in terms of date.
8. Dr Penrose does however encapsulate an important observation i.e. motor management does not work in isolation, in order to obtain a more reliable motor one

needs to take into account the **motor system**. This concept has been proven extensively through the Motor Diagnostics and Motor Health Study conducted by O'Hanlon and Penrose (2003).

9. Process management definition (ASTM, 2012) is the recognition that a **systems approach** forms part of management activities in equipment management in in turn forms part of an asset management system. This aligns and supports Dr Penrose's (2005) view that a **systems-approach** is required to holistically manage the motors. The shortcoming in Dr Penrose's (2005) view however, was that he was actually inferring to the hardware pertaining to the motor system. There also exists supporting views that if an entity improves process management it will aid the need toward reducing weaknesses in the EMM and boost the chances of success (Object Management Group, 2008).
10. The author makes a key observation with regards to the EMM constituents presented in Figure 2.3-2, this is that one crucial constituent, configuration management is omitted in the process management activity within each life cycle phase this constituent is engineering change management (ECM) (also known as change management; also known as configuration management).
11. The maturity level for the domain (EMM in the case of this dissertation) can be calculated when evaluating the maturity levels for each of the sub-domains/key process areas and the respective SCs within each of the sub-domains/key process areas.
12. EMM forms part of a bigger picture approach, in the form of an equipment management system and in turn the equipment management system forms part of the asset management system (International Organization for Standardization, 2014).
13. The large steel manufacturer's current asset management system is deployed in such a fashion where assets are being managed individually (per motor, per gearbox, per pump etc.). Instead the large steel manufacturer opted to group the assets by process.
14. The sub-domain/process area for maintenance at the large steel manufacturer is well defined and well managed, though as elaborated in the preceding paragraphs, maintenance only constitutes one of the key process areas/sub-domains for complete electrical motor management.
15. The key observation in terms of the current asset management deployed at the large steel manufacturer is that there exists no functional hierarchies nor functional block

diagrams to supplement the existing asset hierarchy. The functional hierarchies and functional block diagrams are utilised in defining metrics for performance management and continuous improvement. The functional hierarchies and functional block diagrams are further utilised in the configuration management process to ensure functional parameters are not adversely affected by implementation of configuration requests.

2.6 CHAPTER SUMMARY

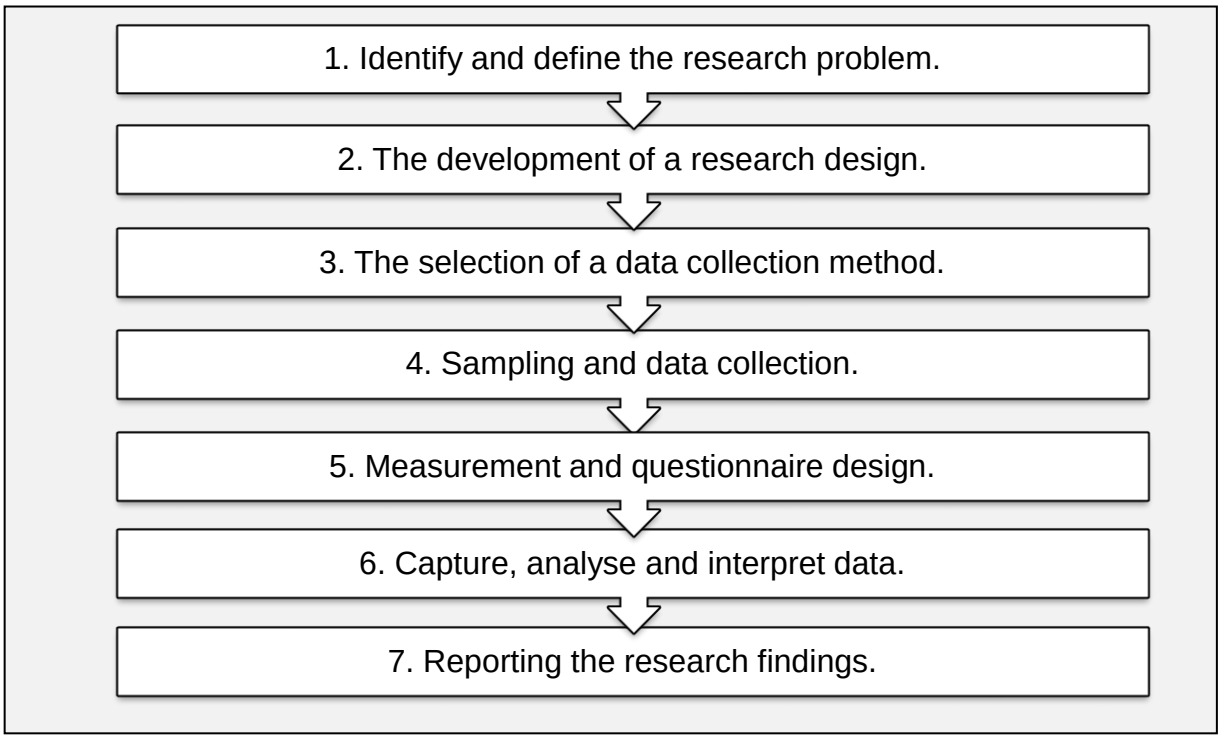
This chapter presented a short descriptive background of the engineering services department within the large steel manufacturer, followed by review of generic maturity models. This provided the necessary insight to how management plans should be analysed by means of maturity models. Literature and industry experts were consulted to determine requirements for electrical motor management, this information was utilised to define the domain for the maturity model and sub-domain components. This was followed by a high level overview of asset management to provide a background and understanding that the EMM-system forms part an equipment management system, which in turn forms part of an asset management system. The chapter was concluded by looking at asset management deployed at the large steel manufacturer.

3 EXPERIMENTAL DESIGN

3.1 INTRODUCTION

For any given study a series of steps or phases have to be followed which is known as the research process (Tustin, 2005:75). The actual steps within the research process vary as different authors include different steps but the actual concept of the research process can be identified when all the different processes are investigated. As for this current study the research process that will be followed is derived from Mostert (2011) and the following steps as illustrated in Figure 3.1-1 are followed during the research concerning this study.

Figure 3.1-1: Steps in the research process



Source: Adapted from Mostert (2011).

As the steps during the research process of this study are clearly illustrated in the above Figure 3.1-1, the research methodology will be discussed next.

3.2 DETERMINE THE RESEARCH DESIGN

The master plan of a research design identifies and specifies procedures and methods for research that need to be followed to collect and analyse required information (Tustin, 2005:82). Tustin (2005:90) further states that there is no standard research design as every research design is unique in terms of the intended purpose, information requisition method and the precision of the hypothesis formed.

When selecting a research design, a choice between qualitative and quantitative research should be made (Ling & Bouma, 2004:9). Three broad research design type categories can be distinguished when referring to research designs and can be identified as *exploratory research, descriptive research and causal research* (Tustin, 2005:83; Fouché & De Vos, 2007:106).

Exploratory research is conducted when insights into the broad nature of the problem is required (Tustin, 2005:84) and the researcher's main objective is to develop initial ideas that have not yet been studied (Struwig & Stead, 2001:7) as there is little prior knowledge for the researcher to build on (Tustin, 2005:84). The need to conduct such research arises when there is a lack of basic information on a new area of interest and the frequent use of qualitative data is implemented by researchers (Fouché & De Vos, 2007:106). Exploratory research requires the gathering of information of a small sample of the population (Struwig & Stead, 2001:7) and implements techniques that are unstructured and qualitative such as focus groups, panels and observations that can be seen as individual and group unstructured interviews (Tustin, 2005:84).

Descriptive research is a type of research where an *underlying relationship of the problem area is already familiar* (Tustin, 2005:86). Who, what, when, where and how questions are questions that need to be answered when constructing descriptive research (Tustin, 2005:86). When conducting descriptive research the researcher might be interested to obtain an accurate representation of a certain situation (Cooper, 2010:32). The research designs used within this particular research design are structured and have a quantitative nature (Tustin, 2005:86). Tustin (2005:83,86) further states that the typical descriptive approaches of this research method are quantitative of nature and consists of personal interviews, telephone interviews, intercept surveys, mail surveys and panels and online quantitative surveys such as web-based surveys, e-mail surveys and online panels. According to Struwig and Stead (2001:8) *descriptive research strives to provide an accurate description of a particular situation and can thus be seen as a research data collection method with little flexibility* and contrasts with exploratory research which has a flexible nature. Although the underlying relationship of the research problem is known certain descriptive questions exist which may be doubtful and risky (Tustin, 2005:87).

The third research design under discussion is causal research which is described by Tustin (2005:87) as *the investigation of the actual impact one variable has on the value of another*

variable. Causal research can also be defined as experimental research and there are various experimental research designs available but the choice of a specific experimental research design depends on the research problem that is under discussion and the span of control the researcher wish to have over the variables (Struwig & Stead, 2001:9). One of these causal research methods as stated by Struwig and Stead (2001:9) is the pre-test-post-test control group design and is one of the most commonly used methods where two randomly chosen groups, an experimental group and a control group are used where both group's conditions are tested before any treatment. A treatment condition or programme is implemented on the experimental group and re-tested after the treatment whilst the control group does not receive any treatment (Struwig & Stead, 2001:9). According to Tustin (2005:87) exploratory techniques are used to determine all the possible causes of a problem and then a combination of causal and descriptive approaches are implemented to narrow down all the possible causes. The realisation of the research objectives can be gained when an appropriate research design is chosen (Tustin, 2005:82).

Initially the researcher had to deploy exploratory research of a quantitative nature by means of conducting surveys and follow up discussions to confirm the primary research objective i.e. how existing EMM within the engineering services department at the large steel manufacturer compares with EMM proposed in literature. This will also provide confirmation of the perceived need for developing/improving EMM-practices at the engineering services department within the large steel manufacturer.

The researcher then deployed descriptive research of a qualitative nature to address the study's secondary objective:

a. Deploy a researched EMM maturity model (prescriptive EMM maturity model) for the engineering services department within the large steel manufacturer as means for identifying levels of maturity for practices relating to EMM serving as a tool for continuous tracking and improvement.

3.3 DESIGN THE DATA COLLECTION METHODS

3.3.1 DATA COLLECTION METHODS

To address certain research goals the researcher should collect research data by implementing a whole range of data collection methods (Stewart, 2005:116). Every research study is inherently unique, as such each research study should deploy an adequate data collection method (Stewart, 2005). Data can be obtained via numerous techniques, but mainly the various data sources can be categorised into two groups, primary data sources and secondary data sources Tustin (2005).

3.3.1.1 Primary data collection

When data concerning the core of the research goal is collected, primary data collection is conducted (Tustin, 2005:89). When secondary data sources are inadequate to meet the research goals and objectives, primary data collection methods are deployed. Primary data collection methods according to McNeil et. al (2005) include:

- conducting surveys,
- conducting interviews, and
- making observations.

When conducting primary data collection the researcher must select the most suitable research method. The research method could be classified as either quantitative or qualitative research and furthermore needs to be complimented by an applicable primary data collection method (Tustin, 2005:89).

3.3.1.2 Secondary data collection

Secondary data can be described as data that already exists which were previously collected for another research problem or purpose and can also be used for the problem at hand (Tustin, 2005:88; Peter & Donnelly, 2001:35). *Secondary data can be categorised in three broad sections* namely raw data that is previously collected such as traffic counts, secondly existing summaries of numbers such as figures supplied by Statistics South Africa and *lastly written dissertations such as books and articles that can all be used as sources for secondary data collection* (Struwig & Stead, 2001:80).

This study will make use of primary and secondary data as a great deal of secondary research concerning EMM has already been done and was utilised in Chapter 2 to gain necessary background information for this particular study. Primary data collection will also

be used as the study aims to gain credible data concerning EMM for a very specific population in the form of the engineering services department within a large steel manufacturer. The primary data will be utilised to form deductions and interpretations regarding EMM at the engineering services department within a large steel manufacturer.

3.3.1.2.1 Primary data collection

Primary data collection can be grouped in three categories namely *quantitative research, qualitative research and pluralistic or triangulated research*.

According to Tustin (2005:90) a qualitative research approach will be used when primary motivations are explored and expressed as personal value judgements which lead to the difficulty to draw a general collective conclusion. This statement can be substantiated by Denscombe (2003:267) which states that common fundamentals within the qualitative research approach indicate the concern with the meaning of and the way respondents understands things as well as the concern about certain patterns of behaviour. Denscombe (2003) further states that data obtained from qualitative research only becomes actual data after the process of interpretation by researchers and thus it can be concluded that the researcher has a significant role when conducting qualitative research as they play an important part in the actual production and interpretation of the qualitative data (Denscombe, 2003:268). The identity, values and believes of the researcher cannot be eradicated from the process (Denscombe, 2003:268). Some disadvantages of a qualitative research methodology are that generalization of the results obtained through the detailed in-depth study to other similar cases are difficult and that the researcher's own identity, background and beliefs have an impact on the creation of the data (Denscombe, 2003:281). During the process of categorizing field notes, text or transcripts the meaning of words may be decontextualized and taken out of context (Denscombe, 2003:281).

Quantitative research as described by Tustin (2005:89), constitutes of gaining primary data from ideally the full population, but this sometimes can prove not to be a feasible option due to time, resource and financial limitations. In these instances primary data can be obtained from a representative sample of the population to draw conclusions about the entire/wider population. Bouma and Ling (2004) states that primary data obtained via quantitative research needs to be processed by the researcher and expressed mathematically by means of numbers, rates and/or percentages. Research findings can be expressed in graphs and tables and can thus be seen as a solid and objective way of research and earns scientific

credibility (Denscombe, 2003:237). Representative data of a population as well as future event forecasts can be obtained as quantitative research results are subjected mathematically and statistically manipulated (Tustin, 2005:89). Disadvantages concerning a quantitative research methodology would be that the quality data is directly dependent on the quality of the research method and large quantities of data may overwhelm the researcher and lastly quantitative research may not be as scientifically objective as it might seem (Denscombe, 2003:265).

Methodological triangulation is a multi-method view where the qualitative and quantitative research methodologies are combined. Values within the phenomenon can be more accurately pinpointed as different methodological viewpoints are combined (Brewer & Hunter, 2006:5). Tustin (2005:91) further states that less structured in-depth interviews provide a better understanding of the results obtained by numerical data. One of the significant advantages obtained by methodological triangulation is that the possibility exists that detailed qualitative descriptions can be converted to quantitative scales for the use of statistical descriptions (Tustin, 2005:92).

In this study methodological triangulation will be implemented in the research design. This choice of integration of these two research methodologies was made when referring to the disadvantages of each methodology. By combining the two research methodologies the maximum strengths can be gained and the weaknesses of both methodologies can be overcome (Tustin, 2005:91).

- Qualitative research has the advantage of depicting reality in a simplistic sense, richness and detail and can be obtained within the data and the possibility of alternative explanations exist (Denscombe, 2003:280). Qualitative data is also used to obtain a better understanding of an existing theory or to better understand a new theory.
- Quantitative research has a scientific respectability, lends credibility to the research, findings are based on measured quantities and data can be presented in an effective way (Denscombe, 2003:264).

When researching aspects pertaining to EMM, methodological triangulation is a favourable research design as the interviews conducted may provide a greater understanding of numerical data obtained through quantitative research (Tustin, 2005:91).

3.3.2 QUANTITATIVE RESEARCH

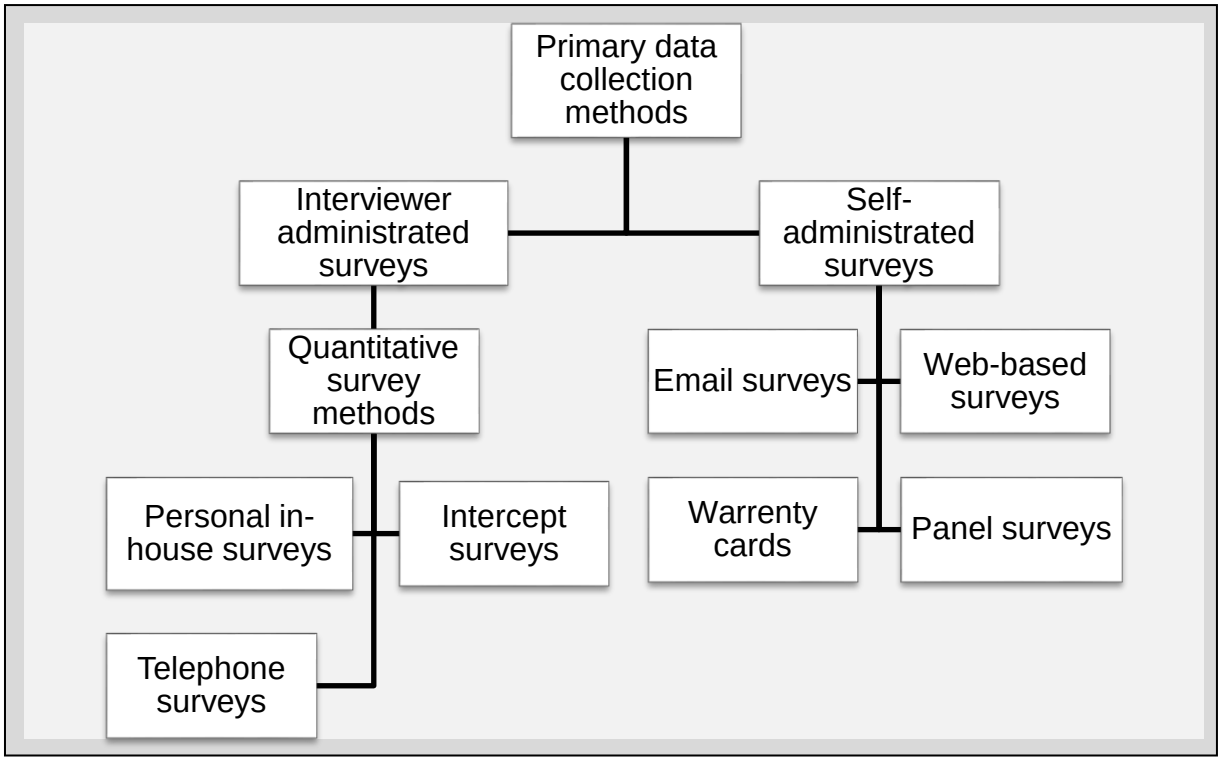
Quantitative research designs or data collection methods include surveys, observations and experiments (Fouché & De Vos, 2007:133; Martins, 2005:143). As with this combined-method study a variety of approaches within certain methods can be implemented, different quantitative data collection methods such as surveys and observations can be used or a combination between methods can be used by implementing qualitative and quantitative data collection methods such as surveys and in-depth interviews (De Vos, 2007:357). Quantitative data collection methods are highly formalised and can be openly controlled (De Vos, 2007:357).

According to Martins (2005:142) primary research data can be collected by implementing a paper-pencil interview (PAPI) or a self-administrated questionnaire (SAQ). According to Gray (2004:99) surveys entail the systematic collection of data in the form of an interview, questionnaire or observation method that reports standardised data. Gray (2004:100) further states that surveys can be divided into two categories namely *descriptive and analytical surveys*. A *descriptive survey is done to determine attitudes, values and opinions and thus describes people's perceptions whilst analytical surveys test a theory in the field of study and explores the associations between variables* (Gray, 2004:102). In this study, combinations of descriptive- and analytical surveys are applicable. The aspects researched are:

- attitudes, values and experiences of employees responsible for electrical motor management (EMM) at the engineering services department (ESD) within a large steel manufacturer (descriptive);
- providing prescriptive means on advancing the EMM maturity levels of the engineering serves department at the large steel manufacturer (analytical to identify shortcomings/advances).

Surveys can be executed in two ways firstly as an interviewer administrated survey which means that the interviewer controls the questionnaire themselves and secondly a self-administrated survey can be done where the respondent completes the questionnaire themselves (Martins, 2005:143). In this study respondents will be required to provide the applicable information to the interviewer whilst the interviewer implements an interviewer administrated survey. Figure 3.3-1 illustrates the difference between interviewer administrated surveys and self-administrated surveys.

Figure 3.3-1: Surveys as a primary data collection method



Source: Adapted from Martins (2005:144) and Ligthelm (2005:185).

There are three quantitative survey data collection methods, which can be classified as interviewer administrative surveys namely, personal in-house surveys, intercept surveys and telephone surveys (Martins, 2005:144).

According to Martins (2005:144) personal in-house surveys, intercept surveys and telephone surveys form part of quantitative survey methods. Personal in-house surveys entail the conducting of an interview with a specific resident (in-house personal household survey) or employee (in-house personal business research) at a selected address with a paper-based questionnaire (Martins, 2005:145). This data collection method is a very costly research method and an increased difficulty to gain access to residents threatens the reliability of this data collection method (Martins, 2005:145). An advantage of this type of survey would be the face-to-face contact between the interviewer and respondent which gives the interviewer the ability to demonstrate products and observe the response first hand (Martins, 2005:147). Collection of quantitative data was achieved by means of conducting surveys and specifically personal in-house surveys will be used as the quantitative survey data collection method in this study as the research population/stakeholders that deal with electrical motor management activities are readily identified and it was deemed feasible to

study the entire population for this study. Filter questions will still be utilised and will be aspect will covered later in this chapter.

Intercept surveys are the second survey quantitative data collection method. Intercept surveys, also known as shopping centre surveys or mall intercepts are very useful as shoppers are recruited within shopping malls, but it should be noted that intercept surveys do not only take place in shopping malls, but can increasingly be found at other locations such as at the workplace depending on what population is being studied (Martins, 2005:152). This survey method has many advantages as a certain extend of control can be implemented by the interviewer as filter questions can be asked to qualify a certain respondent to be further interviewed (Martins, 2005:152). These questions can also be described as screening questions to make sure that an applicable respondent is used within the study as only responses that match the desired respondent profile can participate in the rest of the survey (Martins, 2005:152). Intercept surveys will not be used within this study as the research population/stakeholders that deal with electrical motor management activities are readily identified and it is feasible to study the entire population of this study.

Telephone surveys can be divided into landline telephone interviewing and cell phone interviewing (Martins, 2005:155). Telephone surveys are not as effective as products cannot be demonstrated; the interview must be short which effects the quality of information gained and questions that require elaborate answers are limited by telephone interviews (Martins, 2005:156). A significant dependability on the interviewer's voice poses a great challenge to telephone surveys and poor sample control is a drawback of this data collection method (Martins, 2005:157). An advantage of telephone surveys would be the moderate costs as it is cheaper and quicker than face-to-face interviews (Denscombe, 2003:9; Martins, 2005:158).

According to Ligthelm (2005:184) a researcher should evaluate all internal and external secondary data and determine whether the information is satisfactory enough to solve the particular research problem, if the secondary information is not sufficient a primary research method should be chosen. One of the methods of primary research are self-administrated surveys which are questionnaires that are completed by a respondent without a personal interview as the questionnaire is quite structured and is sent to respondents via regular mail or web-based mail (Ligthelm, 2005:185). As a combined methodological approach is used within this study, self-administrative surveys will be implemented (Ligthelm, 2005:185)

where the survey will be distributed via email for respondents who have limited time available during normal working hours. As such it affords the respondents to fill out the survey at their own time and leisure and send it back to the researcher for processing.

A regular mail/email survey is described by Ligthelm (2005:186) as a structured paper/electronic questionnaire that is sent to a group of respondents to complete in their own time which is then returned to the research unit. The interviewer is not present which means that the questionnaire must be easy to understand by all respondents (Ligthelm, 2005:186). It is of great importance that the survey looks easy as a better response rate will then be gained and surveys with open-ended responses decreases the cooperation rate of respondents dramatically (Ligthelm, 2005:189). Within this study, closed-ended questions will be used that are easily understood by respondents.

Response rates of self-administrated surveys are very low and incentives as well as multiple pre- and post-mailings can increase the response rate (Ligthelm, 2005:193). Factors that can be implemented to increase the response as stated by Ligthelm (2005:193) are monetary incentives, premiums such as pencils and key chains, follow-up postcards or telephone calls, stamped return envelopes, prizes and contributions to charities. The researcher has set a deadline for the self-administered surveys to drive the turn-around times in responses.

Furthermore, accuracy of data obtained by self-administrated surveys are low as reporting errors occur and the questionnaires may be completed by the wrong respondents (Ligthelm, 2005:195). Another significant problem would be that the actual mailing list could be outdated and not completed which can lead to undelivered questionnaires or the delivering of questionnaires to the wrong respondents (Ligthelm, 2005:195). This study will not be exposed to the factors described by Lighthelm (2005:195) as the emailing list is directed to employees in the engineering services department in a large steel manufacturer who has direct contact with the researcher where all respondents need to verbally confirm receipt of the emailed survey.

Although the accuracy of the data obtained by self-administrated surveys are low, many other advantages of regular email surveys do exist. The cost of email surveys are relatively low and regular email surveys is a great way to obtain information about sensitive or embarrassing topics (Ligthelm, 2005:197). A greater geographical area can be covered and

effective processing of the data can be done (Ligthelm, 2005:197). Self-administrated surveys will be implemented as questioning the status quo can in some cases be seen as a sensitive matter and by completing the self-administrative survey more in-depth and quality data can be obtained for the current research.

Other self-administrated surveys such as warranty cards, panel surveys and consumer panels can also be conducted, but will not be used in this study. According to Brewer and Hunter (2006:31) survey research can be used to generalize to the population as survey data has a greater range of applicability.

Observation as described by Ligthelm (2005:265) is the gathering of information about the environment by taking notes of the events. Observation as a primary data collection method has many methods which will be discussed shortly. Natural or contrived setting observation focuses on the observation of a subject in their daily or usual surroundings, disguised or undisguised observation focuses on the extent to what respondents are aware that they are being observed, unstructured or structured observation can be described as the respondent's knowledge of what situation will be observed and under which criteria the observation will take place, human or mechanical observation are used when it is inappropriate for a person to do the observation, direct or indirect observation where direct observation is the most used type of observation and the situation is observed as it occurs while a particular type of behaviour is displayed whereas indirect observation observes the results of a certain behaviour rather than focusing on the behaviour alone (Ligthelm, 2005:269). According to Brewer and Hunter (2006:31) the observations of natural sequences of events can in some cases be seen as an introduction to the use of experimental techniques. Observation as a quantitative data collection method will not be used in this study as the needed information will not be gained.

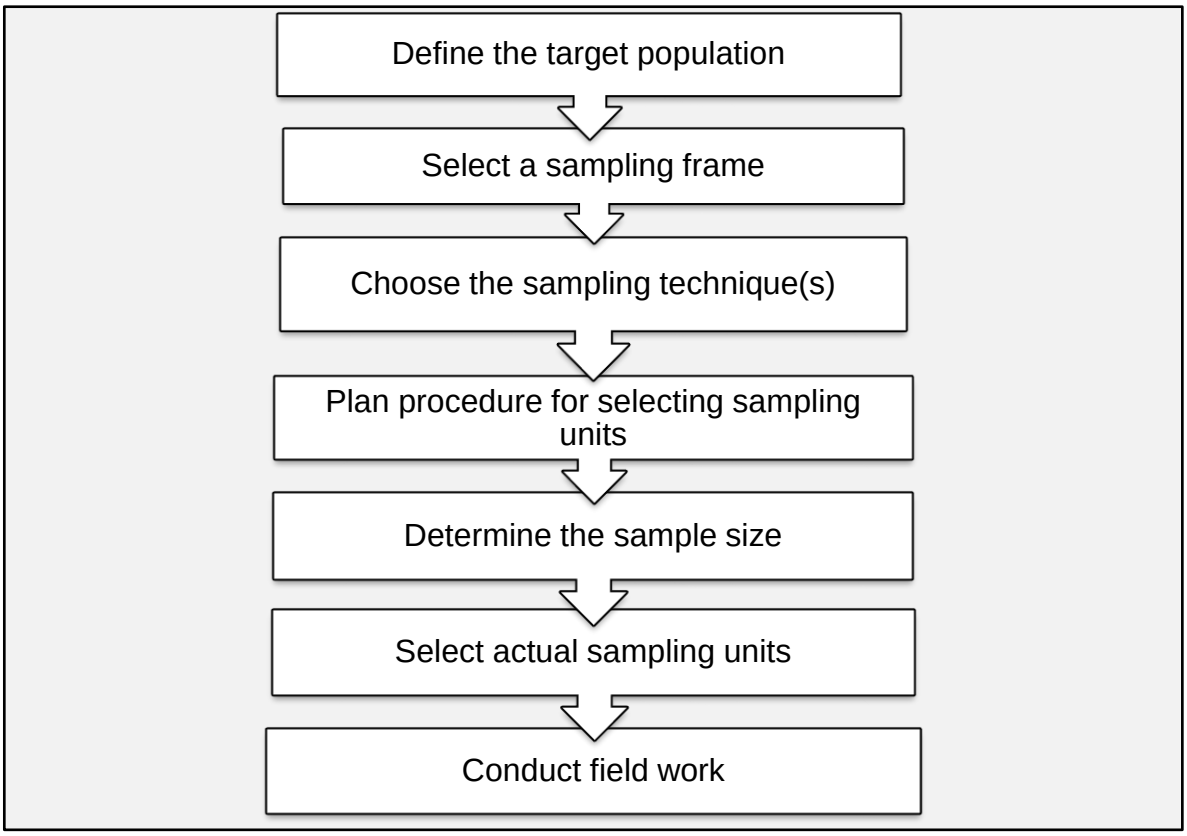
Experiments as a primary quantitative data collection method deliver a clear causal presumption (Brewer & Hunter, 2006:31). Experimental methods collect primary information or data to test the cause-and-effect of relationships (Martins, 2005:290). According to Ling and Bouma (2004:103) experimental designs' main objective is to determine the effect one variable has on anther variable. Experiments will not form part of this study, but it will be used to track the improvement of reliability of electrical motors within the large steel manufacturer after an EMM has been implemented/improved. This will be achieved by means of conducting the first iteration for an EMM-maturity analysis, where the base score

can be recorded for the domain-maturity. A follow-up EMM-maturity analysis can then be deployed (not part of this study) to track positive/negative changes in each respective key process areas (as described in chapter 2.3) and the positive/negative changes can be directly related to a casual deductions i.e. improvements/declines in EMM-maturity scores.

3.3.3 DATA SAMPLING

This section consists of sampling and data collection decisions, which is step 4 in the research process. Researchers have to make several decisions before selecting a sample (Zikmund, Babin, Carr and Griffin, 2010:390). Figure 3.3-2 illustrates decisions as a series of sequential stages, which the researchers are likely to go through when conducting sampling. The order of precedence does not necessarily follow the sequence as presented in Figure 3.3-2 (Zikmund *et* al., 2010:390; Wilson, 2010:189).

Figure 3.3-2: Stages in the selection of a sample



Source: Adapted from Zikmund *et al*. (2010:391) and Wilson (2010:190).

The first step in the sampling process concerns the identification of the target population (Zikmund *et* al., 2010:390; Wilson, 2010:189) as illustrated in Figure 3.3-2 that will be discussed below.

3.3.4 POPULATION

During the collection of representative data some terms have to be understood in order to fully comprehend the process as illustrated in Figure 3.3-2 (Dane, 2011:106; Sekaran, 2006:265). In research, an analysis has to be conducted on gathered data to come to generalisations, new knowledge, conclusions and ultimately to gain insight on how the topic under consideration can be addressed, mitigated or improved (Gomm, 2008:20; Zikmund *et al.*, 2010:5,9). The gathered data can be divided into different sets and subsets, these sets and subsets make use of terminology such as population, elements, sample frame, samples and subjects (Dane, 2011:61; Sekaran, 2006:265; Wilson, 2010:189). Each of these terms will be thoroughly explained in the remaining paragraphs. The population comprises of single members called elements and a grouping of these single members form the population frame (Bayat & Fox, 2007:52; Sekaran, 2006:265). A sample is a subset of the population and must be selected from a sampling frame, where a sample comprises of only some elements of the population. In other words, a section, not the entire population forms a sample (Sekaran, 2006:266). The sampling frame refers to a list of the accessible population from which the researcher is able to draw a sample (Bayat & Fox, 2007:52; Dane, 2011:107; Gray, 2004:83; Wilson, 2010:307; Sekaran, 2006:266). The members within the sample under consideration are referred to as the subjects of a sample (Sekaran, 2006:266).

The population is any case or group of units (people, stores, university students etc.) that share a specified mutual set of characteristics upon which inferences want to be made (Dane, 2011:106; Henn, Weinstein & Foard, 2009:153; Given, 2008:644; Marczyk, De Matteo & Festinger, 2005:18; Buckingham & Saunders, 2004:52).

Defining the target population is one of the primary steps in the sampling process (Wilson, 2010:189; Zikmund *et al.*, 2010:69). As previously stated the population under consideration is a clearly defined group of research subjects which is being sampled. Defining the target population is not always straight forward and it largely depends on the developed research questions as well as the context being studied (Wilson, 2010:189; Marczyk *et al.,* 2005:82). The sampling frame can in some instances be larger than the actual population itself (Gray, 2004:84). By defining an eligibility criteria, it can be determined whether a given data source/ element can be included in the total population, technically this is also known as defining the sampling frame (Given, 2008:644). By properly defining the target population, the correct and relevant sources can easily be identified, these sources can then in turn be used to collect data (Zikmund *et al.*, 2010:390).

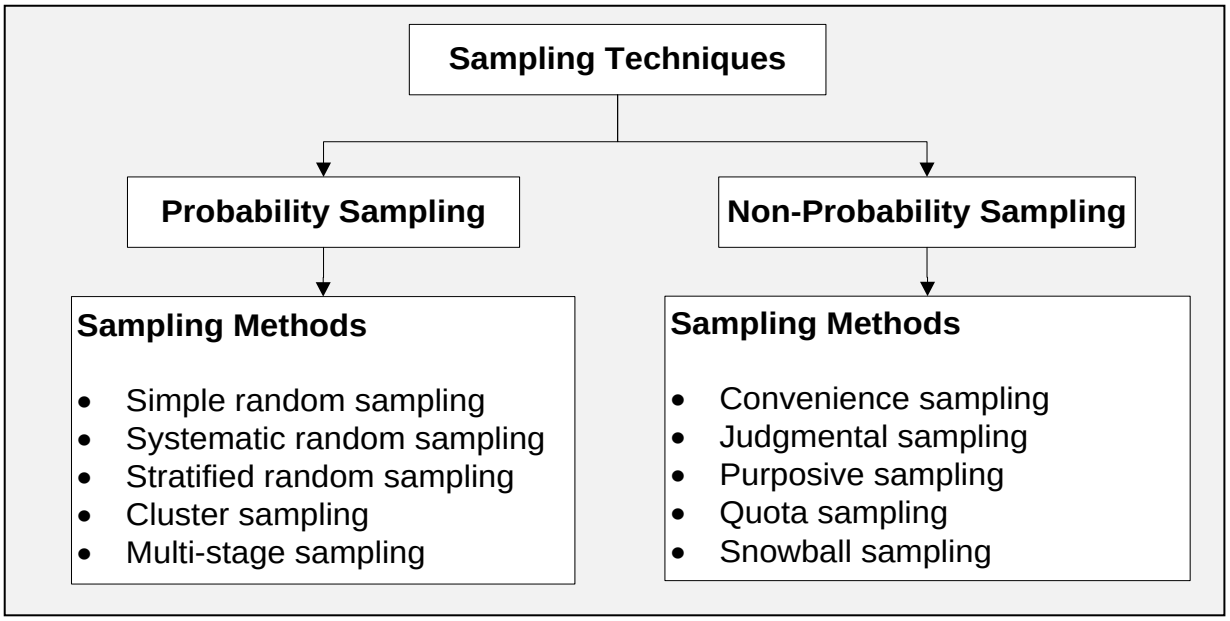
The population under consideration in this research study shall not be contained to demographic qualifiers, but shall be all stakeholders involved in both the process management and operation management activities relating to electrical motor management at the engineering services department within a large steel manufacturer as described in Chapter 2.

After the target population has been chosen the next step consists of selecting the sampling frame (Wilson, 2010:191; Zikmund *et al.*, 2010:391), the sample frame must be representative of the population (Wilson, 2010:191). Sampling can be used to make deductions about the population, but this depends on the choice of sampling technique, which is the third stage of the sampling process (Wilson, 2010:191), that will be discussed next.

3.3.5 SAMPLING TECHNIQUES

There are two types of sampling techniques namely probability/ random sampling and non-probability/ non-random sampling (Wilson, 2010:193; Sekaran, 2006:269) as illustrated in Figure 3.3-3. Sampling is a process of selecting a number of elements from the population (Bayat & Fox, 2007:54; Dane, 2011:106; Sekaran, 2006:266; Cooper & Schindler, 2003:179) so that characteristics of the drawn sample would make it possible to generalise such characteristics to the population elements (Sekaran, 2006:267; Cooper & Schindler, 2003:179). A sample is any subset of elements extracted from the population which is relevant to the purpose being studied (Dane, 2011:107; Zikmund *et al.,* 2010:387; Bayat & Fox, 2007:54; Sekaran, 2006:266; Gray, 2004:83). Samples are drawn when the researcher is forced to limit their research to a certain part of the population, as it is almost impossible in certain situations to obtain information from the entire population (Bayat & Fox, 2007:54). The different sampling techniques as mentioned before are illustrated in Figure 3.3-3 and will be discussed below.

Figure 3.3-3: Sampling techniques



Source: Adapted from Wilson (2010:194) and Bradley (2007:173).

The researcher needs to decide on their broad sampling techniques before a specific type(s) of sampling technique(s) is chosen because more than one sampling method can be decided to be adopted in some cases (Wilson, 2010:194). Figure 3.3-3 shows the two sampling techniques with the respective sampling methods, which will be discussed below.

3.3.5.1 Probability sampling

Any technique that ensures a random sample is known as probability sampling (Dane, 2011:116; Mullins & Walker, 2010:174). Probability sampling can be described as a technique that ensures that each element in the population or sampling frame has an equal chance of being included in the sample (Dane, 2011:116; Wilson, 2010:194; Bayat & Fox, 2007:54; Sekaran, 2006:269; Henn *et al.*, 2009:154; Zikmund *et al*., 2010:395; Gomm, 2008:134; Schiffman & Kanuk, 2009:36). Probability sampling is also known to have a nonzero chance to be included in the sample (Schiffman & Kanuk, 2009:36; Bayat & Fox, 2007:54; Zikmund *et al.,* 2010:395; Cooper & Schindler, 2003:184).

Random sampling can be undertaken by first drawing a sample frame and then use a random number generation computer program to pick a sample from the sampling frame (Dane, 2011:116; Wilson, 2010:194). Probability sampling techniques delivers valid estimates of the population parameters and valid deductions can be concluded about the population (Bayat & Fox, 2007:55). When a random sample is drawn, the amount of sampling error in a sample can be calculated by means of the central limit theorem and

properties of normal distribution (Dane, 2011:116). There are various probability sampling methods which will be conveyed below.

3.3.5.1.1 Simple random sampling

When an unsystematic random selection process takes place it is called a simple random sampling method (Dane, 2011:116; Blaxter, Hughes and Tight, 2006:163). A simple random sampling technique involves identifying every element in the sampling frame and choosing among them on the basis of a planned process that ensures that every element has an equal chance of being included in the sample (Dane, 2011:116; Wilson, 2010:194; Bayat & Fox, 2007:55; Zikmund *et al*., 2010:398, Henn *et al.*, 2009:154). A table of random numbers or a computer program can be used to choose the units of analysis and ensure that every number has an equal chance to be selected (Bayat & Fox, 2007:55; Dane, 2011:116; Henn *et al*., 2009:154; Zikmund *et al*., 2010:398).

3.3.5.1.2 Systematic random sampling

Due to the simplicity of systematic random sampling this method is often used (Bayat & Fox, 2007:56). In the sampling frame all the units of analysis must be identified and consecutive numbers should be given to each unit (Bayat & Fox, 2007:55; Henn *et al*., 2009:154). After numbering all the units in the sampling frame of analysis an initial sample subject is chosen at random from the sampling frame. This random initial sample subject must be between the 1^{st} and the n^{th} elements of the sampling frame (Dane, 2011:117; Wilson, 2010:195; Bayat & Fox, 2007:56; Sekaran, 2006:271; Cooper & Schindler, 2003:192; Zikmund *et al*., 2010:399). The next (second) sample subject from the frame is obtained by using the pre-defined sampling interval of size k, and by moving k units from the first randomly chosen sample subject, the second sample subject for analysis can be obtained (Zikmund *et al*., 2010:399).

3.3.5.1.3 Stratified random sampling

When there are variations within a population the stratified sampling method is often used (Wilson, 2010:195). Stratified sampling is where the population is divided into subgroups where the subgroups are more or less homogeneous relevant to the phenomenon being studied (Dane, 2011:118; Wilson, 2010:195; Bayat & Fox, 2007:55; Henn *et al.*, 2009:155; Sekaran, 2006:272; Gray, 2004:87; Cooper & Schindler, 2003:193; Zikmund *et al*., 2010:400). A random sample is then selected separately for each subgroup in the sampling

frame (Dane, 2011:118; Wilson, 2010:195; Bayat & Fox, 2007:55; Sekaran, 2006:272; Cooper & Schindler, 2003:193; Zikmund *et al*., 2010:400; Henn *et al.*, 2009:157).

3.3.5.1.4 Cluster sampling

Cluster sampling is mostly used when sample frame lists are unavailable (Dane, 2011:118; Strydom, 2005:200; Gray, 2004:87; Zikmund *et al*., 2010:401). When a list of names is not available, but only a geographical area map that is relevant to the study the researcher makes use of cluster sampling (Strydom, 2005:200). Cluster sampling is where the whole population is divided into a number of groups or clusters (Dane, 2011:118; Wilson, 2010:196; Bayat & Fox, 2007:57; Cooper & Schindler, 2003:196; Zikmund *et al*., 2010:401). The entire sampling frame, groups or clusters are listed and a random sample is drawn, where all of the units drawn from the sample frame, group or cluster will be used in the final sample (Dane, 2011:118; Wilson, 2010:196; Bayat & Fox, 2007:57; Cooper & Schindler, 2003:196; Zikmund *et al*., 2010:401).

3.3.5.1.5 Multi-stage sampling

The process of moving from a broad to a narrow sample by using a step-by-step process is known as multi-stage sampling (Wilson, 2010:197). It is not uncommon to combine sampling procedures and it is acceptable to combine any two or more probability sampling procedures (Zikmund *et al*., 2010:402; Dane, 2011:121; Cooper & Schindler, 2003:198; Sekaran, 2006:275) but is not acceptable to combine probability sampling with non-probability sampling (Dane, 2011:121).

3.3.5.2 Non-probability sampling

Non-probability sampling is the probability of each case to be selected from the population in which the elements have an unknown chance of being included in the sample (Dane, 2011:121; Wilson, 2010:198; Bayat & Fox, 2007:58; Henn *et al.*, 2009:156; Sekaran, 2006:276; Cooper & Schindler, 2003:200; Zikmund *et al*., 2010:395). The researcher limits the chance of the elements to be selected for the study as the elements or individuals from the population (Dane, 2011:121). These elements are chosen based on personal judgement (Bradley, 2007:175). It is not possible to make conclusions about the wider population as samples are not drawn randomly and one cannot estimate sampling error when non-probability sampling is obtained (Dane, 2011:121; Wilson, 2010: 198). When the researcher lacks a sampling frame for the population in question, or where there is judged that a

probabilistic approach is not necessary, non-probability sampling is used (Blaxter *et al.*, 2006:163). The non-probability sampling methods will be conveyed below.

3.3.5.2.1 Convenience sampling

The convenience sampling is also known as the accidental or availability sample method (Dane, 2011:121; Wilson, 2010:199; Bayat & Fox, 2007:58). Convenience sampling is when samples are drawn from the population based on the convenience or availability to the researcher (Zikmund *et al*., 2010:396; Dane, 2011:121; Wilson, 2010:199; Bayat & Fox, 2007:59; Henn *et al.*, 2009:157; Gray, 2004:88; Sekaran, 2006:276; Gomm, 2008;152; Schiffman & Kanuk, 2009:37) until the desired number is obtained (Dane, 2011:121; Wilson, 2010:199; Bayat & Fox, 2007:59). Respondents such as family, friends, associates or other people who are near and easily available to the researcher are included in the sample frame (Dane, 2011:121; Wilson, 2010:199; Bayat & Fox, 2007:58; Cooper & Schindler, 2003:201).

3.3.5.2.2 Judgmental sampling

The judgmental sampling is also known as purposive sampling (Wilson, 2010:199; Bayat & Fox, 2007:59; Cooper & Schindler, 2003:201; Zikmund *et al*., 2010:396; Sekaran, 2006:277). Researchers base the selection of their units of analysis on their judgement of own expert opinion to be included in the sample frame (Wilson, 2010:199; Bayat & Fox, 2007:59; Strydom, 2005:202; Cooper & Schindler, 2003:201; Zikmund *et al*., 2010:396; Sekaran, 2006:277; Schiffman & Kanuk, 2009:37). The units selected for the sample frame are units which are regarded as being representative of the population (Bayat & Fox, 2007:59; Gray, 2004:87). This sampling method is used when the researcher wants to obtain a certain type of element relevant for the study undertaken (Wilson, 2010:198; Bayat & Fox, 2007:59; Strydom, 2005:202; Dane, 2011:122).

3.3.5.2.3 Quota sampling

In quota sampling the participants are chosen on previously known information (Bayat & Fox, 2007:60) or predominant characteristics/ categories (Wilson, 2010:198, Dane, 2011:123; Cooper & Schindler, 2003:201) as to ensure that the wider population and the total sample will have the approximately the same distribution (Dane, 2011:123; Wilson, 2010:198; Bayat & Fox, 2007:60; Cooper & Schindler, 2003:201). The sampling participants are divided into groups (categories) which are assumed to feature within the population (Dane, 2011:123; Wilson, 2010:198; Bayat & Fox, 2007:60; Sekaran, 2006:278; Zikmund *et al*., 2010:397; Cooper & Schindler, 2003:201).

3.3.5.2.4 Snowball sampling

Snowball sampling is when the researcher approaches a few individuals from the population that will act as informants as they will be requested to identify other members from the same population who possess similar characteristics to be included in the sample. The individuals identified may also identify a further set of relevant individuals who could make up the sample (Wilson, 2010:198; Bayat & Fox, 2007:59; Cooper & Schindler, 2003:203; Zikmund *et al*., 2010:398; Gray, 2004:88; Henn *et al.*, 2009:158). This sampling method grows in size until the researcher obtained the desired number for the study (Wilson, 2010:198; Bayat & Fox, 2007:59). When a relatively unknown case or in instances when it is difficult to obtain more individuals for the investigation the snowball sampling method is excellent to use (Wilson, 2010:198; Strydom, 2005:203).

Various sampling methods can be combined when conducting research, this means that the researcher does not need to restrict himself/ herself to a single type of sampling technique, but the researcher needs to justify the methods chosen (Wilson, 2010:200). Each sampling method has certain advantages and disadvantage, which must be considered when deciding on the sample method that will be used for the research study.

3.3.5.3 Sampling techniques advantages and disadvantages

Before selecting a sampling method, the researcher must be able to select the most appropriate sample method for a specific study, thus the researcher will identify a number of sampling criteria and the importance of each criterion will be evaluated (Zikmund *et al.,* 2010:404). Table 3.3-1 summarises the strengths and weaknesses associated with each probability sampling method.

Table 3.3-1: Probability sampling methods

Type	Advantage	Disadvantage
Simple random	• Minimal knowledge is needed of the population (Zikmund *et al.,* 2010:405); • Data is easy to analyse and to determine error (Zikmund *et al.,* 2010:405); • Findings can be generalised (Sekeran, 2006:280).	• Needs to work from a sample frame (Zikmund *et al.,* 2010:405; Cooper & Schindler, 2003:199); • Time consuming (Cooper & Schindler, 2003:199); • Create larger errors and is expensive as respondents may be widely spread (Zikmund *et al.,* 2010:405; Cooper & Schindler, 2003:199).

Systematic	• Sample is simple to draw and easy to use (Zikmund *et al.,* 2010:405; Cooper & Schindler, 2003:199; Sekeran, 2006:280) if available population frame exists (Sekeran, 2006:280).	• Results and sample may deviate if the sampling interval is related to periodic ordering of the population (Zikmund *et al.,* 2010:405; Cooper & Schindler, 2003:199); • Systematic deviation can occur (Cooper & Schindler, 2003:199; Sekeran, 2006:280).
Stratified	• All groups in sample are represented (Zikmund *et al.,* 2010:405; Sekeran, 2006:280); • Possibility of comparison among groups/ strata can be made (Zikmund *et al.,* 2010:405; Sekeran, 2006:280).	• If strata on the population have to be created, it can be expensive to prepare this stratified lists (Zikmund *et al.,* 2010:405; Cooper & Schindler, 2003:199); • Accurate information is necessary on the proportion in each stratum (Zikmund *et al.,* 2010:405; Cooper & Schindler, 2003:199).
Cluster	• Low costs of data collection, especially with geographic clusters (Zikmund *et al.,* 2010:405; Cooper & Schindler, 2003:199; Sekeran, 2006:280); • The characteristics of the population and clusters can be estimated (Zikmund *et al.,* 2010:405; Cooper & Schindler, 2003:199) and without a population list it is still easy to do (Cooper & Schindler, 2003:199).	• Statistical efficiency is often lower due to subsets of clusters that are more homogeneous rather than heterogeneous (Cooper & Schindler, 2003:199; Sekeran, 2006:280); • Duplication or omission of individuals will result if the researcher isn't able to assign population members to a unique cluster (Zikmund *et al.,* 2010:405).
Multi-stage	• Depends on the methods combined (Zikmund *et al.,* 2010:405); • If the first stage delivers enough data to stratify or cluster the population, it may result in reduced costs (Cooper & Schindler, 2003:199).	• Depends on the methods combined (Zikmund *et al.,* 2010:405); • If used indiscriminately, it may result in increased costs (Cooper & Schindler, 2003:199).

Table 3.3-2 summarises the strengths and weaknesses associated with each non-probability sampling method.

Table 3.3-2: Non-probability sampling methods

Type	Advantage	Disadvantage
Convenience	• A list of the population is not needed (Zikmund *et al.,* 2010:404); • Convenient, quick and less expensive (Sekeran, 2006:280).	• Cannot make generalisations (Sekeran, 2006:280), no projections allowed to a wider population (Zikmund *et al.,* 2010:404).
Judgemental	• Specific objective can be met, guaranteed by the sample or can be useful for forecasting (Zikmund *et al.,* 2010:404); • Can sometimes be the only meaningful way to investigate (Sekeran, 2006:280).	• It is risky to project data beyond sample (Zikmund *et al.,* 2010:404); • Generalisations cannot be made to the entire population (Sekeran, 2006:280); • Sample bias may take place, which could make the sample unrepresentative (Zikmund *et al.,* 2010:404).
Quota	• No list is required of the population (Zikmund *et al.,* 2010:404); • Some of the stratification of the population is introduced (Zikmund *et al.,* 2010:404).	• To project data beyond sample is risky (Zikmund *et al.,* 2010:404) and generalisation is not easy (Sekeran, 2006:280); • Sampling biases can be introduced (Zikmund *et al.,* 2010:404); • Error from population cannot be estimated if non-random selection within classes takes place (Zikmund *et al.,* 2010:404).
Snowball	• Useful in locating members or scarce populations (Zikmund *et al.,* 2010:404).	• To project data beyond sample is risky (Zikmund *et al.,* 2010:404); • Statistical distortion (inaccuracy) may arise due to sample units not being independent (Zikmund *et al.,* 2010:404).

After analysing the different sampling methods with their respective advantages and disadvantages, the most suitable sampling method can be chosen for this research study.

3.3.5.4 Sampling method selected

The sampling method that will be used in the study is a combination of convenience sampling as well as judgemental sampling which are both part of the non-probability techniques.

In convenience sampling the respondents are associates who are near and easy available were included in the sample frame (Dane, 2011:121; Wilson, 2010:199; Bayat & Fox, 2007:58; Cooper & Schindler, 2003:201). By undertaking non-probability sampling the individuals have an unequal chance of being included in the sample (Dane, 2011:121; Wilson, 2010:198; Bayat & Fox, 2007:58; Henn *et al.*, 2009:156; Sekaran, 2006:276; Cooper & Schindler, 2003:200; Zikmund *et al*., 2010:395) for the purpose being studied.

By undertaking a convenience sampling method the disadvantages include having no control in ensuring accuracy, but this sampling method can still be a useful procedure (Cooper & Schindler, 2003:201). This method doesn't allow the researcher to make conclusions/generalisations about the wider population (Dane, 2011:121; Wilson, 2010: 198; Shiu, Hair, Bush & Ortinau, 2009:480) as one cannot estimate the sampling error when non-probability sampling is used (Dane, 2011:121; Wilson, 2010:198). The commencement of a research paper places the research in an exploratory phase and by using convenience sampling combined with exploratory research delivers the best way of obtaining basic information both quickly and efficiently (Cooper & Schindler, 2003:201; Shiu *et al.,* 2009:480; Zikmund *et al*., 2010:3996; Sekaran, 2006:276).

Even though there are some prominent disadvantages, convenient sampling is least time consuming (Shiu *et al.,* 2009:480; Wilson, 2010:200; Zikmund *et al*., 2010:404; Bradley, 2007:179), inexpensive and convenient for undertaking the study (Wilson, 2010:200; Zikmund *et al*., 2010:404; Bradley, 2007:179). Convenient sampling enables to win quick results and for this reason this method is used in circumstances where the researcher needs questionnaires to be completed both quickly and economically (Blythe, 2006:223). This sampling method does not need a list of the population and is one of the methods that are extensively used (Zikmund *et al*., 2010:404). This method is used when other sampling methods are not practical. For the aforementioned reasons convenient sampling will be used in this research study.

To counter the disadvantage of convenience sampling method (having no control in ensuring accuracy of a representative sample), the researcher has deployed judgemental sampling. Judgemental/purposive sampling allows the researcher to apply a selection of their sample units of analysis on their judgement of own expert opinion to be included in the sample. The units selected for the sample frame are units which are regarded as being representative of

the population. This sampling method is used when the researcher wants to obtain a certain type of element relevant for the study undertaken.

3.3.6 SAMPLE SIZE

After the target population is clearly defined and the sample frame was selected the researcher can decide on the sample size that will be used for the study (Wilson, 2010:201). The nature of the research philosophy is likely to influence the decision of the sample size that will be used (Wilson, 2010:201).

The sampling method used in this research paper is as previously mentioned a non-probability technique, and it is therefore not possible to use the research results to make statistical inferences about the wider population (Wilson, 2010:198; Dane, 2011:121). Non-probability sampling is generally associated with case study research design. Qualitative research tends to put the focus on smaller samples where the core intention is to study real-life occurrences, and is not intended to make inferences to the wider population (Wilson, 2010:198).

According to Zikmund *et al.* (2010:434); Sekaran (2006:286); Wilson (2010:201) and Cooper and Schindler (2003:190) factors which should be taken into consideration when the sample size is determined, is firstly, the margin of error to be tolerated in the data, namely the accuracy required for any estimates made from the sample. Secondly, the confidence level which is needed in the estimate, namely the level of uncertainty that the characteristics of the collected data will represent the characteristics of the total population (Gill & Johnson, 2010:128). Furthermore, key concerns when determining the sample size include, non-response bias to questionnaires and also other important considerations to take note of are amongst, the availability of finances, size of the questionnaire, availability of trained investigators, the condition under which the samples are being conducted and lastly the time available for completion of the research study (Kothari, 2004:175). Taking all the aforementioned factors into consideration (paying explicit attention to constraints in time, cost and resources), the sample size for this research project comprises of all stakeholders in electrical motor management activities within the engineering services department in a large steel manufacturer and included thirty-two technical staff members:

- Procurement staff;
- Managers;
- Engineers;

- Technicians;
- Artisans;
- Planners;
- Clerks;
- Safety officers; and
- Project managers.

Though small, the sample group was a full representation of the actual population of the engineering services department within a large steel manufacturer.

After the sample size is established together with the target population, sampling frame and sampling technique(s), the next step is to collect data for the study (Wilson, 2010:205).

3.3.7 SUMMARY

3.3.7.1 Research design

Initially the researcher had to deploy **exploratory research of a quantitative nature** by means of surveys to confirm the primary research objective:

a. Establish the status quo of existing EMM within the engineering services department at the large steel manufacturer and then make a comparative analysis of how the status quo compares with EMM proposed in literature. This will also provide confirmation of the perceived need for developing/improving EMM-practices at the engineering services department within the large steel manufacturer.

The researcher then conducted descriptive research of **a qualitative nature** to address the study's secondary objective:

b. Determine the maturity levels of EMM-activities by means of researched EMM maturity model (prescriptive EMM maturity model) for the engineering services department within the large steel manufacturer to serve as a tool for continuous tracking and improvement.

The second research objective will aid the need to easily describe and interpret critical shortcomings in current EMM practices (in the case where shortcomings exist) and in so doing it will provide insight on what aspects are critical for advancing the level of maturity of EMM. In the case where no EMM exists, this objective was set in order ***to provide a researched EMM maturity model for deploying motor management activities within the engineering services department at the large steel manufacturer and to provide a***

means to measure and improve/instigate aspects to advance the overall maturity level of EMM. It is important to gain an accurate representation (description) of the status quo and to establish what aspects need attention/development to provide a defined means of improving on key process areas which follows the natural order of progression allowing the best chance for success, which was identified in Chapter 2, as a critical success factor. An assessment of the electrical motor management maturity (EMMM), the significance can be visualised as being three-fold:

a. A comparison existing EMM-activities within the engineering services department at the large steel manufacturer compares with EMM proposed in literature.
b. Internal - The assessment would provide results that are easily understood and communicated. Aligning with Raber et al. (2013), the improvements can be tracked, to allow distinction and recognition between areas of exceptional maturity and areas requiring changes or resources (or both) to bring about improvements.
c. External – Comparisons can be with made between different departments in the large steel manufacturer as well as higher level comparisons between different operating units within the large steel manufacturer or between national and international industries as part of benchmarking.

The research design consists of both descriptive and exploratory research.

3.3.7.2 Data collection method

Methodological triangulation will be deployed (combination of quantitative and qualitative data):

1. Quantitative primary data will be obtained:
    a) **Interviewer administrated surveys** were conducted to allow the researcher a span of control over the respondents from whom the data is collected to assure data credibility. Filter questions were also implemented during interviews to ensure the credibility of answers chosen by respondents. The filters were deployed to measure contradictory statements as such increases/decreases the credibility of the respondent accordingly.
    b) The researcher also deployed **self-administrated surveys** (where the questions match the interviewer administrated surveys) in the form of email surveys as questioning the status quo can in some cases be seen as a sensitive matter (especially when the findings might point out a lack in management activities) and by completing the self-administrative survey more in-depth and quality data can

be obtained for the current research. Self-administrated surveys also allows the respondents to complete the survey at a time convenient to their respective schedules and priorities.

2. Qualitative primary data will be obtained through :
    a) A maturity model will be deployed to obtain a descriptive analysis of the current EMM-activities at the engineering services department within a large steel manufacturer.

The non-probability sampling technique deployed was convenience sampling combined with judgemental sampling where the sample constituted of the entire population i.e. all stakeholders involved in both the process management and operation management activities relating to electrical motor management at the engineering services department within a large steel manufacturer. The same sample shall be utilised for collecting both the quantitative and qualitative data. Non-probability sampling is generally associated with case study research design (Wilson, 2010).

3.4 RESEARCH INSTRUMENTS

This study will make use of a questionnaire that will be discussed below. Thereafter the questionnaire sections, scale types as well as the research instruments included in the questionnaire for this study will be discussed. This is step 5 in the research process. The researcher also made use of a maturity model as an instrument for studying the EMM-domain as was presented in Chapter 2.3.

3.4.1 QUESTIONNAIRE

A questionnaire is a method of data collection (Wilson, 2010:148) and a prepared number of questions are jotted down (Buckingham & Saunders, 2004:43; Bayat & Fox, 2007:88; Kothari, 2004:100) for generating data (Bayat & Fox, 2007:88; Wilson, 2010:148) which is suitable for achieving the objectives of a research project (Wilson, 2010:148).

The research instrument that will be used in the study is a questionnaire. The questionnaire will consist of closed questions, which are questions in which a respondent has to choose from a limited number of potential answers (Wilson, 2010:154; Sekaran, 2006:239; Henn *et al.*, 2009:162; Zikmund *et al*., 2010:340). Closed questions consists of a straightforward yes or no type of question (Wilson, 2010:154; Kothari, 2004:101; Henn *et al.*, 2009:162; Zikmund *et al*., 2010:340). According to Bayat and Fox (2007:91) a closed question is also called a

structured or multiple-choice question which enables respondents to select a category that best fits their answers or responses. Respondents are requested to choose an answer from two or more stated alternatives (Bayat & Fox, 2007:91) and they are able to make quick decisions to choose among a variety of alternatives (Sekaran, 2006:239).

The study will make use of structured questionnaires. According to Kothari (2004:101) structured questionnaires are questions which are definite, concrete and pre-determined. The respondents are forced to reply to the same set of questions through making use of a questionnaire that consists of alternatives to choose from which will be standard in all questionnaires (Kothari, 2004:101). The form in which the questions will be presented is in the form of closed questions and this type of questionnaire is one in which all the questions and answers are specified where respondents' own words are held to a minimum (Kothari, 2004:101). The advantage of using a structured questionnaire is that it is inexpensive to analyse the data (Kothari, 2004:102) and it is easy to administer (Kothari, 2004:102; Sekaran, 2006:239; Henn *et al.*, 2009:162). Henn *et al.* (2009:162) states that closed questions are also easy to ask, easy to understand and quick to answer.

The different types of close-ended questions which will be used in the questionnaires will be examined. The dichotomous response format questions are those questions that can accommodate only two answer possibilities (Bayat & Fox, 2007:93; Zikmund *et al*., 2010:340). These would include questions that state gender (male or female), a yes or no answer (Bayat & Fox, 2007:93; Zikmund *et al*., 2010:340), whether something is a fact or not (Cooper & Schindler, 2003:377). Cooper and Schindler (2003:377) agree that if the dichotomous questions alternative cannot be accepted by participants, they may convert the question to a multiple-choice or rating question by writing in the desired alternative. Nominal data can be obtained with dichotomous questions (Cooper & Schindler, 2003:377).
For the selection of answers to directly correspond to the question being asked a multiple question should be written (Wilson, 2010:155). Multiple-Choice questions are instances where respondents have more than two alternatives to choose from (Wilson, 2010:153; Cooper & Schindler, 2003:377; Bayat & Fox, 2007:93) or when the degrees of preference, interest or agreement are sought (Cooper & Schindler, 2003:377; Bayat & Fox, 2007:93). According to Bayat and Fox (2007:92) to obtain information that can logically be divided into reasonably fixed categories a multi-choice question is used. Answers to certain questions may result in a sequence of numerical values or numerical response variables (Bayat & Fox, 2007:92). It is important to divide numerical response into viable groups because the

possible number of categories is reduced and each category is made as broad as possible to ensure that valuable information is not lost (Bayat & Fox, 2007:92; Cooper & Schindler, 2003:378). Multiple-choice questions usually generate nominal data and when the choices are numbers the structure will provide interval- and sometimes ratio-data (Cooper & Schindler, 2003:379). Cooper and Schindler (2003) further state that multiple-questions generate ordinal data when the choices represents ordered numerical ranges (1-5) or a verbal rating scale such as strongly disagree, disagree, agree, strongly agree (Cooper & Schindler, 2003:379).

Checklist questions are another form of questions that can be used. A checklist is a form of a multi choice question used which contains a number of items such as words, terms, phrases or characteristics which may be arranged in different ways (Bayat & Fox, 2007:92). Zikmund *et al*. (2010:341) agree that a checklist is a fixed alternative that provides multiple answers to a single question by checking off items. If a multiple response to a single question wants to be gathered from a participant a checklist question is used (Cooper & Schindler, 2003:379). Cooper and Schindler (2003) also state that checklists are an efficient form of questions and these checklists generate nominal data (Cooper & Schindler, 2003:379).

A rank order question is an attitude-based question (Wilson, 2010:155). This type of question requires the respondent to rank an attitude statement in their order of preference (Wilson, 2010:155). Ranking is ideal when a relative order of the alternatives is important, thus telling the researcher which factors are more important to the participants (Cooper & Schindler, 2003:379). According to Bayat and Fox (2007:94) ranking order questions are questions which are used to assign numerical values to a sequence of aspects. Ordinal data is gained through ranking questions (Cooper & Schindler, 2003:380).

A questionnaire can also make use of sensitive questions, which are questions that can consist of information which can be seen as private and personal information (Sekaran, 2006:247). Sekaran (2006) states that sensitive questions such as prices/income should be placed at the end of the questionnaire (Sekaran, 2006:247).

In order to better validate answers supplied by respondents the researcher set up few pivot questions. A pivot question is intended to serve as a filter-type question that determines the follow-up action/s required from the respondent. For example:

- *Would you like to see improvements relating to …..? (YES or NO)*

- *If answer in the aforementioned question was "YES", please proceed by answering question 100-105.*
- *If the answer in the aforementioned question was "NO", please skip question 100-105 and proceed to question 106.*

By posing pivot questions the researcher can test the level of accuracy for the survey data supplied from each respondent at various points within the survey. Respondent survey data is considered reliable in instances where the respondent followed the exact follow-up action/s. In instances where the respondent did not follow the exact follow-up action/s the said respondent's survey data is deemed not reliable by the researcher and as such the entire survey for the said respondent is excluded from the research data.

3.4.1.1 MEASUREMENT SCALES INCLUDED IN QUESTIONNAIRE

A scale is an instrument by which individuals are distinguished based on their differences from one another with respect to the variables of interests (Sekaran, 2006:185). There are four different types of scales namely a nominal, ordinal, interval and a ratio, which can be used in questionnaires (Sekaran, 2006:185; Zikmund *et al.,* 2010:296). The measuring scales included within the questionnaire design for this study is as follow:

- A nominal scale signifies the most elementary level of measurement and assigns a value to an object for identification (Zikmund *et al*., 2010:296; Wilson, 2010:215; Sekeran, 2006:185). A variable is measured in terms of two or more qualitative different categories (Van der Stoep & Johnston, 2009:48; Gill & Johnson, 2010:142; Sekaran, 2006:185). Nominal scales are very useful and sometimes are the only appropriate measure to use (Zikmund *et al*., 2010:296);
- Ordinal scales are also known as ranking scales where data can be rank-ordered (Zikmund *et al*., 2010:298; Wilson, 2010:215; Sekeran, 2006:186). Two or more categories that allow differentiation of variables in terms of categories and are known as ordinal scales (Gill & Johnson, 2010:142; Zikmund *et al*., 2010:298; Van der Stoep & Johnston, 2009:52). Different points on the scale indicate the quantity being measured where a degree of ordering is involved (Gill & Johnson, 2010:142; Zikmund *et al*., 2010:298); and
- An interval scale has both nominal and ordinal properties (Zikmund *et al*., 2010:301) and do not have a true zero point (Gill & Johnson, 2010:142). Furthermore, in an interval scale the intervals between numbers are meaningful, this means that the numbers

provides the researcher information on the differences in size between categories with respect to the object being measured (Zikmund *et al*., 2010:301; Sekeran, 2006:187). An example of an interval scale is when points are given on an easy question (Zikmund *et al*., 2010:301).

3.4.2 QUESTIONNAIRE SECTIONS

"What do I need to measure from the respondent in order to answer my research objective?"

Firstly, the researcher had to deploy exploratory research of a quantitative nature by means of surveys (as will be elaborated in this paragraph) to confirm the primary research objective: *Establish the status quo of existing EMM within the engineering services department at the large steel manufacturer and establish the need for developing/improving EMM-activities at the engineering services department (ESD) within the large steel manufacturer.*

The questionnaire was divided into three sections, Section-A, Section-B and Section-C and totalled to 108-questions. Basic demographic information was collected in Section-A (question 1 to 6). Section-B (question 7 to 91) was designed to gain insight to the status quo of EMM activities at the engineering services department (ESD) within a large steel manufacturer. Section-C (question 92 to 108) explored staff and management attitudes as well as their beliefs relating to EMM at ESD within a large steel manufacturer.

3.4.2.1 Section-A: Demographics

3.4.2.1.1 Demographics

The purpose of Section-A of the questionnaire is aimed to obtain demographic details of stakeholders identified as part of the sample group window.

Table 3.4-1: Demographic details

Questionnaire	Response format	Scale
1. What is your gender?	Dichotomous	Nominal
2. What is your population group?	Multiple-choice	Nominal
3. What is your age?	Multiple-choice	Ordinal
4. What is your marital status?	Multiple-choice	Nominal
5. What is your highest academic qualification?	Multiple-choice	Ordinal

6. How many times a month do interact with any electrical motor management activity?	Multiple-choice	Ordinal

3.4.2.2 Section-B: EMM at ESD within a large steel manufacturer

This section of the questionnaire is intended to obtain data relating to EMM at ESD within a large steel manufacturer to aid in establishing the status quo for EMM at ESD within a large steel manufacturer.

3.4.2.2.1 General

For each statement presented in the table below, provide a response to signify how much you tend to agree with the statement. Response values are between values 1-5, where strongly disagree =1; strongly agree = 5.

Table 3.4-2: Intro questions

Questionnaire	Response format	Scale
7. EMM at ESD is very effective	Scaled	Interval
8. EMM activities at ESD are being managed	Scaled	Interval
9. ESD reports on safety management performance indicators	Scaled	Interval
10. ESD reports product/process quality performance indicators	Scaled	Interval
11. ESD reports on EMM performance indicators	Scaled	Interval
12. Roles and responsibilities are defined relating to EMM-activities	Scaled	Interval
13. Which employees need to use EMM:	Multiple-choice (Procurement staff; Managers; Engineers; Technicians; Artisans; Planners; Clerks; Safety officers; and Project managers.)	Nominal
14. Which are the EMM aspects that need to be advanced?	Multiple-choice	Nominal

	(Workflow; Procedures; Approval levels; Ownership; Policies, Processes)	
15. ESD have functional block diagrams to supplement the existing asset hierarchy.	Scaled	Interval
16. Accurate system data for electrical motors are available (technical data, functional KPIs, failure history, condition monitoring history)	Scaled	Interval
17. The main purpose of EMM is control, plan and monitor maintenance and spare parts relating to electrical motors.	Scaled	Interval

3.4.2.2.2 Process management activities

For each statement presented in the table below, provide a response to signify how much you tend to agree with the statement. Response values are between values 1-5, where strongly disagree =1; strongly agree = 5.

The questions presented below are relating to EMM process management activities at EMM at ESD within a large steel manufacturer for all the life-cycle phases.

Table 3.4-3: Process management activities

Questionnaire	Response format	Scale
18. The objective for EMM is clearly defined.	Scaled	Interval
19. Human resources relating to each EMM-activity are clearly defined.	Scaled	Interval
20. Equipment and methods forming part of EMM are clearly defined to aid in achieving the EMM objective.	Scaled	Interval
21. The quality of the processes relating to EMM used to develop, deliver, and support services and production are providing production and service outputs which are high in quality.	Scaled	Interval
22. Long term vision and strategy are defined for EMM	Scaled	Interval

23. Management support forms the premise of process improvement relating to EMM	Scaled	Interval
24. The culture and infrastructure at the large steel manufacturer relating to EMM is supported by the development and deployment of procedures which are maintained, revised and improved.	Scaled	Interval
25. The culture and infrastructure at the large steel manufacturer relating to EMM is enforced through standard operating practices.	Scaled	Interval
26. Procedures, standard operating practices and methods relating to EMM will continue even when authors of the procedures, standard operating practices and methods relating to EMM are no longer working at the organisation.	Scaled	Interval

For each statement presented in the table below, provide a response to signify how much you tend to agree with the statement. Response values are between values 1-5, where strongly disagree =1; strongly agree = 5.

Institutionalised implies that processes are entrenched by the manner in which the work gets executed and there is commitment and consistency to the process being performed. The following **process management activities** relating to EMM are fully institutionalised:

Table 3.4-4: Process management activities institutionalised

Questionnaire	Response format	Scale
27. leadership (PA1)	Scaled	Interval
28. planning (PA2)	Scaled	Interval
29. policies, procedures and internal controls (PA3)	Scaled	Interval
30. personnel and staffing (PA4)	Scaled	Interval
31. financial management (PA5)	Scaled	Interval
32. technology utilisation and management (PA6)	Scaled	Interval
33. records and reporting (PA7)	Scaled	Interval
34. quality management (PA8)	Scaled	Interval

35. risk management (PA9)	Scaled	Interval
36. configuration management (PA10)	Scaled	Interval
37. assessments (P11)	Scaled	Interval

For each statement presented in the table below, provide a response to signify how much you tend to agree with the statement. Response values are between values 1-5, where strongly disagree =1; strongly agree = 5.

I would like to see improvements for **process management activities** relating to EMM in:

Table 3.4-5: Process management activity improvement required

Questionnaire	Response format	Scale
38. Would you like to see improvements relating to process management activities? (YES or NO) a. If answer in question 38 was YES", please proceed by answering question 39 and beyond. b. If the answer in the aforementioned question was "NO", please skip questions 39-49 and proceed to question 50.	Dichotomous (yes/no)	Nominal
39. Leadership (PA1)	Scaled	Interval
40. planning (PA2)	Scaled	Interval
41. policies, procedures and internal controls (PA3)	Scaled	Interval
42. personnel and staffing (PA4)	Scaled	Interval
43. financial management (PA5)	Scaled	Interval
44. technology utilisation and management (PA6)	Scaled	Interval
45. records and reporting (PA7)	Scaled	Interval
46. quality management (PA8)	Scaled	Interval
47. risk management (PA9)	Scaled	Interval
48. configuration management (PA10)	Scaled	Interval
49. assessments (P11)	Scaled	Interval

3.4.2.2.3 Operation management activities – Acquisition life cycle phase

For each statement presented in the table below, provide a response to signify how much you tend to agree with the statement. Response values are between values 1-5, where strongly disagree =1; strongly agree = 5.

The questions presented below are relating to EMM operation management activities at EMM at ESD within a large steel manufacturer for the **acquisition life cycle phase.**

Table 3.4-6: Operation management activities – Acquisition life cycle phase

Questionnaire	Response format	Scale
50. Operation management activities are defined specific to the **acquisition life-cycle phase**	Scaled	Interval

For each statement presented in the table below, provide a response to signify how much you tend to agree with the statement. Response values are between values 1-5, where strongly disagree =1; strongly agree = 5.

Institutionalised implies that operation management activities are entrenched by the manner in which the work gets executed and there is commitment and consistency to the activities being performed. The following **operation management** activities during the **acquisition life-cycle phase** relating to EMM are fully institutionalised:

Table 3.4-7: Acquisition operation management activities institutionalised

Questionnaire	Response format	Scale
51. Requirements determination (PA1)	Scaled	Interval
52. categorisation (PA2)	Scaled	Interval
53. authorisation (PA3)	Scaled	Interval
54. procurement (PA4)	Scaled	Interval
55. construction in progress management (PA5)	Scaled	Interval
56. receiving (PA6)	Scaled	Interval
57. identification (PA7)	Scaled	Interval
58. financial recognition (PA8)	Scaled	Interval

For each statement presented in the table below, provide a response to signify how much you tend to agree with the statement. Response values are between values 1-5, where strongly disagree =1; strongly agree = 5.

I would like to see improvements for operation management activities during the **acquisition life-cycle phase** relating to EMM:

Table 3.4-8: Improvements required for acquisition operation management activities

Questionnaire	Response format	Scale
59. Would you like to see improvements relating to acquisition operation management activities? (YES or NO) a. If answer in question 59 was YES", please proceed by answering question 60 and beyond. b. If the answer in the aforementioned question was "NO", please skip questions 60-67 and proceed to question 68.	Dichotomous (yes/no)	Nominal
60. Requirements determination (PA1)	Scaled	Interval
61. categorisation (PA2)	Scaled	Interval
62. authorisation (PA3)	Scaled	Interval
63. procurement (PA4)	Scaled	Interval
64. construction in progress management (PA5)	Scaled	Interval
65. receiving (PA6)	Scaled	Interval
66. identification (PA7)	Scaled	Interval
67. financial recognition (PA8)	Scaled	Interval

3.4.2.2.4 Operation management – Usage life cycle phase

For each statement presented in the table below, provide a response to signify how much you tend to agree with the statement. Response values are between values 1-5, where strongly disagree =1; strongly agree = 5.

The questions presented below are relating to EMM operation management activities at EMM at ESD within a large steel manufacturer for the usage life cycle phase.

Table 3.4-9: Operation management activities – Usage life cycle phase

Questionnaire	Response format	Scale
68. Operation management activities are defined specific to the **usage life-cycle phase**	Scaled	Interval

For each statement presented in the table below, provide a response to signify how much you tend to agree with the statement. Response values are between values 1-5, where strongly disagree =1; strongly agree = 5.

Institutionalised implies that operation management activities are entrenched by the manner in which the work gets executed and there is commitment and consistency to the activities being performed. The following **operation management activities** during the **usage life-cycle phase** relating to EMM are fully institutionalised:

Table 3.4-10: Usage operation management activities institutionalised

Questionnaire	Response format	Scale
69. Utilisation (PA1)	Scaled	Interval
70. control (PA2)	Scaled	Interval
71. tracking (PA3)	Scaled	Interval
72. maintenance (PA4)	Scaled	Interval
73. safety (PA5)	Scaled	Interval
74. security (PA6)	Scaled	Interval

For each statement presented in the table below, provide a response to signify how much you tend to agree with the statement. Response values are between values 1-5, where strongly disagree =1; strongly agree = 5.

I would like to see improvements for operation management activities during the **usage life-cycle phase** relating to EMM:

Table 3.4-11: Improvements required for usage operation management activities

Questionnaire	Response format	Scale
75. Would you like to see improvements relating to usage operation management activities? (YES or NO) a. If answer in question 75 was YES", please proceed by answering question 76 and beyond. b. If the answer in the aforementioned question was "NO", please skip questions 76-81 and proceed to question 82.	Dichotomous (yes/no)	Nominal
76. Utilisation (PA1)	Scaled	Interval
77. control (PA2)	Scaled	Interval
78. tracking (PA3)	Scaled	Interval
79. maintenance (PA4)	Scaled	Interval
80. safety (PA5)	Scaled	Interval
81. security (PA6)	Scaled	Interval

3.4.2.2.5 Operation management – Disposal life cycle phase

For each statement presented in the table below, provide a response to signify how much you tend to agree with the statement. Response values are between values 1-5, where strongly disagree =1; strongly agree = 5.

The questions presented below are relating to EMM operation management activities at EMM at ESD within a large steel manufacturer for the **disposal life cycle phase.**

Table 3.4-12: Operation management activities – Disposal life cycle phase

Questionnaire	Response format	Scale
82. Operation management activities are defined specific to the **disposal life-cycle phase**	Scaled	Interval

For each statement presented in the table below, provide a response to signify how much you tend to agree with the statement. Response values are between values 1-5, where strongly disagree =1; strongly agree = 5.

Institutionalised implies that operation management activities are entrenched by the manner in which the work gets executed and there is commitment and consistency to the activities being performed. The following **operation management activities** during the **disposal life-cycle phase** relating to EMM are fully institutionalised:

Table 3.4-13: Disposal operation management activities institutionalised

Questionnaire	Response format	Scale
83. Reutilisation (PA1)	Scaled	Interval
84. authorisation to dispose (PA2)	Scaled	Interval
85. transport, storage, and handling (PA3)	Scaled	Interval
86. disposal (PA4)	Scaled	Interval

For each statement presented in the table below, provide a response to signify how much you tend to agree with the statement. Response values are between values 1-5, where strongly disagree =1; strongly agree = 5.

I would like to see improvements for operation management activities during the **disposal life-cycle phase** relating to EMM:

Table 3.4-14: Improvements required for disposal operation management activities

Questionnaire	Response format	Scale
87. Would you like to see improvements relating to disposal operation management activities? (YES or NO) a. If answer in question 87 was YES", please proceed by answering question 88 and beyond. b. If the answer in the aforementioned question was "NO", please skip questions 88-91 and proceed to question 92.	Dichotomous (yes/no)	Nominal
88. Reutilisation (PA1)	Scaled	Interval
89. authorisation to dispose (PA2)	Scaled	Interval
90. transport, storage, and handling (PA3)	Scaled	Interval
91. disposal (PA4)	Scaled	Interval

3.4.2.3 Section-C: Staff and management attitudes and beliefs

This section is intended to explore staff and management attitudes and beliefs relating to EMM at ESD within a large steel manufacturer.

For each statement presented in the table below, provide a response to signify how much you tend to agree with the statement. Response values are between values 1-5, where strongly disagree =1; strongly agree = 5.

Questionnaire	Response format	Scale
92. EMM implementation is largely adversely affected by the existing stakeholder culture.	Scaled	Interval
93. Acceptance from plant personnel is vital for successful implementation of EMM.	Scaled	Interval
94. ESD has enough resources to successfully implement an EMM-program (availability of funds and people)?	Scaled	Interval
95. ESD has a culture that will accept the implementation of EMM	Scaled	Interval
96. When employees are aligned in knowing why, how and when the result of a new program will have positive outcome	Scaled	Interval
97. An ownership culture needs to be driven by management	Scaled	Interval
98. A ownership culture needs to be driven by employees themselves	Scaled	Interval
99. A workplace needs to be supported by strong and well defined processes	Scaled	Interval
100. EMM is too difficult to deploy successfully	Scaled	Interval
101. EMM is too time consuming to deploy successfully	Scaled	Interval
102. EMM-related audits will help drive success and compliance, which will lead to good EMM-related habits amongst employees	Scaled	Interval
103. Outsourcing of EMM-related activities is the only way to make EMM work	Scaled	Interval
104. EMM-related activities requires a dedicated team to ensure success	Scaled	Interval

105. EMM-related activities can be successfully executed by existing stakeholders at ESD	Scaled	Interval
106. ESD have the requisite skills and knowledge for implementing EMM	Scaled	Interval
107. The custodian of EMM is still responsible for their normal daily plant activities	Scaled	Interval
108. Existing EMM activities at ESD are successful	Scaled	Interval

The questions presented in question 1-108 comprised the full scope under consideration for this study within the questionnaire research instrument. The questionnaires submitted to the respondents are detailed in Appendix The next research instrument that was utilised in this research was a maturity model for the domain under consideration (electrical motor management) and will be discussed in the subsequent paragraph.

3.4.3 EMM MATURITY ANALYSIS

The researcher, as part of the descriptive research of **a qualitative nature, utilised a** second instrument to **conduct an** assessment of the electrical motor management maturity (EMMM), the significance can be visualised as being three-fold:

d. A comparison existing EMM-activities within the engineering services department at the large steel manufacturer compares with EMM proposed in literature.
e. Internal - The assessment would provide results that are easily understood and communicated. Aligning with Raber et al. (2013), the improvements can be tracked, to allow distinction and recognition between areas of exceptional maturity and areas requiring changes or resources (or both) to bring about improvements.
f. External – Comparisons can be with made between different departments in the large steel manufacturer as well as higher level comparisons between different operating units within the large steel manufacturer or between national and international industries as part of benchmarking.

The EMM-maturity model and all the constituents have been explored and presented in paragraph 2.3 and is included in Figure 3.4-1 below for ease of reference. The maturity model analysis will be based on the on the underlying maturity level score allocated to each specific condition (SC) within the respective process areas (PAs). The average of the SC will translate into a maturity level score for each PA. In turn, the PA maturity level score will translate into an average maturity level score for the process- and operation management

respectively, which in turn translates in the average maturity level score for each life cycle phase (LCP) and lastly, the 3-LCP maturity level scores are averaged to provide the resulting EMM-domain maturity level score. The maturity ratings for each constituent was analysed against the requirements presented in Chapter 2 (SCs and PAs).

The allocated maturity level scores for each SC stemmed from an analysis of the EMM-activities within the engineering services department at the large steel manufacturer. The levels of maturity for each specific condition can be scored on a scale of zero to five (which aligns with Crosby's maturity grid model (1979)), where the scoring allocation is a direct indication of the maturity score allocation stemming from the following scoring criteria:

- **A score of 0 – Non-existent**

  A score of zero is allocated in instances where the activity has not been conceptualised nor applied.

  Descriptions

  It is usually the where processes haven't been introduced as such no framework exists, duties are unassigned and no task performers are identified.

- **A score of 1 – Basic**

  A score of one is allocated in instances where processes are chaotic, undocumented, and inconsistent, typically the starting point of a process.

  Descriptions

  It is usually the inception of a process where processes consist of basic framework, duties are assigned and task performers are identified.

- **A score of 2 – Structured**

  A score of two is allocated in instances where processes have been defined and understandable, documented and carry the capability of being repeated.

  Descriptions

  The processes are defined, documented, capable of being repeated, understandable.

- **A score of 3 – Consistent**

A score of three is allocated for processes that are prescribed and consistently performed at the engineering services department within the large steel manufacturer with consistent results.

Descriptions

Established and prescribed, consistently performed, consistent results obtained.

- **A score of 4 – Managed**

  A score of four is allocated in for processes that are systematic, have process performance established, and are predictable.

  Descriptions

  Systematic, calculated, regulated, metrics are applied, objectives are established and continuous improvement established.

- **A score of 5 – Optimising**

  A score of five is allocated in for processes that are embedded at the engineering services department within a large steel manufacturer and are supported through all levels of management.

  Descriptions

  Habitual, perpetual, inherent quality, recurrent, culturally embedded, supported throughout all levels of the engineering services department within the large steel manufacturer.

The review panel that conducted the EMM maturity analysis consisted of EMM stakeholders within the sample group as identified in paragraph 3.6. Additional constraints were applied to the EMM maturity analysis panel where explicit attention was given to constraints in time, cost and resources. The conclusion was made to limit the panel to the 6-managers within the within the engineering services department in a large steel manufacturer. The researcher also formed part of the review panel (i.e. review panel consisted of 7-people) to provide guidance and input for each process areas and the specific conditions to ensure that the interpretations aligned to the concepts presented in paragraph 2.3 of this dissertation. The management team have a good overview of the processes and activities

pertaining to the EMM that are being enforced, reported and controlled as this responsibility ultimately lies with the management team. The researcher envisaged that through making the management team part of the review panel the maturity scores allocated will be accepted as the true reflection of the status quo and that a greater level of acceptance will be achieved. This approach was also envisaged to create an increased level of awareness which could create better ownership and leadership for deploying/improving EMM-activities.

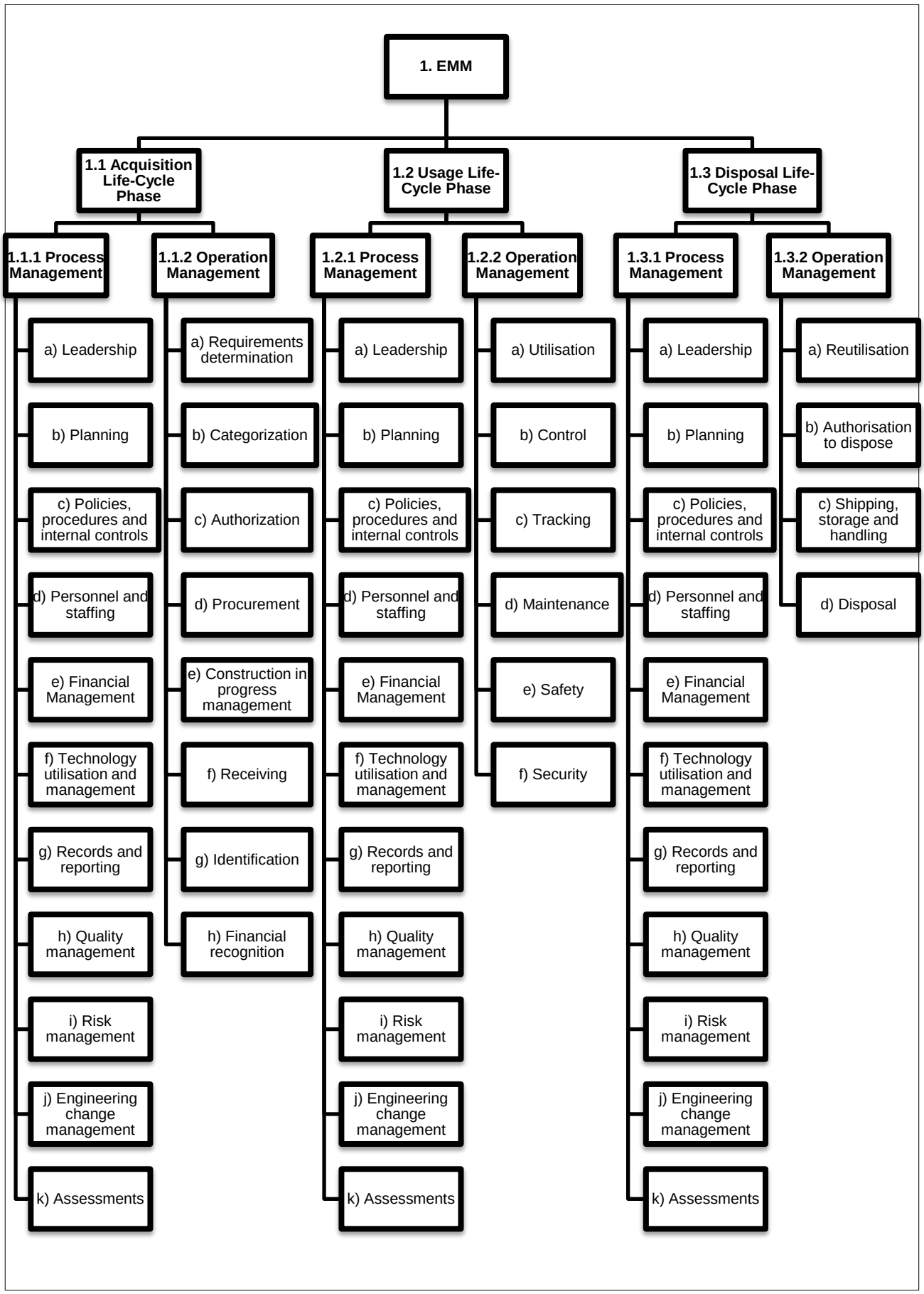


Figure 3.4-1: EMM constituents adapted from (ASTM, 2012)

3.5 CONCLUSION

This chapter described the methodology used in this study by discussing the steps in the research process. The choices and reasons for the methodology used in this study became clear when referring to all the available alternatives as applicable to different stages of the research process. The survey and maturity model were utilised as research instruments to provide required data to analyse aspects pertaining to EMM activities. The analyses and interpretation of data for this study together with the research results and conclusions will be discussed in the chapters to follow.

4 DATA ANALYSIS & INTERPRETATION

Subsequent to collecting primary data by means of the questionnaire and maturity model defined in Chapter 3, the next step comprises of capturing, analysing and interpreting the primary data for the study (Zikmund *et al.*, 2010:462). Whilst compiling and ciphering the data, the researcher needs to be meticulous to ensure the data captured is correct (Zikmund *et al.*, 2010:462). Stage 6 of the research process, analysing and interpreting of the data, will be discussed in the remainder of this chapter (Chapter 4).

4.1 PILOT SURVEY FEEDBACK

The researcher distributed the questionnaire to 3-respondents who were not part of the sample group, nor were they necessarily conversant with electrical motor management related activities. The intention was to get general feedback to identify common errors and to ensure that confusing instructions and questions are eradicated as far as possible.

The feedback did exactly what was expected, i.e. the questionnaire contained grammatical errors, numbering issues and two questions without instruction. A general comment was that the questionnaire was quite long, but the researcher refrained from making the questionnaire shorter owing to the topic being deemed valuable and a deeper understanding of EMM within ESD at a large steel manufacturer had to be obtained through the questionnaire which was utilised as one of the two research instruments.

4.2 ANALYSIS & INTERPRETATION OF RESEARCH DATA

The questionnaire was divided into three sections, Section-A, Section-B and Section-C and comprised of 108-questions. Basic demographic information was collected in Section-A (question 1 to 6). Section-B (question 7 to 91) was designed to gain insight to the status quo of EMM at the engineering services department (ESD) within a large steel manufacturer. Section-C (question 92 to 108) explored staff and management attitudes as well as their beliefs relating to EMM at ESD within a large steel manufacturer. The data collected for each of these sections will be analysed and followed by an interpretation.

During the data processing the researcher noted the accuracies for the questionnaires were very high owing greatly to the interviewer administrated questionnaire. This statement is evident by the fact that all the pivot questions within the questionnaire (which were applied as a filter-type question), were answered and the follow-up action required from the respondent was executed correctly. The average time taken (recorded by the researcher

during the interviewer administrated questionnaire) to complete the questionnaire was 58-minutes. The feedback from the respondents on the time taken was that it took very long, but they felt that their participation would hold beneficial outcomes in opening all EMM-stakeholders' eyes on what needs to be done to get positive momentum. For the subsequent paragraphs the respondent data will be presented, followed by the analysis and interpretation for the said respondent data.

4.2.1 SECTION-A: DEMOGRAPHICS

4.2.1.1 Respondent data

Table 4.2-1 depicts answers from the respondents within the sample group and will be discussed in the subsequent paragraph.

Table 4.2-1: Answers for Section-A

SECTION A - ANSWERS		
	Number of Respondents	**32**
	Number of valid respondents	**32**

DEMOGRAPHIC QUESTIONS											
Question Number	**Question**	**OPTION SELECTED**									
		1		**2**		**3**		**4**		**5**	
		n	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
1	What is your gender?	31	97%	1	3%						
2	What is your population group?	1	3%	30	94%	0	0%	1	3%	0	0%
3	What is your age?	1	3%	7	22%	7	22%	14	44%	3	9%
4	What is your marital status?	7	22%	25	78%	0	0%	0	0%	0	0%
5	What is your highest academic qualification?	12	38%	4	13%	3	9%	13	41%	1	3%
6	How many times a month do interact with any electrical motor management activity?	0	0%	1	3%	2	6%	29	91%		

4.2.1.2 Analysis and interpretation

The population consisted of 97% males; 94% of the population were from the white population group; 44% of the respondents are 46-55 of age; 78% of the respondents are married; 38% of the respondents have qualifications at NQF-level 5 and 41% of the respondents have qualifications at NQF-level 8. 91% of the respondents interact with electrical motors more than 50-times a month.

From the data presented it can be concluded that the respondents are qualified and that they are relevant to the study as 91% of the population interact with electrical motor management activities on a monthly basis.

4.2.2 SECTION-B: EMM AT ESD WITHIN A LARGE STEEL MANUFACTURER

The survey assisted the researcher to obtain data relating to EMM at ESD within a large steel manufacturer to aid in establishing the status quo for EMM at ESD within a large steel manufacturer. This data in turn would assist in comparing EMM at ESD within a large steel manufacturer against what is found in literature.

4.2.2.1 General questions

4.2.2.1.1 Respondent data

Table 4.2-2 below depicts answers from the respondents within the sample group for the general questions and will be discussed in the subsequent paragraph.

Table 4.2-2: Answers to general questions

GENERAL QUESTIONS																			
Question Number	QUESTION	OPTION SELECTED																	
		1		2		3		4		5		6		7		8		9	
		n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
7	EMM at ESD is very effective	7	22%	17	53%	6	19%	1	3%	1	3%								
8	EMM activities at ESD are being managed	0	0%	13	41%	17	53%	1	3%	1	3%								
9	ESD reports on safety management performance indicators	0	0%	0	0%	0	0%	3	9%	29	91%								
10	ESD reports product/process quality performance indicators	0	0%	14	44%	2	6%	16	50%	0	0%								
11	ESD reports on EMM performance indicators	24	75%	5	16%	3	9%	0	0%	0	0%								
12	Roles and responsibilities are defined relating to EMM-activities	2	6%	14	44%	14	44%	2	6%		0%								
13	Which employees need to use EMM:	29	91%	32	100%	32	100%	32	100%	32	100%	32	100%	27	84%	6	19%	3	9%
14	Which are the EMM aspects that need to be advanced?	31	97%	32	100%	17	53%	28	88%	31	97%	32	100%						
15	ESD have functional block diagrams to supplement the existing asset hierarchy.	30	94%	2	6%	0	0%	0	0%	0	0%								
16	Accurate system data for electrical motors are available (technical data, functional KPIs, failure history, condition monitoring history)	21	66%	9	28%	2	6%	0	0%	0	0%								
17	The main purpose of EMM is control, plan and monitor maintenance and spare parts relating to electrical motors.	2	6%	0	0%	0	0%	19	59%	11	34%								

4.2.2.1.2 Analysis and interpretation

EMM Effective

From the survey it is evident that the majority of respondents are not satisfied with the perceived effectiveness of EMM as 75% of the respondents categorised EMM as “not effective”.

EMM managed

A mere 6% of the respondents agreed that EMM activities are in actual fact being managed, this indicates perceived lack of management support and leadership behind EMM.

EMM reported

It is further palpable that management drive and leadership is a problem pertaining to EMM as there are currently no management performance indicators being reported for EMM (0% respondents know of EMM management performance indicators being reported). In contrast management drive exists in safety and quality aspects confirmed by the respondents’ data where 100% agree that safety management performance indicators are being reported and 50% agree that quality management performance indicators being reported.

If no performance indicators for EMM are reported then no management interventions will exist to curb bad performance or to improve EMM-activities, hence further supporting the notion that there is a lack of management support and drive.

EMM Stakeholders

Respondents agree that procurement staff; managers; engineers; technicians; artisans; planners and clerks are involved in EMM-activities and grossly disagree the involvement of safety officers and project managers. This implies the population do understand that EMM relates to many stakeholders other than themselves.

EMM improvement areas

The majority of respondents indicated that they would like to see improvements to EMM activities relating to: workflow (97%); procedures (100%); ownership (88%); policies (97%) and processes (100%). On the contrary, the respondents were fairly happy with the current approval levels as 50% of the respondents deemed this aspect adequate.

Asset management supporting EMM

100% of the respondents indicated that there are no functional block diagrams to support the asset hierarchies, this was found to be in direct contrast to what was proposed in literature (Moubray, 1997) as functional block diagrams are utilised in defining metrics for performance management and continuous improvement, thus implying a direct limitations to current EMM-activities within ESD at the large steel manufacturer.

Accurate system data

94% of the respondents reported that there is complete lack of accurate system data for records pertaining to electrical motor technical data, functional KPIs, failure history and condition monitoring history. In the literature review, record keeping was recognised to be of utmost importance for identifying trends, supporting knowledge retention and identifying sub-standard suppliers/service (Du Toit, 2014).

EMM = Maintenance?

EMM is wrongfully perceived to consist mainly of maintenance management activities, this statement is supported by 94% of the questionnaire respondents indicating the aforementioned statement. A mere 6% were cognisant that EMM is more than just maintenance management. To no surprise the 6% of respondents were in the age bracket 56-65 years. Follow-up discussions with the 6% respondents revealed that their experience over the years have taught them valuable lessons where they were able to identify shortcomings in a “maintenance-only” approach.

4.2.2.2 Process management activities questions

The intention of the part of the questionnaire was to establish the status quo relating to process management related activities as part of EMM and to enable the status quo comparison against literature.

4.2.2.2.1 Respondent data

Table 4.2-3 below depicts answers from the respondents within the sample group relating to establish the status quo for general process management activities and will be discussed in the subsequent paragraph.

Table 4.2-3: Answers for process management activities general questions

PROCESS MANAGEMENT ACTIVITIES											
Question Number	QUESTION	OPTION SELECTED									
		1		2		3		4		5	
		n	%	n	%	n	%	n	%	n	%
18	The objective for EMM is clearly defined.	14	44%	13	41%	5	16%	0	0%	0	0%
19	Human resources relating to each EMM-activity are clearly defined.	15	47%	14	44%	3	9%	0	0%	0	0%
20	Equipment and methods forming part of EMM are clearly defined to aid in achieving the EMM objective.	20	63%	8	25%	4	13%	0	0%	0	0%
21	The quality of the processes relating to EMM used to develop, deliver, and support services and production are providing production and service outputs which are high in quality.	23	72%	8	25%	1	3%		0%		0%
22	Long term vision and strategy are defined for EMM	29	91%	3	9%	0	0%	0	0%	0	0%
23	Management support forms the premise of process improvement relating to EMM	31	97%	1	3%	0	0%	0	0%	0	0%
24	The culture and infrastructure at the large steel manufacturer relating to EMM is supported by the development and deployment of procedures which are maintained, revised and improved.	32	100%	0	0%	0	0%	0	0%	0	0%
25	The culture and infrastructure at the large steel manufacturer relating to EMM is supported and enforced through standard operating practices.	18	56%	11	34%	3	9%		0%		0%
26	Procedures, standard operating practices and methods relating to EMM will continue even when authors of the procedures, standard operating practices and methods relating to EMM are no longer working at the organisation.	21	66%	11	34%	0	0%	0	0%	0	0%

4.2.2.2.2 Analysis and interpretation

84% of the respondents stated that there is no EMM objective defined, which is one direct requirement for EMM. 91% of the respondents stated that human resources relating to EMM are not defined, follow-up discussions with the respondents revealed that resources have not been defined that need to be involved various EMM-activities due to the approach deployed relating electrical motors. Maintenance gets done on job card basis, the problems experienced is that job card data and intervals are not based on actual operating parameters (inaccurate system data), i.e. the job cards are based on a predetermined fixed time intervals for each motor. When the maintenance team go to the motor to execute motor maintenance they find the running hours indicator has been reset (so they don't know how many hours the motor has been in operation and what type of maintenance needs to be executed (each

predefined interval has got different maintenance activities allocated (e.g. bearing lubrication, cleaning, running vibration readings, disposal/rewind etc.)). Other scenarios is that the motor has not been in operation (chopped over as the standby motor). All these factors have contributed to the job cards being perceived less and less important to the point where a firefighting approach has been deployed, i.e. fix it when it breaks. This was found to be a key contributing factor for no dedicated human resources deployed to improve/implement EMM-activities.

From the questionnaire respondent data in Table 4.2-3 the underlying theme is that the processes in terms of EMM are non-existent and not managed. This lack of management interventions and guidance leads to a non-existing culture relating to EMM where employees are not enticed, aligned nor committed to improve EMM-activities. It is clear management needs to do some introspection in this regard to be the source of compliance, inspiration and strategic alignment to develop and nurture an EMM-culture.

Procedures, standard operating practices and methods relating to EMM process management activities need to be developed, deployed, communicated and enforced through management controls and measures. Management need to identify the equipment- and human-resources required to meet the defined EMM-objective.

All the aforementioned lacking aspects pertaining to process management activities form part of the ISO9001 requirements.

4.2.2.3 Process management activities institutionalised

This part of the survey was intended to measure whether processes are entrenched by the manner in which the work gets executed and whether there is commitment and consistency to the process being performed.

4.2.2.3.1 Respondent data

Table 4.2-4 below depicts answers from the respondents within the sample group to establish the status quo as to whether process management activities are institutionalised.

Table 4.2-4: Answers for process management activities institutionalised

PROCESS MANAGEMENT ACTIVITIES INSTITUTIONALISED											
Question Number	QUESTION	OPTION SELECTED									
		1		2		3		4		5	
		n	%	n	%	n	%	n	%	n	%
27	leadership (PA1)	26	81%	3	9%	1	3%	2	6%	0	0%
28	planning (PA2)	16	50%	14	44%	0	0%	2	6%	0	0%
29	policies, procedures and internal controls (PA3)	14	44%	14	44%	4	13%	0	0%	0	0%
30	personnel and staffing (PA4)	13	41%	13	41%	6	19%	0	0%		0%
31	financial management (PA5)	0	0%	0	0%	3	9%	18	56%	11	34%
32	technology utilisation and management (PA6)	0	0%	0	0%	2	6%	27	84%	3	9%
33	records and reporting (PA7)	11	34%	4	13%	13	41%	4	13%	0	0%
34	quality management (PA8)	4	13%	19	59%	1	3%	8	25%	0	0%
35	risk management (PA9)	5	16%	20	63%	3	9%	4	13%	0	0%
36	configuration management (PA10)	27	84%	4	13%	1	3%	0	0%	0	0%
37	assessments (P11)	29	91%	3	9%	0	0%	0	0%	0	0%

4.2.2.3.2 Analysis and interpretation

Leadership (PA1)

The majority (91%) of respondents indicated that the leadership is not effective for EMM-activities.

Planning (PA2)

The majority (94%) of respondents indicated that the planning is not effective for EMM-activities, where staff were appointed to EMM-activities (mostly maintenance, breakdown (procurement and logistics) and troubleshooting activities) ad-hoc basis and that other activities deemed of greater importance always take precedence resulting in little to no continuity in EMM-related efforts, thus indicating a clear shortcoming in the planning activities.

Policies, procedures and internal controls (PA3)

The majority (88%) of respondents indicated that the policies, procedures and internal controls are not effective for EMM-activities.

Personnel and staffing (PA4)

The majority (88%) of respondents indicated that the personnel and staffing are not effective (adequate) for EMM-activities. Follow-up discussions indicated that the staffing were appointed on an ad-hoc basis and that other activities deemed of greater importance always

take precedence resulting in little to no continuity in EMM-related efforts. The respondents also clarified that the present EMM-activities are more like individual efforts opposed to structured team work with predefined responsibilities aligned with the individual's current skills and knowledge.

The respondents were in slight contradiction with question 12 (general question) where a mere 50% indicated that personnel and staffing aspects were not effective and 44% took a neutral stance and 6% deemed this aspect effective. In contrast, for question number 30, there were 0% of the respondents that indicated personnel and staffing as effective.

Financial management (PA5)

The majority of the respondents (91%) indicated that the financial management activities are very effective and the adequate control is exercised. The other 9% of the respondents felt that no cost/benefit trade-offs are done prior to breakdown scenarios, which in their view lead to unnecessary excessive cost being incurred to get operations back on line or within control. More work needs to be done in this regard to minimise breakdown costs (spares, more standby systems to eliminate bottlenecks due to breakdowns).

Technology utilisation and management (PA6)

The majority (88%) of respondents indicated that the technology utilisation and management is effective for EMM-activities.

Records and reporting (PA7)

47% of respondents indicated that the records and reporting for EMM-activities are not effective and 41% of the respondents took a neutral stance. Follow-up discussions revealed that the 41% of the respondents never generated nor used records pertaining to EMM-activities (and that they were not aware of existing documents) and further indicated that they weren't sure whether there was any reporting taking place for EMM-activities. This implies that there is a definite communication shortfall in this regard causing the uncertainty and misalignment to what is "expected" by the leadership team.

Quality management (PA8)

The majority (72%) of the respondents showed to be consistent to the answer they presented in question number 21, i.e. quality management is not effective.

Risk management (PA9)

The majority (72%) of the respondents indicated risk management relating EMM-activities to be not effective.

Configuration management (PA10)

The majority (97%) of the respondents indicated configuration management relating EMM-activities to be not effective.

Assessments (P11)

All the respondents (100%) indicated that the assessments are not effective relating to EMM. Discussions revealed that all the respondents have never seen any assessments relating to EMM. With regards to inventory assessments, inventory within the enterprise resource planning (ERP) software (SAP) gets updated is on a reactive basis (during breakdowns or when old electrical motors are replaced with new ones). There is also no evidence of internal audits nor third party audits relating to EMM activities.

4.2.2.4 Process management activity improvement required

This section is of the questionnaire was intended to establish which aspects the end-users of EMM-activities would like to see improvements for, respondents were tasked with providing an indication whether they would like to see improvements relating to process management. If the respondents indicated that they do not want improvements they were tasked to move on to the next part of the questionnaire

4.2.2.4.1 Respondent data

Table 4.2-5 below depicts answers from the respondents within the sample group to establish the status quo as to whether process management activities require improvement.

Table 4.2-5: Process management activity improvement required

PROCESS MANAGEMENT ACTIVITY IMPROVEMENT REQUIRED											
Question Number	QUESTION	OPTION SELECTED									
		1		2		3		4		5	
		n	%	n	%	n	%	n	%	n	%
38	Would you like to see improvements relating to process management activities? (YES or NO) a. If answer in question 38 was YES", please proceed by answering question 39 and beyond. b. If the answer in the aforementioned question was "NO", please skip questions 39-49 and proceed to question 50.	32	100%	0	0%						
39	Leadership (PA1)	0	0%	0	0%	2	6%	23	72%	7	22%
40	planning (PA2)	0	0%	0	0%	0	0%	27	84%	5	16%
41	policies, procedures and internal controls (PA3)	0	0%	0	0%	2	6%	1	3%	29	91%
42	personnel and staffing (PA4)	0	0%	0	0%	15	47%	16	50%	1	3%
43	financial management (PA5)	0	0%	11	34%	11	34%	10	31%	0	0%
44	technology utilisation and management (PA6)	0	0%	0	0%	11	34%	5	16%	16	50%
45	records and reporting (PA7)	0	0%	0	0%	1	3%	2	6%	29	91%
46	quality management (PA8)	2	6%	14	44%	9	28%	7	22%	0	0%
47	risk management (PA9)	1	3%	16	50%	15	47%	0	0%	0	0%
48	configuration management (PA10)	31	97%	1	3%	0	0%	0	0%	0	0%
49	assessments (P11)	0	0%	0	0%	0	0%	5	16%	27	84%

4.2.2.4.2 Analysis and interpretation

All respondents indicated that they would like to see improvements. An interesting observation here is that the respondents wanted improvements for all aspects except for quality management; risk management and configuration management. Follow up discussions revealed that the respondents felt that the aforementioned aspect should only

be implemented once the basics have been put in place. Their perception was that quality management; risk management and configuration management aspects should be implemented at a later stage. This should be considered during future work in bringing about improvement as success is greatly affected in the level of buy-in from all stakeholders, otherwise they could be felt that their inputs were ignored (the future work needs to be sensitive to the approaches deployed).

4.2.2.5 Acquisition operation management activities institutionalised

This part of the survey was intended to measure whether acquisition operation management activities are entrenched by the manner in which the work gets executed and whether there is commitment and consistency to the process being performed.

4.2.2.5.1 Respondent data

Table 4.2-6 below depicts answers from the respondents within the sample group to establish the status quo as to whether acquisition operation management activities are defined and institutionalised.

Table 4.2-6: Acquisition operation management activities defined and institutionalised

OPERATION MANAGEMENT ACTIVITIES – ACQUISITION LIFE CYCLE PHASE											
Question Number	QUESTION	OPTION SELECTED									
		1		2		3		4		5	
		n	%	n	%	n	%	n	%	n	%
50	Operation management activities are defined specific to the acquisition life-cycle phase	14	44%	18	56%	0	0%	0	0%	0	0%
ACQUISITION OPERATION MANAGEMENT ACTIVITIES INSTITUTIONALISED											
Question Number	QUESTION	OPTION SELECTED									
		1		2		3		4		5	
		n	%	n	%	n	%	n	%	n	%
51	Requirements determination (PA1)	30	94%	2	6%	0	0%	0	0%	0	0%
52	categorisation (PA2)	12	38%	10	31%	10	31%	0	0%	0	0%
53	authorisation (PA3)	1	3%	20	63%	11	34%	0	0%	0	0%
54	procurement (PA4)	0	0%	14	44%	13	41%	3	9%	2	6%
55	construction in progress management (PA5)	0	0%	0	0%	29	91%	3	9%	0	0%
56	receiving (PA6)	0	0%	0	0%	3	9%	21	66%	8	25%
57	identification (PA7)	5	16%	2	6%	0	0%	19	59%	6	19%
58	financial recognition (PA8)	17	53%	5	16%	10	31%	0	0%	0	0%

4.2.2.5.2 Analysis and interpretation

100% of the respondents indicated that the operation management activities for the acquisition life-cycle phase are not defined.

Requirements determination (PA1)

100% of respondents indicated that requirements determination is not effective for EMM-activities.

Categorisation (PA2)

69% of respondents indicated that categorisation is not effective for EMM-activities.

Authorisation (PA3)

66% of respondents indicated that authorisation is not effective for EMM-activities. Follow-up discussions with the respondents indicated that authorisation only occurs on financial related aspects by financial responsible parties, there exists no control point for the EMM-custodian to intervene and check whether technical- and process-requirements were satisfied.

Procurement (PA4)

The majority (44%) of respondents deemed the procurement not effective and 41% of the respondents took a neutral stance. Follow-up discussions with the respondents who allocated a neutral score, indicated that they refrained from scoring on activities to which they have zero input.

The lacking aspects were aspects where the reutilisation possibilities aren't considered prior to the acquisition of new/replacement electrical motors which was directly attributable to outdated inventory within the ERP-system. Further, leasing of electrical motors has never been considered as an option during trade-off studies prior to procurement.

Construction in progress management (PA5)

Most of the respondents (91%) took a neutral stance on this aspect. Respondents indicated that they refrained from scoring on activities to which they have zero input. The other 9% of

respondents are involved in new projects and indicated that the construction in progress management is effective.

Receiving (PA6)

91% of respondents indicated that receiving is effective for EMM-activities.

Identification (PA7)

78% of respondents indicated that identification is effective for EMM-activities.

During follow-up discussions the other 22% of respondents indicated that they felt shortcoming aspects were quality assurance of the goods received as they have in the past put the “new” electrical motors into operation to find the electrical motor winding leads coming into the terminal box connection (internal on the motor side) were incorrect (phases swapped) and in some instances the leads were shorting down to earth. Other comments included that the electrical motor colours of the frame did not match the specification that was sent out.

Financial recognition (PA8)

69% of respondents indicated that financial recognition is not effective for EMM-activities. Newly refurbished motors were not always updated with their new value directly after refurbishments have taken place. These newly refurbished electrical motors were kept on the same low depreciated value (do to the electrical motor already being depreciated for the past 10-15 years prior to the refurbishment).

Follow-up discussions with the other 31% of respondents who allocated a neutral score, indicated that they refrained from scoring on activities to which they have zero input.

4.2.2.6 Improvements required for acquisition operation management activities

This section is of the questionnaire was intended to establish which aspects the end-users of EMM-activities would like to see improvements for, respondents were tasked with providing an indication whether they would like to see improvements relating to acquisition LCP operation management activities. If the respondents indicated that they do not want improvements they were tasked to move on to the next part of the questionnaire

4.2.2.6.1 Respondent data

Table 4.2-7 below depicts answers from the respondents within the sample group to establish the status quo as to whether acquisition operation management activities require improvement.

Table 4.2-7: Improvements required for acquisition operation management activities

IMPROVEMENTS REQUIRED FOR ACQUISITION OPERATION MANAGEMENT ACTIVITIES											
Question Number	QUESTION	OPTION SELECTED									
		1		2		3		4		5	
		n	%	n	%	n	%	n	%	n	%
59	Would you like to see improvements relating to acquisition operation management activities? (YES or NO) a. If answer in question 59 was YES", please proceed by answering question 60 and beyond. b. If the answer in the aforementioned question was "NO", please skip questions 60-67 and proceed to question 68.	32	100%	0	0%						
60	requirements determination (PA1)	0	0%	0	0%	0	0%	3	9%	29	91%
61	categorisation (PA2)	0	0%	15	47%	7	22%	0	0%	10	31%
62	authorisation (PA3)	0	0%	0	0%	10	31%	20	63%	2	6%
63	procurement (PA4)	0	0%	6	19%	4	13%	22	69%	0	0%
64	construction in progress management (PA5)	25	78%	0	0%	7	22%	0	0%	0	0%
65	receiving (PA6)	6	19%	23	72%	3	9%	0	0%	0	0%
66	identification (PA7)	0	0%	9	28%	2	6%	18	56%	3	9%
67	financial recognition (PA8)	0	0%	8	25%	19	59%	5	16%	0	0%

4.2.2.6.2 Analysis and interpretation

All respondents indicated that they would like to see improvements. An interesting observation here is that the respondents wanted improvements for all aspects except for categorisation; construction in progress; receiving and financial recognition. Follow up discussions revealed the perceived value would be negligible and that they would rather address low hanging fruit that would have bigger impact on the maturity levels of EMM-activities. This also aligns with the Pareto-concept that implies focussing efforts on 20% of activities that will give 80% of the results. The Pareto-concept seemed to be very popular amongst the respondents as this concept kept on repeating in the follow-up discussions by various respondents. This concept doesn't seem to fit into the maturity model presented in this research and should be explored as part of future work.

4.2.2.7 Usage operation management activities institutionalised

This part of the survey was intended to measure whether usage operation management activities are entrenched by the manner in which the work gets executed and whether there is commitment and consistency to the process being performed.

4.2.2.7.1 Respondent data

Table 4.2-8 below depicts answers from the respondents within the sample group to establish the status quo as to whether usage operation management activities are defined and institutionalised.

Table 4.2-8: Usage operation management activities institutionalised and defined

OPERATION MANAGEMENT ACTIVITIES – USAGE LIFE CYCLE PHASE											
Question Number	QUESTION	OPTION SELECTED									
		1		2		3		4		5	
		n	%	n	%	n	%	n	%	n	%
68	Operation management activities are defined specific to the usage life-cycle phase	0	0%	16	50%	6	19%	6	19%	4	13%
USAGE OPERATION MANAGEMENT ACTIVITIES INSTITUTIONALISED											
Question Number	QUESTION	OPTION SELECTED									
		1		2		3		4		5	
		n	%	n	%	n	%	n	%	n	%
69	Utilisation (PA1)	0	0%	23	72%	8	25%	1	3%	0	0%
70	control (PA2)	0	0%	0	0%	18	56%	14	44%	0	0%
71	tracking (PA3)	2	6%	16	50%	14	44%	0	0%	0	0%
72	maintenance (PA4)	4	13%	13	41%	15	47%	0	0%	0	0%
73	safety (PA5)	0	0%	0	0%	4	12.5%	22	68.5%	6	19%
74	security (PA6)	0	0%	0	0%	4	12.5%	25	77.5%	3	9%

4.2.2.7.2 Analysis and interpretation

50% of the respondents indicated that the operation management activities for the usage life-cycle phase are not defined and in contrast, 31% stated that it is defined. This contradiction implies that not all stakeholders are aligned or aware of all the usage LCP activities that are currently in existence. The questions that follow (69-74) would shed some light in this regard.

Utilisation (PA1)

The majority (72%) of the respondents felt that the current utilisation activities are not effective. The respondents stated that in accordance with the defined utilisation activities there are shortcomings. There are corrective and preventative measures which have been introduced to maximise electrical motor availability (this constitutes partial implementation of reliability strategies (respondents indicated that only high value electrical motors have been addressed in this regard)). The respondents also indicated that there has been a focus on electrical motor usage optimisation where variable speed drives have been deployed to decrease energy consumption and to provide the ability to control process requirements in a more efficient manner (instead of throttling valves within water treatment processes as an example).

Control (PA2)

44% of the respondents indicated that the control activities are effective and 56% gave a neutral score in this regard. Follow-up discussions with the respondents who allocated a neutral score, indicated that they refrained from scoring on activities to which they have zero input.

Tracking (PA3)

The majority (56%) of respondents deemed the tracking activities not effective and 44% of the respondents took a neutral stance. Follow-up discussions with the respondents who allocated a neutral score, indicated that they refrained from scoring on activities to which they have zero input.

Maintenance (PA4)

The majority (53%) of respondents deemed the maintenance activities not effective and 44% of the respondents took a neutral stance. Follow-up discussions with the respondents who allocated a neutral score, indicated that they refrained from scoring on activities to which they have zero input.

Further points stemming from the follow up discussions indicated that there exists a policy statement combined with a documented reliability process. The 53% respondents who have indicated maintenance as not effective due to the knowledge that they are not complying with their own documented policies and processes. This mainly owing to the fact that roles and responsibilities have not been defined nor have adequate resources been deployed to

roll out the said initiatives. The respondents also indicated that buy-in to EMM will be low if this scenario repeats itself as everyone will start the EMM-activities knowing how it will turn out in the end, i.e. resources will just end up going back to their daily tasks which is deemed of higher importance, hampering any continuity and progress which has caused deleterious effects on esteem toward initiatives (such as EMM improvement efforts).

Safety (PA5)

The majority (87.5%) of respondents deemed safety as effective and 12.5% of the respondents took a neutral stance. Follow-up discussions with the respondents who allocated a neutral score, indicated that they refrained from scoring on activities to which they have zero input.

Security (PA6)

The majority (87.5%) of respondents deemed security as effective and 12.5% of the respondents took a neutral stance. Follow-up discussions with the respondents who allocated a neutral score, indicated that they refrained from scoring on activities to which they have zero input.

From the data presented above, 28% of respondents have indicated that they deem 3 out of 6 activities effective (control; safety and security) and then the same 28% respondents continued to answer neutral to remaining 3 aspects. This has skewed the data for question 68, as these 28% respondents were the same who indicated that the operation management activities are effectively defined specific to the usage life-cycle phase.

4.2.2.8 Improvements required for usage operation management activities

This section is of the questionnaire was intended to establish which aspects the end-users of EMM-activities would like to see improvements for, respondents were tasked with providing an indication whether they would like to see improvements relating to usage operation management activities. If the respondents indicated that they do not want improvements they were tasked to move on to the next part of the questionnaire

4.2.2.8.1 Respondent data

Table 4.2-9 below depicts answers from the respondents within the sample group to establish the status quo as to whether usage operation management activities require improvement.

Table 4.2-9: Improvements required for usage operation management activities

IMPROVEMENTS REQUIRED FOR USAGE OPERATION MANAGEMENT ACTIVITIES											
Question Number	QUESTION	OPTION SELECTED									
		1		2		3		4		5	
		n	%	n	%	n	%	n	%	n	%
75	Would you like to see improvements relating to usage operation management activities? (YES or NO) a. If answer in question 75 was YES", please proceed by answering question 76 and beyond. b. If the answer in the aforementioned question was "NO", please skip questions 76-81 and proceed to question 82.	32	100%	0	0%						
76	Utilisation (PA1)	0	0%	0	0%	1	3%	6	19%	25	78%
77	control (PA2)	0	0%	15	47%	5	16%	9	28%	3	9%
78	tracking (PA3)	0	0%	0	0%	2	6%	26	81%	4	13%
79	maintenance (PA4)	0	0%	0	0%	0	0%	0	0%	32	100%
80	safety (PA5)	0	0%	1	3%	22	69%	8	25%	1	3%
81	security (PA6)	0	0%	21	66%	11	34%	0	0%	0	0%

4.2.2.8.2 Analysis and interpretation

All respondents indicated that they would like to see improvements. An interesting observation here is that the majority of respondents wanted improvements for all aspects except for control and security. This exclusion is also consistent to the answers respondents have presented earlier in question-70 and question-74.

4.2.2.9 Disposal operation management activities institutionalised

This part of the survey was intended to measure whether disposal LCP operation management activities are entrenched by the manner in which the work gets executed and whether there is commitment and consistency to the process being performed.

4.2.2.9.1 Respondent data

Table 4.2-10 below depicts answers from the respondents within the sample group to establish the status quo as to whether disposal operation management activities are defined and institutionalised.

Table 4.2-10: Disposal operation management activities institutionalised and defined

OPERATION MANAGEMENT ACTIVITIES – DISPOSAL LIFE CYCLE PHASE											
Question Number	QUESTION	OPTION SELECTED									
		1		2		3		4		5	
		n	%	n	%	n	%	n	%	n	%
82	Operation management activities are defined specific to the **disposal life-cycle phase**	0	0%	27	84%	5	16%	0	0%	0	0%
DISPOSAL OPERATION MANAGEMENT ACTIVITIES INSTITUTIONALISED											
Question Number	QUESTION	OPTION SELECTED									
		1		2		3		4		5	
		n	%	n	%	n	%	n	%	n	%
83	Reutilisation (PA1)	0	0%	0	0%	2	6%	4	13%	26	81%
84	authorisation to dispose (PA2)	0	0%	3	9%	24	75%	5	16%	0	0%
85	transport, storage, and handling (PA3)	12	38%	8	25%	12	38%	0	0%	0	0%
86	disposal (PA4)	14	44%	5	16%	13	41%	0	0%	0	0%

4.2.2.9.2 Analysis and interpretation

The majority (84%) of the respondents indicated that the operation management activities for the disposal life-cycle phase are not effectively defined.

Reutilisation (PA1)

The majority (94%) of the respondents indicated that the reutilisation activities are not effective. The observation made in this regard is that if the acquisition activities and usage activities that have input to reutilisation activities are deemed not effective it will immediately deem the reutilisation activity not effective due to the preceding LCPs having direct inputs to reutilisation activities. Receiving (PA6) and identification (PA7), part of the acquisition activities, these aspects were deemed effective evident by the respondent data for question-56 and question-57. The problematic input data stems from the usage activities, more specifically utilisation (PA1) and tracking (PA3), these aspects were deemed not effective evident by the respondent data for question-69 and question-71.

Transport, storage, and handling (PA3)

The majority (63%) of the respondents indicated that the transport, storage and handling activities as not effective. Follow-up discussion revealed that after electrical motors are no longer in use they remain on the plant where they were initially installed and remains there

until it erodes to the point of posing safety and security concerns. The aforementioned may be the case for many years up to the point where the motors can no longer be reutilised and is definitely not in line with OEM-storage and handling recommendations.

Disposal (PA4)

The majority (59%) of the respondents indicated that the disposal activities as not effective. This is mainly attributable to electrical motors not being timeously disposed of when it holds greater value than a badly eroded electrical motor with no possible working spares.

4.2.2.10 Improvements required for disposal operation management activities

4.2.2.10.1 Respondent data

Table 4.2-11 below depicts answers from the respondents within the sample group to establish the status quo as to whether disposal operation management activities require improvement.

Table 4.2-11: Improvements required for disposal operation management activities

IMPROVEMENTS REQUIRED FOR DISPOSAL OPERATION MANAGEMENT ACTIVITIES											
Question Number	QUESTION	OPTION SELECTED									
		1		2		3		4		5	
		n	%	n	%	n	%	n	%	n	%
87	Would you like to see improvements relating to disposal operation management activities? (YES or NO) a. If answer in question 87 was YES", please proceed by answering question 88 and beyond. b. If the answer in the aforementioned question was "NO", please skip questions 88-91 and proceed to question 92.	32	100%	0	0%						
88	Reutilisation (PA1)	0	0%	0	0%	0	0%	23	72%	9	28%
89	authorisation to dispose (PA2)	12	38%	13	41%	7	22%	0	0%	0	0%
90	transport, storage, and handling (PA3)	20	63%	11	34%	0	0%	1	3%	0	0%
91	disposal (PA4)	14	44%	14	44%	3	9%	1	3%	0	0%

4.2.2.10.2 Analysis and interpretation

All respondents indicated that they would like to see improvements (question 87). An interesting observation here is that all of the respondents only wanted to see improvements for reutilisation activities (PA1). Follow up discussions revealed that the stakeholders would rather focus their efforts on activities in the acquisition- and usage LCP-activities as they perceive their efforts would add greater value.

4.2.3 STAFF AND MANAGEMENT ATTITUDES AND BELIEFS

This section is intended to explore staff and management attitudes and beliefs relating to EMM at ESD within a large steel manufacturer.

4.2.3.1 Respondent data

Table 4.2-11 below depicts answers from the respondents within the sample group to establish the status quo as to whether disposal operation management activities require improvement.

Table 4.2-12: Staff and management attitudes and beliefs

Number of Respondents	**32**
Number of valid respondents	**32**

STAFF AND MANAGEMENT ATTITUDES AND BELIEFS											
Question Number	**QUESTION**	**OPTION SELECTED**									
		1		**2**		**3**		**4**		**5**	
		n	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
92	EMM implementation is largely adversely affected by the existing stakeholder culture.	0	0%	11	34%	3	9%	15	47%	3	9%
93	Acceptance from plant personnel is vital for successful implementation of EMM.	0	0%	9	28%	3	9%	17	53%	3	9%
94	ESD has enough resources to successfully implement an EMM-program (availability of funds and people)?	14	44%	12	38%	6	19%	0	0%	0	0%
95	ESD has a culture that will accept the implementation of EMM	0	0%	0	0%	3	9%	19	59%	10	31%
96	When employees are aligned in knowing why, how and when the result of a new program will have positive outcome	0	0%	0	0%	0	0%	0	0%	32	100%
97	An ownership culture needs to be driven by management	0	0%	0	0%	0	0%	30	94%	2	6%
98	A ownership culture needs to be driven by employees themselves	0	0%	9	28%	1	3%	21	66%	1	3%
99	A workplace needs to be supported by strong and well defined processes	0	0%	0	0%	0	0%	0	0%	32	100%
100	EMM is too difficult to deploy successfully	8	25%	8	25%	5	16%	10	31%	1	3%
101	EMM is too time consuming to deploy successfully	11	34%	9	28%	7	22%	0	0%	5	16%
102	EMM-related audits will help drive success and compliance, which will lead to good EMM-related habits amongst employees	0	0%	0	0%	0	0%	2	6%	30	94%
103	Outsourcing of EMM-related activities is the only way to make EMM work	0	0%	8	25%	11	34%	13	41%	0	0%
104	EMM-related activities requires a dedicated team to ensure success	0	0%	5	16%	0	0%	13	41%	14	44%
105	EMM-related activities can be successfully executed by existing stakeholders at ESD	0	0%	5	16%	1	3%	13	41%	13	41%
106	ESD have the requisite skills and knowledge for implementing EMM	0	0%	0	0%	0	0%	15	47%	17	53%
107	The custodian of EMM is still responsible for their normal daily plant activities	0	0%	0	0%	5	16%	22	69%	5	16%
108	Existing EMM activities at ESD are successful	2	6%	23	72%	7	22%	0	0%	0	0%

4.2.3.2 Analysis and interpretation

- The majority of respondents (56%) indicated that the existing stakeholder culture will adversely affect the implementation of EMM. Follow up discussions clarified that the existing culture of only doing what is absolutely perceived necessary will have minimalist approach being deployed by the employees, where it has been observed (by 43% of the respondents) that they tend to selectively implement activities they perceive of importance. This implies that the leadership need to clearly communicate:
    - the expected outcomes for each EMM activity and
    - what is envisioned to be achieved by executing each activity.
- 63% of respondents indicated that the acceptance plant personnel is vital to EMM implementation success, which once again can only be achieved if leadership communicated and aligns everyone properly as in the aforementioned bullet.
- 81% of the respondents indicated that there are not enough resources to successfully implement EMM.
- 91% of the respondent indicated that the engineering service department (ESD) at the large steel manufacturer has a culture that will accept EMM-implementation
- 100% of the respondents have indicated that it is of paramount importance to align all stakeholders and communicating why, how and when EMM will be implemented and to communicate when the program is expected to have positive outcomes
- 100% of the respondents have indicated that an ownership culture needs to be driven by management which implies that management will have to develop performance indicators in this regard and conduct weekly and monthly reporting to monitor and provide leadership as to which aspects need to be managed.
- 69% of the respondents have indicated that an ownership culture needs to be driven by the employees themselves. This implies that every stakeholder needs to drive show a leadership attitude to drive success.
- 100% of the respondents have indicated that the workplace needs to be supported by strong and well defined processes. This implies the employees do understand the importance of the structure and that the implementation documented processes defines and controls these structures to support employees in their tasks.
- Question-100 and question-101 were intended to test the attitudes of the respondents, the majority of the respondents have a positive outlook toward implementation of EMM.

- 100% of the respondents fully agree that the audits will aid success by driving the compliance and entrench good EMM habits amongst employees.
- The majority of respondents (41%) believed that outsourcing EMM-activities is the only way for success, while only 25% disagreed with this statement.
- 84% of the respondent indicated that to ensure EMM success is to have dedicated resources focusing on the related activities.
- All the respondents (100%) do believe that the existing employees possess the requisite skills and knowledge to implement EMM.
- The majority of respondents (84%) indicated that the EMM-custodian is still responsible for their normal day to day plant activities.
- The majority of respondents (78%) indicated that the existing EMM-activities are not successful.

4.3 EMM STATUS QUO COMPARED TO REQUIREMENTS IN LITERATURE

The researcher has intentionally set up the survey questions to align with the requirements as found literature to ease the comparison of literature and status quo for EMM at the engineering service department within the large steel manufacturer.

4.3.1 GENERAL

For this section there were no literature requirements, this section was utilised as a means of obtaining additional information required to establish the status quo. The findings were as follow:

- EMM activities are in actual fact not being managed, this indicates perceived lack of management support and leadership behind EMM.
- Majority of respondents are not satisfied with the effectiveness of EMM.
- EMM in not being reported and managed (monitored and controlled) as there are currently no management performance indicators being reported for EMM.
- The population do understand that EMM relates to many stakeholders other than themselves.
- There are no functional block diagrams to support the asset hierarchies, implying that asset management activities are not yet complimenting the EMM-activities.
- There is complete lack of accurate system data for records pertaining to electrical motor technical data, functional KPIs, failure history and condition monitoring history.
- EMM is wrongfully perceived to consist mainly of maintenance management activities, this statement is supported by 94% of the questionnaire respondents indicating the aforementioned statement.

4.3.2 PROCESS MANAGEMENT ACTIVITIES

When comparing the survey data to the requirements in literature the findings were as follow:

- There is currently no EMM objective defined.
- Human resources relating to EMM are not defined.
- Inaccurate system data is adversely affecting electrical motor maintenance efforts and efficiency.
- The EMM-processes are incomplete and not managed.
- There is a lack of management interventions and guidance which leads to a non-existing culture relating to EMM-activities where employees are not enticed, aligned nor committed to improve EMM-activities.

- Management needs to be the source of leadership to drive compliance, inspiration and provide strategic alignment to develop and nurture an EMM-culture.
- EMM process management activities need to be developed, deployed, communicated and enforced through management controls and measures.
- Management need to identify the equipment- and human-resources required to meet the defined EMM-objective.
- EMM-activities at ESD within the large steel manufacturer are not in compliance with ISO9001 requirements to which the large steel manufacturer is accredited.
- Planning is not effective for EMM-activities (yet another ISO9001 aspect).
- Financial management activities are very effective and the adequate control is exercised.
- Technology utilisation and management is effective for EMM-activities.
- Records and reporting for EMM-activities are not effective.
- Quality management for EMM-activities is not effective.
- Risk management relating EMM-activities is not effective.
- Configuration management relating EMM-activities is not effective.
- Assessments are not effective relating to EMM, there exists no evidence of internal audits nor third party audits relating to EMM activities.
- All respondents indicated that they would like to see improvements to process management activities.
- The respondents wanted improvements for all process management activities except for quality management; risk management and configuration management. Respondents felt that the aforementioned aspect should only be implemented once the basics have been put in place. These aspects should be considered and the reasoning needs to be resound and clearly communicated otherwise the respondents (who are also the stakeholders) could be interpret their inputs as ignored and in turn could limit buy-in to the concept of EMM. Success is greatly affected in the level of buy-in from all stakeholders.

4.3.3 ACQUISITION LCP OPERATION MANAGEMENT

When comparing the survey data to the requirements in literature the findings were as follow:

- Operation management activities for the acquisition life-cycle phase are not defined.
- Requirements determination is not effective.
- Categorisation is not effective.

- Authorisation is not effective as it only occurs on financial related aspects by financial responsible parties, there exists no control point for the EMM-custodian to intervene and check whether technical- and process-requirements were satisfied.
- Procurement activities are not effective due to
    - reutilisation possibilities not being considered prior to the acquisition of new/replacement electrical motors which was directly attributable to outdated inventory within the ERP-system.
    - leasing of electrical motors not being considered as an option during trade-off studies prior to procurement.
- Construction in progress management is effective.
- Receiving is effective.
- Identification is perceived effective, but the shortcoming aspects was found to be quality assurance of the goods received.
- Financial recognition is not effective, as an example newly refurbished motors were not always updated with their new value directly after refurbishments have taken place.
- The respondents indicated that they would like to see improvements for all acquisition LCP operation management activities except for categorisation; construction in progress; receiving and financial recognition. During follow up discussions respondents revealed the perceived value pertaining to the said excluded acquisition LCP operation management activities would be negligible and that they would rather address low hanging fruit that would have bigger impact on the maturity levels of EMM-activities. This also aligns with the Pareto-concept that implies focussing efforts on 20% of activities that will give 80% of the results. The Pareto-concept seemed to be very popular amongst the respondents as this concept kept on repeating in the follow-up discussions by various respondents. This concept doesn't seem to fit into the maturity model presented in this research and should be explored as part of future work.

4.3.4 USAGE LCP OPERATION MANAGEMENT ACTIVITIES

When comparing the survey data to the requirements in literature the findings were as follow:

- Operation management activities for the usage life-cycle phase are not defined.
- Not all stakeholders are aligned or aware of all the usage LCP activities that are currently in existence.
- The current utilisation activities are deemed not effective. The respondents stated that in accordance with the defined utilisation activities there are shortcomings. Corrective and preventative measures have been introduced to maximise electrical motor

availability (this constitutes partial implementation of reliability strategies (respondents indicated that only high value electrical motors have been addressed in this regard)).

- The respondents also indicated that there has been a focus on electrical motor usage optimisation where variable speed drives have been deployed to decrease energy consumption and to provide the ability to control process requirements in a more efficient manner (instead of throttling valves within water treatment processes as an example).
- Control activities are effective.
- Tracking activities are not effective.
- Maintenance activities are not effective. A policy statement combined with a documented reliability process has been established for maintenance activities.
- 53% of the respondents indicated that stakeholders are not complying with their own documented policies and processes for maintenance and can be attributed to roles and responsibilities which have not been defined nor have adequate resources been deployed to roll out the said initiatives. The same 53% of the respondents indicated that buy-in to EMM will be low if this scenario repeats itself in EMM-activities.
- Respondents indicated that with previous efforts to roll-out new initiatives, resources just end up going back to their daily tasks which is deemed of higher importance, hampering any continuity and progress which has caused deleterious effects on esteem toward initiatives (such as EMM improvement efforts). This aspect also explains why the Pareto concept was so popular amongst the respondents, as they know that more often than not, they always end up short staffed to comprehensively roll-out initiatives, as such they have to maximise their efforts in every aspect of their jobs.
- Safety activities are effective.
- Security activities are effective.
- All respondents indicated that they would like to see improvements to all operation management activities for the usage life-cycle phase, excluding activities for control and security (which were deemed effective by respondents).

4.3.5 DISPOSAL LCP OPERATION MANAGEMENT ACTIVITIES

When comparing the survey data to the requirements in literature the findings were as follow:

- Operation management activities for the disposal life-cycle phase are not effectively defined
- Utilisation activities are not effective. Acquisition activities and usage activities that have input to reutilisation activities are not effective, this will immediately deem the reutilisation

activities not effective due to the preceding LCP-activities having direct inputs to reutilisation activities.

- Usage activities, more specifically utilisation (PA1) and tracking (PA3), are the aspects that need to be effective for reutilisation (PA1) activities to be more effective (the old saying applies here, scrap input = scrap output).
- The transport, storage and handling activities are not effective. After electrical motors are no longer in use they remain on the plant where they were initially installed and are not stored in accordance with OEM-requirements.
- The disposal activities are not effective and is attributable to electrical motors not being timeously disposed of when it holds greater value than a badly eroded electrical motor with no possible working spares.
- All respondents indicated that they would like to see improvements (question 87), but the improvements, initially has to be limited to reutilisation activities (PA1). Stakeholders would rather focus their efforts on activities in the acquisition- and usage LCP-activities as they perceive their efforts would add greater value (once again the Pareto concept was applied by respondents).

The comparison has confirmed the initial postulation by the researcher, i.e. **a need exists to develop an engineered electrical motor management (EMM) outline** to identify and improve on mismanaged aspects that ultimately exacerbate inefficiencies and reliability issues which affects the total cost of ownership.

The respondents of the surveys indicated that they'd rather want acquisition and usage LCP activities improved, prior to bringing about improvements to the disposal LCP activities. During follow-up discussions the respondents indicated that the perceived benefits of such an approach would hold greater benefits and that the improvements would be supported by more stakeholders as most of the electrical motors in the ESD within the large steel manufacturer can be found in the usage life cycle phase (LCP).

4.4 ANALYSIS OF EMM-MATURITY MODEL DATA

The review panel that conducted the EMM maturity analysis consisted of EMM stakeholders within the sample group as identified in paragraph 3.6. Additional constraints were applied to the EMM maturity analysis panel where explicit attention was given to constraints in time, cost and resources. The conclusion was made to limit the panel to the mangers within the within the engineering services department in the large steel manufacturer. The researcher also formed part of the review panel to provide guidance and input for each process area (PA) and the accompanying specific conditions (SCs) to ensure that interpretations aligned to the concepts presented in paragraph 2.3 of this dissertation. Furthermore, the management team have a good overview of the processes and activities pertaining to the EMM that are being enforced, reported and controlled as this responsibility ultimately lies with the management team to conduct the said activities. The researcher envisaged that through making the management team part of the review panel, the maturity scores allocated will be accepted as the true reflection of the status quo and that a greater level of acceptance/buy-in will be achieved. This approach was also envisaged to create an increased level of awareness which could create better ownership and leadership for deploying/improving EMM-activities.

Processes that are deemed effective integrates the likes of human resources, equipment and methods to work together to achieve a collective objective. The quality of the processes used to develop, deliver, and support services and products are directly proportional i.e. bad quality processes will deliver bad quality services and products. Long term vision and strategy together with the management support and leadership form the premise of process improvement, as such the culture and infrastructure developed at the large steel manufacturer needs to be supported and enforced through procedures, standard operating practices and methods that will continue even when after the authors have moved on. Each process area (PA) identifies a cluster of specific conditions (SCs) that, when performed collectively, achieve a set of goals considered important for enhancing process maturity (Object Management Group, 2008). All the aforementioned aspects (covered in detail in paragraph 2.3.3) need to be analysed to gain an understanding of the domain maturity (the domain being electrical motor management at engineering services department at the large steel manufacturer). The maturity level for the domain (EMM) can be calculated when evaluating the maturity levels for each of the specific conditions (SCs) within the respective process areas (PAs), this process will be covered in the subsequent paragraphs.

4.4.1 ACQUISITION LCP ANALYSIS AND INTERPRETATION

Table 4.4-1 presents the maturity level scores allocated by the review panel for the relevant process management activities and the operation management activities respectively within the **acquisition life-cycle phase**.

The process management activities consists of various process areas (PAs) that consist of various specific conditions (SCs). Each of the SCs have been allocated a maturity level score by the review panel and subsequently these scores were averaged and this resultant average score presents the PA-maturity level score. The next step was to average all the process management PA-scores to produce the process management maturity level score. The same steps were repeated to obtain the operation management maturity level score. Lastly, the process management maturity level score and the operation management maturity level score are averaged to produce the **acquisition life-cycle phase** maturity level score.

Table 4.4-1: Acquisition LCP maturity level score

						Maturity Level Score
1.1 Acquisition Life-Cycle Phase =						**1,02**
		Maturity Level Score				**Maturity Level Score**
Process Area	**1.1.1 Process Management**	**0,55**		**Process Area**	**1.1.2 Operation Management**	**1,48**
PA01	**a) Leadership**	**0,50**		**PA01**	**a) Requirements Determination**	**0,25**
PA01-SC1	Outcome/Process orientation	1		PA01-SC1	Functional spec	0
PA01-SC2	Best value products	1		PA01-SC2	Aligned with company goals	0
PA01-SC3	Personal Initiative	0		PA01-SC3	Cost vs. benefit	0
PA01-SC4	Lines of Authority/Accountability	0		PA01-SC4	Standards	1
PA01-SC5	Best-in-Class Management	1		PA01-SC5	Alternative sourcing	0
PA01-SC6	External Interface	0		PA01-SC6	ROI-analysis	0
PA02	**b) Planning**	**0,67**		PA01-SC7	Life cycle costing	0
PA02-SC1	Strategic Plan	1		PA01-SC8	HAZOP	1
PA02-SC2	Metrics	0		**PA02**	**b) Categorisation**	**1,00**
PA02-SC3	Financial Plan	1		PA02-SC1	Cost goals	0
PA03	**c) Policies, procedures and internal controls**	**0,40**		PA02-SC2	Tax categorisation	1
PA03-SC1	Exercise of Responsibility	1		PA02-SC3	Assign appropriate category	2
PA03-SC2	Sound Policies and Procedures	0		**PA03**	**c) Authorisation**	**1,60**
PA03-SC3	Reutilisation	0		PA03-SC1	Financial authorisation	3
PA03-SC4	Consensus Standards	1		PA03-SC2	Management authorisation	3
PA03-SC5	Available, Implemented, and Enforced	0		PA03-SC3	Configuration manage authorisation	0

PA04	**d) Personnel and staffing**	**0,67**
PA04-SC1	Adequate Staffing	0
PA04-SC2	Requisite Skills and knowledge	1
PA04-SC3	Trained Staff	1
PA05	**e) Financial Management**	**1,29**
PA05-SC1	Funding Mechanism Information Provided	2
PA05-SC2	Financial Accuracy	1
PA05-SC3	Balances Costs and Risks	1
PA05-SC4	Best Value	1
PA05-SC5	Loss/Overage Controls	1
PA05-SC6	Materiality	1
PA05-SC7	Minimize Loss Consequences	2
PA06	**f) Technology utilisation and management**	**1,00**
PA06-SC1	Technology Innovation	1
PA06-SC2	Technology Implementation	1
PA06-SC3	Technology Management	1
PA07	**g) Records and reporting**	**0,43**
PA07-SC1	Access to Information	0
PA07-SC2	Records Maintenance	1
PA07-SC3	Electrical Motor Identification	1
PA07-SC4	Summary Report Information	0
PA07-SC5	Records Retention	1
PA07-SC6	Cross-Functional Integration	0
PA07-SC7	Cost and Performance Data	0
PA08	**h) Quality management**	**0,33**
PA08-SC1	Monitoring and Measurement of Processes	0
PA08-SC2	Continuous Improvement	1
PA08-SC3	Outcome Measures	0
PA09	**i) Risk management**	**1,00**
PA09-SC1	Establish Liability	0
PA09-SC2	Insurance	1
PA09-SC3	Mitigation	2
PA09-SC4	Security	1
PA10	**j) Configuration management**	**0,33**
PA10-SC1	Configurations are identified	1
PA10-SC2	Contents of configurations are controlled	0
PA10-SC3	Configuration management information is reported	0
PA11	**k) Assessments**	**0,00**
PA11-SC1	Self-Assessment	0
PA11-SC2	Physical Inventory	0
PA11-SC3	Metrics	0
PA11-SC4	Third-Party Audits	0

PA03-SC4	Custodian authorisation	0
PA03-SC5	Financial prioritisation	2
PA04	**d) Procurement**	**1,67**
PA04-SC1	Reutilisation possibilities	1
PA04-SC2	Loan/sharing options	1
PA04-SC3	Procure vs. lease	0
PA04-SC4	Negotiate terms	3
PA04-SC5	Plan and manage delivery	3
PA04-SC6	Import restrictions considered	2
PA05	**e) Construction in progress management**	**2,00**
PA05-SC1	Under construction depreciation	2
PA05-SC2	Ready for use depreciation	2
PA06	**f) Receiving**	**2,00**
PA06-SC1	Analyse delivery inconsistencies	1
PA06-SC2	Records and documents receipts	3
PA06-SC3	Storage as per OEM requirements	2
PA06-SC4	Goods received are sent to relevant department	2
PA07	**g) Identification**	**1,33**
PA07-SC1	Categorisation applied	2
PA07-SC2	Identifications plates and markings	1
PA07-SC3	Quality assurance	1
PA08	**h) Financial recognition**	**2,00**
PA08-SC1	Ledgers updated for depreciation	2
PA08-SC2	Statements maintained	2

The process management activities for the acquisition LCP did not manage to achieve a score of 1 (achieved 0.55). This implies that the containing process areas, PA1-PA11, has no framework defined, duties are not assigned and task performers are not identified for each process area and the containing specific conditions. The leadership team need to establish a basic framework for the respective process areas, assign duties and identify task performers. Once again the assessment process area (PA11) was the only process area that was completely overlooked and there was no substantiating evidence of any activities in this regard.

The operation management activities for the acquisition LCP attained a score of 1.48. This implies that the leadership need to start focusing on moving from basic framework toward defining and documenting the processes. The processes need to be understood by all stakeholders and should be able to deliver repeatable results even when processes are followed by different employees.

The overall acquisition LCP maturity level score achieved was 1.02. The ratings allocated by the review panels for the various PAs in the acquisition LCP aligns with the respondent data from the questionnaire where they indicated that the PAs are not effective.

4.4.2 USAGE LCP ANALYSIS AND INTERPRETATION

Table 4.4-2 presents the maturity level scores allocated by the review panel for the relevant process management activities and the operation management activities respectively within the **usage life-cycle phase**.

The process management activities consists of various process areas (PAs) that consist of various specific conditions (SCs). Each of the SCs have been allocated a maturity level score by the review panel and subsequently these scores were averaged and this resultant average score presents the PA-maturity level score. The next step was to average all the process management PA-scores to produce the process management maturity level score. The same steps were repeated to obtain the operation management maturity level score. Lastly, the process management maturity level score and the operation management maturity level score are averaged to produce the **usage life-cycle phase** maturity level score.

Table 4.4-2: Usage LCP maturity level score

	Maturity Level Score
1.2 Usage Life-Cycle Phase =	**1,19**

Process Area	1.2.1 Process Management	Maturity Level Score
PA01	**a) Leadership**	**1,17**
PA01-SC1	Outcome/Process orientation	2
PA01-SC2	Best value products	1
PA01-SC3	Personal Initiative	1
PA01-SC4	Lines of Authority/Accountability	2
PA01-SC5	Best-in-Class Management	1
PA01-SC6	External Interface	0
PA02	**b) Planning**	**1,33**
PA02-SC1	Strategic Plan	2
PA02-SC2	Metrics	1
PA02-SC3	Financial Plan	1
PA03	**c) Policies, procedures and internal controls**	**0,80**
PA03-SC1	Exercise of Responsibility	1
PA03-SC2	Sound Policies and Procedures	1
PA03-SC3	Reutilisation	1
PA03-SC4	Consensus Standards	1
PA03-SC5	Available, Implemented, and Enforced	0
PA04	**d) Personnel and staffing**	**1,33**
PA04-SC1	Adequate Staffing	1
PA04-SC2	Requisite Skills and knowledge	2
PA04-SC3	Trained Staff	1
PA05	**e) Financial Management**	**1,43**
PA05-SC1	Funding Mechanism Information Provided	2
PA05-SC2	Financial Accuracy	1
PA05-SC3	Balances Costs and Risks	1
PA05-SC4	Best Value	1
PA05-SC5	Loss/Overage Controls	1
PA05-SC6	Materiality	2
PA05-SC7	Minimize Loss Consequences	2
PA06	**f) Technology utilisation and management**	**1,67**
PA06-SC1	Technology Innovation	2
PA06-SC2	Technology Implementation	2
PA06-SC3	Technology Management	1
PA07	**g) Records and reporting**	**0,43**
PA07-SC1	Access to Information	0

Process Area	1.2.2 Operation Management	Maturity Level Score
PA01	**a) Utilisation**	**1,29**
PA01-SC1	Authorisation for use	0
PA01-SC2	Financial associations assured	0
PA01-SC3	Availability tracked, reported and corrected	2
PA01-SC4	Electrical motors issues identified	2
PA01-SC5	Usage optimisation	2
PA01-SC6	Reliability strategies deployed	2
PA01-SC7	Identify surplus	1
PA02	**b) Control**	**0,33**
PA02-SC1	OEM instructions followed	1
PA02-SC2	Contractor and subcontractor control	0
PA02-SC3	Interdepartmental control	0
PA03	**c) Tracking**	**1,00**
PA03-SC1	Movements controlled	1
PA03-SC2	Location database maintained	1
PA03-SC3	Records maintained and audited	1
PA03-SC4	Logistics are supportive of needs	1
PA04	**d) Maintenance**	**1,40**
PA04-SC1	Documented strategies for electrical motors	2
PA04-SC2	Strategies executed	0
PA04-SC3	Warrantee maintenance (claims)	3
PA04-SC4	Repair/replace trade-offs	1
PA04-SC5	Breakpoint defined	1
PA05	**e) Safety**	**3,00**
PA05-SC1	Standard operating procedures	3
PA06	**f) Security**	**2,00**
PA06-SC1	Access controlled operating environment	2
PA06-SC2	Compliance with policies & procedures	2

PA07-SC2	Records Maintenance	1
PA07-SC3	Electrical Motor Identification	1
PA07-SC4	Summary Report Information	0
PA07-SC5	Records Retention	1
PA07-SC6	Cross-Functional Integration	0
PA07-SC7	Cost and Performance Data	0
PA08	**h) Quality management**	**0,67**
PA08-SC1	Monitoring and Measurement of Processes	1
PA08-SC2	Continuous Improvement	1
PA08-SC3	Outcome Measures	0
PA09	**i) Risk management**	**1,25**
PA09-SC1	Establish Liability	1
PA09-SC2	Insurance	1
PA09-SC3	Mitigation	2
PA09-SC4	Security	1
PA10	**j) Configuration management**	**0,33**
PA10-SC1	Configurations are identified	1
PA10-SC2	Contents of configurations are controlled	0
PA10-SC3	Configuration management information is reported	0
PA11	**k) Assessments**	**0,00**
PA11-SC1	Self-Assessment	0
PA11-SC2	Physical Inventory	0
PA11-SC3	Metrics	0
PA11-SC4	Third-Party Audits	0

The process management activities for the usage LCP did not manage to achieve a score of 1 (achieved 0.87). This implies that the containing process areas, PA1-PA11, has no framework defined, duties are not assigned and task performers are not identified for each process area and the containing specific conditions. The leadership team need to establish a basic framework for the respective process areas, assign duties and identify task performers. The assessment process area (PA11) was the only process area that was completely overlooked and there was no substantiating evidence of any activities in this regard.

The security and safety process areas are the highest scoring mature level at 2.00 and 3.00 respectively. The operation management activities for the usage LCP attained an overall score of 1.50. This implies that the leadership need to start focusing on moving from basic framework toward defining and documenting the processes. The processes need to be understood by all stakeholders and should be able to deliver repeatable results even when processes are followed by different employees.

The overall usage LCP maturity level score achieved was 1.19. The ratings allocated by the review panels for the various PAs in the usage LCP aligns with the respondent data from the questionnaire where they indicated that the PAs are not effective.

4.4.3 DISPOSAL LCP ANALYSIS AND INTERPRETATION

Table 4.4-3 presents the maturity level scores allocated by the review panel for the relevant process management activities and the operation management activities respectively within the **disposal life-cycle phase**.

The process management activities consists of various process areas (PAs) that consist of various specific conditions (SCs). Each of the SCs have been allocated a maturity level score by the review panel and subsequently these scores were averaged and this resultant average score presents the PA-maturity level score. The next step was to average all the process management PA-scores to produce the process management maturity level score. The same steps were repeated to obtain the operation management maturity level score. Lastly, the process management maturity level score and the operation management maturity level score are averaged to produce the **disposal life-cycle phase** maturity level score.

Table 4.4-3: Disposal LCP maturity level score

						Maturity Level Score
1.3 Disposal Life-Cycle Phase =						**0,96**
		Maturity Level Score				**Maturity Level Score**
Process Area	**1.3.1 Process Management**	**0,85**		**Process Area**	**1.3.2 Operation Management**	**1,08**
PA01	**a) Leadership**	**1,00**		**PA01**	**a) Reutilisation**	1
PA01-SC1	Outcome/Process orientation	2		PA01-SC1	Excess identified	1
PA01-SC2	Best value products	0		PA01-SC2	Age failure risk determined	1
PA01-SC3	Personal Initiative	1		PA01-SC3	Excess recorded and reported	1
PA01-SC4	Lines of Authority/Accountability	2		**PA02**	**b) Authorisation to dispose**	1
PA01-SC5	Best-in-Class Management	1		PA02-SC1	Disposals authorised	0
PA01-SC6	External Interface	0		PA02-SC2	Disposals recorded and reported	2
PA02	**b) Planning**	**1,33**		**PA03**	**c) Transport, storage, and handling**	0,5
PA02-SC1	Strategic Plan	2		PA03-SC1	Traceable	1
PA02-SC2	Metrics	1		PA03-SC2	OEM instructions followed	0
PA02-SC3	Financial Plan	1		**PA04**	**d) Disposal**	1,8
PA03	**c) Policies, procedures and internal controls**	**0,80**		PA04-SC1	Feasible	0

PA03-SC1	Exercise of Responsibility	1
PA03-SC2	Sound Policies and Procedures	1
PA03-SC3	Reutilisation	1
PA03-SC4	Consensus Standards	1
PA03-SC5	Available, Implemented, and Enforced	0
PA04	**d) Personnel and staffing**	**1,33**
PA04-SC1	Adequate Staffing	1
PA04-SC2	Requisite Skills and knowledge	2
PA04-SC3	Trained Staff	1
PA05	**e) Financial Management**	**1,43**
PA05-SC1	Funding Mechanism Information Provided	2
PA05-SC2	Financial Accuracy	1
PA05-SC3	Balances Costs and Risks	1
PA05-SC4	Best Value	1
PA05-SC5	Loss/Overage Controls	1
PA05-SC6	Materiality	2
PA05-SC7	Minimize Loss Consequences	2
PA06	**f) Technology utilisation and management**	**1,67**
PA06-SC1	Technology Innovation	2
PA06-SC2	Technology Implementation	2
PA06-SC3	Technology Management	1
PA07	**g) Records and reporting**	**0,43**
PA07-SC1	Access to Information	0
PA07-SC2	Records Maintenance	1
PA07-SC3	Electrical Motor Identification	1
PA07-SC4	Summary Report Information	0
PA07-SC5	Records Retention	1
PA07-SC6	Cross-Functional Integration	0
PA07-SC7	Cost and Performance Data	0
PA08	**h) Quality management**	**0,67**
PA08-SC1	Monitoring and Measurement of Processes	1
PA08-SC2	Continuous Improvement	1
PA08-SC3	Outcome Measures	0
PA09	**i) Risk management**	**1,25**
PA09-SC1	Establish Liability	1
PA09-SC2	Insurance	1
PA09-SC3	Mitigation	2
PA09-SC4	Security	1
PA10	**j) Configuration management**	**0,33**
PA10-SC1	Configurations are identified	1
PA10-SC2	Contents of configurations are controlled	0
PA10-SC3	Configuration management information is reported	0
PA11	**k) Assessments**	**0,00**
PA11-SC1	Self-Assessment	0
PA11-SC2	Physical Inventory	0
PA11-SC3	Metrics	0
PA11-SC4	Third-Party Audits	0

PA04-SC2	Corporate responsibility adhered	3
PA04-SC3	Timeous	1
PA04-SC4	Donated is considered disposed	2
PA04-SC5	Compliance	3

The process management activities for the disposal LCP did not manage to achieve a score of 1 (achieved 0.85). This implies that the containing process areas, PA1-PA11, has no framework defined, duties are not assigned and task performers are not identified for each process area and the containing specific conditions. The leadership team need to establish a basic framework for the respective process areas, assign duties and identify task performers. The assessment process area (PA11) was the only process area that was completely overlooked and there was no substantiating evidence of any activities in this regard.

The operation management activities for the disposal LCP attained an overall score of 1.08. This implies that the leadership need to start focusing on moving from basic framework toward defining and documenting the processes. The processes need to be understood by all stakeholders and should be able to deliver repeatable results even when processes are followed by different employees.

The overall disposal LCP maturity level score achieved was 0.96. The ratings allocated by the review panels for the various PAs in the usage LCP aligns with the respondent data from the questionnaire where they indicated that the PAs are not effective.

4.4.4 OVERALL EMM MATURITY LEVEL SCORE

The overall maturity level score achieved for the electrical motor management domain was **1.06** (which is also visually presented in APPENDIX C1 OVERALL EMM-MATURITY). The entire electrical motor management domain requires leadership to focus on moving from basic framework toward defining and documenting the processes for each PA in the respective life cycle phases. All the processes need to be understood by all stakeholders and needs to be able to deliver repeatable results even when processes are followed by different employees.

4.5 LITERATURE REVIEW FINDINGS

1. The researcher's own observations revealed that the large steel manufacturer's engineering services department staff do not distinguish between life cycle stages, nor do they distinguish between process management and operation management. This observation is also evident from the respondent data stemming from the questionnaire.
2. Electrical motor management (EMM) has to be deployed/improved to follow a natural maturity progression which implies starting at an initial maturity level and progressing towards a higher level maturity (Raber, et al., 2013). If the constituents of EMM do not follow this natural maturity progression and start of at a very high level of maturity the probability for success will diminish as one first has to get the fundamentals in place for each constituent within EMM before progressing at a pace that could increase the existence of confusion and pitfalls.
3. Maturity models define an outline for **planned, typical, logical, and desired evolution directives for moving from an initial maturity level towards a higher level maturity** (Raber, et al., 2013). In maturity models, stages of growth/maturity emerge in a defined sequence, where solving one set of problems consequentially brings about a new set of problems that require new corrective actions to move forward, evolving towards a new level of maturity (Kazanjian & Drazin, 1989). Success is directly dependant on following the natural maturity level progression to avoid critical pitfalls which would've been solved in the preceding maturity level (Raber, et al., 2013). This observation is evident when analysing the finding by Dr Penrose that a mere 7% of the total motor management programs attempted were successful, though his study did not attribute this to any direct cause (this point was used to provide a statistic of how low success rates are in general and that one of the many contributing factors might be that implementation of EMM starts off at a very high maturity level). The observation is key as the existing electrical motor approach doesn't provide any guidance for **planned, typical, logical, and desired evolution directives for moving from an initial maturity level towards higher levels of maturity.**
4. The existence of the ASTM E2452-12 standard, combined with the important link to the ISO allows the author to skip through the maturity model development phases which aid the descriptive life-cycle phase for the development of a **descriptive** equipment management maturity model. This in turn implies the maturity model immediately progresses from a **descriptive purpose** to a **prescriptive purpose.**

Due to the prescriptive nature being established, the EMM-maturity model can be deemed as the "ideal EMM-approach".

5. The CEE-definition for electrical motor management is vague and only focuses on one aspect within the two levels of equipment management activities i.e. one aspect within process management activities and one activity in operation management in the form of "*on-going policies and procedures*".
6. The Dr Penrose-definition for electrical motor management clearly only considers the hardware aspects once in the use life-cycle phase i.e. focuses on the electrical motor system itself and does not consider process management activities to support the operation management activities.
7. Neither the CEE-definition, nor the Dr Penrose-definition are industry accepted definitions. The closest to industry accepted definitions is the one proposed in this dissertation as it aligns to the industry accepted definition for equipment management. An electrical motor is in fact a specific piece of equipment, but still needs to adhere to the norms of equipment management as presented in the ASTM E2452-12 standard (2012). The ASTM-definition for equipment management is also the most recent industry accepted norm (and academia accepted definition) in terms of date.
8. Dr Penrose does however encapsulate an important observation i.e. motor management does not work in isolation, in order to obtain a more reliable motor one needs to take into account the **motor system**. This concept has been proven extensively through the Motor Diagnostics and Motor Health Study conducted by O'Hanlon and Penrose (2003).
9. Process management definition (ASTM, 2012) is the recognition that a **systems approach** forms part of management activities in equipment management in in turn forms part of an asset management system. This aligns and supports Dr Penrose's (2005) view that a **systems-approach** is required to holistically manage the motors. The shortcoming in Dr Penrose's (2005) view however, was that he was actually inferring to the hardware pertaining to the motor system. There also exists supporting views that if an entity improves process management it will aid the need toward reducing weaknesses in the EMM and boost the chances of success (Object Management Group, 2008).
10. The author makes a key observation with regards to the EMM constituents presented in Figure 2.3-2, this is that one crucial constituent, configuration management is omitted in the process management activity within each life cycle phase this

constituent is engineering change management (ECM) (also known as change management; also known as configuration management).

11. The maturity level for the domain (electrical motor management in the case of this dissertation) can be calculated when evaluating the maturity levels for each of the sub-domains/key process areas and the respective specific conditions (SCs) within each of the sub-domains/key process areas.
12. EMM forms part of a bigger picture approach, in the form of an equipment management system and in turn the equipment management system forms part of the asset management system (International Organization for Standardization, 2014).
13. The large steel manufacturer's current asset management system is deployed in such a fashion where assets are being managed individually (per motor, per gearbox, per pump etc.). Instead the large steel manufacturer opted to group the assets by process.
14. The process area (PA) for maintenance at the large steel manufacturer is well defined and well managed, though as elaborated in the preceding paragraphs, maintenance only constitutes one of the key process areas (PA) for complete electrical motor management.
15. The key observation in terms of the current asset management deployed at the large steel manufacturer is that there exists no functional hierarchies nor functional block diagrams to supplement the existing asset hierarchy. The functional hierarchies and functional block diagrams are utilised in defining metrics for performance management and continuous improvement. The functional hierarchies and functional block diagrams are further utilised in the configuration management process to ensure functional parameters are not adversely affected by implementation of configuration requests. This observation was also confirmed in from the respondent data stemming from the questionnaire.

5 CONCLUSION, RECOMMENDATIONS AND THE WAY FORWARD

The last step, stage 7 in the research process, will report the conclusions of the study, which is an important component of the research process (Zikmund *et al.*, 2010:462). Chapter 5 will be used to draw conclusions about the study.

5.1 RESEARCH GOALS REVIEWED

This section will recapitulate the research goals presented in Chapter 1.3.

5.1.1 PRIMARY RESEARCH OBJECTIVE

Investigate the status quo of existing EMM-activities within the engineering services department at a large steel manufacturer and then conduct a comparative analysis of how the status quo compares with EMM proposed in literature.

Substantiation: A better understanding needs to be obtained of the status quo pertaining to EMM-activities (if at all existing) and how it compares to what literature proposes. This research objective will establish whether the postulated need for developing/improving EMM exists. The objective will uncover aspects requiring improvement or development (where the aspects pertaining to the EMM are not adequately addressed) as to extract full beneficiation of such an approach.

5.1.2 SECONDARY RESEARCH OBJECTIVE

Deploy a researched EMM maturity model for the engineering services department within a large steel manufacturer as means for identifying levels of maturity for EMM-activities serving as a tool for continuous tracking and improvement.

Substantiation: Pending the outcome of the first research objective (whether the need exists), the second research objective will aid the need to easily identify and interpret critical shortcomings in current EMM activities (in the case where shortcomings exist) and to provide insight on what aspects are critical for advancing the level of maturity of EMM. In the case where no EMM exists, this objective was set in order *to provide a researched EMM maturity model for analysing and tracking electrical motor management activities within the engineering services department at the large steel manufacturer to improve/instigate aspects to advance the maturity level of EMM.* It is important to gain an accurate representation of the status quo and to establish what aspects need attention to provide a defined means of improving on key process areas and to ensure that improvements follow

the natural order of progression allowing the best chance for success. The significance of an assessment of the electrical motor management maturity (EMMM), can be visualised as being three-fold:

4. A comparison of existing EMM-activities within the engineering services department at a large steel manufacturer can be drawn with EMM-activities proposed in literature.
5. Internal - The assessment would provide results that are easily understood and communicated. Aligning with Raber et al. (2013), the improvements can be tracked, to allow distinction and recognition between areas of exceptional maturity and areas requiring changes or resources (or both) to bring about improvements.
6. External – Comparisons can be with made between different departments in a large steel manufacturer as well as higher level comparisons between different operating units within the large steel manufacturer or between national and international industries as part of benchmarking.

5.2 ACCOMPLISHING THE RESEARCH GOALS

5.2.1 PRIMARY RESEARCH GOAL

The researcher has conducted a survey by means of a questionnaire (as presented in paragraph 3.4.2). The questionnaire was set up to align with the EMM-activities found in literature to ease the comparison and allowing the researcher to directly come to conclusions to each aspect whether it is deemed effective or not effective (as was presented in paragraph 4.3). The questionnaire aided in establishing the status quo of existing EMM-activities within the engineering services department at the large steel manufacturer. The insight provided by the questionnaire results assisted the researcher to confirm that there are indeed EMM-aspects being mismanaged and aspects that are completely overlooked at present.

Hence, the results confirmed the initial postulation by the researcher, i.e. **a need exists to develop an engineered electrical motor management (EMM) outline**. The questionnaire results further assisted to identify mismanaged aspects that ultimately exacerbated inefficiencies and reliability issues.

5.2.2 SECONDARY RESEARCH GOAL

The researcher consulted various literature resources to obtain a better understanding of maturity models and how they are used to analyse management plans. The next topic

covered was electrical motor management to establish what process areas (PAs) and specific conditions (SCs) need to integrated and analysed throughout the life-cycle of electrical motor management.

Subsequently the researcher conducted a high level review of relevant literature to the field of asset management to establish the links to electrical motor management and to establish the background of how this was deployed at the large steel manufacturer.

With the need for EMM development established (paragraph 4.3), the researcher then proceeded in developing an electrical motor management maturity model (EMMM-model) which was used to conduct a maturity analysis with EMM as the domain. The maturity level for the domain (EMM) was calculated through evaluating the maturity levels for each of the process areas (PAs) stemming from the respective maturity ratings for each specific condition (SC) within each of the process areas (PAs) as defined in paragraph 2.3.2 and paragraph 2.3.3. The maturity levels were established for each PA and SC throughout the full life cycle phases for electrical motors, i.e. the:

1.1) acquisition life cycle phase;
1.2) usage life cycle phase; and
1.3) disposal life cycle phase.

The maturity level scores were presented and discussed in paragraph 4.4. The EMM maturity model scores allows for tracking and monitoring efforts and planning which areas will receive focused efforts within the engineering services department (ESD) at the large steel manufacturer. The EMM maturity model developed provides guidance for planned, typical, logical, and desired evolution directives for moving from an initial maturity level towards higher levels of maturity. The various departments within the large steel manufacturer can also use the same EMMM-model to advance and track and monitor EMM-activities for their respective departments. The large steel manufacturer can then deploy the same EMMM-model as benchmarking tool between operating units nationally and internationally.

5.3 CONCLUSSION

The status quo of electrical motor management for the ESD at the large steel manufacturer has been established by means of questionnaires and subsequently an EMM maturity level analysis was conducted which produced the maturity levels as allocated by the review panel.

Through making the management team part of the review panel the researcher accomplished to have the maturity scores allocated by the review panel accepted as the true reflection of the status quo. This consequently resulted in a greater level of acceptance/buy-in by the leadership team. This approach created an increased level of awareness which established the much required leadership for deploying/improving EMM-activities. This is evident by the management team planning to integrate EMM-targets in line with the EMMM-model for all stakeholders as part of their annual performance appraisals in 2019. The performance targets are said to be aligned with the SCs and PAs for the EMMM-model, though allocations of performance target scores for these aspects still need to be presented, commented on and agreed to by all stakeholders.

The EMM-maturity model presented in this dissertation provided the basis for establishing a new EMM-approach and ensured that the EMM-approach was comprehensive, ensuring the best chance for success. The insights obtained in this research will enable the leadership team at the ESD within the large steel manufacturer to establish an implementation plan in accordance with the EMMM-model, presented in paragraph 2.3.2, paragraph 2.3.3 and paragraph 4.4, to advance the level of maturity for the specific conditions (SCs) within the various process areas (PAs) covered in this dissertation. It is important that the leadership team take cognisance of the very nature of maturity models, i.e. they are intended to bring about progressive improvements and it not recommended to skip through maturity levels, as this was shown in the literature review, to be the common pitfall for success. The proposed approach for EMM also aligns closely to the ISO9001:2015-accredititation requirements:

- process-based approaches;
- leadership;
- continuous improvement;
- a customer focused approach;
- engagement of people;
- evidence-based decisions;
- relationship management.

This alignment of the EMMM-model with the ISO9001:2015 would aid the large steel manufacturer in achieving the said accreditation. The large steel manufacturer is currently accredited for ISO9001:2008 and will have to obtain future ISO9001:2015 in the short term future. The EMM-maturity model serves as a tool for analysing and focusing areas for

improvement in an order of natural progression (maturity level progression), providing the highest possibility of success.

During the literature review the researcher also identified shortcomings in the existing definitions. As such the author has proposed, as part of this dissertation, a new comprehensive definition for electrical motor management (as presented in paragraph 2.3.1)

5.4 FUTURE WORK

Electrical motor management as established in Chapter 2, forms part of a bigger system in the form of asset management as such its proposed that a holistic asset management maturity model analysis be conducted by the large steel manufacturer. This will provide insights to sub-domains that being well managed and sub-domains that require dire attention. As was established in paragraph 4.2.2.1.2, there are sub-domains that are far more mature than others, for example the safety management maturity level (safety management is a sub-domain to the asset management domain) and the risk management maturity level (risk management is a sub-domain to the asset management domain) far exceed that of electrical motor management maturity level (a sub-domain to the asset management domain).

- Maturity levels for management aspects (e.g. risk management maturity levels, quality management maturity levels, technology management maturity levels etc.) within asset management need to be analysed to establish the status quo and to establish strategies for improvement/development.

The concept for the EMM-maturity model aligns to industry accepted standards that were developed in the year of 2012. After the maturity model assessment conducted with the defined review panel, some of the panel members commented that the EMM maturity model aligns closely to the requirements set out in ISO9001 (which was also noted in Chapter 2 and Chapter 4). The researcher upon further investigation found that there is new revision of the quality standard in the form of ISO9001:2015. Future work should explore the how to further optimise the EMM-maturity model to align with ISO9001:2015 to aid future ISO9001-accreditation. The findings of the aforementioned should be communicated to the technical committee of the ASTM E2452-12 and collaborative efforts with the ASTM E2452-12 working group should be affected to update the important industry accepted standard. Further stakeholders that should be informed of this change is the American National

Standards Institute (ANSI, who is an ISO-member), who in turn will inform the ISO of the findings and accompanying updates.

The Pareto-concept seemed to be very popular amongst the respondents as this concept kept on repeating in the follow-up discussions by various respondents. This concept doesn't fit into the maturity model presented in this researched EMM-model and should be explored as part of future work.

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APPENDIX A: QUESTIONNAIRE

This instruction applies to all sections and containing questions presented in this survey; please select one relevant answer (unless instructed to choice more than one option) for the following questions. Please choose the applicable option and indicate the chosen option with an “X” on the appropriate answer (the numbers in each answering block has no significance and is only used to categorise the information for the study). The purpose of this questionnaire is to establish the status quo of electrical motor management (EMM) within the engineering services department (ESD) at a large steel manufacturer.

A1 SECTION-A: DEMOGRAPHICS

The purpose of Section-A of the questionnaire is aimed to obtain demographic details of stakeholders identified as part of the sample group window. Please select one relevant answer (unless instructed to choice more than one option) for the following questions.

DEMOGRAPCHIC QUESTIONS						
		OPTIONS FOR SELECTION (MARK WITH X)				
Question Number	Question	1	2	3	4	5
1	What is your gender?	Male	Female			
2	What is your population group?	Black	White	Coloured	Indian	Asian
3	What is your age?	18-25	26-35	36-45	46-55	56-65
4	What is your marital status?	Single	Married	Divorced	Widow/er	
5	What is your highest academic qualification?	NQF5	NQF6	NQF7	NQF8	NQF9
6	How many times a month do interact with any electrical motor management activity?	1-10	11-20	21-50	>50	

A2 SECTION-B: EMM AT ESD WITHIN A LARGE STEEL MANUFACTURER

Section-B of the questionnaire is intended to obtain data relating to EMM at ESD within a large steel manufacturer to aid in establishing the status quo for EMM at ESD within a large steel manufacturer.

A2.1 GENERAL QUESTIONS

For each statement presented in the table below, provide a response to signify how much you tend to agree with the statement. Response values are between values 1-5, where strongly disagree =1; strongly agree = 5.

GENERAL QUESTIONS										
		OPTIONS FOR SELECTION (MARK WITH X)								
Question Number	Question	1	2	3	4	5	6	7	8	9
7	EMM at ESD is very effective	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree				
8	EMM activities at ESD are being managed	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree				
9	ESD reports on safety management performance indicators	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree				
10	ESD reports product/process quality performance indicators	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree				
11	ESD reports on EMM performance indicators	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree				
12	Roles and responsibilities are defined relating to EMM-activities	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree				
13	Which employees need to use EMM (select more than one if applicable)	Procurement staff	Managers	Engineers	Technicians	Artisans	Planners	Clerks	Safety Officers	Project Managers
14	Which are the EMM aspects that need to be advanced?	Workflow	Procedures	Approval levels	Ownership	Policies	Process			
15	ESD have functional block diagrams to supplement the existing asset hierarchy.	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree				
16	Accurate system data for electrical motors are available (technical data, functional KPIs, failure history, condition monitoring history)	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree				
17	The main purpose of EMM is control, plan and monitor maintenance and spare parts relating to electrical motors.	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree				

A2.2 PROCESS MANAGEMENT ACTIVITIES

The questions presented below are relating to EMM process management activities at EMM at ESD within a large steel manufacturer for all the life-cycle phases. *For each statement presented in the table below, provide a response to signify how much you tend to agree with the statement. Response values are between values 1-5, where strongly disagree =1; strongly agree = 5.*

PROCESS MANAGEMENT ACTIVITIES							
			OPTIONS FOR SELECTION (MARK WITH X)				
Question Number	Question	Scale	1	2	3	4	5
18	The objective for EMM is clearly defined.	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
19	Human resources relating to each EMM-activity are clearly defined.	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
20	Equipment and methods forming part of EMM are clearly defined to aid in achieving the EMM objective.	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
21	The quality of the processes relating to EMM used to develop, deliver, and support services and production are providing production and service outputs which are high in quality.	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
22	Long term vision and strategy are defined for EMM	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
23	Management support forms the premise of process improvement relating to EMM	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
24	The culture and infrastructure at the large steel manufacturer relating to EMM is supported by the development and deployment of procedures which are maintained, revised and improved.	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
25	The culture and infrastructure at the large steel manufacturer relating to EMM is enforced through standard operating practices.	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
26	Procedures, standard operating practices and methods relating to EMM will continue even when authors of the procedures, standard operating practices and methods relating to EMM are no longer working at the organisation.	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree

Institutionalised implies that processes are entrenched by the manner in which the work gets executed and there is commitment and consistency to the process being performed. The following **process management activities** relating to EMM are fully institutionalised, f*or each statement presented in the table below, provide a response to signify how much you tend to agree with the statement. Response values are between values 1-5, where strongly disagree =1; strongly agree = 5.*

PROCESS MANAGEMENT ACTIVITIES INSTITUTIONALISED							
			OPTIONS FOR SELECTION (MARK WITH X)				
Question Number	**Question**	**Scale**	**1**	**2**	**3**	**4**	**5**
27	leadership (PA1)	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
28	planning (PA2)	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
29	policies, procedures and internal controls (PA3)	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
30	personnel and staffing (PA4)	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
31	financial management (PA5)	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
32	technology utilisation and management (PA6)	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
33	records and reporting (PA7)	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
34	quality management (PA8)	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
35	risk management (PA9)	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
36	configuration management (PA10)	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
37	assessments (P11)	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree

For each statement presented in the table below, provide a response to signify how much you tend to agree with the statement. Response values are between values 1-5, where strongly disagree =1; strongly agree = 5.

PROCESS MANAGEMENT ACTIVITY IMPROVEMENT REQUIRED							
			OPTIONS FOR SELECTION (MARK WITH X)				
Question Number	**Question**	**Scale**	**1**	**2**	**3**	**4**	**5**
38	Would you like to see improvements relating to process management activities? (YES or NO) a. If answer in question 38 was YES", please proceed by answering question 39 and beyond. b. If the answer in the aforementioned question was "NO", please skip questions 39-49 and proceed to question 50.	Nominal	Yes	No			
39	Leadership (PA1)	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
40	planning (PA2)	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
41	policies, procedures and internal controls (PA3)	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
42	personnel and staffing (PA4)	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
43	financial management (PA5)	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
44	technology utilisation and management (PA6)	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
45	records and reporting (PA7)	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
46	quality management (PA8)	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
47	risk management (PA9)	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
48	configuration management (PA10)	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
49	assessments (P11)	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree

A2.3 ACQUISTION OPERATION MANAGEMENT ACTIVITIES

The questions presented below are relating to EMM operation management activities at EMM at ESD within a large steel manufacturer for the **acquisition life cycle phase.** *For each statement presented in the table below, provide a response to signify how much you tend to agree with the statement. Response values are between values 1-5, where strongly disagree =1; strongly agree = 5.*

OPERATION MANAGEMENT ACTIVITIES – ACQUISITION LIFE CYCLE PHASE							
			OPTIONS FOR SELECTION (MARK WITH X)				
Question Number	**Question**	**Scale**	**1**	**2**	**3**	**4**	**5**
50	Operation management activities are defined specific to the acquisition life-cycle phase	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree

Institutionalised implies that operation management activities are entrenched by the manner in which the work gets executed and there is commitment and consistency to the activities being performed. The following **operation management** activities during the **acquisition life-cycle phase** relating to EMM are fully institutionalised, *for each statement presented in the table below, provide a response to signify how much you tend to agree with the statement. Response values are between values 1-5, where strongly disagree =1; strongly agree = 5.*

ACQUISITION OPERATION MANAGEMENT ACTIVITIES INSTITUTIONALISED							
			OPTIONS FOR SELECTION (MARK WITH X)				
Question Number	**Question**	**Scale**	**1**	**2**	**3**	**4**	**5**
51	Requirements determination (PA1)	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
52	categorisation (PA2)	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
53	authorisation (PA3)	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
54	procurement (PA4)	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree

55	construction in progress management (PA5)	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
56	receiving (PA6)	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
57	identification (PA7)	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
58	financial recognition (PA8)	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree

For each statement presented in the table below, provide a response to signify how much you tend to agree with the statement. Response values are between values 1-5, where strongly disagree =1; strongly agree = 5.

IMPROVEMENTS REQUIRED FOR ACQUISITION OPERATION MANAGEMENT ACTIVITIES							
			OPTIONS FOR SELECTION (MARK WITH X)				
Question Number	**Question**	**Scale**	**1**	**2**	**3**	**4**	**5**
59	Would you like to see improvements relating to acquisition operation management activities? (YES or NO) a. If answer in question 59 was YES", please proceed by answering question 60 and beyond. b. If the answer in the aforementioned question was "NO", please skip questions 60-67 and proceed to question 68.	Nominal	Yes	No			
60	requirements determination (PA1)	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
61	categorisation (PA2)	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
62	authorisation (PA3)	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
63	procurement (PA4)	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
64	construction in progress management (PA5)	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
65	receiving (PA6)	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
66	identification (PA7)	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
67	financial recognition (PA8)	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree

A2.4 USAGE OPERATION MANAGEMENT ACTIVITIES

The questions presented below are relating to EMM operation management activities at EMM at ESD within a large steel manufacturer for the usage life cycle phase. *For each statement presented in the table below, provide a response to signify how much you tend to agree with the statement. Response values are between values 1-5, where strongly disagree =1; strongly agree = 5.*

OPERATION MANAGEMENT ACTIVITIES – USAGE LIFE CYCLE PHASE							
			OPTIONS FOR SELECTION (MARK WITH X)				
Question Number	Question	Scale	1	2	3	4	5
68	Operation management activities are defined specific to the usage life-cycle phase	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree

Institutionalised implies that operation management activities are entrenched by the manner in which the work gets executed and there is commitment and consistency to the activities being performed. The following **operation management** activities during the **usage life-cycle phase** relating to EMM are fully institutionalised, *for each statement presented in the table below, provide a response to signify how much you tend to agree with the statement. Response values are between values 1-5, where strongly disagree =1; strongly agree = 5.*

OPERATION MANAGEMENT ACTIVITIES – USAGE LIFE CYCLE PHASE INSTITUTIONALISED							
			OPTIONS FOR SELECTION (MARK WITH X)				
Question Number	Question	Scale	1	2	3	4	5
69	Utilisation (PA1)	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
70	control (PA2)	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
71	tracking (PA3)	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
72	maintenance (PA4)	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
73	safety (PA5)	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree

74	security (PA6)	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree

For each statement presented in the table below, provide a response to signify how much you tend to agree with the statement. Response values are between values 1-5, where strongly disagree =1; strongly agree = 5.

IMPROVEMENTS REQUIRED FOR USAGE OPERATION MANAGEMENT ACTIVITIES							
			OPTIONS FOR SELECTION (MARK WITH X)				
Question Number	**Question**	**Scale**	**1**	**2**	**3**	**4**	**5**
75	Would you like to see improvements relating to usage operation management activities? (YES or NO) a. If answer in question 75 was YES", please proceed by answering question 76 and beyond. b. If the answer in the aforementioned question was "NO", please skip questions 76-81 and proceed to question 82.	Nominal	Yes	No			
76	Utilisation (PA1)	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
77	control (PA2)	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
78	tracking (PA3)	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
79	maintenance (PA4)	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
80	safety (PA5)	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
81	security (PA6)	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree

A2.5 DISPOSAL OPERATION MANAGEMENT ACTIVITIES

The questions presented below are relating to EMM operation management activities at EMM at ESD within a large steel manufacturer for the disposal life cycle phase. *For each statement presented in the table below, provide a response to signify how much you tend to agree with the statement. Response values are between values 1-5, where strongly disagree =1; strongly agree = 5.*

OPERATION MANAGEMENT ACTIVITIES – DISPOSAL LIFE CYCLE PHASE							
			OPTIONS FOR SELECTION (MARK WITH X)				
Question Number	**Question**	**Scale**	**1**	**2**	**3**	**4**	**5**
82	Operation management activities are defined specific to the **disposal life-cycle phase**	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree

Institutionalised implies that operation management activities are entrenched by the manner in which the work gets executed and there is commitment and consistency to the activities being performed. The following **operation management** activities during the **disposal life-cycle phase** relating to EMM are fully institutionalised, *for each statement presented in the table below, provide a response to signify how much you tend to agree with the statement. Response values are between values 1-5, where strongly disagree =1; strongly agree = 5.*

DISPOSAL OPERATION MANAGEMENT ACTIVITIES INSTITUTIONALISED							
			OPTIONS FOR SELECTION (MARK WITH X)				
Question Number	**Question**	**Scale**	**1**	**2**	**3**	**4**	**5**
83	Reutilisation (PA1)	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
84	authorisation to dispose (PA2)	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
85	transport, storage, and handling (PA3)	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
86	disposal (PA4)	Interval	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree

For each statement presented in the table below, provide a response to signify how much you tend to agree with the statement. Response values are between values 1-5, where strongly disagree =1; strongly agree = 5.

IMPROVEMENTS REQUIRED FOR DISPOSAL OPERATION MANAGEMENT ACTIVITIES							
			OPTIONS FOR SELECTION (MARK WITH X)				
Question Number	**Question**	**Scale**	**1**	**2**	**3**	**4**	**5**
87	Would you like to see improvements relating to disposal operation management activities? (YES or NO) a. If answer in question 87 was YES", please proceed by answering question 88 and beyond. b. If the answer in the aforementioned question was "NO", please skip questions 88-91 and proceed to question 92.	Nominal	Yes	No			
88	Reutilisation (PA1)	Interval					
89	authorisation to dispose (PA2)	Interval					
90	transport, storage, and handling (PA3)	Interval					
91	disposal (PA4)	Interval					

A3 SECTION-C: STAFF AND MANAGEMENT ATTITUDES AND BELIEFS

This section is intended to explore staff and management attitudes and beliefs relating to EMM at ESD within a large steel manufacturer.

For each statement presented in the table below, provide a response to signify how much you tend to agree with the statement. Response values are between values 1-5, where strongly disagree =1; strongly agree = 5.

SECTION C

STAFF AND MANAGEMENT ATTITUDES AND BELIEFS						
		OPTIONS FOR SELECTION (MARK WITH X)				
Question Number	Question	1	2	3	4	5
92	EMM implementation is largely adversely affected by the existing stakeholder culture.	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
93	Acceptance from plant personnel is vital for successful implementation of EMM.	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
94	ESD has enough resources to successfully implement an EMM-program (availability of funds and people)?	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
95	ESD has a culture that will accept the implementation of EMM	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
96	When employees are aligned in knowing why, how and when the result of a new program will have positive outcome	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
97	An ownership culture needs to be driven by management	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
98	A ownership culture needs to be driven by employees themselves	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
99	A workplace needs to be supported by strong and well defined processes	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
100	EMM is too difficult to deploy successfully	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
101	EMM is too time consuming to deploy successfully	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
102	EMM-related audits will help drive success and compliance, which will lead to good EMM-related habits amongst employees	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
103	Outsourcing of EMM-related activities is the only way to make EMM work	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
104	EMM-related activities requires a dedicated team to ensure success	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
105	EMM-related activities can be successfully executed by existing stakeholders at ESD	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
106	ESD have the requisite skills and knowledge for implementing EMM	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
107	The custodian of EMM is still responsible for their normal daily plant activities	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
108	Existing EMM activities at ESD are successful	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree

APPENDIX B: SURVEY RESULTS

SECTION A - ANSWERS	
Number of Respondents	**32**
Number of valid respondents	**32**

DEMOGRAPHIC QUESTIONS											
Question Number	**Question**	**OPTION SELECTED**									
		1		**2**		**3**		**4**		**5**	
		n	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
1	What is your gender?	31	97%	1	3%						
2	What is your population group?	1	3%	30	94%	0	0%	1	3%	0	0%
3	What is your age?	1	3%	7	22%	7	22%	14	44%	3	9%
4	What is your marital status?	7	22%	25	78%	0	0%	0	0%	0	0%
5	What is your highest academic qualification?	12	38%	4	13%	3	9%	13	41%	1	3%
6	How many times a month do interact with any electrical motor management activity?	0	0%	1	3%	2	6%	29	91%		

SECTION B - ANSWERS	
Number of Respondents	**32**
Number of valid respondents	**32**

GENERAL QUESTIONS																			
Question Number	**QUESTION**	**OPTION SELECTED**																	
		1		**2**		**3**		**4**		**5**		**6**		**7**		**8**		**9**	
		n	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
7	EMM at ESD is very effective	7	22%	17	53%	6	19%	1	3%	1	3%								
8	EMM activities at ESD are being managed	0	0%	13	41%	17	53%	1	3%	1	3%								

9	ESD reports on safety management performance indicators	0	0%	0	0%	0	0%	3	9%	29	91%								
10	ESD reports product/process quality performance indicators	0	0%	14	44%	2	6%	16	50%	0	0%								
11	ESD reports on EMM performance indicators	24	75%	5	16%	3	9%	0	0%	0	0%								
12	Roles and responsibilities are defined relating to EMM-activities	2	6%	14	44%	14	44%	2	6%		0%								
13	Which employees need to use EMM:	29	91%	32	100%	32	100%	32	100%	32	100%	32	100%	27	84%	6	19%	3	9%
14	Which are the EMM aspects that need to be advanced?	31	97%	32	100%	17	53%	28	88%	31	97%	32	100%						
15	ESD have functional block diagrams to supplement the existing asset hierarchy.	30	94%	2	6%	0	0%	0	0%	0	0%								
16	Accurate system data for electrical motors are available (technical data, functional KPIs, failure history, condition monitoring history)	21	66%	9	28%	2	6%	0	0%	0	0%								
17	The main purpose of EMM is control, plan and monitor maintenance and spare parts relating to electrical motors.	2	6%	0	0%	0	0%	19	59%	11	34%								

PROCESS MANAGEMENT ACTIVITIES											
Question Number	QUESTION	OPTION SELECTED									
		1		2		3		4		5	
		n	%	n	%	n	%	n	%	n	%
18	The objective for EMM is clearly defined.	14	44%	13	41%	5	16%	0	0%	0	0%
19	Human resources relating to each EMM-activity are clearly defined.	15	47%	14	44%	3	9%	0	0%	0	0%
20	Equipment and methods forming part of EMM are clearly defined to aid in achieving the EMM objective.	20	63%	8	25%	4	13%	0	0%	0	0%
21	The quality of the processes relating to EMM used to develop, deliver, and support services and production are providing production and service outputs which are high in quality.	23	72%	8	25%	1	3%		0%		0%
22	Long term vision and strategy are defined for EMM	29	91%	3	9%	0	0%	0	0%	0	0%
23	Management support forms the premise of process improvement relating to EMM	31	97%	1	3%	0	0%	0	0%	0	0%

24	The culture and infrastructure at the large steel manufacturer relating to EMM is supported by the development and deployment of procedures which are maintained, revised and improved.	32	100%	0	0%	0	0%	0	0%	0	0%
25	The culture and infrastructure at the large steel manufacturer relating to EMM is supported and enforced through standard operating practices.	18	56%	11	34%	3	9%		0%		0%
26	Procedures, standard operating practices and methods relating to EMM will continue even when authors of the procedures, standard operating practices and methods relating to EMM are no longer working at the organisation.	21	66%	11	34%	0	0%	0	0%	0	0%

PROCESS MANAGEMENT ACTIVITIES INSTITUTIONALISED											
Question Number	QUESTION	OPTION SELECTED									
		1		2		3		4		5	
		n	%	n	%	n	%	n	%	n	%
27	leadership (PA1)	26	81%	3	9%	1	3%	2	6%	0	0%
28	planning (PA2)	16	50%	14	44%	0	0%	2	6%	0	0%
29	policies, procedures and internal controls (PA3)	14	44%	14	44%	4	13%	0	0%	0	0%
30	personnel and staffing (PA4)	13	41%	13	41%	6	19%	0	0%		0%
31	financial management (PA5)	0	0%	0	0%	3	9%	18	56%	11	34%
32	technology utilisation and management (PA6)	0	0%	0	0%	2	6%	27	84%	3	9%
33	records and reporting (PA7)	11	34%	4	13%	13	41%	4	13%	0	0%
34	quality management (PA8)	4	13%	19	59%	1	3%	8	25%	0	0%
35	risk management (PA9)	5	16%	20	63%	3	9%	4	13%	0	0%
36	configuration management (PA10)	27	84%	4	13%	1	3%	0	0%	0	0%
37	assessments (P11)	29	91%	3	9%	0	0%	0	0%	0	0%

PROCESS MANAGEMENT ACTIVITY IMPROVEMENT REQUIRED											
Question Number	QUESTION	OPTION SELECTED									
		1		2		3		4		5	
		n	%	n	%	n	%	n	%	n	%
38	Would you like to see improvements relating to process management activities? (YES or NO) a. If answer in question 38 was YES", please proceed by answering question 39 and beyond. b. If the answer in the aforementioned question was "NO", please skip questions 39-49 and proceed to question 50.	32	100%	0	0%						
39	Leadership (PA1)	0	0%	0	0%	2	6%	23	72%	7	22%
40	planning (PA2)	0	0%	0	0%	0	0%	27	84%	5	16%
41	policies, procedures and internal controls (PA3)	0	0%	0	0%	2	6%	1	3%	29	91%
42	personnel and staffing (PA4)	0	0%	0	0%	15	47%	16	50%	1	3%
43	financial management (PA5)	0	0%	11	34%	11	34%	10	31%	0	0%
44	technology utilisation and management (PA6)	0	0%	0	0%	11	34%	5	16%	16	50%
45	records and reporting (PA7)	0	0%	0	0%	1	3%	2	6%	29	91%
46	quality management (PA8)	2	6%	14	44%	9	28%	7	22%	0	0%
47	risk management (PA9)	1	3%	16	50%	15	47%	0	0%	0	0%
48	configuration management (PA10)	31	97%	1	3%	0	0%	0	0%	0	0%
49	assessments (P11)	0	0%	0	0%	0	0%	5	16%	27	84%

OPERATION MANAGEMENT ACTIVITIES – ACQUISITION LIFE CYCLE PHASE											
Question Number	QUESTION	OPTION SELECTED									
		1		2		3		4		5	
		n	%	n	%	n	%	n	%	n	%
50	Operation management activities are defined specific to the acquisition life-cycle phase	14	44%	18	56%	0	0%	0	0%	0	0%

ACQUISITION OPERATION MANAGEMENT ACTIVITIES INSTITUTIONALISED											
Question Number	QUESTION	OPTION SELECTED									
		1		2		3		4		5	
		n	%	n	%	n	%	n	%	n	%
51	Requirements determination (PA1)	30	94%	2	6%	0	0%	0	0%	0	0%
52	categorisation (PA2)	12	38%	10	31%	10	31%	0	0%	0	0%
53	authorisation (PA3)	1	3%	20	63%	11	34%	0	0%	0	0%
54	procurement (PA4)	0	0%	14	44%	13	41%	3	9%	2	6%
55	construction in progress management (PA5)	0	0%	0	0%	29	91%	3	9%	0	0%
56	receiving (PA6)	0	0%	0	0%	3	9%	21	66%	8	25%
57	identification (PA7)	5	16%	2	6%	0	0%	19	59%	6	19%
58	financial recognition (PA8)	17	53%	5	16%	10	31%	0	0%	0	0%

IMPROVEMENTS REQUIRED FOR ACQUISITION OPERATION MANAGEMENT ACTIVITIES											
Question Number	QUESTION	OPTION SELECTED									
		1		2		3		4		5	
		n	%	n	%	n	%	n	%	n	%
59	Would you like to see improvements relating to acquisition operation management activities? (YES or NO) a. If answer in question 59 was YES", please proceed by answering question 60 and beyond. b. If the answer in the aforementioned question was "NO", please skip questions 60-67 and proceed to question 68.	32	100%	0	0%						
60	requirements determination (PA1)	0	0%	0	0%	0	0%	3	9%	29	91%
61	categorisation (PA2)	0	0%	15	47%	7	22%	0	0%	10	31%
62	authorisation (PA3)	0	0%	0	0%	10	31%	20	63%	2	6%
63	procurement (PA4)	0	0%	6	19%	4	13%	22	69%	0	0%
64	construction in progress management (PA5)	25	78%	0	0%	7	22%	0	0%	0	0%
65	receiving (PA6)	6	19%	23	72%	3	9%	0	0%	0	0%
66	identification (PA7)	0	0%	9	28%	2	6%	18	56%	3	9%
67	financial recognition (PA8)	0	0%	8	25%	19	59%	5	16%	0	0%

OPERATION MANAGEMENT ACTIVITIES – USAGE LIFE CYCLE PHASE											
Question Number	QUESTION	OPTION SELECTED									
		1		2		3		4		5	
		n	%	n	%	n	%	n	%	n	%
68	Operation management activities are defined specific to the usage life-cycle phase	0	0%	16	50%	6	19%	6	19%	4	13%

USAGE OPERATION MANAGEMENT ACTIVITIES INSTITUTIONALISED											
Question Number	QUESTION	OPTION SELECTED									
		1		2		3		4		5	
		n	%	n	%	n	%	n	%	n	%
69	Utilisation (PA1)	0	0%	23	72%	8	25%	1	3%	0	0%
70	control (PA2)	0	0%	0	0%	18	56%	14	44%	0	0%
71	tracking (PA3)	2	6%	16	50%	14	44%	0	0%	0	0%
72	maintenance (PA4)	4	13%	13	41%	15	47%	0	0%	0	0%
73	safety (PA5)	0	0%	0	0%	4	13%	22	69%	6	19%
74	security (PA6)	0	0%	0	0%	4	13%	25	78%	3	9%

IMPROVEMENTS REQUIRED FOR USAGE OPERATION MANAGEMENT ACTIVITIES											
Question Number	QUESTION	OPTION SELECTED									
		1		2		3		4		5	
		n	%	n	%	n	%	n	%	n	%
75	Would you like to see improvements relating to usage operation management activities? (YES or NO) a. If answer in question 75 was YES", please proceed by answering question 76 and beyond. b. If the answer in the aforementioned question was "NO", please skip questions 76-81 and proceed to question 82.	32	100%	0	0%						
76	Utilisation (PA1)	0	0%	0	0%	1	3%	6	19%	25	78%
77	control (PA2)	0	0%	15	47%	5	16%	9	28%	3	9%
78	tracking (PA3)	0	0%	0	0%	2	6%	26	81%	4	13%

79	maintenance (PA4)	0	0%	0	0%	0	0%	0	0%	32	100%
80	safety (PA5)	0	0%	1	3%	22	69%	8	25%	1	3%
81	security (PA6)	0	0%	21	66%	11	34%	0	0%	0	0%

OPERATION MANAGEMENT ACTIVITIES – DISPOSAL LIFE CYCLE PHASE											
Question Number	QUESTION	OPTION SELECTED									
		1		2		3		4		5	
		n	%	n	%	n	%	n	%	n	%
82	Operation management activities are defined specific to the **disposal life-cycle phase**	0	0%	27	84%	5	16%	0	0%	0	0%

DISPOSAL OPERATION MANAGEMENT ACTIVITIES INSTITUTIONALISED											
Question Number	QUESTION	OPTION SELECTED									
		1		2		3		4		5	
		n	%	n	%	n	%	n	%	n	%
83	Reutilisation (PA1)	0	0%	0	0%	2	6%	4	13%	26	81%
84	authorisation to dispose (PA2)	0	0%	3	9%	24	75%	5	16%	0	0%
85	transport, storage, and handling (PA3)	12	38%	8	25%	12	38%	0	0%	0	0%
86	disposal (PA4)	14	44%	5	16%	13	41%	0	0%	0	0%

IMPROVEMENTS REQUIRED FOR DISPOSAL OPERATION MANAGEMENT ACTIVITIES											
Question Number	QUESTION	OPTION SELECTED									
		1		2		3		4		5	
		n	%	n	%	n	%	n	%	n	%
87	Would you like to see improvements relating to disposal operation management activities? (YES or NO) a. If answer in question 87 was YES", please proceed by answering question 88 and beyond. b. If the answer in the aforementioned question was "NO", please skip questions 88-91 and proceed to question 92.	32	100%	0	0%						
88	Reutilisation (PA1)	0	0%	0	0%	0	0%	23	72%	9	28%
89	authorisation to dispose (PA2)	12	38%	13	41%	7	22%	0	0%	0	0%
90	transport, storage, and handling (PA3)	20	63%	11	34%	0	0%	1	3%	0	0%
91	disposal (PA4)	14	44%	14	44%	3	9%	1	3%	0	0%

SECTION C - ANSWERS

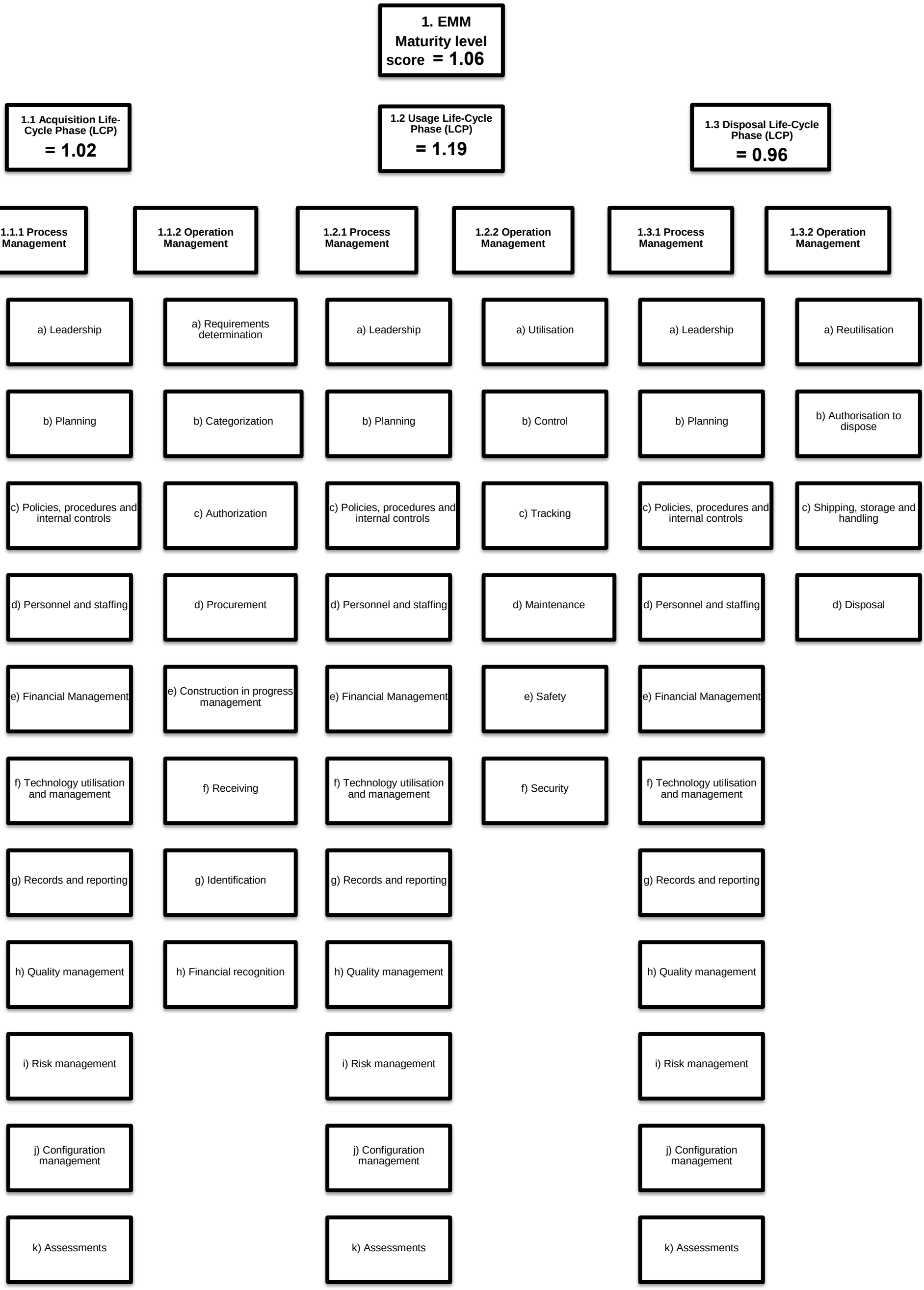
Number of Respondents	**32**
Number of valid respondents	**32**

STAFF AND MANAGEMENT ATTITUDES AND BELIEFS											
Question Number	QUESTION	OPTION SELECTED									
		1		2		3		4		5	
		n	%	n	%	n	%	n	%	n	%
92	EMM implementation is largely affected by the existing stakeholder culture.	0	0%	11	34%	3	9%	15	47%	3	9%
93	Acceptance from plant personnel is vital for successful implementation of EMM.	0	0%	9	28%	3	9%	17	53%	3	9%
94	ESD has enough resources to successfully implement an EMM-program (availability of funds and people)?	14	44%	12	38%	6	19%	0	0%	0	0%
95	ESD has a culture that will accept the implementation of EMM	0	0%	0	0%	3	9%	19	59%	10	31%

96	When employees are aligned in knowing why, how and when the result of a new program will have positive outcome	0	0%	0	0%	0	0%	0	0%	32	100%
97	An ownership culture needs to be driven by management	0	0%	0	0%	0	0%	30	94%	2	6%
98	A ownership culture needs to be driven by employees themselves	0	0%	9	28%	1	3%	21	66%	1	3%
99	A workplace needs to be supported by strong and well defined processes	0	0%	0	0%	0	0%	0	0%	32	100%
100	EMM is too difficult to deploy successfully	8	25%	8	25%	5	16%	10	31%	1	3%
101	EMM is too time consuming to deploy successfully	11	34%	9	28%	7	22%	0	0%	5	16%
102	EMM-related audits will help drive success and compliance, which will lead to good EMM-related habits amongst employees	0	0%	0	0%	0	0%	2	6%	30	94%
103	Outsourcing of EMM-related activities is the only way to make EMM work	0	0%	8	25%	11	34%	13	41%	0	0%
104	EMM-related activities requires a dedicated team to ensure success	0	0%	5	16%	0	0%	13	41%	14	44%
105	EMM-related activities can be successfully executed by existing stakeholders at ESD	0	0%	5	16%	1	3%	13	41%	13	41%
106	ESD have the requisite skills and knowledge for implementing EMM	0	0%	0	0%	0	0%	15	47%	17	53%
107	The custodian of EMM is still responsible for their normal daily plant activities	0	0%	0	0%	5	16%	22	69%	5	16%
108	Existing EMM activities at ESD are successful	2	6%	23	72%	7	22%	0	0%	0	0%

APPENDIX C: EMM-MATURITY EVALUATION MATRIX

C1 OVERALL EMM-MATURITY



C1.1 ACQUISITION LCP MATURITY MATRIX

	Maturity Level Score
1.1 Acquisition Life-Cycle Phase =	**1,02**

Process Area	1.1.1 Process Management	Maturity Level Score
PA01	**a) Leadership**	**0,50**
PA01-SC1	Outcome/Process orientation	1
PA01-SC2	Best value products	1
PA01-SC3	Personal Initiative	0
PA01-SC4	Lines of Authority/Accountability	0
PA01-SC5	Best-in-Class Management	1
PA01-SC6	External Interface	0
PA02	**b) Planning**	**0,67**
PA02-SC1	Strategic Plan	1
PA02-SC2	Metrics	0
PA02-SC3	Financial Plan	1
PA03	**c) Policies, procedures and internal controls**	**0,40**
PA03-SC1	Exercise of Responsibility	1
PA03-SC2	Sound Policies and Procedures	0
PA03-SC3	Reutilisation	0
PA03-SC4	Consensus Standards	1
PA03-SC5	Available, Implemented, and Enforced	0
PA04	**d) Personnel and staffing**	**0,67**
PA04-SC1	Adequate Staffing	0
PA04-SC2	Requisite Skills and knowledge	1
PA04-SC3	Trained Staff	1
PA05	**e) Financial Management**	**1,29**
PA05-SC1	Funding Mechanism Information Provided	2
PA05-SC2	Financial Accuracy	1
PA05-SC3	Balances Costs and Risks	1
PA05-SC4	Best Value	1
PA05-SC5	Loss/Overage Controls	1
PA05-SC6	Materiality	1
PA05-SC7	Minimize Loss Consequences	2
PA06	**f) Technology utilisation and management**	**1,00**
PA06-SC1	Technology Innovation	1
PA06-SC2	Technology Implementation	1
PA06-SC3	Technology Management	1
PA07	**g) Records and reporting**	**0,43**
PA07-SC1	Access to Information	0
PA07-SC2	Records Maintenance	1
PA07-SC3	Electrical Motor Identification	1
PA07-SC4	Summary Report Information	0
PA07-SC5	Records Retention	1
PA07-SC6	Cross-Functional Integration	0
PA07-SC7	Cost and Performance Data	0
PA08	**h) Quality management**	**0,33**
PA08-SC1	Monitoring and Measurement of Processes	0
PA08-SC2	Continuous Improvement	1
PA08-SC3	Outcome Measures	0
PA09	**i) Risk management**	**1,00**
PA09-SC1	Establish Liability	0
PA09-SC2	Insurance	1
PA09-SC3	Mitigation	2
PA09-SC4	Security	1
PA10	**j) Configuration management**	**0,33**
PA10-SC1	Configurations are identified	1
PA10-SC2	Contents of configurations are controlled	0
PA10-SC3	Configuration management information is reported	0
PA11	**k) Assessments**	**0,00**
PA11-SC1	Self-Assessment	0
PA11-SC2	Physical Inventory	0
PA11-SC3	Metrics	0
PA11-SC4	Third-Party Audits	0

Process Area	1.1.2 Operation Management	Maturity Level Score
PA01	**a) Requirements Determination**	**0,25**
PA01-SC1	Functional spec	0
PA01-SC2	Aligned with company goals	0
PA01-SC3	Cost vs. benefit	0
PA01-SC4	Standards	1
PA01-SC5	Alternative sourcing	0
PA01-SC6	ROI-analysis	0
PA01-SC7	Life cycle costing	0
PA01-SC8	HAZOP	1
PA02	**b) Categorisation**	**1,00**
PA02-SC1	Cost goals	0
PA02-SC2	Tax categorisation	1
PA02-SC3	Assign appropriate category	2
PA03	**c) Authorisation**	**1,60**
PA03-SC1	Financial authorisation	3
PA03-SC2	Management authorisation	3
PA03-SC3	Configuration manage authorisation	0
PA03-SC4	Custodian authorisation	0
PA03-SC5	Financial prioritisation	2
PA04	**d) Procurement**	**1,67**
PA04-SC1	Reutilisation possibilities	1
PA04-SC2	Loan/sharing options	1
PA04-SC3	Procure vs. lease	0
PA04-SC4	Negotiate terms	3
PA04-SC5	Plan and manage delivery	3
PA04-SC6	Import restrictions considered	2
PA05	**e) Construction in progress management**	**2,00**
PA05-SC1	Under construction depreciation	2
PA05-SC2	Ready for use depreciation	2
PA06	**f) Receiving**	**2,00**
PA06-SC1	Analyse delivery inconsistencies	1
PA06-SC2	Records and documents receipts	3
PA06-SC3	Storage as per OEM requirements	2
PA06-SC4	Goods received are sent to relevant department	2
PA07	**g) Identification**	**1,33**
PA07-SC1	Categorisation applied	2
PA07-SC2	Identifications plates and markings	1
PA07-SC3	Quality assurance	1
PA08	**h) Financial recognition**	**2,00**
PA08-SC1	Ledgers updated for depreciation	2
PA08-SC2	Statements maintained	2

C1.2 USAGE LCP MATURITY MATRIX

	Maturity Level Score
1.2 Usage Life-Cycle Phase =	**1,19**

Process Area	1.2.1 Process Management	Maturity Level Score 0,87
PA01	**a) Leadership**	**1,17**
PA01-SC1	Outcome/Process orientation	2
PA01-SC2	Best value products	1
PA01-SC3	Personal Initiative	1
PA01-SC4	Lines of Authority/Accountability	2
PA01-SC5	Best-in-Class Management	1
PA01-SC6	External Interface	0
PA02	**b) Planning**	**1,33**
PA02-SC1	Strategic Plan	2
PA02-SC2	Metrics	1
PA02-SC3	Financial Plan	1
PA03	**c) Policies, procedures and internal controls**	**0,80**
PA03-SC1	Exercise of Responsibility	1
PA03-SC2	Sound Policies and Procedures	1
PA03-SC3	Reutilisation	1
PA03-SC4	Consensus Standards	1
PA03-SC5	Available, Implemented, and Enforced	0
PA04	**d) Personnel and staffing**	**1,33**
PA04-SC1	Adequate Staffing	1
PA04-SC2	Requisite Skills and knowledge	2
PA04-SC3	Trained Staff	1
PA05	**e) Financial Management**	**1,43**
PA05-SC1	Funding Mechanism Information Provided	2
PA05-SC2	Financial Accuracy	1
PA05-SC3	Balances Costs and Risks	1
PA05-SC4	Best Value	1
PA05-SC5	Loss/Overage Controls	1
PA05-SC6	Materiality	2
PA05-SC7	Minimize Loss Consequences	2
PA06	**f) Technology utilisation and management**	**1,67**
PA06-SC1	Technology Innovation	2
PA06-SC2	Technology Implementation	2
PA06-SC3	Technology Management	1
PA07	**g) Records and reporting**	**0,43**
PA07-SC1	Access to Information	0
PA07-SC2	Records Maintenance	1
PA07-SC3	Electrical Motor Identification	1
PA07-SC4	Summary Report Information	0
PA07-SC5	Records Retention	1
PA07-SC6	Cross-Functional Integration	0
PA07-SC7	Cost and Performance Data	0
PA08	**h) Quality management**	**0,67**
PA08-SC1	Monitoring and Measurement of Processes	1
PA08-SC2	Continuous Improvement	1
PA08-SC3	Outcome Measures	0
PA09	**i) Risk management**	**1,25**
PA09-SC1	Establish Liability	1
PA09-SC2	Insurance	1
PA09-SC3	Mitigation	2
PA09-SC4	Security	1
PA10	**j) Configuration management**	**0,33**
PA10-SC1	Configurations are identified	1
PA10-SC2	Contents of configurations are controlled	0
PA10-SC3	Configuration management information is reported	0
PA11	**k) Assessments**	**0,00**
PA11-SC1	Self-Assessment	0
PA11-SC2	Physical Inventory	0
PA11-SC3	Metrics	0
PA11-SC4	Third-Party Audits	0

Process Area	1.2.2 Operation Management	Maturity Level Score 1,50
PA01	**a) Utilisation**	**1,29**
PA01-SC1	Authorisation for use	0
PA01-SC2	Financial associations assured	0
PA01-SC3	Availability tracked, reported and corrected	2
PA01-SC4	Electrical motors issues identified	2
PA01-SC5	Usage optimisation	2
PA01-SC6	Reliability strategies deployed	2
PA01-SC7	Identify surplus	1
PA02	**b) Control**	**0,33**
PA02-SC1	OEM instructions followed	1
PA02-SC2	Contractor and subcontractor control	0
PA02-SC3	Interdepartmental control	0
PA03	**c) Tracking**	**1,00**
PA03-SC1	Movements controlled	1
PA03-SC2	Location database maintained	1
PA03-SC3	Records maintained and audited	1
PA03-SC4	Logistics are supportive of needs	1
PA04	**d) Maintenance**	**1,40**
PA04-SC1	Documented strategies for electrical motors	2
PA04-SC2	Strategies executed	0
PA04-SC3	Warrantee maintenance (claims)	3
PA04-SC4	Repair/replace trade-offs	1
PA04-SC5	Breakpoint defined	1
PA05	**e) Safety**	**3,00**
PA05-SC1	Standard operating procedures	3
PA06	**f) Security**	**2,00**
PA06-SC1	Access controlled operating environment	2
PA06-SC2	Compliance with policies & procedures	2

C1.3 DISPOSAL LCP MATURITY MATRIX

	Maturity Level Score
1.3 Disposal Life-Cycle Phase =	**0,96**

Process Area	1.3.1 Process Management	Maturity Level Score 0,85
PA01	**a) Leadership**	**1,00**
PA01-SC1	Outcome/Process orientation	2
PA01-SC2	Best value products	0
PA01-SC3	Personal Initiative	1
PA01-SC4	Lines of Authority/Accountability	2
PA01-SC5	Best-in-Class Management	1
PA01-SC6	External Interface	0
PA02	**b) Planning**	**1,33**
PA02-SC1	Strategic Plan	2
PA02-SC2	Metrics	1
PA02-SC3	Financial Plan	1
PA03	**c) Policies, procedures and internal controls**	**0,80**
PA03-SC1	Exercise of Responsibility	1
PA03-SC2	Sound Policies and Procedures	1
PA03-SC3	Reutilisation	1
PA03-SC4	Consensus Standards	1
PA03-SC5	Available, Implemented, and Enforced	0
PA04	**d) Personnel and staffing**	**1,33**
PA04-SC1	Adequate Staffing	1
PA04-SC2	Requisite Skills and knowledge	2
PA04-SC3	Trained Staff	1
PA05	**e) Financial Management**	**1,43**
PA05-SC1	Funding Mechanism Information Provided	2
PA05-SC2	Financial Accuracy	1
PA05-SC3	Balances Costs and Risks	1
PA05-SC4	Best Value	1
PA05-SC5	Loss/Overage Controls	1
PA05-SC6	Materiality	2
PA05-SC7	Minimize Loss Consequences	2
PA06	**f) Technology utilisation and management**	**1,67**
PA06-SC1	Technology Innovation	2
PA06-SC2	Technology Implementation	2
PA06-SC3	Technology Management	1
PA07	**g) Records and reporting**	**0,43**
PA07-SC1	Access to Information	0
PA07-SC2	Records Maintenance	1
PA07-SC3	Electrical Motor Identification	1
PA07-SC4	Summary Report Information	0
PA07-SC5	Records Retention	1
PA07-SC6	Cross-Functional Integration	0
PA07-SC7	Cost and Performance Data	0
PA08	**h) Quality management**	**0,67**
PA08-SC1	Monitoring and Measurement of Processes	1
PA08-SC2	Continuous Improvement	1
PA08-SC3	Outcome Measures	0
PA09	**i) Risk management**	**1,25**
PA09-SC1	Establish Liability	1
PA09-SC2	Insurance	1
PA09-SC3	Mitigation	2
PA09-SC4	Security	1
PA10	**j) Configuration management**	**0,33**
PA10-SC1	Configurations are identified	1
PA10-SC2	Contents of configurations are controlled	0
PA10-SC3	Configuration management information is reported	0
PA11	**k) Assessments**	**0,00**
PA11-SC1	Self-Assessment	0
PA11-SC2	Physical Inventory	0
PA11-SC3	Metrics	0
PA11-SC4	Third-Party Audits	0

Process Area	1.3.2 Operation Management	Maturity Level Score 1,08
PA01	**a) Reutilisation**	1
PA01-SC1	Excess identified	1
PA01-SC2	Age failure risk determined	1
PA01-SC3	Excess recorded and reported	1
PA02	**b) Authorisation to dispose**	1
PA02-SC1	Disposals authorised	0
PA02-SC2	Disposals recorded and reported	2
PA03	**c) Transport, storage, and handling**	0,5
PA03-SC1	Traceable	1
PA03-SC2	OEM instructions followed	0
PA04	**d) Disposal**	1,8
PA04-SC1	Feasible	0
PA04-SC2	Corporate responsibility adhered	3
PA04-SC3	Timeous	1
PA04-SC4	Donated is considered disposed	2
PA04-SC5	Compliance	3