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Reduction in Outage Durations at ESKOM Power Plants in South Africa

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A **Research Report** submitted to the Faculty of Engineering and the Built Environment, University of the Witwatersrand, in fulfilment of the requirements for the Degree of Masters in Engineering.

Date: 14 May 2021

DECLARATION

I declare that this coursework - Research Project Proposal submitted to the Faculty of Engineering and the Built Environment, University of the Witwatersrand, in fulfilment of the requirements for the Degree of Masters in Engineering, is entirely my own work and does not include any plagiarised information. All information sources that were reviewed, in order to compile this Research Project, have been referenced appropriately.

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ABSTRACT

Inefficiencies and capacity constraints in the power industry, managed by government-owned ESKOM, has led to load-shedding across South Africa, and affected many consumers. Outage maintenance projects within the ESKOM environment revolves around shutting down units, disassembling machine components, refurbishing these components, dependent on the condition after inspections, reassembling the machine components, commissioning and synchronisation to the national grid. This research report sought to investigate the factors that are leading to increased durations of outages and increased costs, limited to the study of outage projects specific to the turbine, generator and auxiliary components. The critical aspects of performing an outage was determined, the constraints of the processes was reviewed and compared to best practice methods, and finally recommendations were stated to improve efficiency. A comprehensive literature review was completed with content specific to planned maintenance activities showing the optimum level of maintenance based on a balance between preventive and corrective maintenance. Previously published research pertaining to ESKOM was reviewed and results showed there are significant challenges in risk management, procurement practices as well as skills and training. Different types of best practice project management techniques were considered, such as 'Project Management Body of Knowledge' PMBOK, agile and lean methodologies. An exploratory approach was taken using participant observation at a specific outage project on a power plant. In order to triangulate results and ensure reliability and validity, secondary methods of research were conducted namely, interviews conducted with subject matter experts, and a document analysis. It was found that challenges experienced in terms of poor workmanship, lack of skills/training, variation from standard procedures/ processes, spares not being procured and supplied in time, and general overall poor planning, led to delays in the outage project. An emergent factor of poor cultivated culture amongst workforce leads to complacency and no importance on focused results. Further recommendations such as a review of outage philosophies, application of PMBOK for more structure in project management processes, application of lean techniques using the Timken South Africa model, and automated systems can lead to improved overall performance on outage projects by reducing time, and costs.

CHAPTER 1

INTRODUCTION

1.1 Background and Context

Power plant facilities require maintenance so that continued operation of the facilities' are efficient, natural resources' are used wisely and customers receive high quality service. The general steps required in maintenance of the power plants starts with identification of the actual work to be performed, reviewing the general day to day maintenance records, or daily operating trends, identifying risks associated with the work to be performed and then prioritising the proposed work. In order for power plants to perform the maintenance activities, the systems are shut-down completely. (Brown, 2004)

Power plants usually have multiple units where each unit is given a name and operates individually from other units. Each unit is capable of generating electricity in its own entirety. Each unit consists of a turbine and generator as well as the auxiliary systems. Power plants refer to maintenance on one of these units as 'General Overhaul's' (GO's), where the unit is shutdown to perform maintenance. These GO's are projects in its own entirety and are usually referred to as 'outages' in the power generation environment. Thus a 'General Overhaul' (GO) is synonymous with an 'outage'. (Eskom, 2014) Maintenance services are offered throughout the value chain of electricity, and ESKOM is responsible for performing these maintenance services.

During the primary energy phase – handling of bulk material is necessary, during generation of electricity, maintenance of turbines, generators and other auxiliary equipment is also required for prolonged life expectancy. The transmission and distribution phases of electricity production; also requires a significant amount of maintenance to ensure equipment is functional. Determining the scope of work (SOW) on a specific unit in the plant is the responsibility of the ESKOM operational engineers based at different power plants. (Eskom, 2014)

Units are the different machine systems that run individually to generate electricity to supply the national grid. Each unit consists of a turbine, generator, boiler, and other auxiliary equipment, etc. Original Equipment Manufacturers (OEM's) are responsible for manufacture of these turbines, generators, and other auxiliary systems. (Eskom - Centre of Excellence (COE), 2019)

The SOW is determined based on the performance of that specific unit, the operating and maintenance history of the unit, the standard regulations that govern safety in the power industry; as well as the statuary inspections that fall under these regulations.

1.2 Problem Statement/Motivation

General overhauls (GO's) or 'outages' as they are referred to, are major projects where the scope of work (SOW) is identified, planning the work prior to the shut-down of the unit should occur, scheduling the work would be of paramount importance where critical paths would be identified, and finally the actual execution of the work would occur. (Brown, 2004) The downtime on the units affords the maintenance department opportunities' to perform critical work needed on the units so as to ensure that the refurbishment is successful and the unit can run efficiently once back in service. (Brown, 2004)

The downtime of the units means that the power plant will not be producing electricity during this time, and will not be earning the required monetary value during this time. The 'outage project duration' is, thus, considered critical since it negatively affects the financial gains of the power plant. More efficient and effective running of 'outage project duration' equates to success in returning units to service in a cost effective manner, and thus, ensuring the profitability of the power plant. Management of outage projects amongst the entire ESKOM Fleet is challenging because of the various problems of deterring factors experienced, whilst these projects are executed. These problems lead to increased costs during the outages projects and increased duration of the outage projects. (Outage projects herein referred to as 'outages'.) This research seeks to investigate these factors.

1.3 Research Question

"What factors in 'Outage Maintenance Projects' in ESKOM Power Plants pertaining to generator, turbine and auxiliary systems, are leading to increased costs during the outages' and increased durations of the outages'?"

1.4 Research Objectives

The aim of this research project, is to determine the problems' or deterring factors', experienced during management of General Overhauls (GO's) or 'outages' as they are referred to, at an ESKOM power plant, which leads to consequential increased costs of outages and increased durations of outages.

The objectives are:

1.4.1. To determine the critical aspects of performing an outage at a specific power plant.
1.4.2. To determine constraints in the processes followed, during an outage.
1.4.3. To compare the outage performed in a specific power plant against best practice methods using established project management processes.
1.4.4. To establish methods/processes that can improve the efficiency of outages.

1.5 Summary of Research Method

Research was conducted based in the ESKOM environment and specific to a power plant owned by ESKOM. Power deficits have been experienced within South Africa since 2007, due to generation capacity constraints. (Stacey Mwale, 2014) The research aims to investigate the reasons why constraints are experienced specific to processes of 'outage maintenance projects'. A critical literature review was completed to source either other countries or other industries in South Africa, experiencing similar aspects of increased durations of outages and increased costs.

Techniques of how the problems were solved was considered and referenced to, within the 'conclusion and recommendations' – section 6. In order to triangulate the research three methods were used within this research, namely:

- Participant observer research
- Interviews conducted after establishing the sampling method, through 'focus groups'
- Document review and analysis.

Access was granted to a specific outage project that was completed at a specific power plant and can be considered as 'participant observer research' for this project. The summary of events was documented and discussed further in section 5. The validation of these factual experiences was compared with the other two methods used.

Conducting interviews was based on 'focus groups' that worked on the outage; some of these interviewees were considered experts because of the amount of experience that they have carried in their careers. 'Interviewing experts' holds significance as it obtains good results quicker, as described in section 3. The interview questions were developed from reviewing the relevant literature, and focusing on problematic areas, as well as gathering information during the participant observer phase. The information received from the interview sessions was coded and placed into specific themes. The interviews were transcribed using the 'Intelligent Verbatim' method. (Summa Linguae Technologies, 2021) Adhering to ethical considerations only one of the interviews is provided in Appendix C, Section 7.3.2, where confidential information has been removed.

The statistics from the outcome of the themes were then discussed further in section 5. Lastly a document review was conducted to integrate the underlying themes across all methods of research, through access to the ESKOM information centres, research conducted by other personnel based within ESKOM, as well as other sources of information relevant to this topic of research pertaining to the ESKOM processes used during outage planning and execution. The document review was compared to the best practice methods used in project management, and recommendations of improvement were outlined in sections 5 and 6.

1.6 Delimitations

The boundary in which the research was conducted is within the ESKOM environment within South Africa only, excluding other countries in Africa. ESKOM is government-owned and supplies majority of the power across South Africa and other countries in Africa. Political influences governs ESKOM, however the research aims to achieve the factual information relating to planning and executing processes of outages, and thus, does not consider the external influences on ESKOM.

The research is also based on a particular power plant in South Africa, owned by ESKOM. With qualitative-based research, the following factors can be considered delimitations:

- Biases of the researcher – In order to provide the reader with a robust view on the substance of the research, the biases of the researcher was stated, so that the reader can decide on the overall presentation of research.

- Amount of current research available is limited in South Africa so a broad range of literature was covered to establish if companies worldwide experience the same problems. Aspects on how these companies resolved the problems were noted and applied to the discussion.

- Sampling in terms of which personnel were selected to participate in interviews can be limiting, as this might affect the representation of the full population and no lead to saturation of results. (Fountouki & Antigoni, 2018) Careful selection of 'interview participants' was considered. Interviews unlike surveys, where the researcher cannot control the course of the investigation an example being participants' not completing specific questions in a survey, with interviews the interviewee is dedicated attentively, during the time period of the interview. (Fountouki & Antigoni, 2018)

- This research report is limited to the study of the work done on the turbine and generator as well as auxiliary systems only. The study does not include other systems such as the boiler, ash plant system, bulk storage areas, etc.

1.7 Outline of Sections/Chapters

1.7.1 Chapter 1: Introduction and Context of Research

Chapter 1 outlines the reasons why the research was conducted. South Africa is in desperate need of establishing changes within the power generation industry, to ensure sustainability in the future, and to grow the economy of South Africa. Improvements through efficiency of processes that govern outages in ESKOM is necessary to ensure that the power plants are not only generating electricity effectively but also being utilised as profit 'powerhouses or in business terms as cash-cows'. Chapter 1 also outlines the objectives of the research as well as the delimitations of the research.

1.7.2 Chapter 2: Critical Literature Review

Chapter 2 outlines the theoretical information from reliable sources that have been reviewed to show similar problems experienced within the power generation industry and the techniques or methods used to solve these problems. A review on the processes that were used by other such companies was also considered so that it could be compared to the results. Successful companies which were able to achieve reduced outage durations and reduced costs, were highlighted, so that it could be compared with best practice methods to provide recommendations that could be implemented within ESKOM.

1.7.3 Chapter 3: Research Methods

Chapter 3 outlines the Qualitative research methods that were used in order to resolve the problem statement. Producing good quality research was also considered, so establishing methods to ensure that accurate data is obtained and accurate results were achieved is described in this section. Validity and reliability were considered in each aspect of the three research techniques, as mentioned in section 1.5 above and applied to the research in the most effective way possible. Triangulation in order to achieve

accurate results was also considered and thus the research conducted had three aspects of data collection, as stated below:

- Participant observation in an outage performed at an ESKOM power plant.
- Interviews with Subject Matter Experts (SME's) and sampling amongst groups of personnel working on the outage.
- Document analysis – process of completing an outage from planning to commissioning the unit.

1.7.4 Chapter 4: Analysis and Results

Chapter 4 outlines the analysis based on all the data received under the three methods of research, and the results are presented in a logical manner in which similarities and conclusions were drawn from. Graphical and tabulated representation showed factors of the research that were most pertinent.

1.7.5 Chapter 5: Discussion

Chapter 5 outlines the interpretation of the results achieved in Chapter 4. The discussion draws back to all other chapters, and describes the relationships of the findings. The discussion makes use of the literature review as reference, in order to answer the research question, and to solve the objectives of the research conducted.

1.7.6 Chapter 6: Conclusion and Recommendations

Chapter 6 outlines the significance of why the research was conducted, and how the recommendations can be implemented in order to fix the potential problem that was highlighted under the "Problem Statement". The conclusion shows the reader that the completion of research matters significantly because the creation of awareness of the factors that affect performance on outages can be addressed further in order to

continuously improve, reaching higher levels of success within ESKOM and the power industry.

CHAPTER 2

LITERATURE REVIEW

The purpose of this literature review is to present an overview of previous written work related to the topic of reduction of outage durations. In section 2.1 previous literature has been reviewed and compared to highlight themes and resolutions to solve the problem of increased costs and increased durations of outages. In section 2.2 the process of managing outages in the ESKOM Rotek Industries (ERI) environment is explained. Best practice project management methods outlined in Appendix A – section 7.1 has been compared to the resolutions used by other countries or companies; to outline which techniques generate success in the management of outages.

2.1 Planned Maintenance Projects

General Overhauls' (GO's) within the power generation industry is considered as planned maintenance. The units' operates for a set amount of hours, and shutdowns of the units is controlled, in order to ensure that inspections are completed. These inspections are completed for a multitude of reasons; one is to ensure the safety of people because heavy machinery in the workplace puts significant risk on human life if failures occur. (Dekker, 1996) Other reasons revolve around replacement/repair of machines when failure occurs. Poor managed maintenance, leads to decreased reliability, future poor performance of machinery as well as downtime losses. (Yang, 2004)

When a new system is established in terms of machinery integrated to perform an end result (product/service) such as the production of electricity, over a significant amount of time, deterioration of the equipment occurs and maintenance must be completed on the system to restore the system as best possible - back to its original form. Maintenance can be classified into two categories, namely: Preventive Maintenance (PM) and Corrective Maintenance (CM). Time-based and condition-based maintenance are two major categories of PM, whereas maintenance performed after failure occurs is CM. (Yang, 2004) The reasons for performing PM is to ensure that problems are detected early on, so that repairs can be done in time before failure occurs, thus preventing losses. Improvement Maintenance (IM) is also

a type of maintenance that is completed during design phases of systems. (Yang, 2004) The systems are designed in such a way as to minimise maintenance, or to eliminate it completely. Some examples of this can also be to ensure that some systems are running 24/7 and maintenance is performed simultaneously, duplication of systems/ bypass's – two pumps can perform the same operation but one will be in operation at any point in time, alternation of operation of the pumps allows the other to be refurbished/maintained.

ESKOM has an established system that monitors vibrations on turbine and generator equipment – this can be considered as condition-based maintenance. If vibrations are found out of tolerance – depending on the severity, the system can be shut down and fault finding can occur, the necessary replacement/repair of components will follow. This method of monitoring aids in the prevention of catastrophic failure. (Eskom - Centre of Excellence (COE), 2019)

Planned outage projects within ESKOM has a set scope of work completed on units after a specific amount of time, which is classified as time-based maintenance. During the outage project; disassembly of machinery takes place, inspections are performed on components and the condition of these components are determined to be either acceptable or not. If the components are not acceptable to return to service as is – further work must be completed either through refurbishment or replacement which is considered to be condition-based maintenance and also 'scope-creep', which can potentially further increase the duration of the outage.

The advantages of planned maintenance are to ensure that effective and efficient maintenance is completed, and availability of machinery is increased leading to increased revenue. Once effective and efficient planned maintenance occurs in an organisation, a balance of costs ensues. An optimum level of cost is reached which is the lowest overall total maintenance cost as shown in Figure 1 below. The more preventive maintenance that is performed leads to reduced corrective maintenance. Organisations cannot perform planned maintenance to a degree as to eliminate corrective maintenance completely as this might gather unnecessary significantly high upfront costs, thus there is a unique balance found between preventive costs and corrective costs. (The Machine Tool Industry Research Association, 1979)

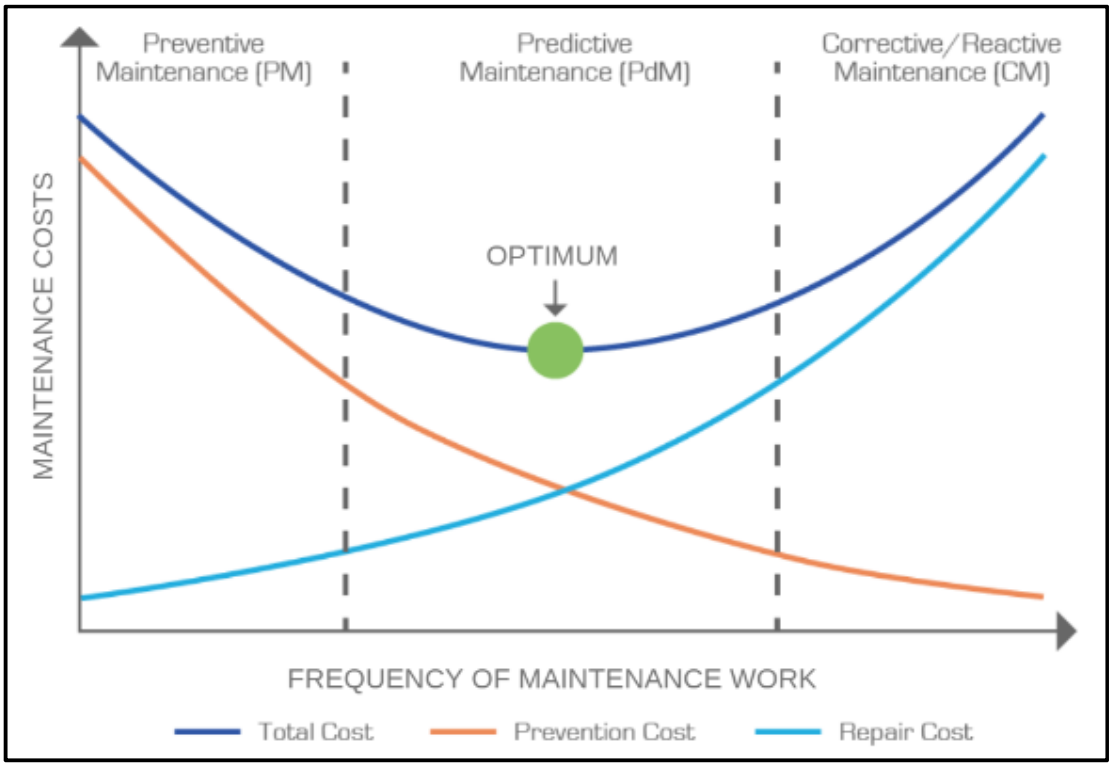


Figure 1: Balance of Predictive and Corrective Maintenance showing optimum point. (Kananesan & Kavina, 2019)

Some of the challenges experienced in power plants whilst performing maintenance activities are listed below. (Mathilde, 1996)

- Complexity of scheduling a multitude of tasks that requires efficient co-ordination and execution of these tasks, leads to delays. This includes management of programmes of different Contractors working on different systems, sequencing of activities, human resources, tools, equipment, specialised services, etc.

- Availability of resources' as some resources' will be working as operations personnel as well as maintenance personnel.

- Reliance on people to perform work based on experience and not based on data provided by systems. (Non-technological advancement in maintenance practices.)

- The need to work with specific detailed work instructions to perform tasks to meet quality standards, however these might not be available or time-pressures might subject personnel to finding easier ways to get the work done faster.

- Dealing with unplanned situations, where stakeholders are required to make decisions that cause further delays.

Some strategies to improve performance of planned maintenance are listed below.

a) Total Productive Maintenance (TPM) involves the whole organisation contributing to maintenance activities, from higher management down to employees on the 'shop floor'. The main aim of TPM is to eliminate losses through zero defects, zero failures, and zero accidents. (Raj, et al., 2018)

   The six steps outlined below are used in TPM:

   - Step 1: Equipment criticality evaluation criteria and ranking.
   - Step 2: Reversing deterioration and rectify defects.
   - Step 3: Development of an information management system.
   - Step 4: Development of a robust periodic maintenance system.
   - Step 5: Development of a predictive maintenance system.
   - Step 6: Measurement of effectiveness of the implemented PM system.

A case study; in a gas producing plant completed by Dr. M. Raj, et.al. 2018, showed significant improvement when the six steps above were applied over a period of time and results were captured. The study concluded that:

- The major breakdown detected in the plant was identified as support roller bearings, which was permanently eliminated.

- Average number of failures significantly reduced.
- Mean Time between Failure (MTBF) increased.
- Mean Time to Repair (MTTR) decreased.
- Equipment availability increased from 98.2% to 99.64%.

b) The use of computer systems to enhance scheduling accuracy is also used in PM. Computerised Maintenance Management System (CMMS) is an example of one of the techniques used in PM. The aim of the tool is to provide a scheduling programme after input variables of human resources, preventive maintenance tasks, and availability of equipment. (Senra, et al., 2017) Whilst the CMMS method significantly improves scheduling, it also has some limitations that need to be considered further. It is best to have an overall review of the solution provided by the CMMS solution and it should not be followed without question. Some of the limitations are listed below.

- The system only considers criticality of tasks and does not show the results of tasks not being completed in time.
- The urgency of situations shifts during maintenance due to volatility in discovering component conditions thus spares and resources need to be allocated accordingly. The CMMS method might not provide the necessary intelligence in deciding factors.

2.2 Published Research on 'Outages' at ESKOM

A list of articles relating to ESKOM was reviewed, as listed below.

1. Risk Management during Outage Projects at Power Plants, by S.C. Hlophe & J.K. Visser. (South African Journal of Industrial Engineering November 2018 Vol 29 (3) Special Edition, pp 82-91)

2. Project Management Approach for Turbine Maintenance in Power Utility Plants: The Case of a South African Maintenance Company, by T. Mtembi and M.G Kanakana. (Proceedings of the 2015 IEEE IEEM)

3. Current energy landscape in the Republic of South Africa, by Bruno G. Pollet, Iain Staffell, Kerry-Ann Adamson. (International Journal of Hydrogen Energy, 40, 2015)

4. Energy efficiency in South African industry, by H Fawkes (Journal of Energy in Southern Africa, Vol 16, No 4, November 2005)

Hlophe and Visser (2018) point out that, one of the critical questions is whether or not risk management in outages is recognised as a success factor or not. These Researchers' made use of a survey that was sent to selected individuals who were involved in the management of outages. The results showed that further training was needed for risk management amongst individuals, and a culture change where support would be required from management towards improvement strategies for outages. In a similar article, addressing project management issues in a South African Maintenance Company performing work at a power utility in South Africa, the major factors forming barriers for implementing projects was due to procurement processes (Mtembi and Kanakana, 2015). The article reviewed aspects such as risk, quality and stakeholder management. Mtembi and Kanakana made use of a qualitative research method using a survey amongst targeted personnel within the organisation.

Comparison of the two articles showed that whilst outlining some of the definite factors affecting the success of the projects, the overall approach of the research provided only a high-level view of the problems. Both articles did not show the root causes of these problems or it was unclear, and the recommendations provided would also need more details regarding implementation, where it is necessary to understand the purpose of applying specific techniques to obtain specific end-results. Tables 1 and 2 show the highlighted problems and recommended solutions of both articles. Point 1 in both Tables 1 and 2 highlight the fact that training is needed or competent personnel must be used to manage or perform work on outage projects. Hlophe and Visser (2018) refer to a supportive organisational culture needed within ESKOM - this point can be cross-referenced to Point 3 in Table 2 where Mtembi and Kanakana (2015) refer to clear roles and responsibilities in keeping all Stakeholders up to date in communication. Various stakeholders have the ability to make decisions and thus managing stakeholders during

execution of a project can lead to more support, effectively changing the culture of an organisation.

Table 1: Summary of the article Hlophe and Visser (2018) with regards to risk management on outages.

Item	Highlighted Problems	Recommended Solutions
1.	Challenges facing ESKOM are: a) Declining plant performance and increases in unplanned shutdowns. b) Unavailability of space in the work schedule for planned outages.	Ensure that projects are managed through the right personnel who have the right competence and level of experience and apply risk management to projects, throughout the life cycle.
2.	Conventional Project Management Practices is lacking in Risk Management and is too focused on operational planning and control. Three areas of uncertainty in estimates, project stakeholders and the stages of the project life cycle.	ESKOM is aware of the benefits of risk management; however application of risk management practices is low.
3.	Internally generated risks arise within project management teams or organisations from their management systems, culture, and decisions. Risks arise because of uncertainty in projects.	Supportive organisational culture to be established within ESKOM.
4.	Level of Compliance of Risk Management Processes is below standards. And Risk Management is not applied consistently throughout the project life-cycle.	The use of the Centre of Excellence within ESKOM as the major stakeholder for outage risk management. Hiring of an individual to ensure risk management practices are standardised across various Business Units' (BU's) in ESKOM.

Table 2: Summary of the article written by Mtembi and Kanakana (2015).

Item	Highlighted Problems	Recommended Solutions
1.	Risk Analysis should be incorporated into Project Management. 70-90% of problems experienced on Projects are predictable and preventable.	Training for Project Personnel and Technical Personnel in Project Management Practices. The use of the following Risk Concepts as stated below: • Identify the risks • Analyse the risks • Evaluate the risks • Resolve the risks • Monitor and review the risks
2.	Quality Management	Technical Skills and Skills Transfer, as well as collaboration with Original Equipment Manufacturers (OEM's).
3.	Stakeholder and Communication Management	Training for Project Personnel in Project Management Practices specific to communication of common goals and other related criteria to all stakeholders involved.
4.	Delays in the Procurement Processes.	The responsible Procurement Departments/ personnel need to be involved in planning before the project begins, in all stages of planning the project, even years before the project is executed.

The results of the research by Mtembi and Kanakana (2015) showed that only 12% of projects were successful as compared to 55% of projects that were considered less successful. The understanding of successful projects was also tested amongst the sample group of personnel, leading to a majority of 53% having a complete understanding of all related aspects to project management – the management of time, cost and quality. The

use of risk-based project management software such as 'Delphi' was not used, but rather the use of manual documentation and checksheets, as well as collaboration efforts amongst Teams. Statistical data received from surveys showed that majority of personnel viewed the procurement processes as a significant barrier in project execution. (Mtembi and Kanakana, 2015)

As outlined by Hlophe and Visser (2018), Planning in risk management is necessary to ensure that a project can be controlled successfully, and one of the aspects of good planning would be assessing the project programme, highlighting the risks associated with the critical path, and ensuring that in order to reduce the duration of the outage, one must consider protecting the critical path.

One of the ways of ensuring that the critical activities on a project programme is safeguarded is through assigning more resources in order to complete the critical activities sooner, whereas other activities which are not critical can finish later, with less resources. Ashok et al. (2011) advised that Activity Crashing in shutdown maintenance in power plants becomes difficult to perform, due to the high complexity involved in managing these particular projects. It was recommended that the projects be completed in a minimum amount of time due to the fact that the plant unit remains idle during this time. These types of projects have a high degree of uncertainty due to the amount of repair work discovery; only after inspections' of components after the shutdown takes place (Ashok et al., 2011).

Ashok et al. (2011) conducted a case study in a thermal power plant in Orissa State in India. The research was focussed on activities on the boiler sub-system of the power plant unit. This may be extrapolated to the turbine and generator activities as well and can reduce the duration of outage projects. The case study refers to a time-cost trade-off, where additional resources can be added to reduce time, but only within a budget limitation. Table 3 below shows the problems experienced as outlined in the research and the recommended solutions.

Table 3: Problems associated with Activity Crashing and recommended solutions (Ashok et al., 2011).

Item	Highlighted Problems	Recommended Solutions
1.	The highlighted problems across projects are defined as: • Uncertainty (Time Dependency on condition of components.) • Resource Constraints (Less resources assigned to projects.) • Non-availability of Spares - allowing low inventory costs. • Activity Relationship (Co-dependency on other activities and interruptions.) • Estimate of Cost of Crashing (Difficult to estimate additional costs involved.) • Non-availability of accurate time standard – amount of unique work required. • Quality Requirements – difficulties in specifying. • Organisational Behaviour Aspects – changes in teams, and clarification of roles. • As equipment gets older – more maintenance is required.	a) The duration of an outage can be managed through activity crashing which aligns to increased costs and resources. b) Experienced personnel use shortcuts in performing work, thus the management system needs to be reviewed. c) A particular diagram or method might not work for the same work during every refurbishment and sequence as well as precedence of activities are based on a Manager's style. d) Complex problems of activity crashing can be solved by qualitative assessment through participation, involvement of people and teamwork.

The highlighted problems shown is Table 3 above defines the method of Activity Crashing, which can be used to mitigate some of the risks, experienced on outages

through ensuring more time is saved on the critical path activities, essentially creating a larger float in project programmes. Even spares were highlighted as a concern due to power plants keeping a low inventory stock.

Delays in procurement processes, as outlined in Point 4, Table 2 is another concept that speaks to delays in receiving spares in time to perform an outage or not having contracts in place in time, in order to execute services. A specific scenario of this was highlighted in the media when ESKOM delayed coal contracts due to corruption, thus risking coal supply to plants, thereby affecting electricity generation. (Styan, 2019) The consistent supply of material, spares and services is an example of "Just in Time" (JIT) which is one of the pillars in Lean Management of projects, eliminating waiting time/waste.

Whilst S. C. Hlophe and J. K Visser referred to ESKOM being aware of various processes required such a risk management of outages, the application of these methods during execution of outages was not consistent amongst the fleet, and allowing the Centre of Excellence (COE) which is a division in ESKOM to manage all risk amongst all power plants; projects onto the outcome from a study conducted by Shawn St. Germain as a co-author, with regards to the management of outages in nuclear plants. (Shawn St. Germain, 2014)

Shawn amongst his colleagues recommended that an 'Outage Control Centre' (OCC) be a central command centre for the control and monitoring of outages as well as the communication of information to various stakeholders based on a real-time approach. ESKOM's Centre of Excellence (COE) is a division that manages information and conducts statistical analysis and the concept of using the division as a central command centre can be considered further.

James-Brent Styan advises in his book – '*Blackout – The ESKOM Crisis'* that even if ESKOM significantly improves in maintenance and energy availability, the existing ESKOM Fleet of machinery is old and falling apart, as some of these power plants' were supposed to be decommissioned after a service of 50 years. One way to address the energy availability crisis in South Africa is through the introduction of Independent Power Producer's (IPP's).

Since ESKOM owns the power grid, the cost of IPP electricity is still more expensive than electricity produced by ESKOM, due to the additional tariffs for distributing the electricity produced by IPP's. Thus it can be seen from the literature that ESKOM indeed needs to fix the problems within, as increased costs for consumers is not an option, by lowering operating costs of ESKOM, the tariffs can significantly drop thus ensuring that IPP electricity is also at an affordable amount.

2.3 Project Management Practices

Project Management techniques have been standardised into many theoretical books over many years of practice or experimental methods. The Project Management Body of Knowledge (PMBOK) clearly defines the different phases of a project, and provides the necessary tools and techniques for adequately completing a project from start to finish. A clear definition of a project is given below:

"*A project is a temporary endeavour undertaken to create a unique product, service or result. The temporary nature of projects indicates that a project has a definite beginning and end. The end is reached when the project's objectives' have been achieved or when the project is terminated because its objectives will not or cannot be met, or when the need for the project no longer exists*." *(PMI - Project Management Institute - Global Standard, 2013)*

Project Management is essentially described as changes in a business such as the power industry business that is needed during the normal operations of the business. The normal operations of the business would be to control processes within the operating environment and to achieve the standardised results on a day to day basis or a shift to shift basis. The difference in projects and functional operations can be seen in Figure 2 below. It is therefore immediately apparent that there is a fundamental difference between project management (project management teams') and functional or line management (normal operations management teams'). (Lester, 2017) While the Project Manager thrives on and is proactive to change, the Line Manager is reactive to change and hates disruption of normal day to day operational activities. (Lester, 2017)

(a) Project organization	(b) Functional or line organization
Building a house	Manufacturing bricks
Designing a car	Mass producing cars
Organizing a party	Serving the drinks
Setting up a filing system	Doing the filing
Setting up retail cash points	Selling goods and operating tills
Building a process plant	Producing sausages
Introducing a new computer system	Operating credit control procedures

Figure 2: Difference in management of projects and general operations management. (Lester, 2017)

Each project undergoes a life cycle which can be seen in Figure 3 below; starting with conception or generation of ideas that lead to a business need identified. Business needs are developed into business cases and feasibility studies are completed to validate if the results will be beneficial and the organisation has the required funds, time, resources etc. British Standard (BS) 6079 shows a very generic life cycle; whilst the Association for Project Management (APM - UK) shows sub-divisions in the phases of the project and finally MoD (Military of Defence – USA) shows a generic life cycle for a weapons system project as shown in Figure 3 below.

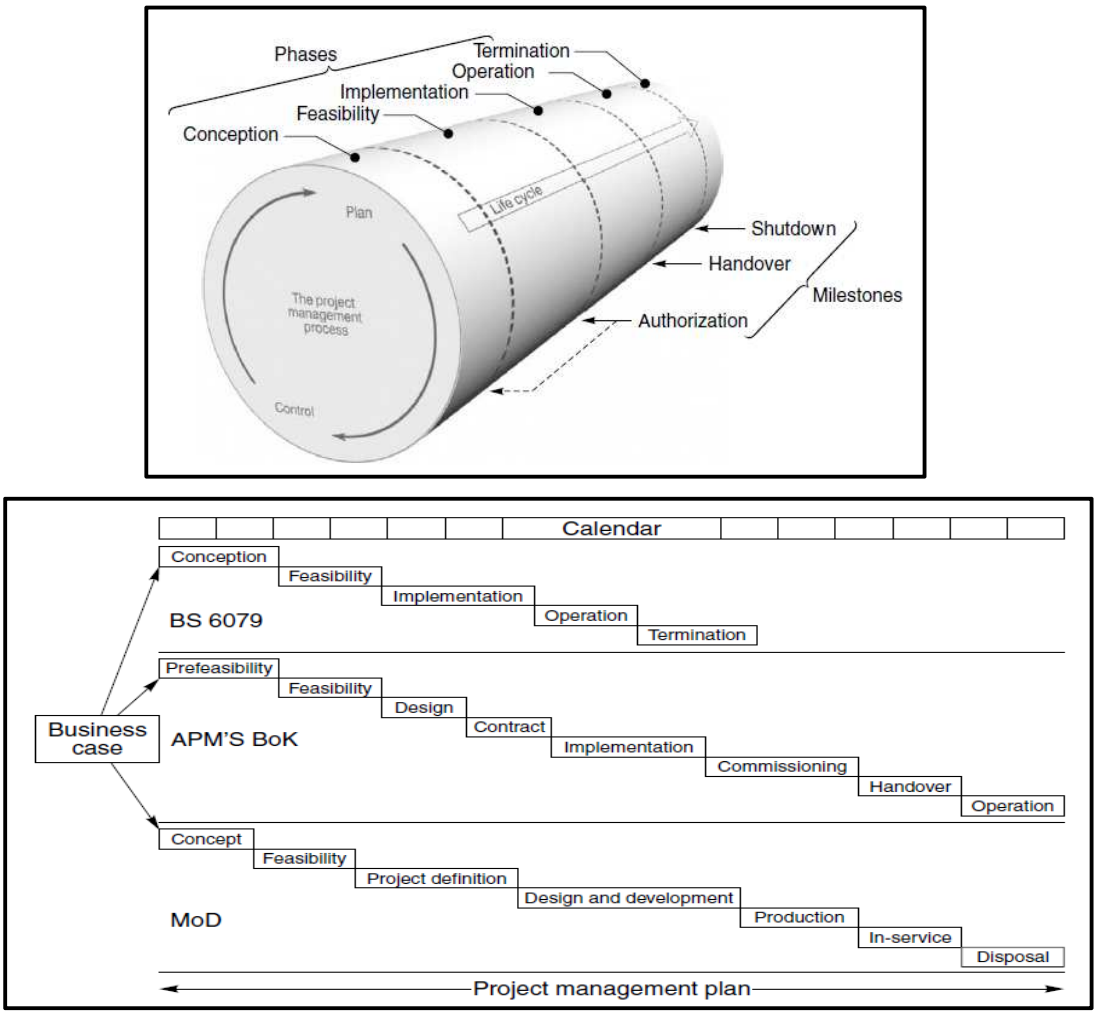


Figure 3: Project Life Cycle. (Lester, 2017)

Project Management processes described in PMBOK includes the following topics (PMI - Project Management Institute - Global Standard, 2013):

a) Project Management Processes
b) Project Integration Management
c) Project Scope Management
d) Project Time Management
e) Project Cost Management
f) Project Quality Management
g) Project Human Resource Management
h) Project Communications Management
i) Project Risk Management

j) Project Procurement Management
k) Project Stakeholder Management

Project Management can be described through the "Triangle of Equilibrium" as shown in Figure 4 below, where all forces need to be in balance or have dependent and interdependent relations; in order to successfully achieve the objectives of the project.

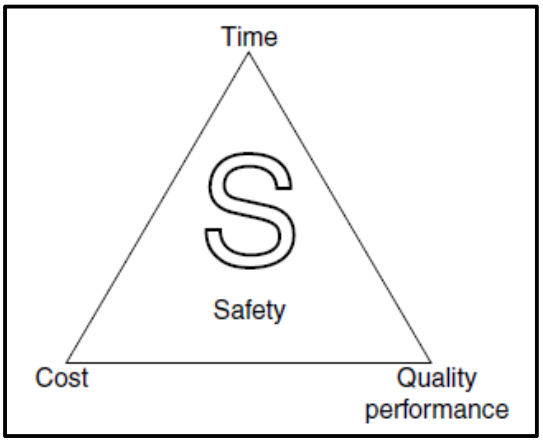


Figure 4: Time, Cost and Quality Project Management Triangle (Lester, 2017).

The Project must be completed within time, accomplished successfully within the project's budgeted cost, and must meet all prescribed quality requirements. (Lester, 2017) In addition to time, cost and quality performance, is associated scope management where changes in the scope of work (SOW) to be performed leads to changes in the time, cost and potentially quality of the project, thus leading to changes in the outcome or objectives of the project.

2.3.1 Project Management Body of Knowledge Structure (PMBOK)

The PMBOK method, is one of the most utilised approaches to Project Management practices around the world. The PMBOK method describes the different phases of a project and provides techniques on how to manage each phase of the project. Each phase of the project is outlined by each process group, which should be managed by different processes. (Anon., 2013) Each process

group has a specific set of inputs and outputs, which feed into other process groups as shown in Figure 5 below.

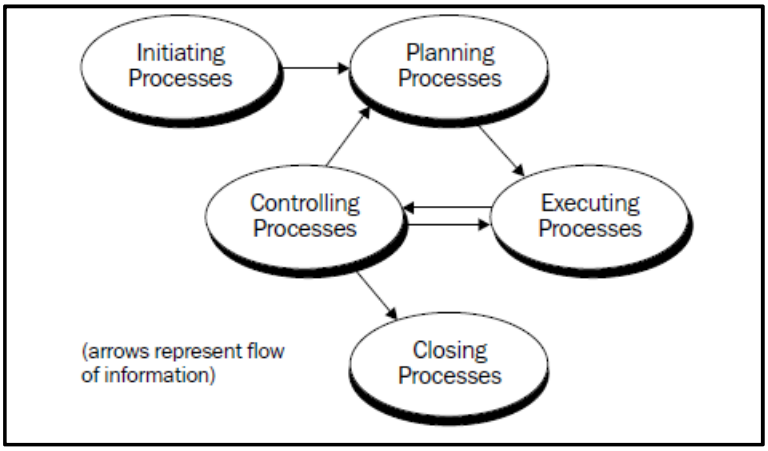


Figure 5: Links amongst Process Groups in a Phase. (Anon., 2013)

The areas of project management within the PMBOK method are depicted as per Figure 6 below, showing both core processes and facilitating processes that are dependent on each other.

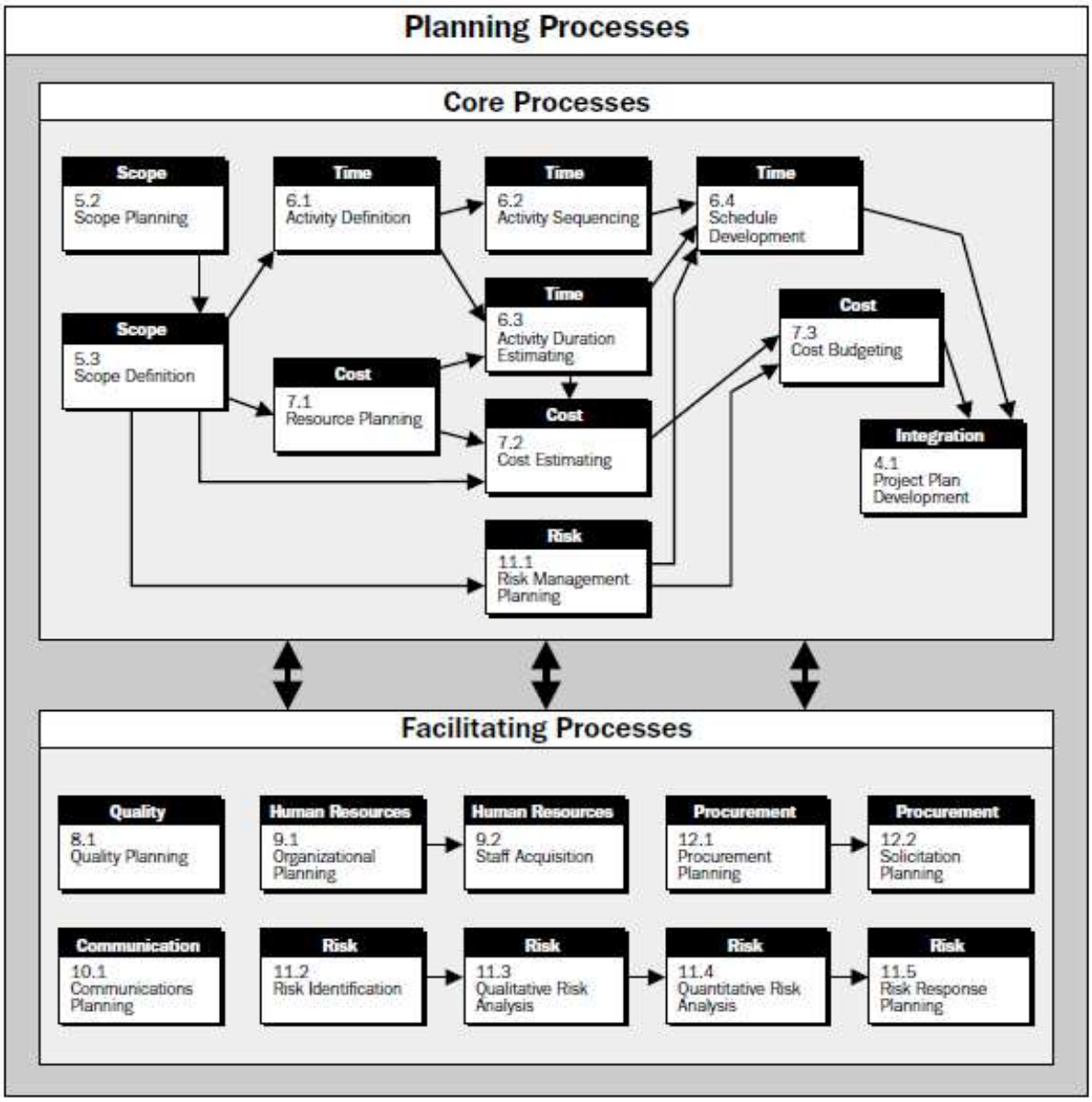


Figure 6: Relationships amongst the Planning Processes. (Anon., 2013)

2.3.2 Agile Project Management Practices and Waterfall Project Management Techniques

Agile Project Management practices can best be described as project types where the objectives of the project will change or evolve during the actual execution of the project. (T.O.C, 2016) Figure 7 below shows the difference

between Agile Project and Traditional Project Management styles. It is clearly outlined that 'features' which are objectives of a project is estimated, or evolving within an Agile Project Management environment.

In Traditional Project Management practices, requirements or objectives of a project is fixed, or referred to as set-points. The Waterfall Project Management technique is more of a traditional style – it has a specified timeline and specified objectives that are discussed and agreed upon at the beginning of the project. Teams work through the tasks in sequence completing one task before moving to the next one. The Waterfall method is often used in construction projects.

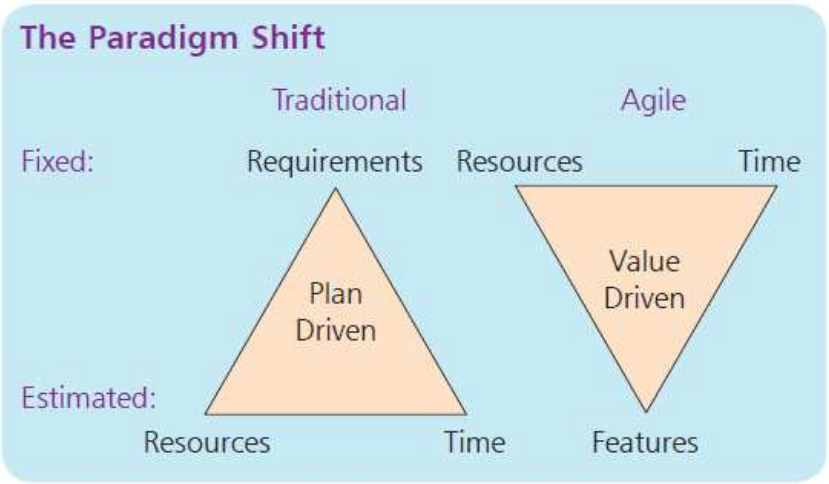


Figure 7: The Paradigm Shift - Agile Projects vs. Traditional Projects. (T.O.C, 2016)

The Agile Project Management Methodology originates from software industries where there was a huge need to decrease the amount of documentation within the project controls, and move towards a more efficient and effective way of managing software projects specifically. The Agile Project Management basis can be clearly described as per Figure 8 below. Agile Project Management techniques create more flexibility during the project life cycle. The method is less structured and breaks down larger projects into smaller manageable mini-projects – like iterations also known as 'sprints'.

At the end of execution, of each iteration, a consequential result is produced. (Taymor, 2016) Employees ranging from designers, developers' and business associates, from different departments in an organisation that practices Agile techniques, work together simultaneously. Some of the major benefits of Agile techniques are personalised individual interactions, less documentation practices, customer collaboration, and responding to change in an optimistic way. (Taymor, 2016)

The Waterfall method differs from Agile techniques since the objectives of the project do not change, the SOW of the project does not change, thus this method is often limited to very little changes which could be accommodated during the project life cycle. Figure 8 below shows the typical flow of phases in a Waterfall styled project. (The Beginner's Guide to Project Management Methodologies - Wrike, 2016) Extensive planning in the beginning of the project is completed and thus the end result is more accurate as the goal of the project is to achieve the requirements as outlined in the SOW. Teams also don't collaborate on a scale as they would in the Agile styled project. (T.O.C, 2016)

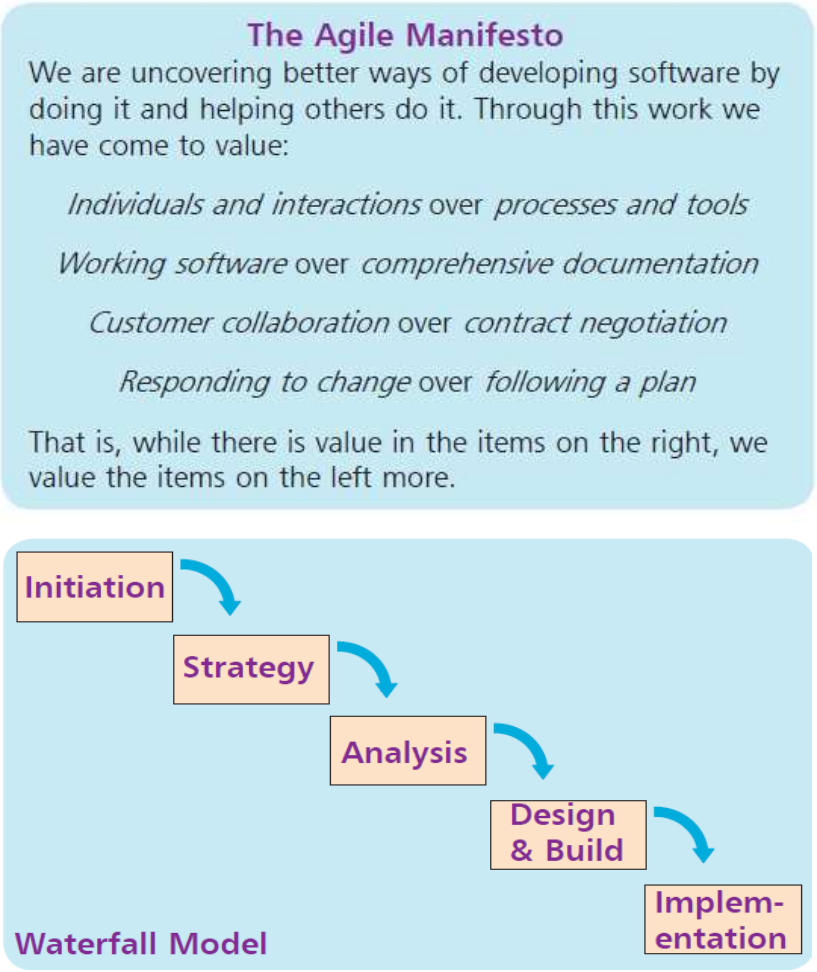


Figure 8: The Agile Manifesto - Agile Project Management basis and the Waterfall Model. (T.O.C, 2016)

Constraints in Agile techniques are the number of resources and the time period allowed for completion. So by prioritising the objectives of the project and delivering on only high priority objectives – the project can subsequently remain within budget. (T.O.C, 2016) Some of the major benefits of agile techniques are listed below. (Taymor, 2016)

- Speed to Market – after sprints are completed, results can be shared with end users and this can lead straight to implementation into the market place.

- Flexibility – Is not ultimately dependent on achieving a specified SOW, ideas are taken into consideration at any point in the project, and thus changes can be completed.

- Risk Management – because of the fast effective way of achieving quick results, pilot products or pilot services can be implanted quickly and thus defects can be identified quickly. Management of risk is also done throughout the process, with the collaboration of employees.

- Cost Control – If Clients are vigorously involved in the process of getting a product or service to the market, then resultant features would be streamlined thus spending less money on developing precisely what you need instead of lavish spends on features not necessarily needed.

- Quality – consistent team collaboration is beneficial since quality is also managed effectively throughout the process, and a higher quality product or service is delivered.

- Right Product – Having releases on a product or service earlier on helps you improve your product, even if this is not yet released to the market.

- Transparency – 'hand-in-hand' with high performance teams, having the team collaborate together consistently, removes silos' which are often experienced in traditional project management styles.

2.3.3 Lean Project Management Practices

"Waste not, want not!" Lean is all about finding the path of least resistance to get the results you want. (The Beginner's Guide to Project Management Methodologies - Wrike, 2016) The term for finding constraints in the system is "Mura" – creation of process flows, identification of constraints as well as 'wasted time' is the Lean way. Lean Project Management focuses on customer satisfaction, and also focuses on continuous improvement. The goal is to do

more with less: deliver high-value, high-quality work with less manpower, less money, and less time. (The Beginner's Guide to Project Management Methodologies - Wrike, 2016)

A good example of a Lean company is Timken Bearings USA. The company practices Lean Management Techniques and has established well defined Lean Processes, and Training for Employees. Figure 9 below shows the "House of Lean Project Management" established in Timken Bearings USA. Many of the strategies and tools used by Timken Bearings USA are developed from Toyota's implementation of Lean Management Techniques.

> *"Having a proper awareness of the problems, and an extremely low tolerance for the current condition is a proper attitude and starting point for any activities in Lean Techniques." – Isao Kato (Father of standardised work and Toyota's Supervisor and Team Leader Development Program)* (Timken Bearings USA, 2013)

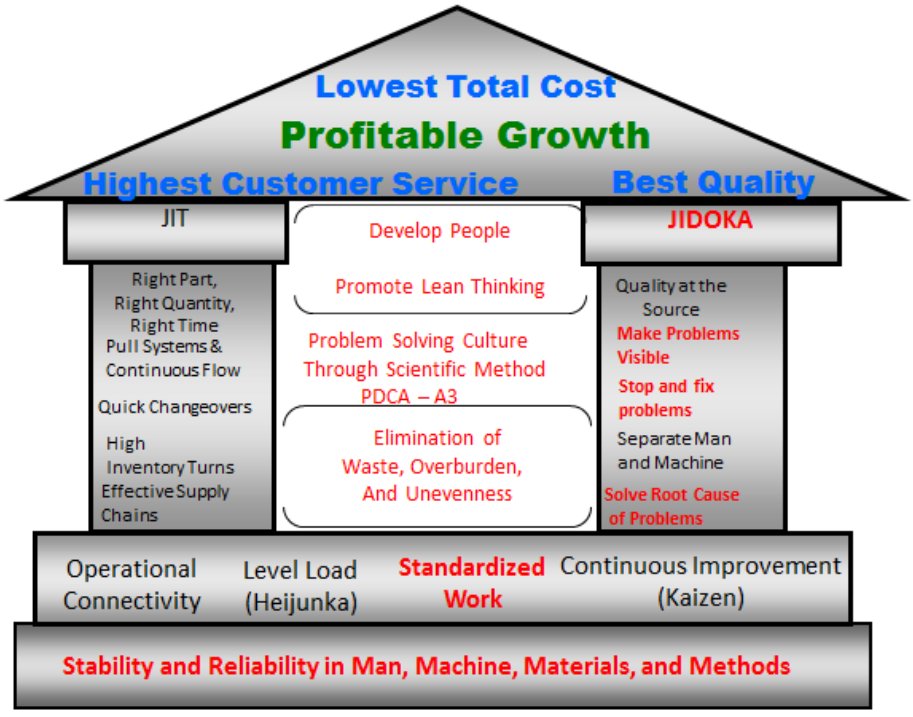


Figure 9: Timken Bearings (USA) – House of Lean Project Management. (Timken Bearings USA, 2013)

In Figure 9 above it can be seen that the principles of "Just in time" (JIT) is used receiving all the right parts, equipment, and tools, etc. in time to be able to perform a task timeously and effectively. Included in this and relevant to ESKOM would be receiving engineering decisions in time, in order to continue with work. The purpose of JIT would be to maintain a steady workflow so that time is not wasted in any way.

"Jidoka" is another concept used in Lean Management Techniques and Figure 10 below shows the evolution of Jidoka. (Lean Enterprise Institute, Inc., 2000-2019) Automation of processes leads to more efficiency – the ultimate end result that needs to be achieved is a self-monitoring machine for mass production. Making problems visible and solving problems immediately, not solving the symptoms' of the problems but rather solving the root causes of the problems experienced in operations or projects. (Lean Enterprise Institute, Inc., 2000-2019)

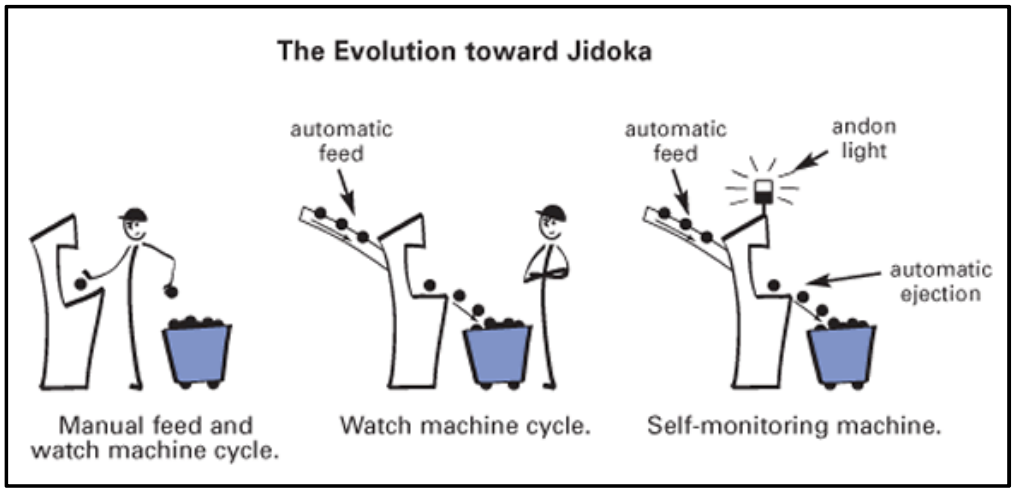


Figure 10: The Evolution of Jidoka principles in Lean Management Techniques. (Lean Enterprise Institute, Inc., 2000-2019)

Timken Bearings USA has a quality system referred to as the "Timken Quality Management System" (TQMS), as shown in Figure 11 below. At the base of the pyramid and forming the foundation of the system is Process Control

techniques. Included in this is a Global Quality Tracking System (GQTS) usually software that is used to keep track of customer complaints. Quality certification is important in maintaining a good standing with customers.

Auditing processes forms the next level where it must be noted that by means of auditing, a company can improve in its processes. Customer Acceptance Review and Evaluation (CARE) is also a value-adding process and helps to improve the process from a different viewpoint. (Timken Bearings USA, 2013) Standard Work and Standard Training also speaks to Jidoka as, standardising helps to follow the best, easiest and safest methods to accomplish a task. Training in Standard Work accomplishes 'Standard Training' which helps to ensure that all employees are familiar with the work and understands what's needed together as a team.

Out of the Auditing Processes, comes 'Lessons Learned' in which new implementation of new processes can also be achieved, and employees that are fairly new can also learn from the past, through these lessons. Failure Modes Effects Analysis (FMEA) is also practiced in Timken Bearings USA, and software is available for the analysis. (Timken Bearings USA, 2013) This is the stepwise approach of identifying risks in processes; quantifying the risks dependant on a standardised categorisation of risks in the organisation and finally prioritising the risks, so that the highest risks are dealt with first (through means of preventative actions).

Risk Priority Number (RPN) is at the height of the pyramid in Figure 11 below, and forms the goal of the quality management system – to manage all risks by reducing the risks or eliminating the risks entirely. (Timken Bearings USA, 2013)

Error Proofing is a means of eliminating the risk involved entirely. A simple example of Error Proofing is the design of a three pin plug in South Africa – there is only one way to insert the plug into the socket, thus eliminating the risk of it being inserted in any other way. In line with all the steps outlined within the

pyramid in Figure 11 below, are the processes that are managed as well, such as Supplier Management and Flawless Launch (launch of a new product). (Timken Bearings USA, 2013) There are other tools and techniques that can also be used in Lean Management such as Six-Sigma's statistics based process improvement, which focuses on minimising process variation. (Lean Enterprise Institute, Inc., 2000-2019) It helps to understand the trends that occur in processes and mass production to help create efficient processes.

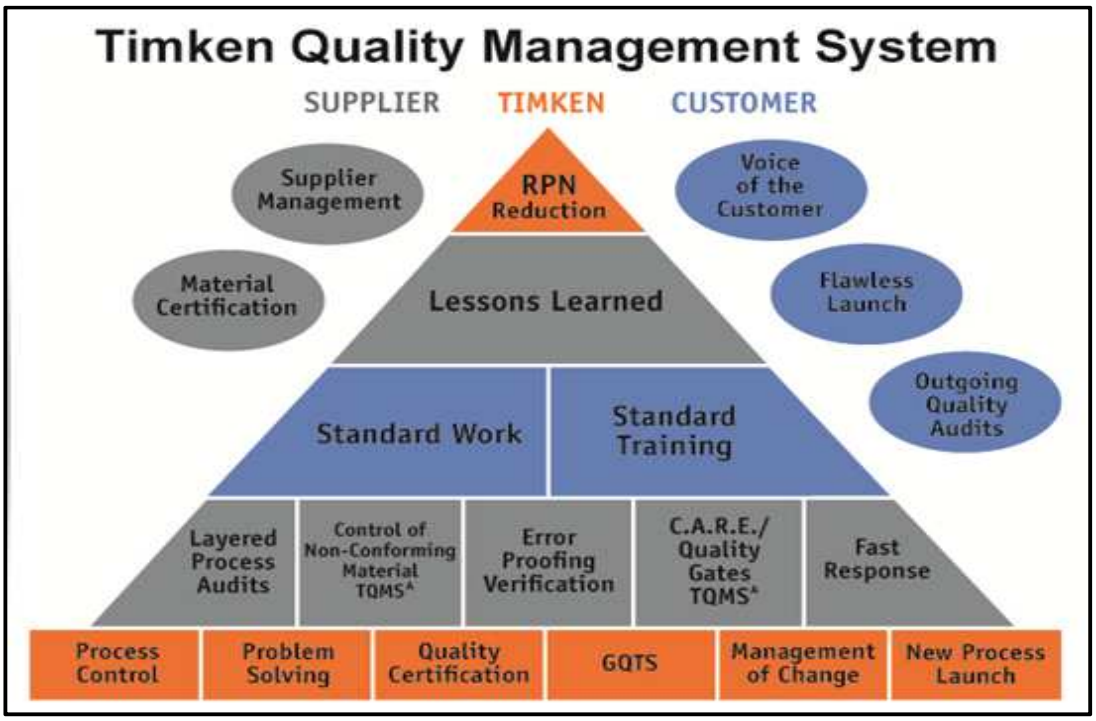


Figure 11: Timken Quality Management System (TQMS) – Foundation for Excellence. (Timken Bearings USA, 2013)

2.3.4 Five-Dimensional Project Management (5DPM) Techniques

The development of the 5DPM practice was based on large infrastructure projects that were more complex than the traditional projects experienced in organisations. (Shane, et al., 2015) In addition to these new complex projects, it also addresses the complex renewal projects where a certain degree of

establishment (project was completed and has results) is achieved, and there is a higher involvement of external stakeholders that need to be addressed.

An example of a complex renewal project would be the current M2 highway refurbishment project in South Africa, due to high levels of instability in this specific road-network infrastructure, called for a refurbishment project for the road-network. Critical to this specific project is the divergence of traffic to other routes and consequential traffic congestion on other routes. South African civilians would be a major external stakeholder that is currently affected due to the complex renewal project of the M2 Highway refurbishment.

Project complexity is based on multiple factors: project types, engineering complexity, size, modality, jurisdictional control, financing approach, contract type, and delivery method, where each project calls for a distinct project management style and approach. (Shane, et al., 2015) The 5DPM approach for complex projects is not new; however it has been extensively developed, over the years.

The five dimensions are outlined below.

1) Cost (Project Estimates, Uncertainty, Contingency, Project-related Costs and Project Cost Drivers as well as Constraints)
2) Schedule (Time, Schedule Risk, Prescribed Milestones and Availability of Resources)
3) Technical (Scope of Work, Internal Structure, Contract, Design, Construction, Technology and Nature of Constraints)
4) Context (Stakeholders, Project-specific Issues, Local Issues, Environmental Issues, Legal and Legislative Issues, Global and National Issues and Unexpected Occurrences)
5) Finance (Public Funding, Financing a Future Revenue Stream, Exploiting Asset Value, Finance-Driven Project Delivery Methods, Financial Techniques to Mitigate Risk, Differential Inflation Rates, and Commodity-Based Estimating)

The 5DPM techniques' would be successfully used if the following aspects were followed; stated below. (Shane, et al., 2015) Figure 12 below shows the 5DPM Management Plan Overview.

1) Define Critical Project Success Factors by each dimension, as required.
2) Assemble the Project Team.
3) Select Project Arrangements.
4) Prepare early cost model and finance plan.
5) Develop Project Action Plans.

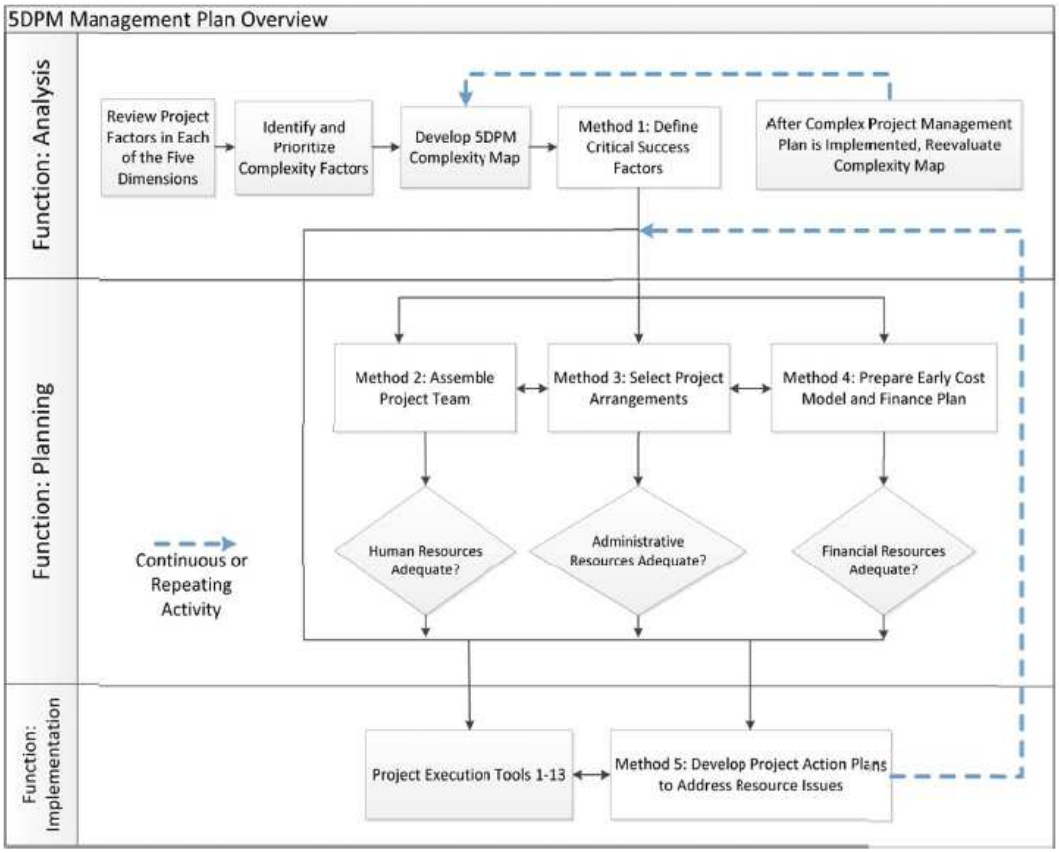


Figure 12: Overview of complex-project management and 5DPM process flow.

In Figure 12 above it is seen that mapping out the complexity of the project helps the team differentiate between the Analysis of the Project, the Planning Phase of the Project and the actual execution of the Project (Implementation). The Team also focuses on major deliverables (critical success factors), manages

resources effectively based on the specialised operations during implementation and establishes the tools that go hand-in-hand with the project action plans.

Figure 13 below shows the initial assessments of projects outlined in the 5DPM approach. This initial planning and documenting of the planning can lead to improved future projects, which all begins with core-analysing of problems in projects.

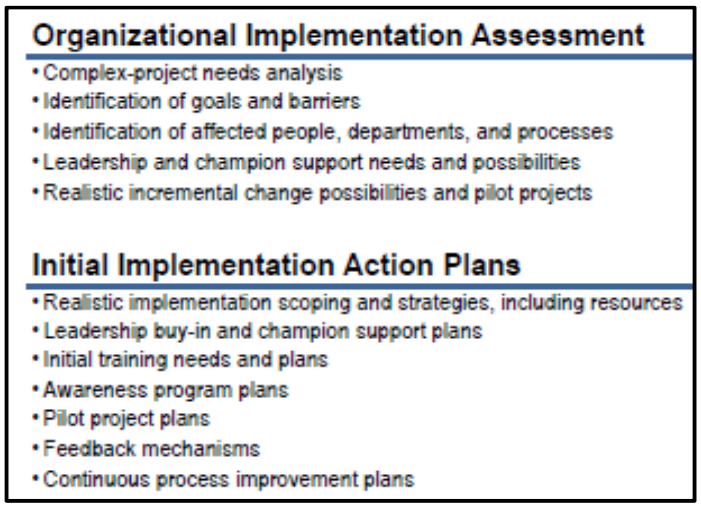


Figure 13: Initial 5DPM implementation approaches for projects. (Shane, et al., 2015)

Project Management Tools based on the 5DPM approach are listed below.

- Tool 1: Incentivise Critical Project Outcomes.
- Tool 2: Develop Dispute Resolution Plans.
- Tool 3: Perform Comprehensive Risk Analysis.
- Tool 4: Identify Critical Permit Issues.
- Tool 5: Evaluate Applications of Off-Site Fabrication.
- Tool 6: Determine Involvement in Right-of-Way (ROW) and Utilities.
- Tool 7: Determine Work Packages and Sequencing.
- Tool 8: Design to Budget.
- Tool 9: Collocate the Team.

- Tool 10: Establish Flexible Design Criteria.
- Tool 11: Evaluate Flexible Financing.
- Tool 12: Develop Finance Expenditure Model.
- Tool 13: Establish Public Involvement Plans.

Figure 14 below, shows the overview of selecting Project Management Tools beginning with defining the 'Critical Project Success Factors'. Figure 15 below, shows the process of Tool Selection. (Shane, et al., 2015) Following the techniques of 5DPM, success in projects can be accomplished. The 5DPM techniques are well-established practices in American Industries, for major construction projects (new and renewal projects).

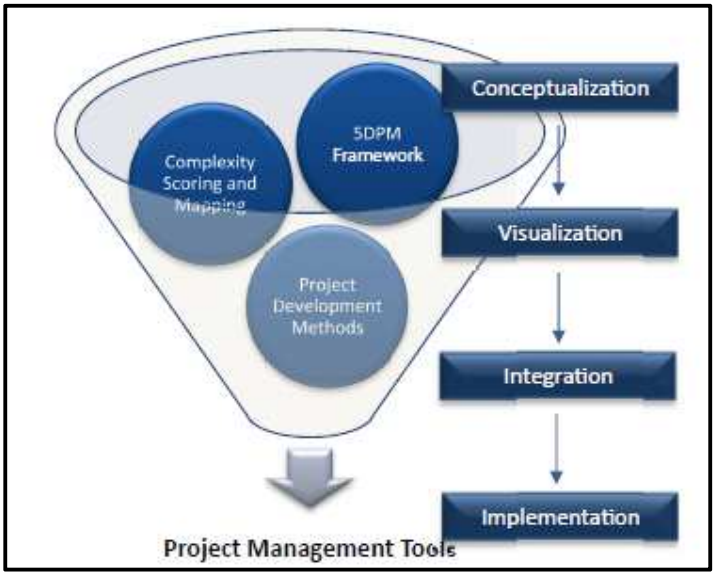


Figure 14: 5DPM conceptual process funnel for Tool Selection.

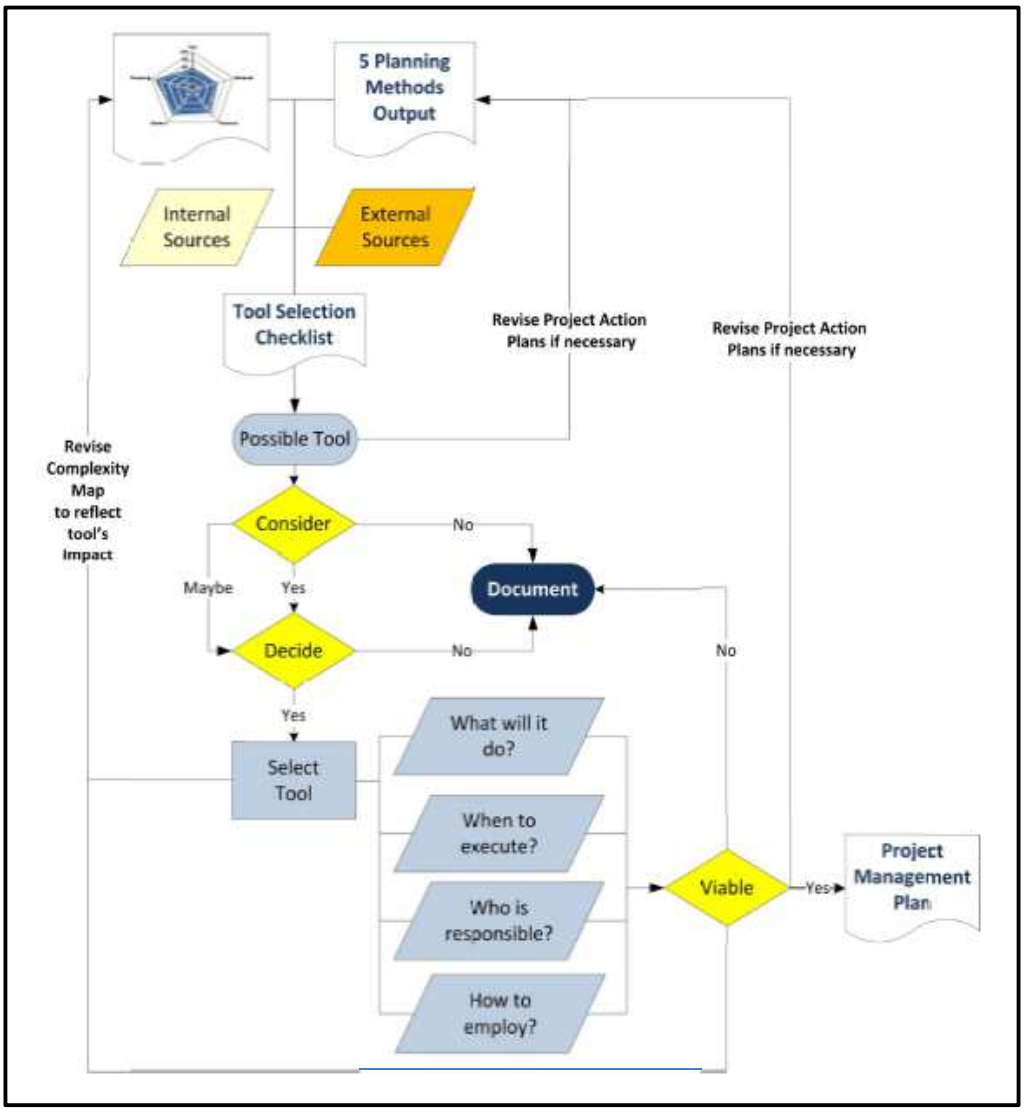


Figure 15: Tool Selection Process. (Shane, et al., 2015)

Table 4 below outlines both pros and cons of all project management styles that have been reviewed in this report.

Table 4: Highlights of Pros' and Cons' per Project Management Style.

(The Beginner's Guide to Project Management Methodologies - Wrike, 2016)

Project Management Style	***Pros***	***Cons***
1. PMBOK (PMI - Project Management Institute - Global Standard, 2013)	A structured approach outlining the different phases of a project.	Can result complicated approach for small projects leading to increased costs.
	Well established terminology and analytical methods to determine value at certain stages of the project.	Might not be able to address large scale complex projects effectively.
	Encompasses the company's goals or strategies.	Sometimes fails in addressing the iterative process of planning and monitoring processes in general.
2. Agile Project Management	This approach is beneficial for creative projects with goals that are flexible and can be modified.	Timelines and Budgets are difficult to define, and stakeholders require constant feedback on time, and also sometimes like to be actively involved in the day to day work.
3. Lean Project Management	Analytical approach to identifying risks in the project, and efficient tools outlined in managing the risks.	Mostly applied in mass production companies.
	Helpful in cutting budgets, meet small quick deadlines or obtain good results with a small team.	Prompt decisions need to be completed by stakeholders, taking too long with decisions inhibits the Lean Process.
	Examines the entire production process to identify improvements even before defects may occur.	Less flexibility after the planning process – puts a limit on the Team's innovative ideas.
4. 5DPM (Shane, et al., 2015)	Addresses the re-iterative process of different stages of the project	Might be too complex for small scale projects that are not subjected to lots of changes.
	A very technical approach in the methodology which summarises the key risks in a project.	Very interactive process which requires many resources.

2.4 Summary of Literature Review

Methods reviewed in the literature that have been applied across organisations, in order to reduce outage durations and reduce costs associated with outage projects have proven successful, however it is still unclear from the literature how these methods should be applied within ESKOM and how it can be sustained within ESKOM.

The main theme relating to all articles reviewed was a lack of control leading to inefficient processes and resulting in poor quality product associated with increased expenses. As outlined in Chapter 1 where the critical question was to determine the factors that are leading to increased costs and longer durations, the literature has eloquently summed up that due to the lack of control of processes there is no preferential balance between time, cost and quality in these specific types of projects.

Some of the key concepts that were generated from the review of some of the articles were risk management during outages, project management training and skills required, thorough planning of project programmes, the use of techniques such as Lean, Six Sigma and Value-Stream Mapping, and the ability to make informed decisions around maintaining plant equipment using specific techniques which point to project management methodologies, tools and techniques.

Total Productive Maintenance (TPM) showed the most significant amount of success in Planned Maintenance (PM) techniques. It is clear from the results shown in the study that application of detailed methods in PM during outages in ESKOM can lead to success, if practiced religiously within ESKOM. This type of technique feeds into Lean Project Management Practices that will ensure increased efficiency in processes. From the previously published literature on ESKOM performance, it can be seen that many challenges face ESKOM and thus managing all the associated risk in plant performance is necessary; however application of the required processes is not completed. Waiting time in processes is significantly high, thus there is room for improvement in terms of elimination of waste in processes.

It is important for any organisation to ensure that there is a foundation for project management within the organisation. PMBOK covers a very robust foundation for project management techniques, however due to the volatility and variability in outage projects within ESKOM, it is necessary to amalgamate different types of project management techniques, ultimately leading to the highest levels of efficiency.

The 'Timken Quality Management System' integrates the necessary efficiency required in production management with project management techniques. The purpose of a project is to ultimately ensure all risk is identified, prioritised and managed in the most effective way possible – there are many techniques to help with management of risk. These techniques are easily obtainable once a problem statement is clearly defined. Problem statements can range from technical issues, process-related concerns, resource levelling, stakeholder communication, skills competency, quick precise decision making and financial considerations - ultimately leading to the balance of time, cost and quality in projects.

CHAPTER 3

RESEARCH METHOD

3.1 Research Design

The research design is based on a qualitative - multiple methods research technique. The term 'multiple methods' is used when more than one qualitative method is used in a single study. (Anu Kajamaa et al, 2020) Qualitative research stems from 'Social Sciences' where groups of societies are studied to answer specific phenomena observed. Unlike quantitative research which is based on numerical data analyses to reach a conclusion, qualitative research is a means to investigate answers to questions about the evolution of an experience or phenomenon via observation. (Jackson, 2007) Table 5 below shows a description of the research design used in this report; it utilises the strategy as described by Anu Kajamaa et al, 2020.

Table 5: Description of Research Design - Qualitative - Multiple Methods Research

Question	Answer based on this Report
1. What is the overarching aim of the Study?	The main aim of the study is theory building – exploring phenomena.
2. Which is the dominant method?	The dominant method is a qualitative research technique.
3. Is the data collection, sequential or parallel?	The data collection was completed in a sequential manner.
4. At what stage does the integration of the methods occur?	Integration occurs at the end when concluding, after assessing the results. The latter methods of data collection were used to corroborate the initial dominant data collection method. (can also be considered as the creation of validity in the research)
5. Is the qualitative method explanatory or exploratory?	The qualitative method is exploratory.

The research conducted in this specific study is best described as 'exploratory' since it explores the situation through observation and produces results, the latter methods of data collection of the interviews conducted and the document review completed, further corroborates the results deducted from the predominant method of observation. It can be deduced from Table 5 above that this particular research design method is,

- Predominantly 'qualitative-exploratory' in nature, where the participant observer method was dominant, and the results validated through the supplementary data-collection methods used (data-collection completed in a sequential manner).

- Three types of qualitative instruments were used, namely:
  - Participant observer research on the power plant – outage project (predominant method)
  - Interviews (secondary method)
  - Documentation Review (secondary method)

Data collection occurred in three phases. The first step of the research method was to observe the outage project conducted on an ESKOM power plant. The second step of the research was to perform interviews with personnel based on a purposeful sampling process. The third step was to perform a document analysis. Figure 16 below shows a description of the research steps. Results drawn from the interview phase, and the document analysis phase were used to corroborate the results outlined in the participant observer phase. Integration of the results is outlined in Chapter 4. Full texts can be reviewed in the following Appendices:

- Appendix A – Article review on British Energy
- Appendix B – Participant Observation – Full Text and categories' for coding.
- Appendix C – Interview Questions.
- Appendix D – Document Analysis – Full Text.
- Appendix E – Additional ESKOM Statistics – produced by the Organisation, linked to Appendix D above.
- Appendix F – Additional information, supporting Chapters 3 & 4 (Research Method and Results)

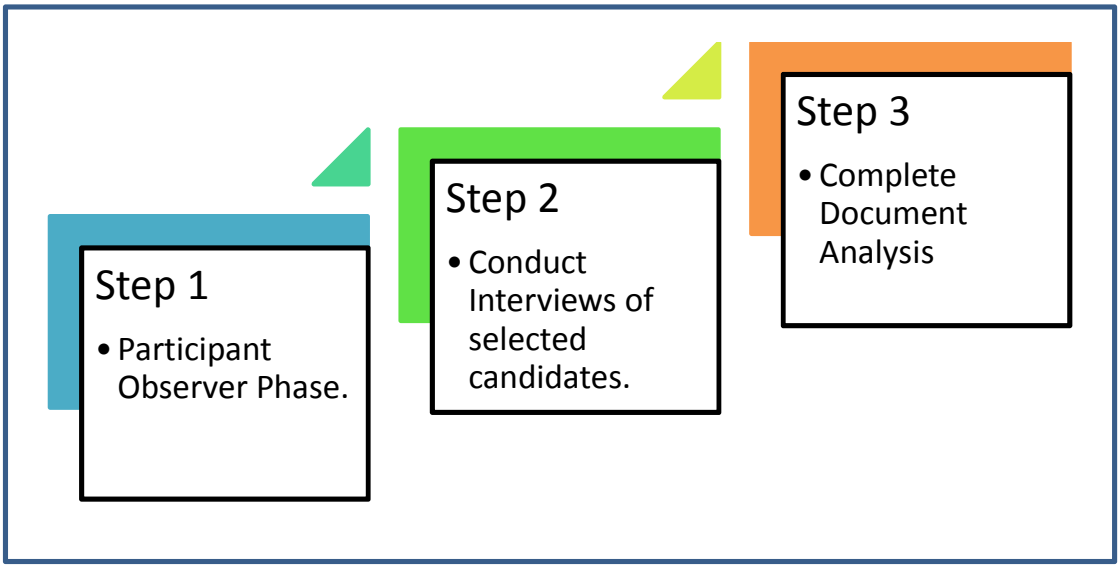


Figure 16: Description of Research Steps during the data collection phase.

3.2 Qualitative Instruments

3.2.1 Participant Observer

The aim of the role of the researcher as a 'participant observer' was to witness the events on the 'outage project' and to report on these events as honestly as possible. A true reflection of the events that occurred during the outage was significant for obtaining accurate results in the research. This approach of data-collection allows the researcher to fully embrace the culture of the situation over an extended period of time.

Complete participation occurs when researchers turn their ordinary situations into research settings, unlike non-participation which requires separation from the observed situation and personnel. (Sandiford, 2015) By using this style of data-collection, the 'participant observer' has the ability to experience the events as they occur, have conversations with informants that are also experiencing the same events as they occur, thus gathering information that is factual. (Takyi, 2015)

The ‘observation protocol’ was developed considering the process steps of conducting an outage according to the established ESKOM procedure/ policy. (Eskom Business Management System Document, 2010)

i. The process of the outage project is mapped in Figure 17 below. Physical observation started during the execution phase of the project. Observation is limited to Phase 2 and Phase 3 of the outage project. Observation could not take place during Phase 1 – planning, due to the fact that the research was conducted in a time frame that fell out of this period. Observation of the execution of the outage work occurred over a six-month period from October 2018 until March 2019.

ii. Key deliverables as per the phases outlined above was extracted from the ESKOM procedure/policy. Observation then occurred in order to identify whether these key deliverables was achieved in accordance to the established ESKOM procedures. This method compares the actual events against the set standards.

iii. Informal conversations with all participants were documented, through field notes. Pictures’ of critical information was captured, in order to allow the reader to visualise the events in more detail. The full text of the participant observation techniques can be reviewed in Appendix B. A coding mechanism was used for all three types of data collection methods, in order to analyse the data further and extract underlying themes.

iv. The results obtained from the participant observer data-collection technique were documented in ‘Chapter 4 – Analysis’. The result was a summary of the comparison of the set standards that should occur against the reality of events that did occur based on the different phases of the outage project. All influential factors that compromised the achievement of the set standards was documented further and elaborated on in ‘Chapter 5 – Discussion’. Delays in the processes were documented, and

themes were represented and explored further in 'Chapter 5 - Discussion'.

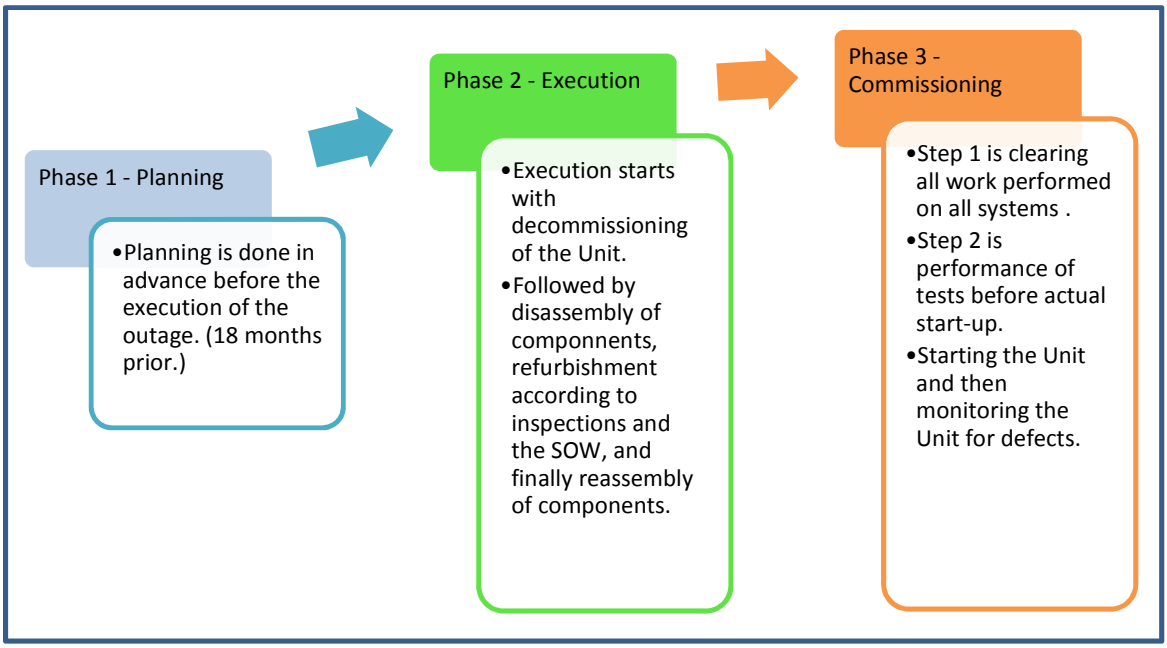


Figure 17: Phases of the Outage Project from the ESKOM Procedure/ Policy. (Eskom Business Management System Document, 2010)

3.2.2 Interviews

The purpose of conducting interviews was to gather an in depth knowledge of what problems are experienced in performance of the 'outage projects' from the opinions of personnel that have experienced outage project management within ESKOM. Conducting face-to-face interviews highlighted personnel's knowledge of how outages are performed in ESKOM as well as their knowledge or perception of how outages are performed in other countries or the best possible ways of actually managing outages in order to gain successful completion within time, cost and quality.

The purpose of having face-to-face interviews allows the researcher to gather in-depth knowledge of experiences. Unlike surveys that are impersonal and have limitations such as no access to in-depth knowledge during data-collection, the

interview process allows the researcher to expand on themes with interviewees', which can add value to the interpretation at the end of the research. There are three types of face-to-face interview sessions namely: (Ryan, et al., 2009)

- 'Structured Interviews' – can be described as a list of questions prepared prior, and no deviations from these questions are allowed during the interview process. This allows for the researcher to obtain comparable results amongst the interviewees', thus noting its similarity to a survey being used.

- 'Semi-structured Interviews' – can be described as a researcher who prepared a list of questions prior, but allows the interview process to be flexible. The interviewee can express other experiences that are related to the topics being discussed. The Interviewer thus allows the Interviewee to elaborate further on knowledge. This allows the interview process to be a more interactive session to an extent. The researcher must note careful attention to guard against leading on the interviewee, in any way.

- 'Unstructured Interviews' – can be described as open-ended and the interviewer does not have a list of questions in which to reference to. This allows the individuals to have a conversation about the topic at hand. This type of style of interviewing is based on research topics where little is known about the topic, and establishment of themes is the goal.

In this particular research, the 'semi-structured' style of interviewing was adopted, as there is some related literature known about the topic of reducing outage durations, therefore predetermined questions were thought of, that stemmed from the processes witnessed prior to and during the participant observation phase. The purpose of the interviews conducted was to assess whether the results gathered during the interviews could be compared to the results of the participant observer phase.

Since the participant observer phase has a limitation of gathering data during one particular situation, it may or may not be inferred to other situations. By selecting the right individuals' who experience outage projects across the ESKOM fleet through consideration of purposeful sampling, 'information rich' data was obtained.

This study aims at solving the objectives set out in Chapter 1, and thus cannot be considered as an inference on the rest of the population. The themes that were established and discussed further in this research can be tested further through a different investigational analysis, which will consider an inference on the rest of the population. The rest of the population can be defined as all management activities throughout all power plants in the ESKOM fleet.

i. Sampling and Selection of Respondents

Llewellyn, et al., 2001, suggests that 'most qualitative research relies on the strategy of non-probability purposive sampling, where the sample is selected based on the area of interest, and not on how adequately the sample represents the population'. Some of the types of sampling used in qualitative research are listed below. (Gwynnyth, et al., 2001)

- *Combination or Mixed Purposeful Sampling* – using a combination of strategies to achieve the most desirable sample relevant to the research.
- *Intensity Sampling* – choosing informants that hold a significant amount of experience in the field of chosen expertise, relevant to the research.
- *Extreme or Deviant Case Sampling* – informants chosen that are somewhat unique in a way to the research.
- *Homogenous Sampling* – informants that are very similar to each other.
- *Snowball or Chain Sampling* – using chosen informants to suggest more informants.
- *Typical Case Sampling* – informants that are most 'typical' in nature that can represent the wider group.

For the purpose of this research, 'Intensity Sampling' was used. Selected 'Subject Matter Expert's' (SME's) were targeted - these personnel work directly on the outage projects and have lengthy years of service, thus bare a certain amount of familiarity of the environment, business and culture. The selected personnel varied in age, skill-set, management style, experience, race, gender, academic backgrounds, and positions held in the company. Personnel are defined as, engineers, technicians, project managers, senior managers, etc.

'Research previously conducted and published on "Interviewing Experts", shows that it is an effective means of quickly obtaining results and, indeed, of quickly obtaining good results in qualitative research methods. (Alexander Bogner, 2009) This will be appealing to most Researchers' seeking to provide validated and reliable data.

The term 'expert' can be questioned, since the definition of an 'expert' can vary. One can consider that an 'expert' is thrown into a difficult situation, and is able to find a solution to that particular situation, whereas others might consider that, years of experience constitutes an 'expert'. Although years' of experience does play a significant role in expertise, one must also consider the methods of practice that might not be highly efficient or effective during these many years of service. The personnel whom were assumed to be 'SME's' were divided into groups of expertise, namely:

a) Service Engineering (Comprised of Engineers, Senior Engineers, Chief Engineers, Junior Engineers Commissioning Engineers, and Specialist Engineers - two interviews completed.)

b) Project Services (Comprised of Project Supervisors, Project Technicians, Quality Technicians, Project Managers, Senior Project Managers, Project Expeditors, Project Planners, and Planning Managers – four interviews completed.)
c) Site Maintenance (Comprised of Maintenance Technicians and Maintenance Supervisors – one interview completed.)

d) Works Services (Comprised of Generator Supervisors, Rotor Winders, Stator Winders, Generator Engineers, Bladers, and Works Project Managers – one interview completed.)

Purposive Sampling has a core limitation, as outlined below, however it also has a core advantage. (Palinkas, et al., 2013)

- *Advantage:* Personnel were familiar with the topic of research, and offered 'information rich data', which if random statistical samples were chosen as one would have used in probability sampling, then chosen personnel might not have had relevant experience pertaining to the research topic. A sample from a population based on size of population may represent different life experiences; and this could be considered a threat to the internal validity of the results.

- *Disadvantage:* As led in the point above, purposive sampling cannot be inferred onto the rest of the population, meaning that the main aim is not to represent the entire population through a statistical sample.

ii. Development of the Interview Questions

Face-to-face interviews have two elements to consider, one would be the development of the questionnaire and the other would be the human interaction. In order to cover both aspects so that the results obtained from the interview sessions were of good quality, reliable and valid, a literature review was completed on how to develop the questions, as well as how to interact with the respondent during the interview process.

The primary objective of the cognitive interview is to comprehend the feedback that will be received from respondents'' – thought patterns of the various responses' was considered in an iterative process, and questions adjusted to remove ambiguity. (Willis & Gordon, 2015)

The questionnaire was developed to try and answer the research question. After reviewing the process steps outlined in the project plan documentation, questions revolved around each process step. The questions were a balance between open-ended questions and structured guidance questions, where it allowed the Interviewees' to explore his/her own perceptions and provide more elaborative responses – this technique supports the semi-structured interview process. Supporting the structured questions were probing questions, which allowed the respondents' to elaborate further when answering specific questions, thus more in depth information was gathered. (Willis & Gordon, 2015) The interview questions can be reviewed in Appendix C.

iii. The Interview Process

The interview sessions were conducted after the execution of the outage project at that particular site, in a lockable container office isolated from the turbine floor. (The turbine floor is usually noisy and conversations cannot take place in this area) Some interviews were also conducted in ESKOM offices, which were not located at a power plant, in a lockable boardroom. The container was used for meetings during the outage. It was possible to ensure that both the Interviewer and the Interviewee were engaged due to isolation, and maintained focus during the interview session. The container as well as the boardroom, was not exposed to noise levels and was thus comfortable environments' for both the Interviewer and the Interviewee.

The interview sessions were planned via a Meeting Request, ensuring that the Interviewee allocated a precise amount of time, focusing on the interview and engaging with the Interviewer, without disruptions. The atmosphere was relaxed and thus ensured that the Interviewer and Interviewee were comfortable during the interview process. Interviews were conducted with eight employees in total. The interview sessions were semi-structured and each Interviewee was lectured on the process that was followed. Sessions lasted on average, at approximately 1.5 hours. The process steps are defined below:

- Gratitude displayed to the Interviewee for taken the time and consideration to complete the interview.
- Explanation of the background of the research that was being conducted.
- Description of the Consent Form and a request for permission to audio-record the session. All Interviewees' were requested to sign the Consent Form.
- Declaration that no information will be shared without consent granted from the Interviewee.
- List of semi-structured questions were asked with prompting in certain dialogue, when required for the purposes of further elaboration.
- Closing of the interview session.

iv. Analysis of the Interview Data

Gathering information using the qualitative instruments is gathering 'raw data' that needs to be synthesised further. In order to perform a synthesis on the raw data collected in this research – the method of coding was applied to answers from the respondents'. (Bruscia, 2005) Coding is assigning a title which may consist of a number, colour, word or phrase, etc. This is done for all collected statements in the data in order to identify the 'categories or themes'. Different styles of coding can be applied, namely: (Bruscia, 2005)

a) A descriptive code taken from the data, that very closely matches the raw data, it is created without the researcher making inferences or interpretations of the data.

b) An interpretive code in which the researcher makes an inference, fitting the piece of data into a category, after judging it, based on the researcher's perception or insight – thus already taking the step to interpret the data.

Information gathered from respondents' during the interview process, was grouped together into themes. These themes were given specific codes as defined in Appendix C. The answers from the respondents' were then coded using a combination of

descriptive and interpretive codes. Based on the researcher's discretion, whenever an answer resembled a specific theme, the code was placed next to that answer. After full coding of all answers was completed, a count mechanism was used to count the number of occurrences of the themes.

Graphical representation was used to show the number of themes, the highest count of themes, and percentage weightings of themes against each other. This method of analysis transferred the qualitative data into quantitative data i.e. statistical/ numerical data. Interpretation of the occurrence of themes was then compared with the results achieved in the participant observation analysis.

3.2.3 Document Analysis

Document Analysis is a qualitative instrument in which a range of documents are reviewed where data can be examined and interpreted to gain understanding and develop empirical knowledge. Document analysis was used as a means of triangulation with both participant observer analysis and interview analysis – this was completed to ensure, that the research portrays credibility.

In every aspect of the research project, the main aim was to structure the necessary items to gain insight on how to solve the objectives. (Bowen, 2009) In order to perform the document analysis careful consideration of many aspects are required. Some of the process steps in which to follow, based on relevant literature, are listed below. (Wach, et al., 2013) Each of these process steps was applied to solving the objectives in this research report, and thus key concepts in the 'ESKOM literature' where identified, in which 'information rich data' was sourced, thereby in an attempt to achieve best suited results. There were no limitations set for time periods of documents; however an attempt to gain the latest information was executed.

a) 'Setting inclusion criteria for documents' – documents were chosen based on two types inquiry, one was to understand the processes in project management in ESKOM, and the other was to understand what statistics/ historical data exists relevant to outage performance.

b) ‘Collecting documents’ – public documents were reviewed but not included in the final document analysis. The core documents were retrieved through ESKOM official communication channels internal to the organisation and available to all employees.

c) ‘Document coding’ – since the information was gathered in two groups, it was seen as best practice to outline why would coding be used in order to gain what specific result. Thus coding was only used where it was deemed necessary, relevant to the statistical/historical data. A comparative approach was undertaken for the first group of data – documents aligned to project management practices in ESKOM.

d) ‘Articulating key areas of analysis and verification’ – documents were judged on content, significance, use, control, revisions, comprehension and comparison with best practice methods.

Document analysis has some limitations, as outlined below, however it also has some advantages. (Bowen, 2009)

- *Advantage:* Documents can provide guidance on what to look for in observations, or other scenarios of data-collection.

- *Disadvantage:* It might be shown explicitly through the documentation that indeed the organisation stands by it, and executes in accordance. Documents cannot be regarded as official either, and correctness of reporting can be skewed.

The Document Analysis was divided into two sections, namely:

- *Section A* - Existing Range of Documents specific to project management practices in ESKOM, and as outlined by PMBOK.

- *Section B* - Existing statistics in ESKOM regarding outage durations, and consequent root-cause problems.

A range of documents was reviewed for Section A, for this research project, namely – project programmes, policies, procedures, checksheets, process quality plans, completed project documents, early warnings, non-conformance reports (NCR's), system deficiency reports (SDR's), philosophies, work instructions, work packages, minutes of meetings, business management system procedures and vision statements, etc. Please refer to Appendix D for the full text on document analysis for Section A, where only the critical information on documents reviewed to solve the objectives of this research, is portrayed.

The documents were then categorised, and a percentage weighting assigned to each category. Themes were extracted from the documentation and compared with best practice techniques outlined in the literature review under PMBOK.

Section B focused on statistical presentations that showed results in the organisation's outage durations, processes, quality concerns, and root-cause problems. The documentation that was reviewed in this section showed a good reflection of repeating problems, since the information that was gathered was over a significant period of time.

A comparison analysis for Section A, against PMBOK was completed, in order to determine if ESKOM follows a structured method of management of outages, as well as to identify the similarities and dissimilarities that was presented in the participant observer phase. Coding was completed in Section B in order to compare the results obtained in this section against the other two qualitative instruments, to conclude if the results corroborated what was found in the other two qualitative instruments.

3.3 Validity and Reliability

Validity in research can be categorised as Internal Validity and External Validity. Internal Validity refers to the extent to which research findings are a true reflection or representation of reality rather than being the effects of extraneous variables. (Brink, 1993) External Validity refers to the degree or extent to which such representations or reflections or reality, are legitimately applicable across groups. (Brink, 1993)

Reliability refers to the consistency, stability and repeatability of the informant's accounts as well as the investigator's ability to collect and record information accurately – to be able to produce the same results over repeated testing periods. (Brink, 1993) In order to create validity, which is the accuracy and truthfulness of the findings in this research report, the following procedures/ tools were implemented.

3.3.1 Validity and Reliability Methods for 'Participant Observer' and Interview Phases, of data collection

a) Descriptive validity refers to the accuracy of the data, thus the data must accurately reflect what the interviewee has stated. (Marvasti, 2008) Direct and true reflections of the events that occurred were documented. This was completed through accurate note-taking, recordings of interview sessions, and asking others (non-respondents') if interpretation of situations were valid, based on difference in perceptions.

b) The Researcher – the person who conducted the research often has underlying values, opinions and biases about the research topic. All underlying values and opinions are stated in this research report so that readers are aware of the biases that exist when interpreting the findings. (Brink, 1993)

c) Biases' can also be experienced from the respondents' of the interviews. In order to ensure that validity was created – an explanation of the research was provided to the respondents' and each respondent was asked to provide answers

objectively- mentioning the pros' and cons'. A trust relationship was built with the respondents'; during the participant observer phase as well as the interview phase, so that respondents did not feel intimidated when providing answers. (Brink, 1993)

d) Respondents' can feel somewhat threatened in providing answers if a feeling of scrutiny or criticism is created. In order to conduct the research in an ethical manner, respondents' were made aware of the research, throughout data-collection practices. The only reliance was based on the trust that was created amongst the respondents' in order to provide honest perceptions, and the Researcher being fully immersed into the situation, thus living the actual culture of the 'society' at hand, so that relationships formed. Simultaneously, the Researcher had to ensure detachment from the situation so that data could be recorded objectively, and interpretation could be provided objectively.

e) It was necessary to accurately describe the setting in which the information was gathered during the observation and interview phases, so that in the event, one had to embark on a similar type of research, then repeatability can be judged. This is mainly to ensure that the reader has a full understanding of the environment when evaluating the interpretation. (Brink, 1993)

f) The 'Interview Questionnaire', is imperative to ensure the validity of the results. Reviewing of unwarranted assumptions in the questionnaire was completed with colleagues (non-respondents'), who provided input after assessment through trial-run interviews. (Ormrod, et al., 2016)

3.3.2 Validity and Reliability Methods for Documents Analysis

a) Access to specific important documents which aided in the ability to solve the objectives of the research was secured early on. These common groups of documents showed statistics, trends, and methods used. Documents were treated in a confidential manner, and a general ESKOM reference/specific reference was

used where necessary. This would allow for reliability in the sense that if the topic were to be researched again, the documents can be sourced.

b) Understanding the background of the documents and how they materialised, actively observing how the documents were used, and collecting data from the documents after identifying themes within the documents to create a summary of best practices within the research field. (Marvasti, 2008, pp. 52-53)

c) Coding applied as an iterative process to double-check relevant themes, and reviewing how the organisation itself categorised items, thus learning the 'methods/techniques' employed. Impartiality and dependability was considered during coding – 'an analysis is considered 'dependable' if another reader would have 'reached the same general conclusion given the opportunity to analyse the same set of documents under similar conditions'. (Wach, et al., 2013)

d) It is assumed that most documents which are reviewed are already established and actually the researcher has no influence over, which makes the data valid and reliable due to zero objectivity from the researcher. (Bowen, 2009)

3.3.3 The Researcher's Biases/Viewpoints as drawn from previous companies' during employment periods.

a) A fair amount of experience, approximately 9 years, in which project management activities were completed in other companies forms a basis for comparison of these practices in other companies against ESKOM's project management practices. The researcher considers another company holding a higher level of standard in project management practices, and illustrated this in the Literature Review – Chapter 2, under Lean Management practices.

b) Training in other companies is of a superior standard, not necessarily linked to great facilitators, but also the organisation, and system of training, purely based on the researcher's experience in other companies.

c) Management of newly recruited Project Managers is not based on "throw him/her into the deep end and allow them to swim on their own, while in execution of the project". Rather, other companies have established training methods, a combination of theory and practical approaches incorporated, as well as direct independent mentorship including a high supportive degree of direct line management involvement. Managers at ESKOM are expecting that their direct reports engage him/her, on their duties, rather than a structured approach in advising the employee of their duties or roles and responsibilities, which is not entirely a fault, however a clear balance is needed, based purely on the researcher's opinion.

d) A top-down approach of management style is often necessary while allowing direct reports employees'; flexibility to perform his or her duties – after the necessary training is acquired by the employee – thus a results/goal obtainable focused culture is created, which is actually proven successful in other companies, based purely on the researcher's experience.

3.4 Ethical Considerations

This particular research relied on the use of human resources in order to complete the investigations. Approval was granted from ESKOM, in which to complete the studies with the available resources, access to ESKOM information and access to the particular outage project during execution. Application for ethics clearance was completed with the School of Ethics Committee, and approved with reference number **MIAEC 091/18.**

In concluding Chapter 3 - the purpose of the different methods of collecting data was used to establish triangulation – which means the collection of data through various methods and establishing congruency amongst them. (Brink, 1993) The collection of data through the method of Participant Observer was the dominant method which outlined factual events. To support the information during this phase, additional information was gathered through interviews conducted and data collected through the document review process.

CHAPTER 4

ANALYSIS AND RESULTS

This chapter presents the summary of the findings from the research on reduction of outages across ESKOM power plants. It follows from Chapter 3 and is divided into the following sections:

- Analysis and Results of the Participant Observer Phase
- Analysis and Results of the Interviews conducted
- Analysis and Results of Document Review

The findings were collected in a sequential manner starting with the 'Participant Observer Phase' where the researcher was involved in, and observed an outage on one of ESKOM's power plants. Data was gathered during observing, by means of field notes, documents, meetings, conversing etc. Once the data was gathered it was analysed through the structured project process phase's i.e. planning, execution and commissioning. The reiteration of events through written text was coded on emergent themes, resulting in recognising relationships between the identified themes, as well as themes taking precedence over others.

The second data gathering technique was through interview conducted with selected candidates. The interviews were semi-structured with questions developed which tried to address the answer to the research question. The data was captured through audio recordings and later was transferred to written text, where codes were applied to the emergent themes. The reoccurrence of themes per interview session, was analysed using graphical representation (counting the number of occurrences per theme), resulting in specific themes that had a higher number of occurrences.

The last data gathering technique was a review of selected documentation of the project process of management of outages within ESKOM. The documentation was reviewed and again codes were applied that were then placed into themes, and sorted into graphical representation.

4.1 Analysis and Results of Participant Observer Research

The purpose of the observation was to witness and be involved in a General Overhaul (GO) – outage project during actual execution on one of ESKOM's power plants. The researcher had the ability to observe the GO from start to finish, once the unit was shut-down. Observation began from site establishment, disassembly of the machine components, refurbishment of machine components, reassembly and commissioning, until site de-establishment. During the course of observations, the researcher was able to converse with personnel, attend meetings, review documentation, and take pictures in specific instances in order to portray results.

4.1.1 Observation Context

The research revolved around the management of an outage project, which entails work conducted on the unit's generator and turbines, as well as auxiliary equipment. Figure 18 below shows the top-view layout of the most important equipment that this study concentrates on (generator and turbines); and Figure 19 below, gives a horizontal view of the machine components that are related to this study.

Each machine component is referred to as a module when working on outage projects. For example the high pressure turbine would be referred to as the 'HP Module'. The 'turbine floor' is where the majority of the work was executed. The containers that were used for human resources and storage of equipment as well as tools are highlighted in blocks in Figure 18 below. Figure 20 below, is a picture of the layout, with a front view of the generator. The Participant Observer phase was divided in to the following phases, namely:

i. Planning Phase – no observation took place during this period as this phase occurred before October 2018, however from specific observations during the execution phase, inferences were made to the planning phase of the outage project.

ii. Execution Phase – observation was conducted on the power plant during this phase from October 2018 until March 2019. Execution involved the following stages:

- Disassembly of the Machine components of the low pressure (LP) turbines 1 and 2, generator, exciter, high pressure (HP) turbine valves, specific auxiliary systems, etc.

- Refurbishment of all components after inspections, either on site or off site.

- Reassembly of all components once all refurbishment activities were completed.

iii. Commissioning Phase - observation was conducted on the power plant during this phase from March 2019 until April 2019. This phase entailed all the necessary checks and testing before the start-up of the machine. All systems' permits were cleared before start-up of the machine occurred.

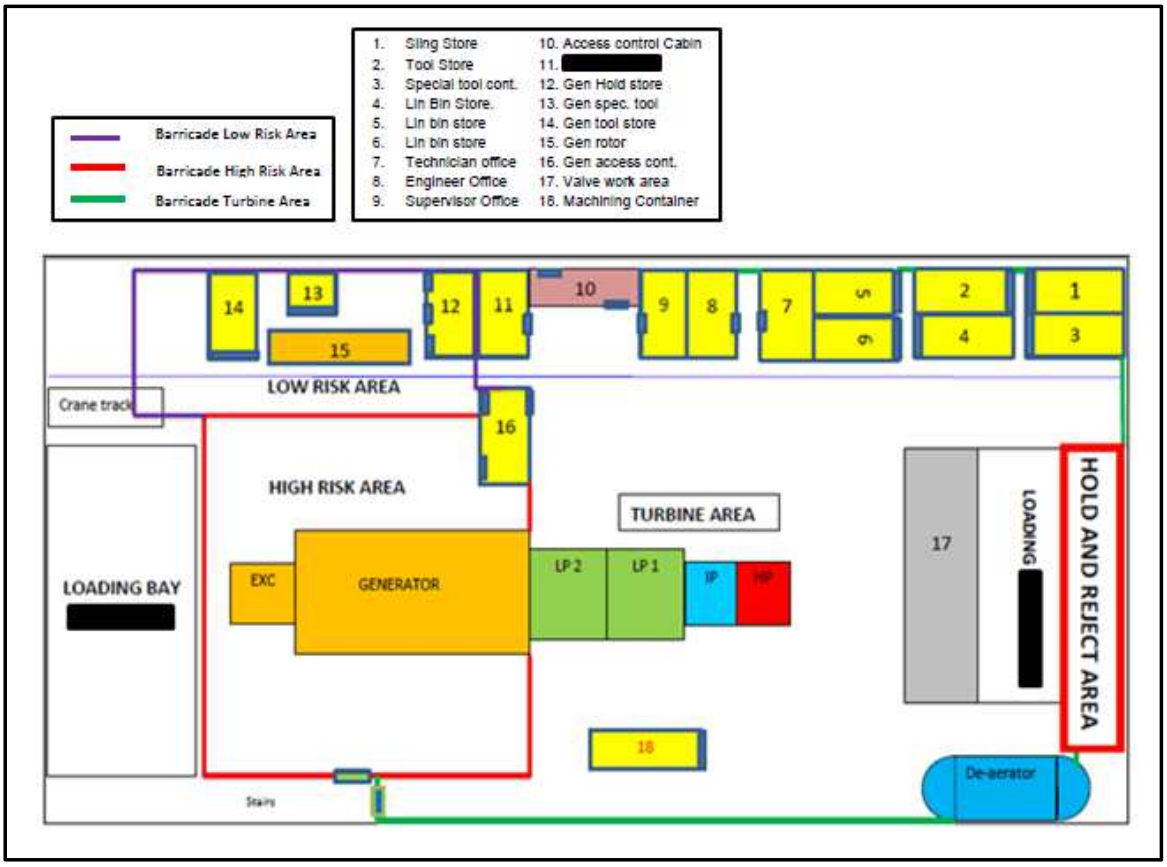


Figure 18: Layout of the machine equipment on the turbine floor. (Eskom Business Management Document, 2010)

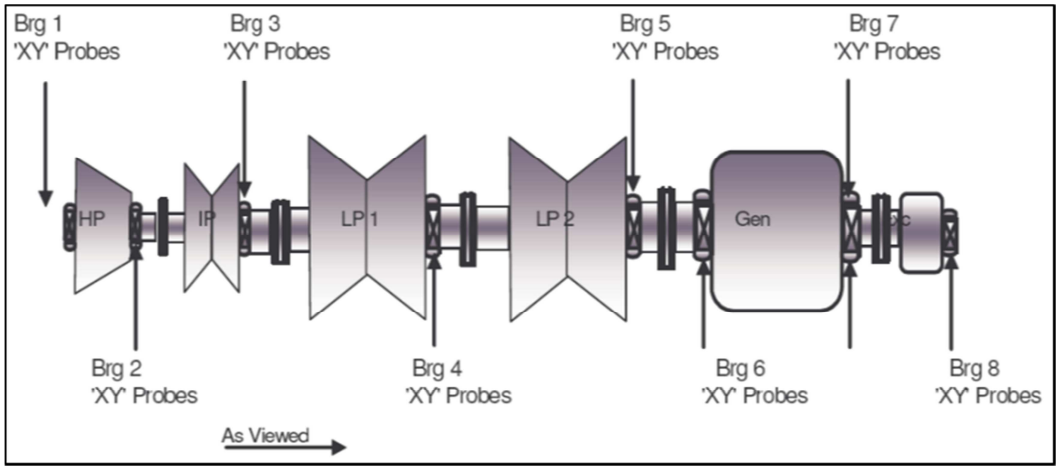


Figure 19: Horizontal View of the Machine Train - from Turbines to Generator and position of Bearings (Brg.) on the unit. (Eskom Business Management Document, 2010)



Figure 20: Visual Imagery of the Turbine Floor Level. Turbine Area and Generator area shown.

Analysis and Results of the Execution Phase

In this section the following topics are covered,

a) Overall Results from Coding, showing significant themes
b) Programme Analysis and detailed delays per module

c) Technical Notification (TN) Analysis

d) Early Warnings – Risk Analysis, and the relationship between Cost, Time and Quality

Overall Results from Coding, showing significant themes

Interpretive and/or descriptive codes were used for categorising the data documented under the participant observer phase during execution. The analysis can be viewed in Appendix B, 8.2.1 – 8.2.3.

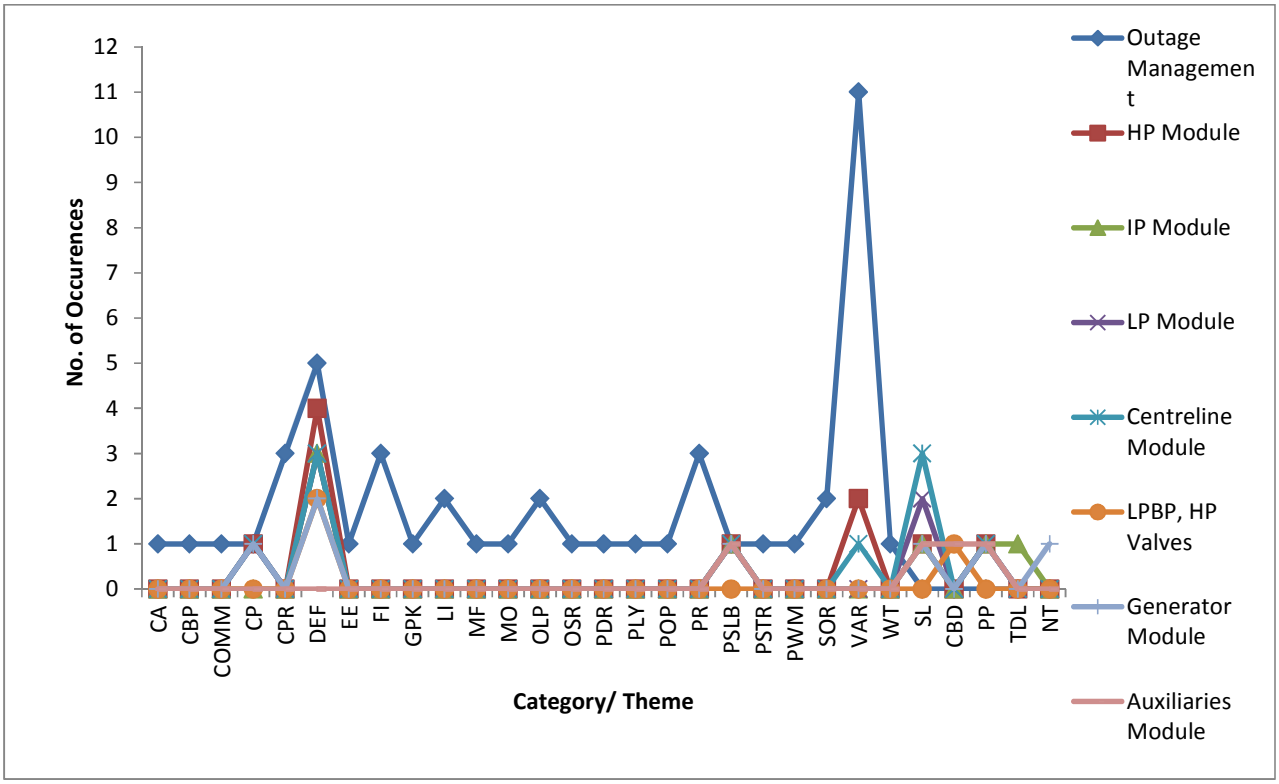


Figure 21: Comparison of Themes found in the participant observer phase during execution.

Figure 21 above shows the initial coding results obtained. The modules of the outage project were managed by different, smaller teams, in terms of supervisors, artisans, and unskilled labour. Each team was responsible for a specific module, such as Generator Module, Low Pressure Turbine Module (LP Module), etc. Outage Management was conducted by another team that managed the entire project. Since

the teams operated independently as well as collectively, data was gathered and coded for each team. These data sets were then plotted in terms of amount of occurrences per module, per code.

Figure 22 below, draws upon Figure 21 where each code was categorised into a significant theme. Appendix B provides a detailed narration of the events that occurred of the outage, and also outlines waiting time periods.

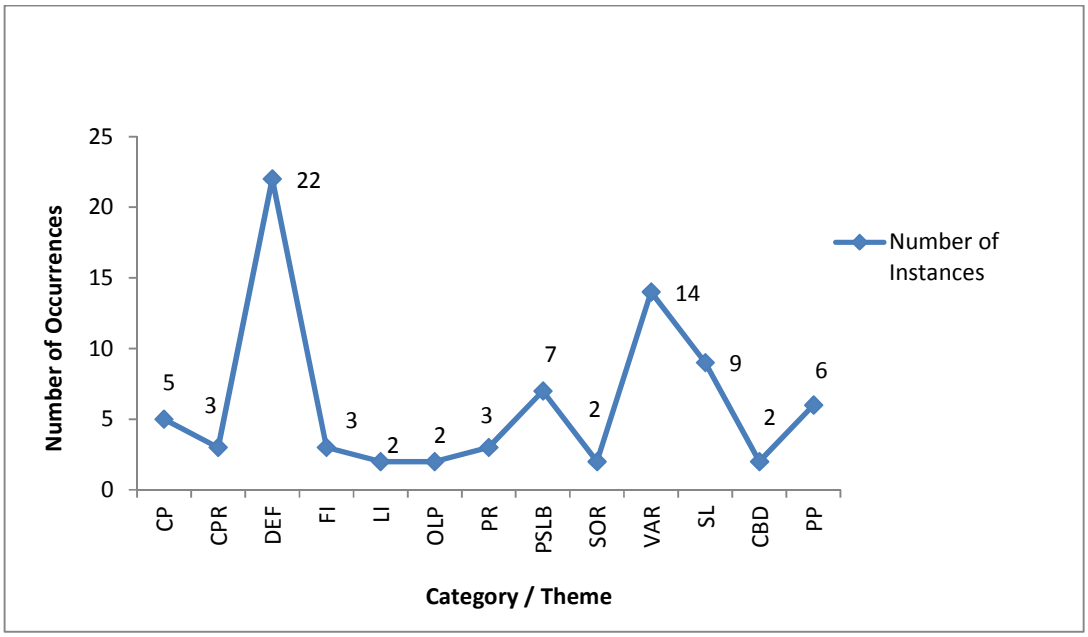


Figure 22: Significant themes in participant observer phase during execution.

Figure 22, shows the following results, starting with the highest occurrences:

- 'DEF' (22 occurrences) – which is classified as 'Defects' holds the most number of occurrences during the outage execution. A 'Defect' is caused by not following processes (poor workmanship), technical issues, etc. This theme thus relates to poor workmanship.

- ‘VAR’ (14 occurrences) – which is classified as ‘Variation’ is the second highest occurring theme. This refers to ‘Variation’ in processes, which leads to confusion and loss of control, and affects time, cost and quality.

- ‘SL’ (9 occurrences) – which is classified as ‘Spares Late’, is the third highest theme portrayed. This is related to the management of spares in ESKOM, experiences in delays of receiving spares on outages due to many factors.

- “PSLB and PP’ (7 and 6 occurrences respectively) are both related to procurement processes, which is the fourth ranking theme illustrated in Figure 22. ‘PSLB’ – which is classified as ‘Poor Supplier - Labour Broker’ and ‘PP’ which is classified as ‘Procurement Processes’ are both negative aspects that were extracted from the participant observer data. This entailed delays in procurement processes and poor performance from Labour Broker suppliers, which caused delays in the outage.

- The last theme that has ranked high is ‘CP’ (5 occurrences) which is classified as ‘Compressing Programmes’. When the outage programme was compressed with no reasoning, other than to complete the outage within a shorter timeframe – no justification leading to false information being communicated.

Programme Analysis and detailed delays per module

This section covers details on the project programme throughout execution of the project.

Table 6 below indicates that the original outage project was first planned in 2017 with a duration of 100 days, however, the outage project was then moved to 2018. The reason for movement was based on supply of electricity to the national grid, and thus the unit could not be shut-down for planned maintenance.

Table 6: Evolution of project programmes during the course of the outage project.

Program	Start Date (PTW)	End Date (Mechanical Completion	No. of Days
Original Program	08/04/17	16/07/17	100
Program 1 (B)	25/10/18	15/01/19	84
Program 2 (R1)	25/10/18	16/02/19	115
Program 3 (AMC)	25/10/18	09/03/19	136

The first programme that was accepted and signed by the Client was Programme 1, in October 2018 which represented the baseline programme for this outage project at 84 days in duration. (Baseline Programme represented as 'B' in Table 6 above.)

Table 7: Number of days of delay shown, for each module on the outage project.

Module (Comparison on Days	Program 1 (B)	Program 2 (R1)	Program 3 (AMC)	Add. No. of Days (AMC to B)	Add. No. of Days (AMC to R1)
HP Turbine	69	90	93	24	3
IP Turbine	51	67	134	83	67
LP Turbines	65	93	127	62	34
Centreline (CP)	***84***	***115***	***136***	***52***	***21***
Turbine Valves	68	107	117	49	10
CVA's	56	57	57	1	0
Generator	71	90	126	55	36
Gen-Exc Align	14	15	26	12	11
Aux	71	103	103	32	0
C&P	57	76	76	19	0

Programme 2 was a revised programme signed in December 2019, and targeted completion in February 2019 which represented revision 1 of the programme with full duration of 115 days. (Revised Programme represented as 'R1' in Table 6 above.)

Programme 3 was never signed and accepted by the Client, but was the actual completion date of the project on a contractual basis. The project was completed in March 2019 at 136 days in duration. Table 7 above outlines the number of days based on the different programmes. (Actual Mechanical Completion Programme represented as 'AMC' in Table 6 above.)

The comparisons of the programme durations showed that the process of updating the programme once every two weeks was not adhered to, as stipulated contractually. Actual completion of 136 days against the baseline - 84-day programme meant that the outage was late by 52 days.

Table 7 above shows the duration of each module of the project – the centreline being the critical path, with the longest duration (based on activities to complete the centreline module). The modules that took the longest duration to complete, extracted from Table 7 above, are:

- Centreline Module at 136 days
- IP Turbine Module at 134 days
- LP Turbines' Module at 127 days
- Generator Module at 126 days.

A calculation on major days of delay on programmes Actual Mechanical Completion (AMC) versus R1 is listed below.

- 136 days (AMC) – 115 days (R1) = 21 days of delay.
- 8 days delay on IP casing movement.
- 1 day delay on bearing no. 5.
- 3 day delay on incorrect coupling bolts supplied for Gen/Exc.
- 3 days due to Poor Workmanship (PWM).
- 6 days due to waiting for spares.

A calculation on major days of delay on programmes AMC versus B. is listed below. Figure 23 below, is a summarised version of the total number of days of delays experienced on the outage, showing 31 + 21 = 52 days in total. Figure 23 shows the actual technical reasons for delays caused during the outage – but these technical descriptions can be categorised into the themes of this research project. For example the three major contributors to delays in the outage project from Figure 23 below are:

- Oil and water not available – oil was needed for various tasks to be performed and the oil was not available due to it not being purchased in time – this can be categorised into ‘poor procurement processes’. Water was not available due to it being drained out of the condenser, as the operations personnel did not follow instructions when the unit was shut-down. Water was needed in the condenser at a required level in order for the full weight of the machine to be considered during alignment and concentricity practices. It takes a significant amount of time to fill water in the condenser, this further delayed completion of tasks.

- Machining – personnel in the project team could not complete machining due to sub-standard equipment, lack of required tools, and lack of skills. A sub-contractor had to be contracted to subsequently complete the machining tasks. This can be catergorised as ‘defects’ – poor workmanship.

- Pin drilling – the personnel in the project management team only knew of one method to complete this task and it was subject to gaining access at a particular angle. This process was delayed because the access at the required 90 degree angle was obstructed by other components. A decision was taken approximately 3 weeks later to change the angle from 90 degrees to 45 degrees, access was no longer obstructed and the task could be completed without affecting the functionality of components. (“Out of the box thinking”.) This can be categorised as late decision making, or lack of new advanced technology/ equipment to perform difficult tasks.

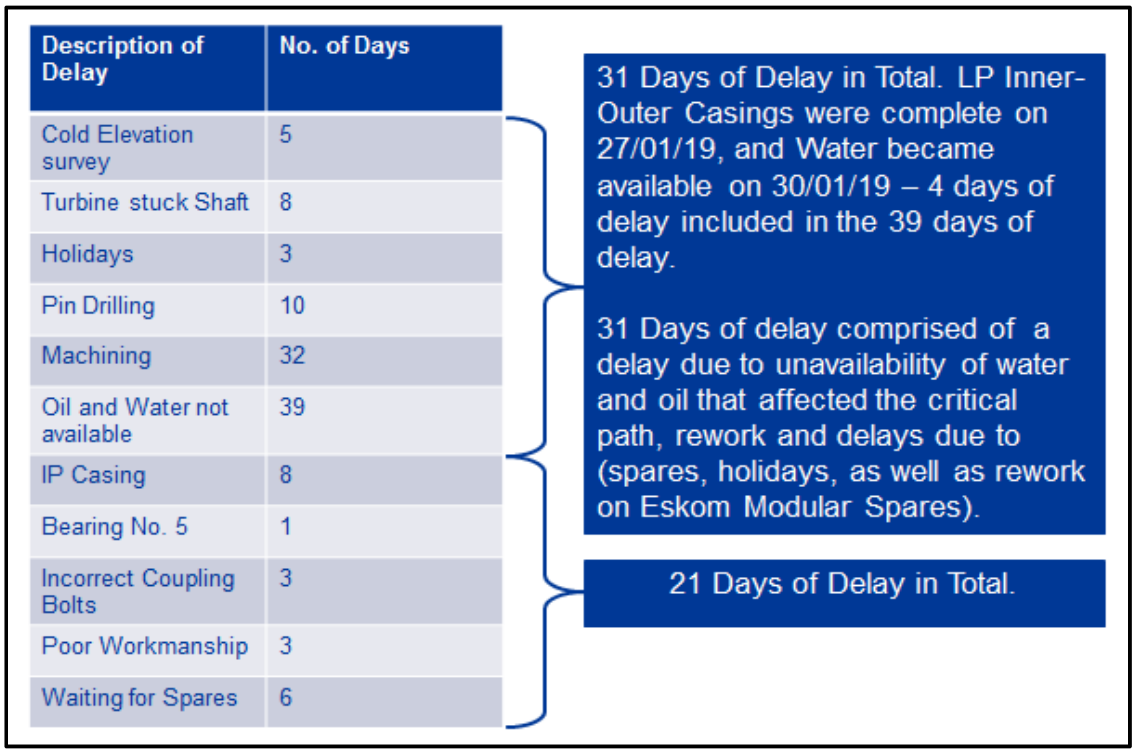


Figure 23: Reflection of the days of delay caused on the outage.

- 136 days (AMC) – 84 days (B) = 31 + 21 days of delay [52 days].
- 5 days of delay due to the cold elevation survey.
- 8 days of delay due to the turbine stuck shaft.
- 3 days of delay due to the holidays – 25th, 26th Dec 2018 and 01st Jan 2019.
- Pin-drilling activities – 10 days of delay due to poor access.
- Rework on machining activities on turbine valves, and blue checks, 32 days of delay.
- No oil and water available – 39 days waiting period. Alignment was due to start on 22/12/18 however it only started once the condenser levels were accepted by engineering – on 30/01/19. (Total Recovered Time – [39+32] – 31 = 40/8 days. [Work completed in parallel])
- 8 days delay on IP casing movement.
- 1 day delay on bearing no. 5.
- 3 day delay on incorrect coupling bolts supplied for Gen/Exc. 21 days
- 3 days due to Poor Workmanship (PWM).
- 6 days due to waiting for spares.

Technical Notification (TN) Analysis

A good overall indication of scope of work (SOW) efficiency is based on the number of Technical Notifications (TN's) issued during outage execution. The reasoning behind this is that, if the SOW is planned well, then outage execution will be in accordance to the original SOW. However, if there are significant variations with regards to SOW, then an increase in TN's follows. This can be based on; conditions of the components after inspections, or missed scope, or new scope because of rework incidents. The TN's were also categorised as defined below in Table 8 which shows the number of TN's raised per category and the time impact associated with the TN.

Table 8: Number of TN's as per the associated categorisation.

Description	Total Number of TN's	Negative Time Impact	No Time Impact
A	12	11	1
B	9	9	0
C	5	5	0
D	34	25	9

- Additional SOW and uncontrollable – (negative time impact or no time impact) ***(A)*** [Stuck Shaft, cutting of gland steam pipes, modular spares, IP Casing.]

- Additional SOW and controllable – (negative time impact, defective contractor/subsidiary process) ***(B)*** [re-machining, rework, generator and valves)

- Additional SOW and controllable – (negative time impact, defective ESKOM Process ***(C)*** [Waterbox, bearing no. 5, safety valve – incorrect calibration, modular spares re-machining.]

- Normal SOW – (negative time impact or no time impact) (D) [normal refurbishment process and TN's for information – planned for and expected.]

It can be seen from Table 8 above that whether the risks experienced on the outage project was either controllable or not, it has a lasting negative time impact on the outage project – meaning that an increase in duration of the outage was caused. Items B and C above are categorised as delays linked to defects, rework and poor control of processes. Category B and C can be combined showing a total of 14 TN's issued, because ESKOM and any sub-contractor can be seen as working on the same team to complete the outage project. Items A and D are linked to conditions, meaning that these were natural occurring incidents that could not be avoided, however one could question that if processes were followed correctly in some circumstances, then the resultant conditions would differ.

Early Warnings – Risk Analysis, and the relationship between Cost, Time and Quality

The early warning process is a contractual process in which either the contractor or the employer notify the other party of a potential risk that might occur, which will affect targets being met. The function of the early warning notification is to ensure that adequate warning is given prior to the risk materialising and allows both parties to discuss resolutions in order to mitigate/eliminate the risk, in a meeting called a risk reduction meeting. During the course of the outage project, risk reduction meetings were combined with normal scope of work (SOW) meetings with the Teams. Not much emphasis was based on collaboration of both parties solving risks before materialisation.

The total amount of early warnings issued from the Project Team (Project Manager) was 49. The early warnings were categorised based on the defined codes in Appendix B. Figure 24 below, shows a breakdown of the early warnings and provides the percentages per category.

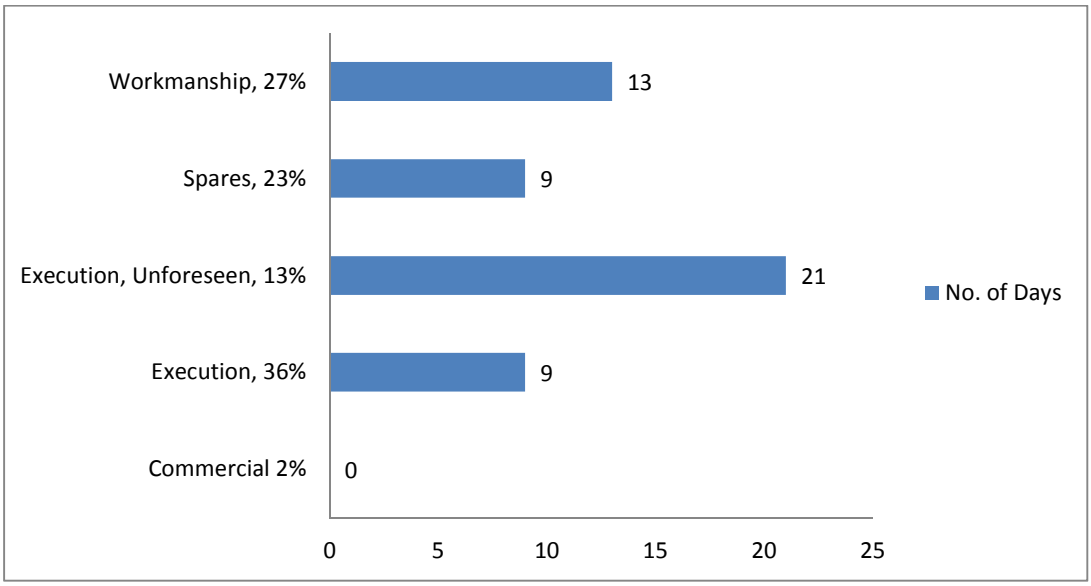


Figure 24: Number of days lost per category for the outage project.

The early warning notifications were categorised as per the definitions below.

- Deficiency in Commercial Processes – Commercial processes not followed in time or delays in the actual process. ***(Commercial)***
- Deficiency in Execution, improved control and planning, can be implemented, inclusive of Tools and Equipment, preparation for work commencement. ***(Execution)***
- Execution, Unforeseen – risks that occur that are uncontrollable. ***(Execution, Unforeseen)***
- Spares – lack of spares supplied in time. ***(Spares)***
- Workmanship – poor quality of work leading to rework activities. ***(Workmanship)***

The greatest time impact on the outage was due to 'Execution – Unforeseen' issues even though the percentage of occurrences at 13% ranked low, these were risks that materialised that were not controllable by the Teams', and was due to conditions of the components. It must be noted that not following the correct processes could have an impact on the conditions of the components. This can be during operation of the unit or due to incorrect processes followed whilst shutting the machine down. Due to massive

temperatures of components during the decommissioning phase – controlled cooling is necessary, to ensure the integrity of the components.

The other aspects related to negative time impact on the outage was due to poor workmanship (number of occurrences at 27%) – defects leading to rework, late spares – leading to increased waiting time and other controllable risks, which were not managed by the management Teams leading to further delays in the outage project.

An analysis of the Time, Cost and Quality Triangle was also completed based on the categorisation of the early warnings. Time is dependent on quality of work, and cost (inclusive of all types of resources – human resources, tools and equipment, etc.). Figure 25 below, shows the relationships between the aspects stated above.

- Deficiency in Commercial Processes – Commercial processes not followed in time or delays in the actual process. ***(Commercial) – Falls under Resources.***

- Deficiency in Execution, improved control and planning, can be implemented, inclusive of Tools and Equipment, preparation for work commencement. ***(Execution) – Falls under Time and Resources.***

- Execution, Unforeseen – risks that occur that are uncontrollable. ***(Execution, Unforeseen) – Falls under Time.***

- Spares – lack of spares supplied in time. ***(Spares) – Falls under Resources.***

- Workmanship – poor quality of work leading to rework activities. ***(Workmanship) – Falls under Quality.***

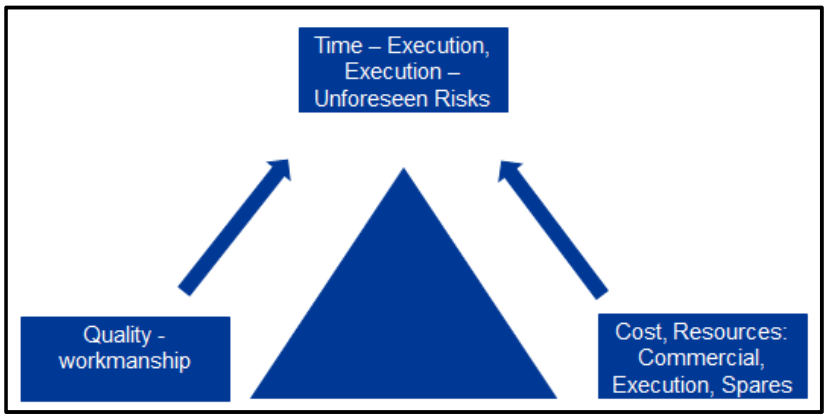


Figure 25: Categories relating to Quality Cost and Time.

In summary the participant observations revealed that decommissioning and shutdown is the responsibility of the power plant's operations personnel. Once the unit is shut-down, it is handed-over to the project team, and a permit to work (PTW) is accepted. The team then proceeds with disassembly of the components of all modules (turbines, generator, auxiliary equipment, etc.). Measurements are then taken and verified; and inspections are completed both visual and non-destructive. Components are sent to the workshop environment which is located off-site for refurbishment (diaphragms, bearings, rotors, etc.) whilst other components are refurbished on site. (casings, pumps, valves, etc.)

Once all components are tested, and validated as fit for use, the reassembly phase starts, and components are put back together in sequence, and tests are completed. The last major activity of the outage is concentricity and alignment of the rotor train. This means that couplings which join the rotor train from the turbines to the generator, have to be machined and placed at certain tolerances, so that concentricity and alignment is achieved. If this activity is not completed correctly, it can lead to vibrations and even catastrophic failure, which is why a dedicated amount of time approximately 4-6 weeks is prioritised for this activity. Once all activities are completed, mechanical completion is then declared.

The next step is to align the operations personnel, and ensure all tests are completed before commissioning can take place. Once the unit is operational again, more tests are conducted and vibrations are monitored. These vibrations have to fall within a specific

standard tolerance in order for the machine to be accepted as 'returned to service'. If defects are found, it can also lead to shutting the machine down again and re-opening of the machine at the problematic point, in order to fix the problem, which increases the duration of the outage, and is considered as fixing a defect.

Fortunately for this particular outage project, vibrations were acceptable, and in the end the machine was considered to be one of the best performing machines, for the power plant. The reader must also consider that during the entire process of the project, the engineering team evaluates, and take decisions based on the results obtained throughout the project. The engineering team also consists of the plant operational engineers as well as the engineers from the project team.

4.2 Analysis and Results of Interviews Conducted

Interviews were conducted amongst 8 employees in total, after the participant observer phase. The data recorded from the interview sessions were coded using the codes defined in Appendix B. Figures 26 to 33 show the results of the emergent themes from the interview sessions.

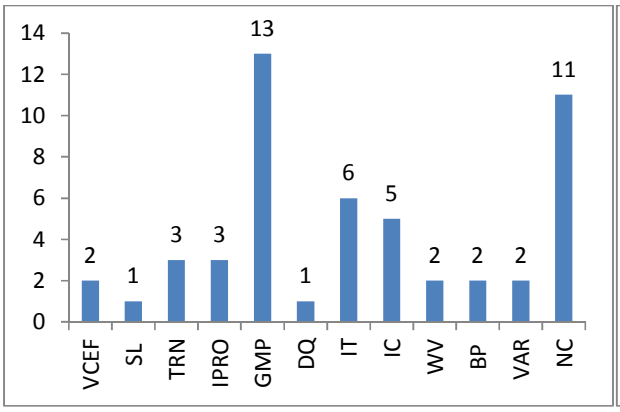


Figure 26: Results of Respondent No. 1

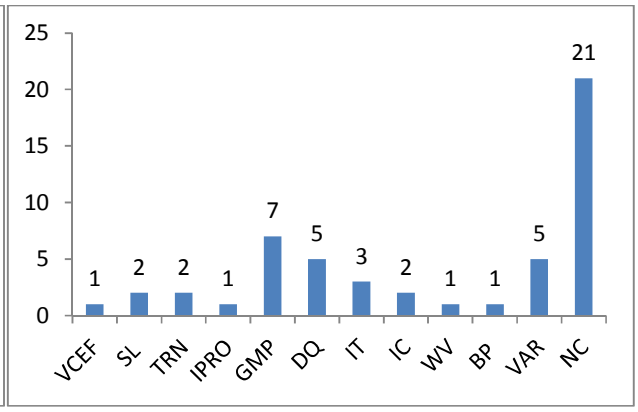


Figure 27 Results of Respondent No. 2.

Figure 26 above shows results from Respondent No. 1 – where 'GMP' was ranked as the highest occurring theme related to 'General Management Processes', also inclusive of poor management of information - document systems, and poor planning. Increased

time (IT) and increased cost (IC) are also themes that ranked high, but these themes show the reader that the respondent has agreed that factors affecting outage performance, highlighted in training (TRN), spares being late (SL), variances (VAR) in processes and varying culture, external factors (VCEF) leads to increased time and increased costs, and the respondent explained situations during the interview where it was catergorised either into IT or IC. No comment (NC) was when a respondent provided information, which could not be categorised in any of the themes, and this information was disregarded in the research.

Figure 27 above shows results from Respondent No. 2 – the high ranking theme was GMP, followed by decreased quality (DQ). The reader should be aware of the leading indicators and the lagging indicators. DQ, IT, and IC would be lagging indicators of poor performance on outage projects, and themes such as inefficient procurement processes, spares being late and training needed are leading indicators of poor performance on outage projects. This can be understood as poor training of individuals on outages can lead to mistakes being made which leads to rework and decreased quality, as well as increased time and increased cost.

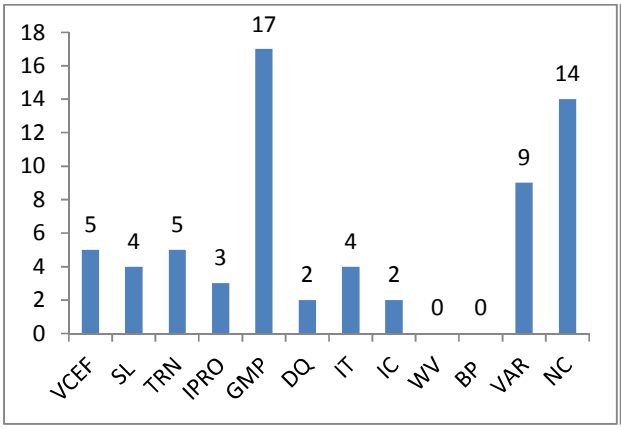


Figure 28: Results of Respondent No. 3

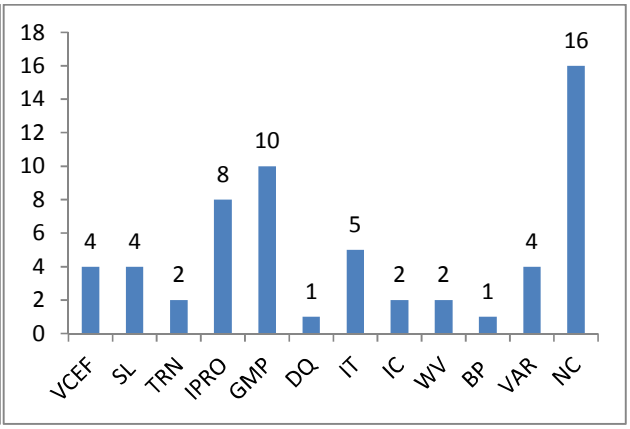


Figure 29: Results of Respondent No. 4

Figures 28 and 29 above, are the results from Respondents No. 3 and No. 4 respectively, where again it can be seen that GMP was ranked high, followed by inefficient procurement processes, training, varying culture and external factors.

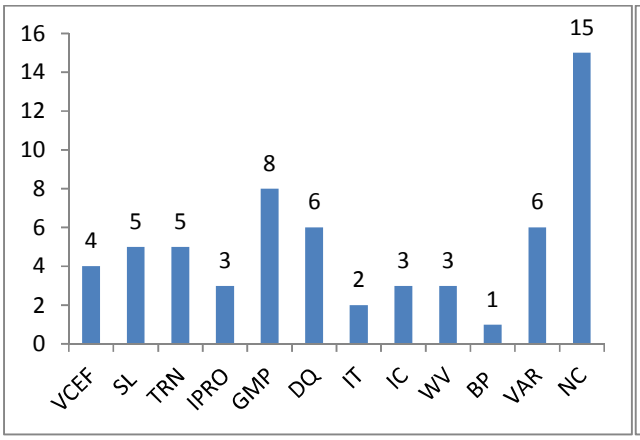


Figure 30: Results of Respondent No. 5

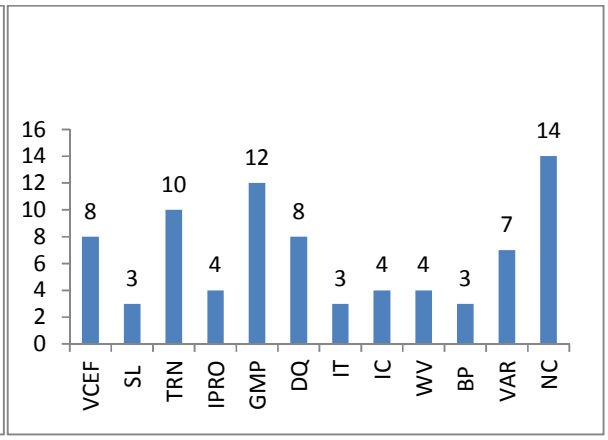


Figure 31: Results of Respondent No. 6

Figures 30 and 31 above, shows the results obtained from Respondent No. 5 and No. 6 respectively. As per the above respondents, GMP ranks high, and also variation in processes.

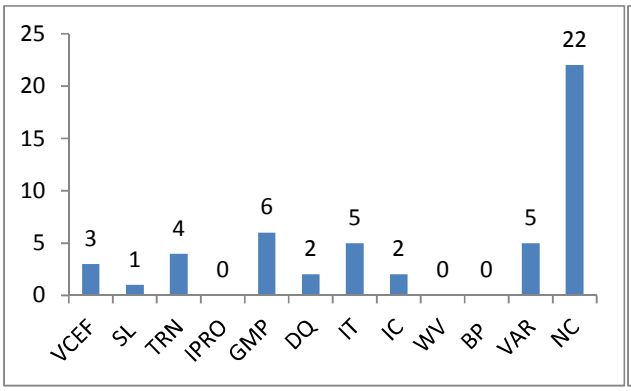


Figure 32: Results of Respondent No. 7

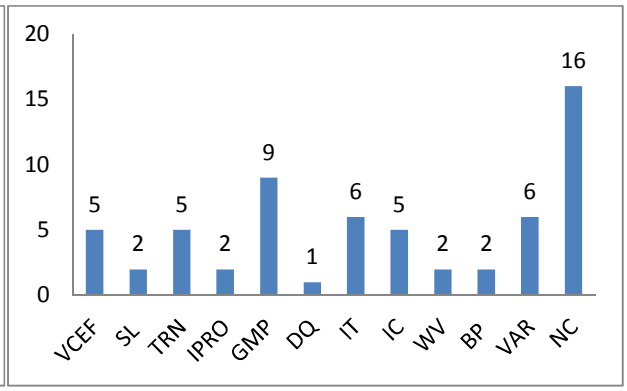


Figure 33: Results of Respondent No. 8

Figures 32 and 33 above are the results from Respondents No. 7 and No. 8 respectively, its unanimous amongst all respondents that GMP ranks the highest theme, followed closely by VCEF, TRN, and IT, IC, this also shows the reader the relationship between leading indicators which has more occurrences and lagging indicators following closely afterwards

Figure 34 below, shows a graphical representation of all the respondents themes compared with one another's. This demonstrates the highest occurring themes amongst the respondents'.

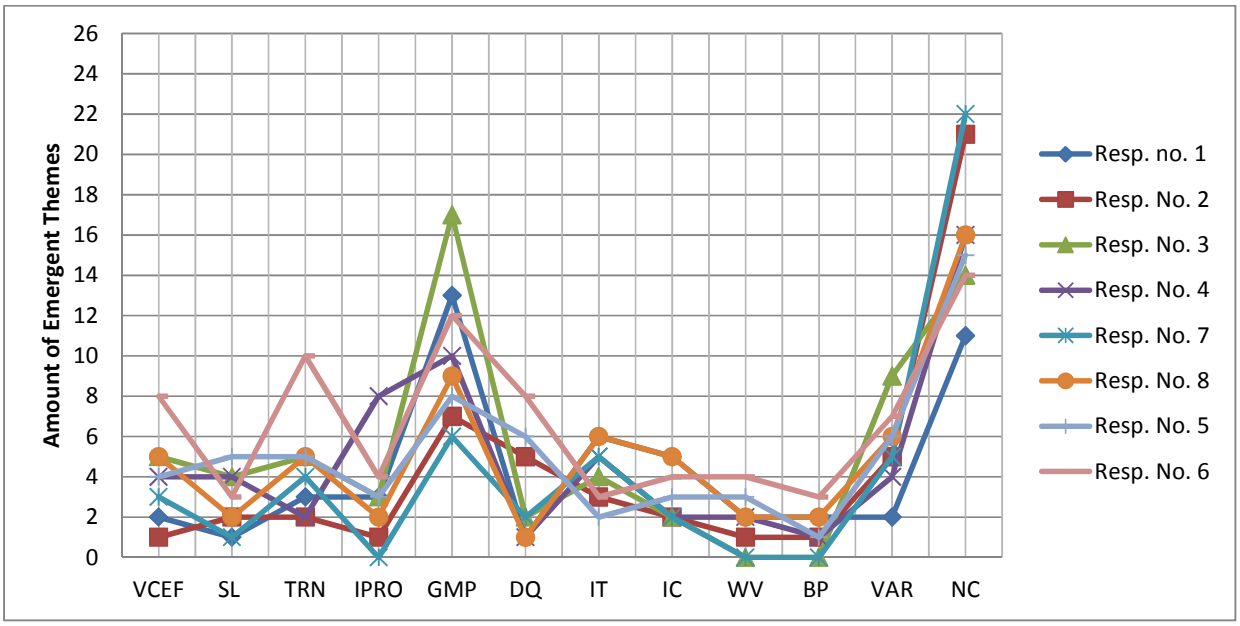


Figure 34: Results of Respondents showing highest occurrence of emergent themes.

Figure 35 below, shows the frequency of the emergent themes. The highest reoccurring themes are:

- General Management Processes (GMP) at 17% - This theme is related to procedures and policies in the ESKOM environment, respondents outlined the lack of employees following the management processes, and the disconnection between actual execution based on the ideal standards portrayed in the processes.

- Variation in Processes (VAR) at 9% - This theme is related to employees who have indicated how the processes are not followed in accordance with the standard documentation, and variation from these processes might either be detrimental or beneficial to actual execution of work.

- Training Needed (TRN) at 8% - This theme is related to respondents outlining a general lack of competence in performing work amongst all levels of employment. The lack of training leads to inefficiencies during work execution, through rework.

- Varying Culture, Environment Factors (VCEF) at 7% - This theme is related to the type of culture that has been created over the years where sub-standard methods of working

have been accepted and are currently not easy to change. The theme also relates to the external influences in the execution environment, this ranges from government enforced rules or regulations that are significant in terms of influence in the execution environment.

- Increased Time (IT) at 7% - Respondents outlined how factors have led to increased time in outage execution work.

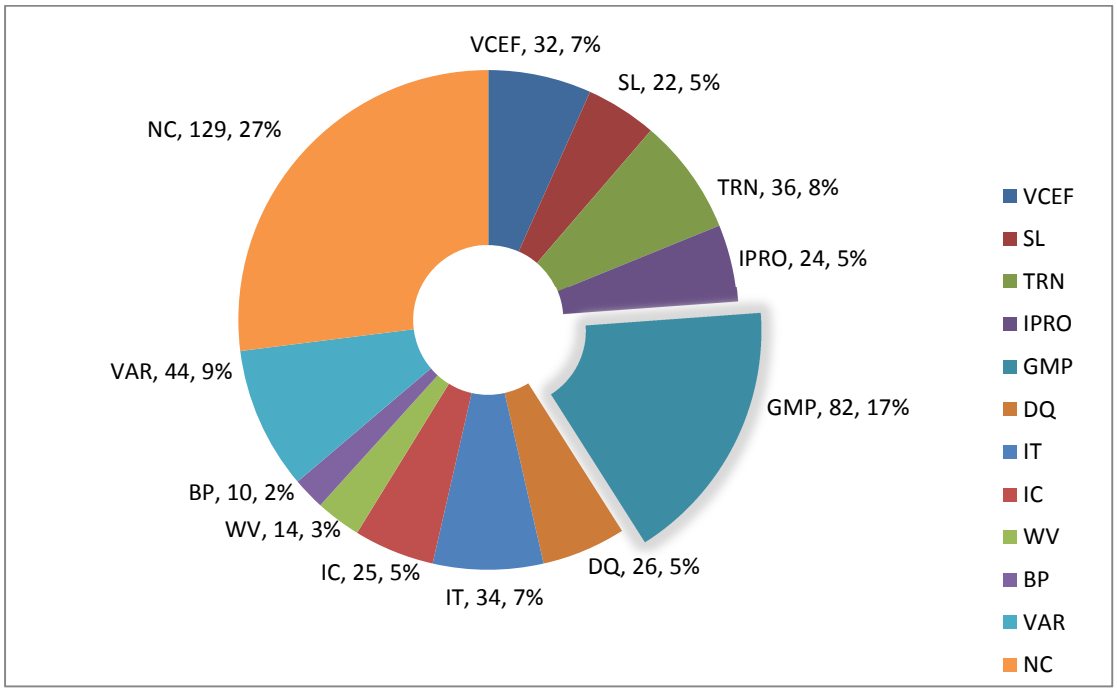


Figure 35: Percentages of emergent themes, from the interview analysis.

4.3 Analysis and Results of Document Review

Drawing from the Research Methods in Chapter 3, the document analysis was conducted in three stages as stated below.

i. Stage 1 – analysis of a range of documents associated with PMBOK and a comparison method used. This selection of documents, was to ensure that the

process of project management in the organisation was learned, and then compared against best practice methods such as PMBOK. A comparative table method was used to represent the results – Data Set 1.

ii. Stage 2 – analysis of statistical information-rich data based on outages performed amongst ESKOM power plants. This was to ensure that available historical data was reviewed, to understand the trends in management of outages, across the ESKOM fleet. Coding was completed for this stage – Data Set 2.

iii. Stage 3 – analysis of 'post mortems' of outages conducted across the ESKOM fleet from 2018 until 2020. Post mortems are presentations completed by plant personnel after completion of outages. It usually involves a range of Team members and the lessons learned are extracted during these post outage reviews. Coding was completed for this stage – Data Set 3.

Stage 1 – analysis of a range of documents associated with PMBOK.

The most crucial extracts, from the documents that were reviewed under this section can be obtained in Appendix D – 8.4. Project Management processes described in PMBOK includes the following topics (PMI - Project Management Institute - Global Standard, 2013):

The various documents chosen, was based on the categories relevant to PMBOK, described in Section 2.3 of the literature review. These documents included:

- **Project Process Flow Document** (can be classified under PMBOK Management and Quality Processes)
- **Outage Readiness Indicator** (can be classified under PMBOK Management and Integration Processes)
- **Outage Philosophies** (can be classified under PMBOK Scope Management Processes)

- **Operational Plans** (can be classified under PMBOK Management, Stakeholder, and Risk Processes)
- **Document Management System** (can be classified under PMBOK Management and Quality Processes)
    - **Quality Risk Management Documents** (can be classified under PMBOK Management and Quality Processes)
    - **Outage Programmes and Costing Sheets** (can be classified under PMBOK Time, Cost and Human Resource Management Processes

Table 9 below shows the coding system that was used for the documents that have been reviewed. The documents were categorised under the PMBOK categories stated above.

Table 9: Coding System for Categorisation of Documents.

Item No.	*Description - Areas of Knowledge in PMBOK*	*Code*
1	Project Management Processes	MP
2	Project Integration Management	IM
3	Project Scope Management	SM
4	Project Time Management	TM
5	Project Cost Management	CM
6	Project Quality Management	QM
7	Project Human Resource Management	HRM
8	Project Communications Management	COMM
9	Project Risk Management	RM
10	Project Procurement Management	PRM
11	Project Stakeholder Management	STKM

Figure 36 below, shows a graphical representation of the number of documents that were reviewed. The majority of the documents reviewed fell under management processes (55%), quality processes (17%), scope management processes (5%), procurement management processes (10%) and cost management processes (5%).

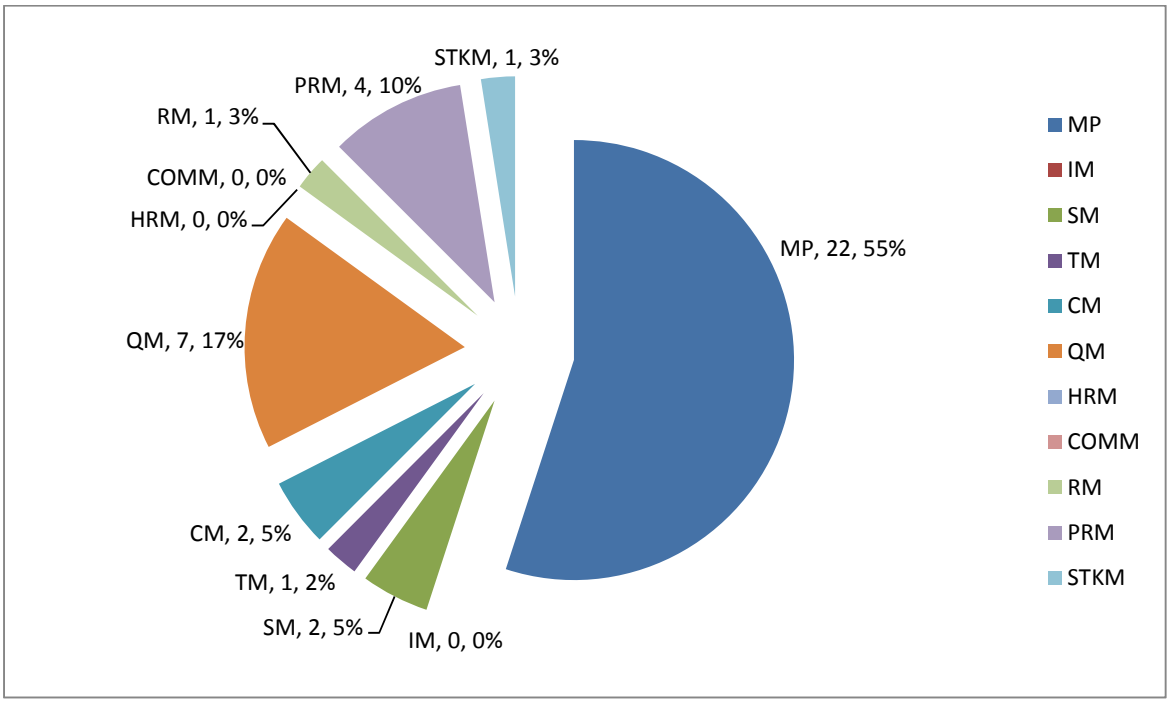


Figure 36: Amount of documents reviewed and categorised as per the codes developed.

Table 10 below shows the comparisons between the documents reviewed within ESKOM against the PMBOK processes/literature. Aspects that were deemed positive and negative were stated and an overall result was provided based on the classification stated below.

- Excellent – the document reflects approximately 90% correlation with the PMBOK processes/literature.
- Good – the document reflects approximately 75% correlation with the PMBOK processes/literature.
- Satisfactory – the document reflects approximately 50% correlation with the PMBOK processes/literature.
- Poor – the document reflects approximately 35% correlation with the PMBOK processes/literature.

Table 10: Comparative Method of Documents in ESKOM versus the PMBOK Processes.

Document Description	Positive Aspects	Negative Aspects	Overall Result
Project Process Flow Document	• Timelines are stipulated, references are stated and the document reflects a project plan.	• The document is limited in details, it could show more details around project charter, project plans in terms of communication, etc.	Good
Outage Readiness Indicator	• Shows tracking and control of processes before the outage starts. Manages procurement items needed and other related topics.	• None.	Excellent
Outage Philosophies	• Shows good details involving the different types of outages to be performed related to scope management.	• None.	Excellent
Operational Plans	• Shows good information on stakeholder management, SWOT, etc.	• Has limitations as the information is generic and does not provide concrete execution methods.	Satisfactory

Document Management System	• Corresponds to ISO standards.	• Has poor accessibility and search methods, no training provided to new recruits, significance emphasis on manual control.	Poor
Quality Risk Management Documents	• Good control of technical aspects on outages.	• Significant emphasis on manual control. Poor separation between ISO standards and technical quality control on outages.	Satisfactory
Outage Programmes	• Has good details included per modules, good integration and emphasis on critical paths.	• None	Excellent
Costing Sheets	• Has good details in terms of rates, amount of resources per module, resource levelling, and governance approval. Format is also user-friendly.	• None	Excellent

An outage philosophy document is a document that states what the estimated amount of time should be for an outage. GO's are considered outages with the most amount of work to complete when the unit is shutdown. MGO is a Mini-GO, in which less amount of work is completed. 'IN, IR, ST, BTI, and SS are types of inspections and interim repairs, where the scope of work is also easy to manage and less as compared to a GO. According to the scope of work outlined for different types of outages and across the ESKOM fleet, the average number of days was calculated, where it can be seen that General Overhauls – GO's are approximately 77.4 days in total planned duration.

Figure 37 below, shows the review of the outage philosophies' completed for power plants. The graph indicates that, amongst all the power stations, the planned time for completion of a GO is on average 77.4 days. If you add the UCF, PCLF, and UCLF factors, you reach 100%. This means that plants should be operating at 82.75% capability, 9.791% of the time is planned for shutdowns – loss factor, and 7.56% is unplanned downtime such as breakdowns. In future research one can explore the UCLF where these percentages will most likely be high, because of the increased durations on outages, thus lowering the capability of the plant. This is explained in more detail in Appendix D.

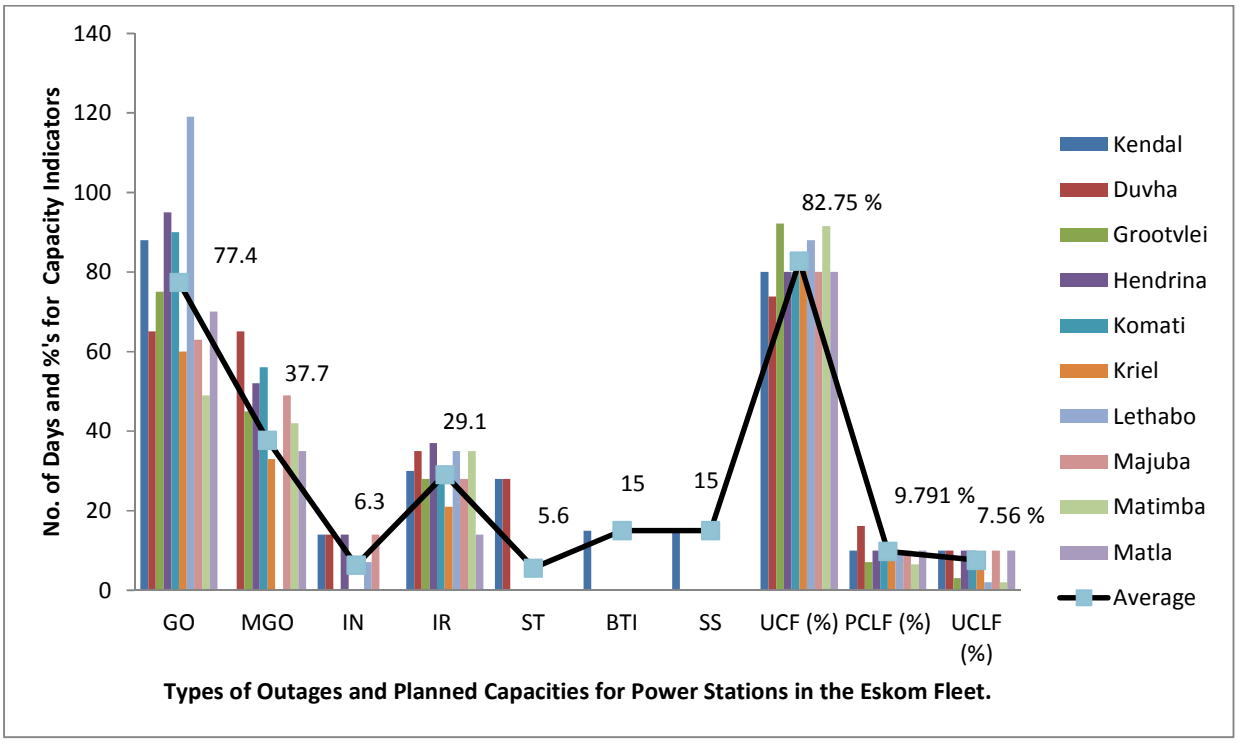


Figure 37: Comparison of outage philosophies amongst outages and power plants in ESKOM.

Figure 38 below shows the survey that was completed amongst ESKOM employees.

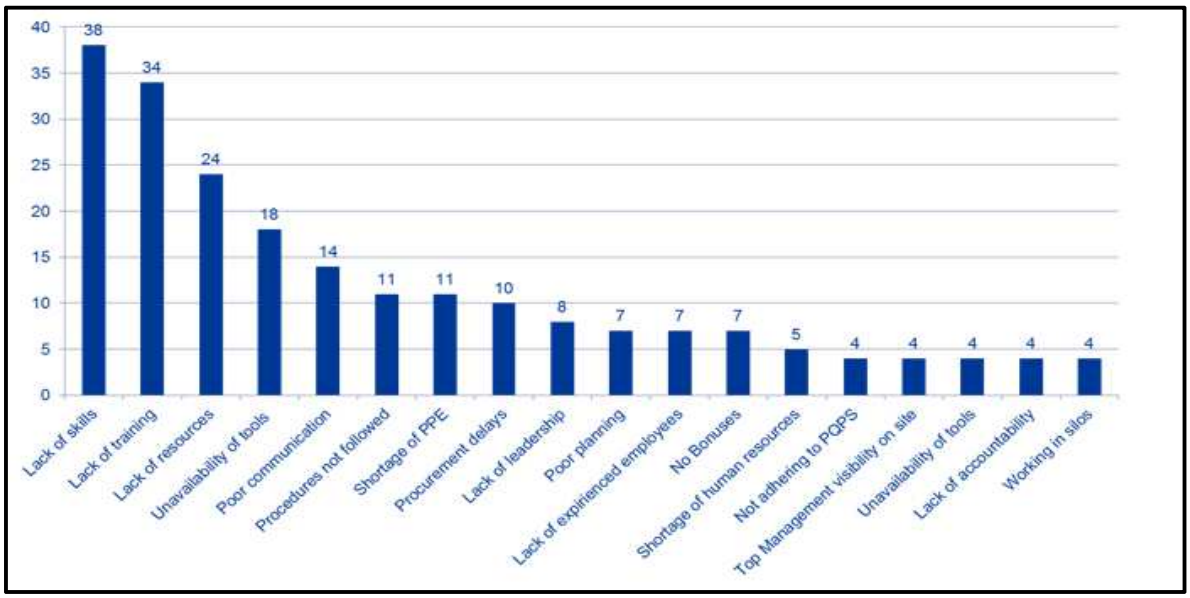


Figure 38: Graph showing the statistics of a survey done amongst ESKOM employees relevant to quality. (Quality Drive, 2018)

The trends' in the survey were recorded, and the top 6 categories are stated below:

- No.1 – Lack of skills.
- No. 2 – Lack of training.
- No. 3 – Lack of resources.
- No. 4 – Unavailability of tools.
- No. 5 – Poor communication.
- No. 6 – Procedures not followed.

Stage 2 - analysis of statistical information-rich data based on outages performed amongst ESKOM power plants.

Information that was sourced for this section can be reviewed in Appendix E – 8.5. The historical data reviewed is a good means of obtaining data as the researcher has had no influence on the data, as outlined in Chapter 3, Section 3.2.3. The data was coded using the established codes in the participant observer phase and the occurrence of themes was counted. The points below explain the results shown in Figure 39 below.

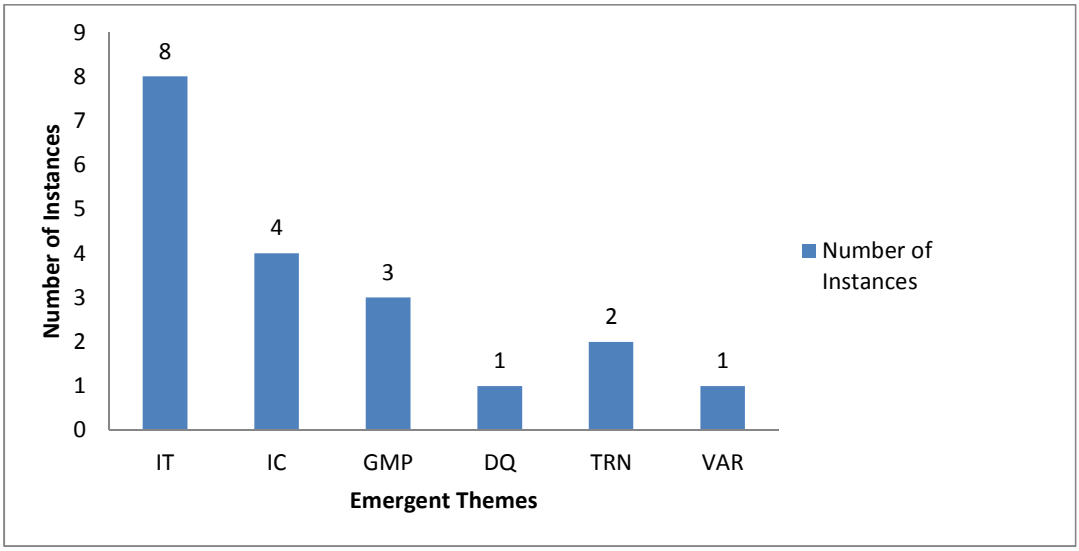


Figure 39: Data Set 2 - Document analysis - statistics in the organisation.

- ‘IT’ – Increased Time was the most reoccurring theme in the data. All documents and graphs that were reviewed showed outages that extended in durations.

- ‘IC’ – Increased Cost was the second most reoccurring theme in the data. All documents and graphs that were reviewed showed outages that increased in costs, as compared to the initial costing completed.

- ‘GMP’ – related to all General Management Processes, also inclusive of Management of Information - Document Systems, and Poor Planning, was a reoccurring theme that was found.

- ‘TRN’ – related to training within the ESKOM environment, training that is needed for a specific task, or an individual who has these core skills that need to be transferred or utilised on the job.

- ‘DQ’ and ‘VAR’ – Decreased quality – poor workmanship and variance in processes were two other themes that were extracted from the data.

From the results shown in Figure 39 above it can be seen that increased time and increased costs are resultant themes, from poor control of processes, poor planning, lack of required training and rework activities.

Stage 3 - analysis of ‘post mortems’ of outages conducted across the ESKOM fleet from 2018 until 2020.

Information in this section can be reviewed in Appendix E – 8.5.1. Coding was used for this information extracted from the various presentations across the ESKOM fleet. Figure 40 below, shows a graphical representation of the number of occurrences of categories.

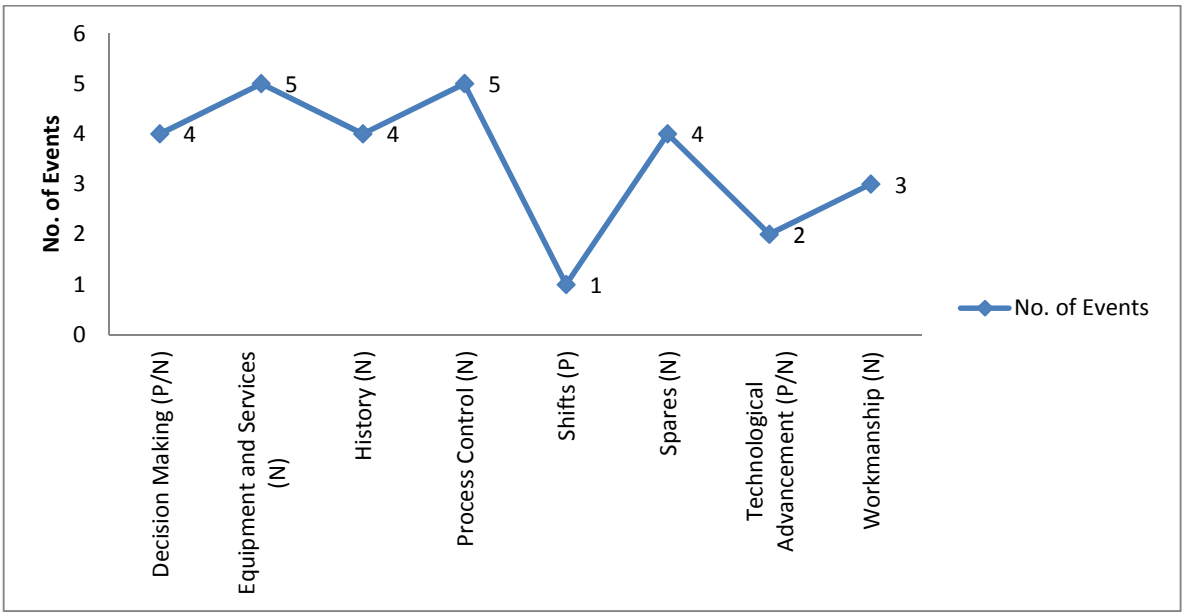


Figure 40: Comparison of Lessons Learned on outages across the ESKOM fleet.

The categories have been defined below:

- 'Decision Making' which can also include decisions from management Teams as well as the Technical Notification process. Both positive and negative results were shown. Decisions either aided the faster completion of the outage or delayed the outage.

- 'Equipment and Services' which was categorised as having negative effects only – which meant that outages were delayed, in terms of equipment and services, not being reliable and available when needed.

- 'History' – this is categorised as the statistical operational data of the unit. Relevant personnel not reviewing the necessary statistical information, or not having this information readily available led to delays in the outage or poor informed decisions.

- 'Process Control' - from the analysis conducted its shown that process control is ranked as the highest occurring theme amongst outages across the ESKOM fleet. This means personnel not adhering to general procedures/policies.

- ‘Shifts’ – associated with a positive scenario that occurred on one of the outages where a 3-shift mechanism was used which yielded more productive results in terms of completion of the outage in time.

- ‘Spares’ – associated with late spares – and had negative time impacts on outages.

- ‘Technological advancement’ - both positive and negative thus in some instances, more innovative methods of performing work on outages is completed whilst on other outages there are less innovative techniques being used which might not necessarily be efficient.

- ‘Workmanship’ – instances where rework was caused due to poor quality workmanship, creating negative time impact on outages.

4.4 Validity and Reliability

In order to ensure there was consistent validity in the results of this research, careful selection of an outage project was considered. This outage project encompassed one of the larger sized projects where the scope of work was large. If a smaller sized project was chosen, the exploration of the phenomena would have been limited. The larger outage project chosen, gave the researcher the ability to observe all related factors that influence costs and time. Precise documented records of the outage work, was necessary to ensure that the results obtained was a true reflection of the actual events. This was completed through notes taken during the outage project, pictures to capture real-time events, and cross-referencing amongst other observers’ on site, if there was agreement to specific phenomena witnessed.

Reliability during the participant observer phase was achieved through accurate descriptions and referencing of the major aspects of performing the outage project. If another researcher were to choose a similar type of outage project to observe, similar results would be obtained. This research, given the method that was followed in outlining the process flow of the outage, also provides the next researcher a substantial platform to repeat the exercise in an attempt to achieve similar results.

During the interview phase – validity was gained by interviewing respondents that have been considered experts in the field, thus gaining accurate information-rich data. If other candidates were chosen, this might have been a threat to the reliability of the results, as information might have been based more on opinions if the respondents did not have direct experiences in the type of work, which was under research. Again accurate extraction of data was obtained from recordings of the interviews. Reliability was achieved, if a future researcher might conduct this research method again with similar types of respondents, similar results would be achieved, as well as if the future researcher were to conduct the research by broadening the selection of respondents, the intended expectation of results might not be met, thus validating the concept of threats to validity of results.

Validity and reliability was achieved in the Document Analysis phase because of the use of existent information, thus the researcher had no influence on the information obtained. Information to support the research was selected carefully and if a future researcher were to conduct the research again, the same information can be obtained and later information can be obtained to assess trends, developments, and possibly even improvements from the historical data.

4.5 Summary of Results

The top three significant themes produced in the participant observer phase were, defects, variation in processes, and spares late. These themes had negative impacts on the outage project and caused significant delays, which is proven in the outage project programme, initially at 100 days, then compressed to 84 days, and finally completion at 136 days – in total a delay of 52 days, if compared with the compressed programme. After interpretation of the project programme delays, the most significant causes of delay were, oil and water not available, machining and pin-drilling.

When classified further it can be seen that oil and water not being available fell into the theme of “VAR” – variation of processes this means that the correct processes were not followed which led to water being drained out of the condenser tank – alignment and concentricity could not be completed due to the condenser affecting the weight of the

turbine train. The operations personnel did not follow clear instructions on leaving the condenser at acceptable levels, and the reader must be alerted to the fact that it takes a significant amount of time to re-fill the condenser. Oil was not available because it was not purchased in time. Not having oil and water significantly delayed other tasks that relied on these mediums for completion.

Machining can be catergorised as "DEF" – defects where rework was completed continuously because of a few factors which were incorrect tools used for the task, and incompetence of personnel. A sub-contractor had to be contracted in order to complete the machining activities, which meant that the assigned ESKOM personnel failed the task at hand. Inconvenient access led to delays in completion of the pin-drilling activities – by allowing one of the senior personnel to make a decision in changing positions of the access point, thus the team could then complete the task.

The analysis on the technical notification (TN) process showed that in category A, the additional scope of work was uncontrollable, with majority of the TN's leading to a negative time impact on the outage project. The speculation would be based on the condition of equipment given that the equipment is old – this can lead to more refurbishment work required. Categories B and C can be combined totalling 14 TN's issued, which was additional scope of work, however this could have been controlled through adequate planning processes and the negative time impact could have been eliminated.

The analysis on the early warnings that were issued on the outage project showed that the largest contributing factor to negative time impact on the outage project was based on circumstances (13%), where it was out of control of the project management team – example – stuck turbine shaft, even though the number of occurrences was lower than the other factors such as poor workmanship (27%), spares being late (23%) and poor execution practices. (36%)

The analysis of the interviews conducted showed respondents questioning the general management processes/procedures, and highlighting the variation in processes. The procedures/processes not being followed is a direct relation to the variation in

processes. Varying culture also ranked high where majority of respondents stated that sub-standard methods of working has been accepted, and this theme relates to another - “training needed”. Respondents also portrayed the lack of skills as a leading factor in poor outage project performance.

The results obtained from the document analysis confirmed that ESKOM indeed practices the PMBOK style of project management techniques, in terms of the documents being present. Majority of the documents reviewed was project management documents (55%). The reader should also note that less risk management documents, and stakeholder management documents (3%) were reviewed, it is speculated that these percentages of documents could represent the actual amounts of documents present in the organisation, meaning that far less consideration was given to these sections of PMBOK. The reader should also note that integration management documentation (0%) was not featured at all, during the documentation review, as well as communications and human resources documentation (0%).

Reviewing historical documents again showed poor planning in terms management processes/procedures, variation in processes and decreased quality – by the increase in amount of rework incidents. Reviewing post mortems of previous outages conducted showed lack of process control, lack of reliable equipment and services, spares being received late, and poor workmanship incidents.

The pre-dominant method of research was the participant observer phase showing the factors that have led to increased time and subsequently increased costs on the outage project. To further support these results obtained in phase 1 of the research; was the interview analysis and the document analysis that showed similar results that affect outage project performance.

CHAPTER 5

DISCUSSION

This chapter critically examines the findings of this research. The first section discusses critical aspects of performing an outage, addressing the first objective of this study; the following three sections discuss the remainder of the objectives. In the last section, the critical research question is answered.

Objective 1: Determining the critical aspects of performing an outage at a specific Power Plant.

The critical aspects of performing an outage project is split into six distinct phases namely; 1 - planning (usually 18 months in advance), 2 - decommissioning and shut-down of the unit, 3 - disassembly of components of the turbine, generator, etc., 4 - refurbishment of inspected components, 5 - re-assembly of all components, and 6 - commissioning of the unit to synchronise back to the main grid. The planning phase did not form part of the research project. The disassembly, refurbishment, reassembly and commissioning phases, when combined, form the live execution of the project. Symptoms of poor planning showed during the live execution of the project.

The benefit of planning ensures that one completes a goal in a precise controlled manner. (PMI - Project Management Institute - Global Standard, 2013) This is clearly depicted in best practice methods outlined in PMBOK, in section 2.3.1 where the planning process is divided into core processes and facilitating processes in Figure 6. Emphasis in PMBOK best practice methods is based on planning, scope, costs, time, as well as human resources – facilitating processes, risk and quality. A simple example of poor planning is depicted during the participant observer phase where the layout of the floor plan resulted in time wastage in the outage. As shown in the results section 4.1 - Figures 18 and 20, the placement of containers in heavy duty areas right next to the rotor train, where the larger components could have been placed, increased the crane utilisation time period. Planning of layouts on the outage is critical for optimised crane travel and heavy duty areas are marked next to the rotor train for a reason – to have the heavy components close to the unit, so that

this minimises crane travel. The usage of the crane is also divided per module on the rotor train, so each team that works on each component should have a scope of work (SOW) planned for the day, and thus know the time periods for the utilisation of the crane. SOW's was discussed in morning meetings with the Supervisors. This was a high level one page document, and did not show depth of details in the plans for the day. It was observed that the project management team also became observers and the personnel witnessed the outcomes of the work on a daily basis instead of controlling specific aspects of the project, this led to increased duration of the outage project.

The project management team also relied on the supervisors to perform their own work i.e. their own method of work and relied heavily on the experience of the personnel, rather than systems or processes. This led to increased variation in processes, and many rework incidents on specific modules where the supervisor was less experienced. For example, the generator module which depicted a higher level of rework, as the supervisor assigned to this role was completing the work himself for the first time. In previous years the supervisor was guided by specialists from the original equipment manufacturer (OEM). This aspect can be compared to Lean practices i.e. standard work, as described in section 2.3.3 of the literature review, where standardising on work activities creates sustainability and routine, and moves from the known to the predictable, which in turn creates statistical trends. Moving even further into the future, the statistics can be gathered, analysed and improved methods of working can be applied. There is an evident relationship between rework incidents and poor quality depicted in the results, stemming from a general lack of control of processes and inadequate training of personnel.

A company as large as ESKOM should have availability to many types of resources in order to apply these resources in the best strategically controlled manner to achieve the goal. Having access to the many types of resources does not, however, guarantee that a company would utilise these resources in the best possible way. This is evidenced by the poor layout plan, where there is a dedicated department of industrial engineers which should be working on optimisation methods for outage projects, or poor communications/integrations of team's in order to achieve common goals. PMBOK also placed significant emphasis on the integration of teams, and communication controls.

The units at any power station can be considered as a large machine that needs a service at a required interval and there should be a checklist from the manufacturer of what items to check for which should set the goals for establishing the timeframes of when outages are completed and what work is needed during these outages. Specific reference is made to 'outage philosophies' in the document review analysis in the results, section 4.3 – stage 1, depicted in figure 37, where these types of documents for the different stations outline the station's goals in completion of an outage i.e. maintenance projects. Timelines associated with the maintenance intervals are outlined in outage philosophies. This particular outage project, however, proved that the duration extended past what the regular time interval should be. Why then are the philosophies in place, when these rules are not adhered to? The answer could potentially mean either the philosophy needs to be reviewed because it does not show a true reflection of outage duration or the timelines are just not controlled within the outage philosophies.

What resulted from the participant observer phase in section 4.1 as well as the interview phase in section 4.2 was that scopes' of works' were not adhered to. The variation in scopes of work had both positive and negative impacts on the outage project. In some cases the variation in processes led to rework, and in other cases the variation in processes led to reduction in time. This is also depicted by the technical notification (TN) process outlined in the results under section 4.1. In Table 8, there were 9 incidents of TN's issued which formed additional SOW, and had a negative impact on the outage project by increasing the duration. Rework incidents on machining were caused by not having the right spares and equipment in time. These 9 incidents were related to the project team. Even on the operational side, with the plant personnel, there was an additional 5 incidents that also led to increased duration of the outage, yet could have been controlled.

The issuing of TN's and also early warnings during an outage project is an indication of variances in processes, and SOW's. In Figure 24 under section 4.1 it was shown that 13 days of delay was caused due to rework incidents which contributed to 27% of the total delay of the outage project. There were also 9 days of delay caused because of inadequate execution practices. This meant that there was a lack of poor planning or lack of control from the teams, related to tools and equipment and poor preparation work.

Given that opportunistic maintenance must be implemented, it, therefore, must considered. If outages are rolled over and missed dates occur, cramming all the check-list items into one outage that does occur is not an efficient method of working. This means more time is required, there is a higher probability of failure of components because these components were not changed in the regulated timeframe, and it would cost you more. These missed intervals of performing the outage is shown in the project programme under the results section 4.1, as well as in section 8.2.2 - Appendix B, where the outage moved from the originally planned date in 2017 to 2018, with pro's (more time to plan) and cons (cramming work to be done in the same amount of time and risk of failure - running machines past the maintenance interval timeslot). Even though additional time was provided due to the change in outage commencement dates, some of the spares, tools and equipment were still not co-ordinated, and not purchased in time.

Another critical aspect of the project programme is the lack of control of timelines of critical activities. As shown in the literature review under section 2.2 where Ashok et al. (2011) highlights the importance of activity crashing, whereby the critical tasks are given priority and protected by always assigning more resources or changing of plans on an hourly/daily basis, whilst the non-critical activities may finish later. Similar problems which were highlighted in the article as mentioned above, were witnessed on the outage project, such as non-availability of spares, resource constraints, and non-availability of accurate standardised task time –durations, to perform the work, so programme timelines become more estimates rather than a control mechanism, almost as if the programme follows the project, meaning the project is deemed an uncontrollable force.

As shown in the literature review under Figure 1 in section 2.1,where the optimum level of maintenance (balance of preventive and corrective) is achieved under predictive maintenance, this means that an organisation, after performing projects over many years would have established methods of working and would have identified problematic areas of concern (identified risks) and would have improved in these areas (implement control processes).

During the participant observer phase the issues of late spares meant that the 'just in time' principle was not followed, as stated in the literature review under section 2.3.3 – lean

management practices. If planning occurred 18 months in advance there would have been a procurement plan for the purchasing of spares during the 18 month period. To date the organisation should have a historic overview of what spares are required, both long lead items ordered from off-shore as well as the locally manufactured spares needed. In fact, there is a separate workshop dedicated to the manufacture of local spares such as nuts and bolts that services all ESKOM stations during outage projects. The control measure should be - knowing what spares are needed during all phases of execution of the project, ordering these spares in time, and storing these spares in a space readily available for utilisation, taking into consideration the shelf-life of the required spares. Ordering of spares should also be automated to a certain degree, if an organisation has a controlled inventory space. Spares were lost during the execution of the project – meaning that there was inadequate control of spares being kept on site as well as off-site in the workshop area.

It was evident during the outage project that planning of spares was happening during the outage execution when it should have been planned way in advance, with master track sheets, which was just not shown during the outage execution. Lists of spares were being developed during the outage execution. In previous years what was mentioned by personnel during the participant observer phase was that there was dedicated personnel to the management of spares and co-ordination of spares during the outage, in this particular project there were no such personnel and supervisors were left to co-ordinate spares themselves, whilst performing their own duties of managing their artisans and the scope of work. This could have been the root cause of lost spares during the execution phase.

Objective 2: Determining constraints in the processes followed, during a General Overhaul Outage (GOO).

The constraints that were discovered in the research are based on sequential completion of activities, if necessary materials (components, equipment and tools) or resources are not present for some activities (shown in section 4.1 under significant themes in Figure 22); it inherently delays other activities, as per normal project management practices. What was depicted in Figure 22 during the participant observer phase was spares being late, ranked the third highest delay factor during the outage project. As discussed in the literature review

in section 2.2.3 under lean practices, one of the more efficient methods of working on projects is to ensure that spares arrive 'just-in time'.

Figure 9 in section 2.2.3 described above shows the pillars adopted by Timken Bearings SA where emphasis is based on factors such as quality at the source, stability and reliability in man, method, machine and materials, as well as standardised work and continuous improvement. Constraints were experienced in all categories mentioned above, man – resources were not fully available at the start of the outage. Resources were deployed in a staggered manner as described in Appendix B – 7.2.1. Methods – resources were not skilled in performance of work such as the machining activities where the internal machining team failed at performing the machining tasks on the valves and thus a sub-contractor had to be called in to perform and finish the work.

The constraints behind the machining activities, was inadequate advanced machines available for the machining process and lack of skills of the resources performing the work which led to a 32 day delay. This was described in detail in section 4.1 under programme analysis. In the same section in Figure 23, the same machinists' team was also responsible for the pin drilling, where a 10 day delay was experienced due to not having access to perform the work, and delayed engineering decisions. Decision making was left to the engineering team, but until one of the more experienced engineers was called in, where he advised that the pin drilling access should be changed because it does not hinder the function of the machine, then subsequent progress was made on this particular activity. Constraints in the process have led to complacency amongst personnel, and thus the need for continuous improvement is almost non-existent amongst personnel, as observed. Usually a team that is motivated and passionate about achieving goals is a team that can subsequently think 'out of the box' in order to get work done, smarter. Change is something that does not happen, because of the culture that has been created over the years through leadership roles, or lack of sustainability, which is depicted clearly from the observation of the outage project.

Another limitation was non-technological advancement in terms of equipment and tools used on the outage project, which also led to rework in terms of machining. This could be seen not only in the type of tools that were used or the methods of working, but also the

process related documents and manual systems that delayed efficiencies during the outage project. A work package project was implemented on the project, but never materialised because there was no control over the implementation, as described in Appendix B – section 7.2.1. Costs were incurred on the project for detailed work packages to be made available, yet was not being implemented in the way it was initially intended to, where employees would tick of each item of work done on documents, manually. During the interview sessions amongst some of the respondents, the amount of manual checksheets and paperwork to be completed on an outage project was brought up as a deterring factor. History of services completed on the unit before were not available directly.

One would have to drive to a specific area off-site, and look through a file facility in a room, in order to obtain information which is not user friendly and laborious. Respondents also exclaimed information was missing. Instead, rather, the site personnel rely on people to obtain information and not on systems, and when employees leave the organisation they leave with valuable information. As described in section 7.1 – Appendix A, there are 11 distinct principles outlined in Table 11, in an article written by Dick Kovan on British Energy and how they achieved reduction in outage durations from approximately 90 days to 42 days. Specific reference is made to establishment of systems, and division of roles and responsibilities, continuous improvement, ending the overtime culture, and optimising maintenance strategies. All of these factors can be applied to the ESKOM environment where a detailed plan of action should be developed for each aspect of performing outages, through the use of the industrial engineering department to utilise the principles as set out in Lean practices.

Although senior management teams enforce rigorous time constraints on projects, it does not influence the actual completion of the outage project, as discovered in this research study. Part of the reason, is based on the condition of aging equipment, which only upon disassembly of a unit, one can deduce the additional scope of work required for completion. Constraints in the process are also dependent on the condition of the equipment after shutdown of the unit and inspections are completed, this means that the factors in the outage project are volatile and changing, and even through a project usually has structure you would then have to incorporate a good balance of an agile method of working. Contained within the literature review in section 2.3.2, is information on an agile approach

to projects. Figure 7 is a good description of the difference between traditional projects which are plan based which can be considered as PMBOK best practice methods, against value driven methods where interactions change and improvements are done in the project whilst the project is running. As a reader you would consider a combination of both PMBOK best practice methods with agile management techniques to manage an outage project which could lead to successful results. It was evident from the results in this research project that variability in processes, did not always mean a lack of control of processes, given the pin-drilling access example earlier – change in process/ agility led to progress and reduced time for that specific activity, when the experienced engineer looked at the situation from a different point of view.

Objective 3: Comparing the outage performed in a specific Power Plant against best practice methods using established Project Management processes.

The best practice methods of PMBOK rely on planning and a structured approach to management of outage projects. Initially the 'rules' are laid out through standardised methods of working through aspects such as a detailed scope of work, a project programme aligned to the scope of work, budgeting cost per activity and controlling activities during execution within your 'rules of engagement'. Integration of teams are good communications structures are set-up. PMBOK even plans for risks that might occur during execution of an outage project. All of the upfront planning and consideration during PMBOK practices ensures that there are no surprises during projects, but how then do you control a an outage project that is bound to provide surprises during execution or any part of the phases of the project? The system or the structure has to be built to accept change and quickly respond to save time on projects.

Inclusive in best practice methods are Lean principles, first used by the organisation – Toyota. Lean is a brilliant way of removing time-wasting activities from work, establishing new creative methods of working, creating a positive environment, and ensuring sustainability leading to efficiency. Timken South Africa, was one of the companies that adopted the lean principles as well as quality principles and created a company specific approach to manage the organisation. An amalgamation of best practice methods, like Timken SA has achieved as described in section 2.3.3 in Figure 11, can be used at ESKOM.

Although there is a significant amount of project management documentation aligned to the PMBOK method of practice, a lack of controlling these processes in actual execution was observed. This was further corroborated through the interview analysis, and the document analysis where lack of process control was a similar dominant theme. During the observation phase, variation in processes was a significant theme, and this was also dominant in the interview analysis. The variation in processes can be viewed from different vantage points, meaning that further questions can be asked if personnel consciously choose to disobey rules of processes to establish more agile methods, in other instances it was proven that not following protocol and not following instructions led to defects, and rework.

Further comparisons found from the research conducted in the participant observer, interview analysis and document analysis phases against the literature review were:

- lack of risk management – very few documents were reviewed in the established project management documents related to risk management. As indicated by Hlophe and Visser (2018), there is a lack of focus on risk management and more focus on operational control. The result obtained in this research was a general lack of planning which interlinks with planning for risks, some of the activities experienced in the participant observer phase were corrective actions taken to fix mistakes, rather than having planned for the risks before materialisation of the risks.

- level of compliance of risk management processes are below standards, in relation to processes not being followed correctly.

- Mtembi and Kanakana (2015) also shared similar results stating that risk management should be incorporated into the project management practices, poor quality because of lack of skills, poor communication between stakeholders and delays in procurement processes. The results obtained in this research aligns to what was discovered in the literature review, however there is a lack of depth in terms of the literature review that this research has provided.

Emergent Factors

What was outlined in this particular research which did not feature in the literature review was the culture that has been established over many years that influences performance on outage projects. An example of an unexpected finding was that labour has an advantage in monetary earnings, if durations of outages are increased, thus rework incidents can be questionable. One significant finding in the research showed that when an outage worked on a three - shift cycle, where less overtime would be paid, due to 24 hour work coverage, then the subsequent decreased duration of the outage was experienced. It can be viewed that there are a multitude of factors to consider on outage projects, which needs to be managed effectively in order to save time and money and grow the economy of South Africa through ESKOM. Deficits in power delivery affect businesses across South Africa, when load-shedding is experienced. One of the factors that aid in load-shedding is the increased downtime of units.

Objective 4: Establishing methods/processes that can improve the efficiency of Outages.

The techniques outlined in the different types of project management in the literature review has brought to light, that to manage such types of complex outage projects, one might consider an amalgamation of such techniques. In some instances in the participant observer phase it could be seen that variation in processes actually led to saving time, and adding value aligned to the agile method of working. Although quality processes were present, it was somewhat very operationally driven and lacked a strategic vantage point, because results shown in the document review analysis in Figure 39 section 4.3 – stage 2, was from past events, and these negative events that affect the performance of outage projects are still occurring, thus there is a lack of continuous improvement and eradication of negative events.

Poor workmanship leading to defects, poor planning and inefficient processes are some of the factors that have been highlighted in the research study. Drawing back from the literature review, under section 2.3.3 – Lean Project Management Practices, Figure 11 is a good overall interpretation of how a company should fall back on control of

management processes, as well as a focus on quality and customer satisfaction. The integration shown in Figure 11 in this section, incorporates the pillars of lean techniques, and provides a good summary; it also shows a build-up to lessons learnt and risk priority number. (RPN) Ultimately in every business, it revolves around, people, product and processes. If ESKOM were to establish a lean approach in management of outage projects, more efficiency in processes can be created, thus leading to decreased defects, a decrease in wastage of time, ultimately leading to decreased costs. The suggested improvements below that one would consider as the outcome of the research report are:

- More emphasis on planning is required, even though the research report excludes the planning phase of the project, poor planning is evident in execution. Firstly a well-established project methodology needs to be described with a combination of PMBOK structure, control through lean methods of working by eliminating time wasting and the ability to be agile during all phases of the project. Secondly and lastly an A3 report technique (lean principle) can be used to improve processes through identification of time wastage and implementation of new efficient methods of working.

- Clearly defined roles and responsibilities' of teams' will help divide work and trust relationships would be built through reliable performance, meaning delivering on promises. In section 2.2 of the literature review the use of an 'outage control centre' helps to plan, organise and execute efficient maintenance projects. If ESKOM were to take this approach, true authority must be given to such a centre, and the centre must be trusted to deliver in terms of increased performance.

- Making the best of historical information. ESKOM has the ability to establish statistical control, through setting us sustainable systems, where information can be gathered, trends can be analysed and improvements in methods can be established by comparing methods to best practices in first world countries, or leading companies.

- Cultural changes that last and breathe the right atmosphere in a positive working environment targeting goals and achievements'. Overall focusing in processes, then people, and finally quality of product/service delivery, but all three areas hold similar significance.

Limitations of the research study

Although this research study might present an accurate reflection of events related to an outage project, there are some limitations that the reader must consider, as stated below. The limitations identified below, if studied further will give the reader a better understanding of how the root causes of the events that occurred on the outage project, led to increased duration.

- the research does not cover the planning phase of the outage project, and it would have been advantageous to review this phase. This will allow the researcher to gather in-depth information in terms of the constraints in the procurement of services, equipment, tools, and spares, witness the preparation work (training) of personnel to perform the work on outages, and understand the layout of the project programme and sequencing of events.

- the research is conducted on site at the power plant, but the reader must consider that refurbishment work is also conducted in workshops outside of the plant, and these workshop processes must also be investigated further to deduce constraints, as some of the key aspects experienced on the outage project were delays caused by refurbished components from the workshops not delivered to the plant in time.

- the purposive sampling applied in the research by means of selected 'subject matter experts' is specific and thus the results obtained cannot be inferred to a larger population.

- the current research in South Africa was limited and thus a broader range of literature was reviewed. External influences outside of ESKOM were not considered in this research study.

- When a unit is shut-down for maintenance work, other areas of the unit also undergoes maintenance such as the boiler, ash plant, cooling towers, etc. Delays were caused in these areas during the outage project that was under investigation in this research report. Thus the research is limited to the turbine and generator area.

"What factors in 'Outage Maintenance Projects' in ESKOM Power Plants pertaining to generator, turbine and auxiliary systems, are leading to increased costs during the outages' and increased durations of the outages'?"

The results confirm for this specific research, that outage projects are indeed affected by factors that increase the duration of the outage project, leading to increased costs associated with the outage project. The major factors reflected from the results section are poor workmanship leading to many defects found, which can be related to a lack of skills/training, variation from standard procedures/ processes which has led to loss of control, spares not being procured and supplied in time, and general overall poor planning leading to inefficiencies in execution processes. Undefined roles and responsibilities amongst Team's also plays a significant role in leading to confusion and a struggle for control/authority.

The relationship between time and cost has been established, when reviewing the results; increased durations actually lead to increased costs. More time delays means more resources on sites for longer, rework/defect incidents means more use of resources, equipment and materials to fix mistakes and inherent delays in decision making increases waiting/standing time. Failure to learn from past events and lack of establishing systems has led to information being lost, and no sustainability or improvement in outage projects. The same mind-set of the way work is executed continues repeatedly and thus a general lack of attention to changing so that continuous improvement can be established.

CHAPTER 6

CONCLUSION

It is evident that ESKOM in South Africa has experienced challenges in the control of power delivery to consumers. This is depicted through capacity constraints leading to load-shedding across South Africa, and has affected operations in multiple businesses. The maintenance projects conducted in the ESKOM environment on turbines and generators has been inundated with increased durations, and costs. This research report sought to identify the factors leading to increased durations and costs on outage projects. The methodology set out for the research project was a structured, exploratory approach by reviewing the aspects of performing an outage project, determining the constraints, in the processes, comparing these processes to the best practice processes and finally recommending improvements to improve on efficiencies.

The literature review did not provide a comprehensive understanding of how outage projects are managed in the ESKOM environment, and only identified high level challenges such as generic procurement issues, lack of risk management, lack of communication etc. This research report provides the reader with a better understanding of what are the steps involved in managing an outage project, and providing specific challenges experienced in each of these steps. The literature review did provide a good understanding of the best practice project management methods, but the application of these methods are still to be reviewed. One approach as highlighted in the discussion section is to amalgamate different types of project management methods, in order to develop a structure that works for outage projects in an effective manner targeting improved efficiency in complexities. The outage projects are complex, and as much as it's difficult to control the details, it must be done.

The results drawn from the research report, clearly defined the challenges experienced in terms of poor workmanship, lack of skills/training, variation from standard procedures/ processes, spares not being procured and supplied in time, and general overall poor planning, leading to an inefficient execution phase. Other emerging factors that affect outage performance in the culture created over years, where monetary gains can be achieved by workforce, if outages are extended in durations. Therefore there is no motivation to finish outage projects earlier than the original time allocation. These complex projects are managed at a very manual level and thus needs more structure through PMBOK methods in terms of control of processes, as well as the

teams being able to be agile in decision making in order to achieve value in the required amount of time. In some instances during the observation of the outage project it was seen that the team behaved in this manner of being structured and agile when the need arose.

Timken Bearings is also a well-established company that operates in many different countries and has devised a structure that is suited to a manufacturing industry and relies heavily on the application of Lean methods. The British Energy Company has also applied lean practices in their organisation in order to reduce outage durations, by focusing on creating the right type of culture amongst people, improving end-results (quality) through revising maintenance strategies and controlling processes more effectively.

It is important that changes are made urgently in ESKOM to help sustain more efficient management of projects, so that the country can develop further, making energy reliable and cheaper across South Africa. It is evident that there are many challenges related to performance of outage projects, and if these factors that have been identified in the research report are not investigated further, it will lead even further decreased performance and collapse of an organisation that will rely heavily on external funding to maintain the 'inefficiencies'.

A late spare as an example is a symptom of poor procurement practices and initial upfront planning. The historical data also should provide the responsible personnel a clear understanding of the spares which are needed at a specific time during an outage project. Rework incidents is a result of poor training/lack of skills, or non-conformance to processes. Failed attempts of manual work packages trying to control the processes must be reviewed. The existent cycle that ESKOM experiences of establishing new methods of working that eventually is not sustained should indicate that the true root causes of challenges/problems are not being addressed.

Recommendations on further studies

- A new outlook on the way ESKOM manages the maintenance of outages using the outage philosophy approach, as compared to the historical analysis, of outage projects over a period of years. In this instance outage philosophies might need to be revised. (Basis of rules/regulations, the primary governance of

maintenance projects.) This investigation should be matched against planned maintenance methods, inclusive of how predictive and reactive maintenance is completed so that an optimum level of maintenance can occur.

- A detailed study of the planning phase of an outage and the constraints experienced in the planning phase. Fixing constraints in the planning phase will have a significant improvement in the execution phase of the outage. Integration of teams during the planning phase will help ensure that risks are addressed early on.

- The PMBOK review requires more in-depth analysis of how the techniques are applied. An example of this would be the control of cost management in the outage, and whether the 'S curve' is followed, earned values are calculated, and whether budget values can be adhered to. Processes need to be studied in order to determine the structure applied and the lean principles that can apply, improving on sustainability.

- More in-depth research in procurement practices, the external factors that influence procurement factors, and how to make these practices more efficient whilst still controlling external influences.

- The application of systems to enhance process automation and optimisation, inclusive of new methods of training or technological advancement. Inclusive of this should be the application of lean methodologies to eliminate waste in the management of outage projects.

- Incentivised methods of working with staff/employees, that are results based.

- Capacity constraints other than performance on outage projects, analysis of supply and demand, on the national grid, and review of high performing power stations against poor performing ones.

7. APPENDICES

7.1 APPENDIX A - Article Review on British Energy

In the October 2000, Dick Kovan wrote a newspaper article on British Energy relating to improvements made in the organisation in order to improve on costs. British Energy was privatised in 1990, and a decade later the company showed significant improvement in doubling output on some plant systems, halving staffing requirements and improving safety performance. (Kovan, 2000) A detailed look at this article is shown in Table 11 below.

Table 11: Strategies employed by British Energy in order to reduce Costs and Optimise Processes. (Kovan, 2000)

Item	Improvement Strategy	Description
1.	Fix It Now (FIN)	A separate Team that deals with fixing defects leaving the regular staff to deal with routine maintenance.
2.	Organisational Changes	Reduction of Reporting levels and more authority assigned to personnel in order to make decisions.
3.	System-based Maintenance Regime	The plant is divided into systems and each engineer is responsible for maintenance with a multi-skilled workforce.
4.	Downsizing of staff	Some personnel were sent to other countries to work in, or were retrenched through the cost saving approach.
5.	Planning	A 13 rolling week planning schedule was introduced. All statutory work is completed first, and percentage of schedule completion is tracked on a daily basis.
6.	Ending the "Overtime Culture"	Introduction of a Stable Income Scheme - each Department and each Team have agreed overtime payments at the beginning of the year. The monetary value is paid throughout the year

		regardless of how much overtime is actually completed in the month. The necessary work including reaching targets is completed either with overtime or without.
7.	Maintenance Manager's Role	Increased direct reports and more interaction with personnel.
8.	Investment in people and facilities and the Work Management Project (WMP)	The organisation has invested in upgrading facilities for all personnel. Development of an asset management system (WMP) for planning, documenting and managing work, assessing risks, and controlling access.
9.	Cultural Changes	Team Building is used as a high priority mechanism to build relationships away from the plant and create integration with personnel. A no-blame culture has been created amongst the employees where all incidents are reported on. Disciplinary Action is looked at in a different light and mistakes are allowed.
10.	Reviewing Maintenance Strategies	Reviewing reports of the systems so that a decrease in regular maintenance can be achieved. Challenging requirements on plant life, in order to extend periods of operation of particular equipment.
11.	Business Plan Enablers	Two Strategies are reviewed regularly by the Teams: a) Outage Durations – optimising outage duration through utilisation of best practice methods around the world. b) "Pence per Unit" – A lean approach by optimising processes to cut costs, without affecting safety.

7.2 APPENDIX B – Participant Observer Full Text Analysis

7.2.1 Summary of the Experience of the Events on the Outage Project during the Execution Phase

The initial planning for the outage project started in 2015 and the execution of the outage project was initially scheduled for 2017, however execution of the outage project did not commence in 2017. [MO, POP, VAR] During 2015 the standard process of planning for a new outage commenced with regards to preparing the SOW and finalising the SOW. At the beginning of 2017 the SOW was finalised which led to the completion and finalisation of the project programme as well as the Staff Request Form (SRF), and request for sub-contractor services via the procurement process. The 'staff' as stated above refers to the amount of resources needed for the outage project, based on the SOW.

In 2017 some Purchase Orders (POs') via the procurement process were completed. The Team was prepared for the start of the execution of the outage in 2017; however the outage was postponed for a period of approximately over a year, from April 2017 until October 2018. The outage was kept on the weekly outage programme submitted to all employees for this period of time, and was updated to reflect the outage starting every two weeks (reflected false information with regards to the start of the outage with every communication sent out). [FI, PR, VAR]

The SOW for the outage was finalised and signed by all relevant parties' on the 26th of June 2018, approximately 3-4 months before the project commenced. [OLP, VAR] The total duration of the outage was based on the aforementioned start and finish in 2017 which was at a duration of 100 days. Durations of outage projects are based on programmes developed by the assigned Project Manager, planned over a certain time period from "Permit to Work" (PTW) to Mechanical Barring (MB) or Electrical Barring (EB). Please refer to the nomenclature at the beginning of the report for definitions. The original project programme was issued to the Client (Power Station Outage Manager) for acceptance in 2017.

A meeting was held on the 16th of October 2018, with higher management members from ESKOM confirming that the unit will be taken off load on the 18th of October 2018. [COMM] The discussion was based on readiness to perform the outage, to which the Team confirmed at 100% readiness indication, as per the Outage Readiness Indicator (ORI). [FI, PR, VAR] The Outage Readiness Presentation (ORP) was completed on the 4th of October 2018, as the Management Team had foreseen the start of the outage in October 2018 and acted proactively at that moment in time, before receiving confirmation on the start date of the outage.

The ORP consisted of a high level summary of SOW, POs', payment schedule, and profit margins from both all departments. The request from the Client was to reduce the initially planned outage duration of 100 days to 84 days. [CP] A new programme with re-sequenced activities, based on the same SOW was issued to the Client for acceptance, and was accepted by the Client on the 28th of November 2018.

Resources were mobilised to the power plant from the 22nd of October 2018 until the 24th of October 2018, spanning over a 3 day period. [LI] A total of 217 resources were estimated on the SRF, consisting of permanent labour and temporary labour. The amount of 217 resources that was requested for was not supplied, thus there was a shortage in the requested resources. [SOR] One of the reasons for the short supply of the resources was that one of the Labour Brokers had experienced a tax problem and could not supply their allocated amount of resources. [PSLB]

Work commenced on the 25th of October 2018 when the safety inductions were complete and the PTW was accepted. The resources were sourced one week prior to the start of the outage via the old PO's that were completed in 2017, which according to the procurement process would not have been valid. [VAR] The various Labour Brokers (seven in total) had to deploy these resources immediately. [VAR] Permanent resources were supplied and assigned to specific modules on the machine.

The Client had requested in 2017 that experienced resources be supplied for the outage, this included both Temporary Employment Services (TES) and permanent resources.

Approximately 57% of the resources, which had been requested for, from the Client, were supplied. [PDR]

All resources on site knew their specific positions, specific work to be completed on a specific module and were familiar with the direct reporting structure as well as the escalation process. [GPK] Figure 41 shows the line management structure, Figure 42 shows the direct reports of the Project Engineer for the outage and Figure 43 shows the direct reports for every Project Technician on the outage. Initially there were two Project Technicians on the outage, afterwards a third Project Technician joined. [OSR] Two Project Technicians completed the day shift activities based on the SOW, and the third Project Technician was sent to night shift to complete activities on the SOW outlined for night shift only. Figure 44 showed the support staff for the outage and these employees reported directly to the Project Manager. The Assistant Project Manager was assigned to the Generator Module only.

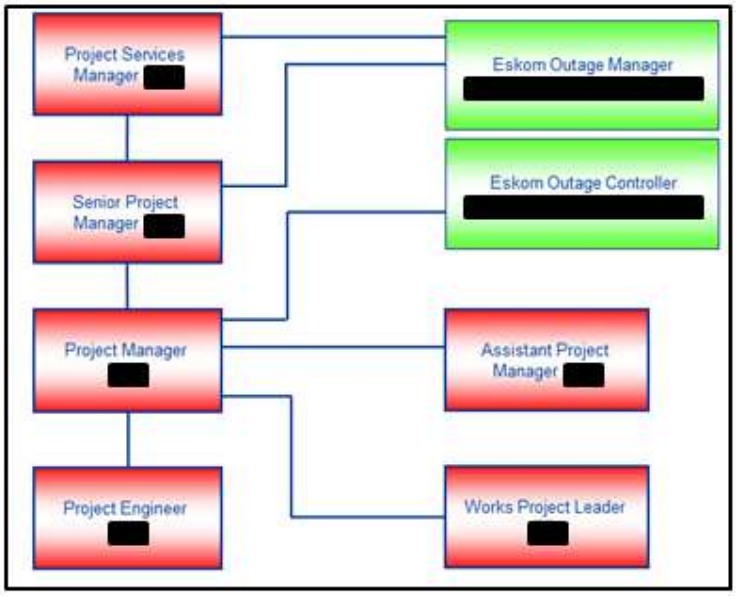


Figure 41: Line Management Structure of the outage project.

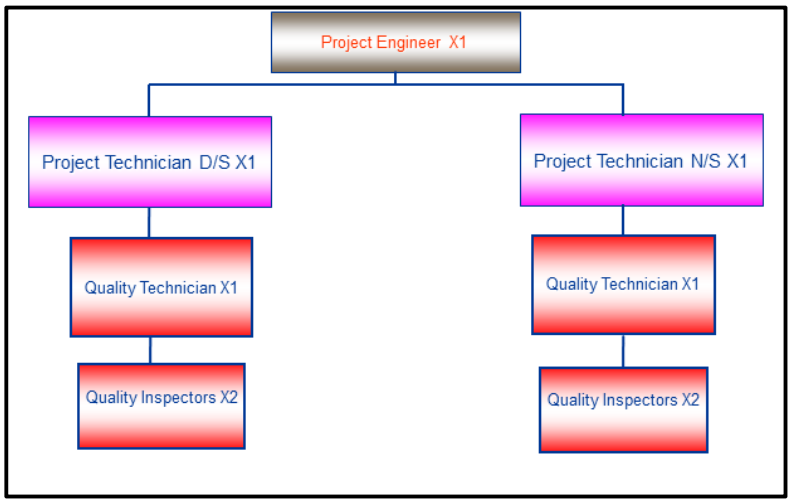


Figure 42: Reporting Structure for a Project Engineer on the outage project.

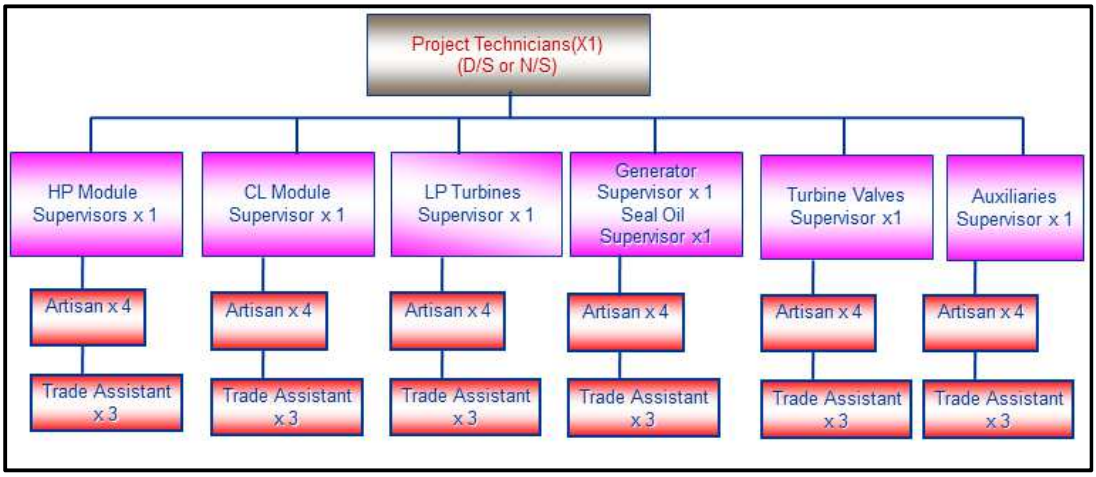


Figure 43: Reporting structure for a Project Technician on Outages.

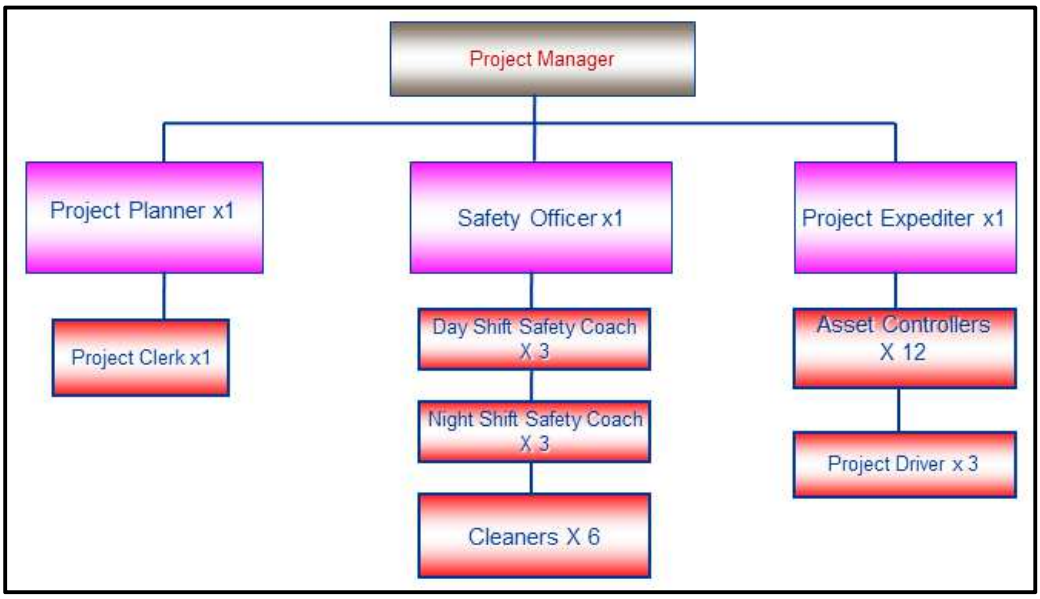


Figure 44: Support Staff for the Project Manager during Outages.

Before any work commenced on the outage project, safety inductions were completed. Safety inductions were conducted by two Teams on two separate occasions, thus all assigned staff had to complete two safety inductions. [CPR] Permits were issued to all employees for access to the power plant, valid for the duration of the project. Resources were mobilised on the 22nd of October 2018. The first induction for the resources was held in a sequence over three days from the 22nd of October 2018 until the 24th of October 2018. The reason for the three days of induction was because of the staggered resource mobilisation. Permanent resources had already completed both inductions and were thus ready to start work on the 25th of October 2018, however temporary staff needed to complete both inductions, thus not all resources could start work on the 25th of October 2018.

It must also be noted that completion of one of the inductions took a longer period of time, seven days in total, because of the multiple contractors booking the safety inductions on a daily basis and the facilities not being able to handle an excessive amount of employees. [LI] Other contractors were used during the outage, supplying other related services of scaffolding, civil work, pipeline work, etc.

High level refurbishment work for the modules is stated below and the final project programme included activities under each module. The decommissioning period was over a seven day period in which a process of forced cooling was completed, rundown tests, and removal of cladding and lagging on the machine was also completed. It must be noted that the operating personnel did not complete forced cooling according to the relevant procedures, and caused the turbine to get 'stuck' within its casing. [VAR, DEF] The decommissioning work was done by a different Team (inclusive of sub-contractors) and not the assigned Project Team.

Cleaning of the turbine and generator area, in preparation for commencement of work, was also done as cladding and lagging poses problems of dust and fibreglass particles that can settle on the machine components and within the lube oil system, when the machine is disassembled. Once all of the above items were completed, the Responsible Authority (RA) accepted a PTW, and the Project Team could commence with work – stated above, as the 25th of October 2018. It must be noted that before the RA accepted the PTW, he had to reject the condition of the area, in which case the sub-contractor cleaned again and then the PTW could be accepted. [DEF, PWM]

The high level SOW per module is given below, and Figure 45 shows the layout of the Turbine and Generator Areas (known as the turbine floor).

a) HP Turbine – Palm loading completion during phases of the project, replacement of HP Valve Chests (HP ESV's and CV's).
b) IP Turbine – Palm Loading completion during phases of the project, and refurbishment of Valves only (IP ESV's, IP CV's).
c) LP Turbines – Replacement of Rotors, and refurbishment.
d) Centreline – Refurbishment of all bearings, and alignment activities.
e) Turbine Valves – LPBP Valves.
f) Control Valve Actuators (CVA's) – Refurbishment of pistons, and re-setting of spindles. CVA's are found on the Turbine Valves.
g) Generator – Refurbishment work on the stator and generator rotor, replacement of components and pressure testing.

h) Gen Exciter Alignment Activities – Alignment of the Generator Exciter coupling.

i) Control and Protection, inclusive of Auxiliaries' Activities – Refurbishment of pumps and other mechanical equipment related to the Lube Oil Systems and Jacking Oil Systems. Some Auxiliary Equipment is found below the turbine floor.

j) Commissioning Activities – Pressure testing activities, acceptable lifts on bearings, and various activities during start-up of the unit.



Figure 45: Visual Imagery of the turbine floor Level. Turbine Area and Generator Area shown.

A Kick-Off Meeting was not completed with the entire Team, but rather information about the project was contained within the safety induction and communicated to all employees on the Project Team. [CBP] Employees were guided by their direct line managers with regards to layout of the containers on the floor and position of facilities (Supervisor, Project Technician, Project Manager, Project Engineer, etc.)

A series of meetings commenced during the outage duration. Table 12 below shows the timeline associated with meetings during the outage. It must be noted that it was compulsory for the Project Manager to attend all meetings on a daily basis. [CPR]

Table 12: Daily Meetings during the outage project.

Item No.	***Meeting Description***	7	7 30	8	8 30	9	9 30	10	10 30	11	11 30	12	12 30	13	13 30	14	14 30	15	15 30	16	16 30	17	17 30
1	SOW Meeting																						
2	Technical Meeting																						
3	Outage Controller Meeting																						
4	Outage Meeting																						

A brief description of the meeting agendas' are given below.

1. SOW Meeting (Daily from 7:30am till 8:00am) – The attendees for the Daily SOW Meeting were the Supervisors per module, the Site Technicians, Engineers, Project Manager, Planner, and any other relevant authorised personnel, in addition to the above mentioned cluster of people that needed or wished to attend the meeting. The SOW was discussed with the supervisors in a high level format. High level activities per module planned for completion during the shift was discussed, and all attendees were allowed to ask questions pertaining to the SOW, or any work related matter.

2. Technical Meeting (Daily from 8:30am till 9:30am) – The attendees for the Technical Meeting were the Engineers, the Client Engineers and any other Client Representatives if required, the Assistant Project Manager, Planner, the Outage Controller, and the Project Manager as well as relevant authorised personnel who wished to attend. Various technical matters were discussed between the Engineers and timelines were addressed with the Project Manager. The daily SOW document was discussed as well as witness/hold points, and technical notifications'. The Outage Controller attended Technical Meetings only twice throughout the entire project duration.

3. The Outage Controller Meeting (Daily from 10:00am till 11:00am) – This meeting was chaired by the ESKOM Outage Controller (Client) and the SOW was discussed as well as various commercial issues. The attendees for the Technical Meeting were the Client Engineers, the Planner, the Outage

Controller, the Project Manager and the Assistant Project Manager (Generator Only).

4. The Outage Meeting (Daily from 11:00am till 12:00pm) – This meeting was chaired by the ESKOM Outage Manager and all subcontractors working in the different areas of the plant. All contractors were requested to provide feedback in this specific meeting. Actual percentages against planned percentages were reported from each subcontractor. The Project Manager was requested to attend and was reporting on the critical path which was the turbine - generator work. The other areas of the plant were the Boiler, the Ash Plant, the Mills, the Secondary Air Heaters, the Fans, etc. Risks were reported in this meeting relevant to spares, engineering aspects, and/or timelines on projects. The critical path mentioned, was in relevance to all other systems.

The activities completed by the Project Team are highlighted in Figure 46 below. Work started at 7:00am, and the day shift ended at 5:30pm. The Labour Force Team inclusive of the Project Technicians attended required meetings in the morning, prepared for the daily activities as outlined in the daily SOW, and then completed the work as required. The daily SOW was prepared primarily by the Project Technician, and Project Engineer. The Project Manager also provided input into the process of scope preparation based on timelines, but not on a daily basis.

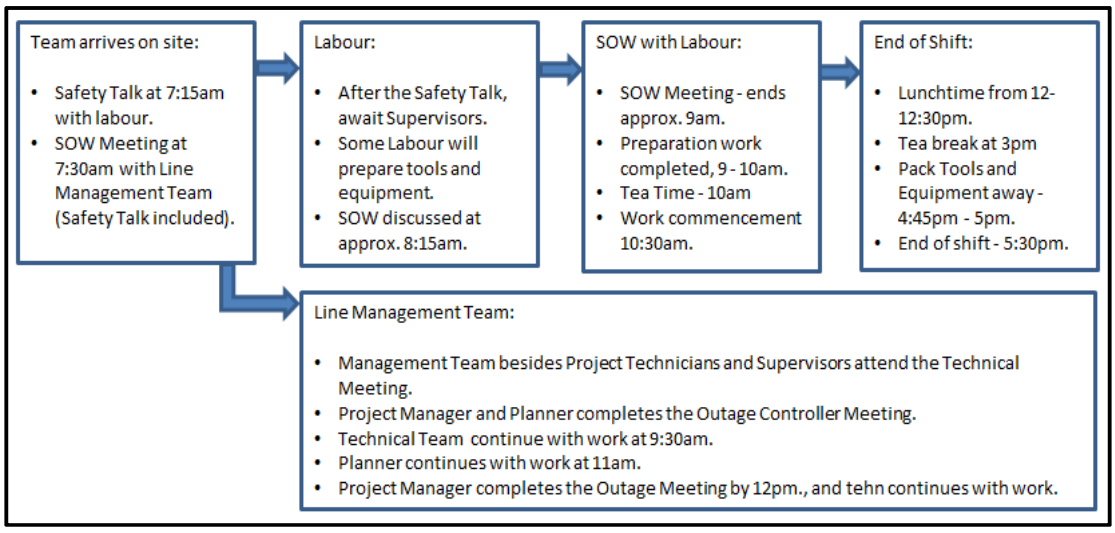


Figure 46: Activities' completed by the Project Team on site, on a daily basis.

All roles and responsibilities were outlined in the Contract Plan, which the Managers' in the Team accepted by signing on the document. The Project Technicians were responsible for preparing the SOW, and managing the Supervisors per module. Work was completed as per the SOW, and checksheets were used to record measurements. Checksheets were then taken to the Project Engineer where it was verified, and necessary signatures were completed.

All the checksheets combined for all the modules served as evidence for the Process Quality Plan (PQP), and was stored as hardcopies in a file – thus a manual storage process. [MF] It must be noted that prior to the start of the outage the PQP is developed by the Project Engineer, Project Technician and Quality Technician – aligned to the SOW. In this process of PQP development – the assigned ESKOM Engineers also verify and accept the PQP.

When variation was experienced in terms of the SOW, the Artisan was responsible for notifying the Supervisor who was responsible for notifying the Project Technician. If the variation could not be solved and required engineering input, the Project Technician would notify the Project Engineer. The Project Engineer would then follow the Technical Notification Process (TN Process).

The Project Engineer would submit the Technical Notification (TN) to the ESKOM Engineers (Client) and after acceptance the work would be completed. The TN would highlight the deviation, the risks concerned if the deviation is not completed, and the impact on the project duration (the impact was stated and not given as a numerical value of days; i.e. number of days was not stated). [VAR]

The Quality Technician on site was responsible for the Quality Inspectors who would verify measurements on checksheets. The Quality Technician would raise internal System Deficiency Reports (SDR's) if deviations in processes were experienced. SDR's were also raised against other departments; an example would be if defective components are allowed to be transported to site. Only one internal SDR was raised within the Projects Team, however four SDR's were raised to another department for defective components. [DEF]

After work was completed on day shift, a handover meeting was conducted from the day shift Project Technicians to the night shift Project Technician. The night shift Team was not subjected to the series of meetings held in the day shift and thus only SOW's were discussed and work continued. It must be noted that the Project Engineer would not remain on night shift, and thus if the night shift team required engineering support, they would contact the Project Engineer telephonically and communicate through visual aid – pictures. The Project Manager remained on site until night shift was established and would leave past the 10 hour day shift time period often working between 10-16 hours a day. There was no Project Manager assigned to night shift on the outage project. [SOR]

The Project Manager was responsible for providing feedback via Whatsapp communication before 7am on specific groups created for Management Teams. Communications via Whatsapp was sent out on a daily basis at around 6am. Feedback on each module was given in the various meetings which the Project Manager attended, inclusive of other special request meetings outside of the regular meetings described in Table 12 above. The Project Manager requested the Technical Team to be present when technical issues needed further explanations' during meetings. The contractual notifications were completed by the Project Manager to the Client. [CPR]

Commercial coverage in terms of payment assessments, and invoicing was completed by the Project Manager. Updates on the project programme were completed by the Project Planner showing percentages of actual completion per module. Review of the updated project programme was completed by the Project Manager, before communications were completed to the management Teams during meetings and Whatsapp Feedback.

When the Project Manager identified a risk with the Team, an Early Warning Notification (EWN) was sent to the Outage Controller. Most EWN's that were communicated, requested the Outage Controller to attend a Risk Reduction Meeting (RRM). In this meeting the parties were supposed to have agreed on mitigation steps that should be completed and revised project timelines. In the few risk reduction meetings that were held, the project programme was never revised and the project completion date remained the same. [OLP, VAR]

Non-Conformance Reports (NCR's) were sent from the Project Team to the Client and vice versa – this was in correlation with processes that were not followed correctly. The NCR's needed to have corrective actions as well as preventative actions outlined. Close-out of the NCR's were completed by the Project Team, however the close-out actions was not completed by the Client, thus this paperwork remains incomplete to date. [DEF, VAR]

In December 2018 it became clear to the higher management Teams that the completion date – 15th of January 2019, of the outage project would not be achieved. After intervention from the Power Plant Manager, all parties were called for a special meeting in which the clear impact on the outage was discussed. The list of Early Warnings was displayed and relevant questions were asked about the process that was followed. At this point in time the ESKOM Power Station Manager was not aware of all the risks that were experienced on the outage, as well as all the delays in correlation to the risks that had been communicated. [FI, PR]

A new revised project programme was then submitted in January 2019 and the new completion date of the outage was the 16th of February 2019. At the end of January 2019 it became clear that the completion date outlined for February 2019, would not be achieved due to new risks and delays that were experienced in the month of January 2019. There was no new revised programme submitted or signed. Completion of the outage was achieved on the 9th of March 2019 (Machine ready for Mechanical Barring). [VAR]

Other aspects that were observed during the outage are listed below.

- Crane Availability – It is the responsibility of the power plant to ensure that the cranes are available and are in working order during the outage. Cranes were approximately available at an 85% ratio against the full 100% duration of the outage due to the cranes having breakdowns. There are three cranes situated above the unit, and one crane was permanently out of operation due to a breakdown throughout the duration of the outage project. When the

largest crane was in use at the Generator, if other modules required the use of the large crane, then the work on the other modules had to wait. [CA]

- Layout – The layout of the containers and storage of components on the turbine floor was not optimal, which increased the use of the cranes, thus increasing travel time of components on the turbine floor and ultimately delaying activities. There are certain heavy duty concreted areas for heavy components on the turbine floor right next to the unit. Containers were placed next to the unit whereas it could have been placed further away and the area next to the unit could have been used for storage of heavy components.

- Figure 47 shows an area where containers were placed, whereas it could have been used for storage of heavy components. Containers were placed in these heavy duty areas where large components should have been placed – reducing the travel time of components across the turbine floor. Figure 48 shows an example of containers placed in heavy duty areas, however good storage of valve components is placed opposite the containers which allowed for quick crane travel time to the unit. Figure 49 also shows under-utilised storage space in the basement, next to the unit. [PLY, PSTR]

- No. of Containers – A total of 43 containers was used for the outage, which was an excessive amount and the number of containers used can be decreased for the number of resources that were supplied. [EE]

- Working Times – a 10 hour shift was worked for both day and night, later on in the project a 12 hour shift was worked. Productivity on each shift was different. The day shift Team was less productive then the night shift Team due to the greater amount of people and disruptions on the turbine floor. The night shift Team was more successful in completing their targets aligned to the scope because they adjusted their working times – eliminating tea-breaks and including a longer lunch, starting earlier in the shift with the reward of leaving earlier. The day shift Team took their tea-breaks in the morning and

in the afternoon thereby starting work later in the day and finishing work earlier in the day but not meeting their targets as aligned to the scope. [WT]



Figure 47: Containers placed next to the unit – this area could have been utilised for storage of heavy components.



Figure 48: Containers placed in 'heavy duty areas' where heavy components could have been placed; and valve components stored next to the unit.



Figure 49: Basement of the unit showing storage space that can be utilised more effectively.

Figure 50 below shows the amount of grit taken out from one of the bearing pedestals never seen before on any other outage, as expressed by experienced personnel. This was

due to the excessive amount of sand-blasting activities that delayed activities on the outage. [DEF]



Figure 50: Grit taken out from one of the bearing pedestals in the unit.

Oddly enough after the unit was declared mechanically complete and after experiencing many challenges on the outage, which extended the outage by a two month period, the unit was returned to service, without any vibrations experienced on any of the bearings. If vibrations were experienced on any of the bearings – not within tolerable limits, the unit would have had to be disassembled again, for further analysis and the outage would have extended in duration by an increased amount of time. The outage was one of the most technically successful outages experienced in the ESKOM fleet over a long period of time – returning the unit to service without any technical problems.

7.2.2 Identified Risks specific to each Module, on the Outage Project

Tables' 13-19 below refers to the risks that were experienced and the subsequent delays in time associated with the risk per module, in the project.

Table 13: Risks experienced on HP Module Only and associated time delays.

	Comments
HP - Valve Chest Replacement ***Program Completion (Rev 1) 22/01/19*** ***Program Completion (AMC) 25/01/19*** ***Additional No. of Days: 3***	• Impact on start date of outage due to elevation survey by sub-contractor – 4 days delay. [CP] • Impact of 8 days on Stuck Turbine Shaft. [DEF] • Impact caused by sandblasting activities 14 days, delay in machining and NDT activities. [PSLB,PP] • Pin Drilling – Additional SOW, Original estimated duration was 4 days, actual duration 10 days, on bottom valve chests. [VAR, DEF] • Additional SOW machining of sealing faces on HP Valve Chests 2 days. [VAR] • 1 day delay – movement of the main steam pipe by sub-contractor. [DEF] • Risk – Fitment of HP Retaining Nuts and Steam Admission Nuts, OEM performed fitment checks – 1 day delay. [DEF] • Delay in receiving 4 off Seals – spares needed. [SL]

Table 14: Risks experienced on IP and Turbine Valves Modules Only and associated time delays.

	Comments
IP Turbine and IP Turbine Valves ***Program Completion (Rev 1) - 30/12/18 (IP Turbine) AND 07/02/19 (IP Turbine***	• Impact caused by sandblasting activities 14 days, with prioritisation on HP and IP, delay in Machining and NDT activities, recovered 6 days due to increase in resources. OSM impact. [PSLB,PP] • Delays in machining activities on IP CV's and

Valves) ***Program Completion (AMC) - 07/03/19 (IP Turbine) AND 16/02/19 (IP Turbine Valves)*** ***Additional No. of Days: 67 (IP) AND 9 (IP Turbine Valves)***	ESV's which led to failed blue checks and delays in final blue checks on valves, 32 days impact. [DEF] • IP Bonnets sent back to the OEM for machining – defective spares, 3 days of delay. [DEF] • Delay in performing the IP Bump Check due to prioritisation of removal of LP Rotors which was indicated as rework. IP Bump Check performed later and caused an 8 day delay. [DEF] • Delay in performing alignment activity due to a decision made on weight of valves included. [TDL] • Delays in receiving General Spares. [SL]

Table 15: Risks experienced on LP Turbines Module Only and associated time delays.

	Comments
LP Turbines (1 and 2) ***Program Completion (Rev 1) - 25/01/19*** ***Program Completion (AMC) - 28/02/19*** ***Additional No. of Days: 34***	• Impact on start date of outage due to elevation survey by sub-contractor – 4 days delay. [CP] • Impact of 8 days on Stuck Turbine Shaft. [DEF] • Impact caused by sandblasting activities 14 days, delay in completion of module work. [PSLB,PP] • Impact due to oil availability, oil received on 11/01/19 [SL] • Grinding and scraping of inner outer casings, 13 days of delay, due to rework, poor workmanship. [DEF] • LP Rotors sent back to Rosherville for re-machining – 2 days of delay. [DEF] • Delays in receiving General Spares, OEM Gaskets and sealant with Gaskets. [SL]

Table 16: Risks experienced on Centreline Module Only and associated time delays.

	Comments
Centreline (Bearings and Alignment) ***Program Completion (Rev 1) - 16/02/19*** ***Program Completion (AMC) - 09/03/19*** ***Additional No. of Days: 21***	• Impact on start date of outage due to elevation survey by sub-contractor – 4 days delay. [CP] • Impact of 8 days on Stuck Turbine Shaft. [DEF] • Impact caused by sandblasting activities 14 days, delay in completion of module work. [PSLB,PP] • Spare Bearings / Modular Bearings received late on site, 6 days of delay. [SL] • Impact due to oil availability, oil received on 11/01/19 which was 9 days of delay. Impact due to Condenser Water Levels not available, water became available on 30/01/19, 39 days of delay. [SL, VAR] • Delays in receiving General Spares, Gaskets for Jacking Oil Pumps. [SL] • Incorrect coupling bolts supplied for the Gen/Exc Coupling, 3 days of delay. [DEF] • Bearing No. 5 – thermocouple ports machined in the wrong position – returned to OEM, - 1 day delay. [DEF]

Table 17: Risks experienced on LPBP Valves, and HP Valves Module Only and associated time delays.

	Comments
LPBP Valves and HP Valves ***Program Completion (Rev 1) – LPBP Valves 08/02/19***	• Delays in machining activities on LPBP CV's and ESV's which led to failed blue checks and delays in final blue checks on valves, 32 days impact. [DEF] • Delay due to seat removal – unforeseen,

AND 14/02/19 - HP Valves ***Program Completion (AMC) - – LPBP Valves 18/02/19 AND 15/01/19 - HP Valves*** ***Additional No. of Days: 10 LPBP Valves AND, 0 HP Valves***	uncontrollable risk. [CBD] • Delay in LPBP ESV No. 1 due to misalignment of drain line pipe. [DEF] • Delays experienced as per HP Turbine Module.

Table 18: Risks experienced on Generator Module Only and associated time delays.

	Comments
Generator ***Program Completion (Rev 1) - 22/01/19*** ***Program Completion (AMC) - 27/02/19*** ***Additional No. of Days: 36***	• Impact on start date of outage due to elevation survey by sub-contractor – 4 days delay. [CP] • Impact of 8 days on Stuck Turbine Shaft. [DEF] • Impact caused by sandblasting activities 14 days, delay completion of module activities. [PSLB,PP] • Poor Workmanship – rework on some activities – end shields, locking plates, air-gap ring, H2 Seals, slip ring. 7 days of delay. [DEF] • Delay in receiving the Dow Corning Pump for the sealant, 8 days of delay. [NT] • Delay in receiving spares – viton gaskets, O-rings, etc. [SL]

Table 19: Risks experienced on Auxiliaries Module Only and associated time delays.

	Comments
Auxiliaries ***Program Completion (Rev 1) - 04/02/19*** ***Program Completion (AMC) - 04/02/19*** ***Additional No. of Days: 0***	• Delays in receiving spares, gaskets, bearings, etc. Old bearings had to be used for CEP's. Delay in gaskets for Jacking Oil Pumps. [SL] • Sandblasting activities 14 days - delayed completion of work on Strainers. [PSLB,PP] • Delay in spares for strainers, 9 days of delay. [SL] • Unforeseen risk on alignment of Motor on CEP, laser alignment was accepted, 3 day delay. [CBD] • CVA's delay in receiving oil for testing – 16 days of delay. [SL]

7.2.3 Definition of Codes Developed for the Participant Observer, Interviews and Document Analysis Phases.

Tables 20 and 21 below, shows the descriptions of the codes used in the participant observer analysis.

Table 20: Description of Codes used in Analysis.

Item No.	***Category***	***Description of Category***	***Code***	***Links***
1	Culture/ External Factors	Macro Environment, Political, Economic, Social, and Technological (PEST) factors. Varying, volatile, environment. (Cooper, 2014)	VCEF	GMP
2	Spares Late	Management of spares in ESKOM, experiences in delays of receiving spares on outages due to many factors.	SL	IPRO
3	Training Needed	Training within the ESKOM Environment, training that is needed for a specific task, or an individual who has these core skills that need to be transferred or utilised on the job.	TRN	DQ, IT, IC
4	Inefficient Procurement Processes	Procurement Processes, delays experienced in the project environment.	IPRO	GMP
5	General Management Processes	General Management Processes, also inclusive of poor Management of Information - Document Systems, and Poor Planning.	GMP	
6	Decreased Quality	Quality Control aspects that are deficient, and leads to decreased quality in the project environment.	DQ	
7	Increased Time/ Schedule	Time/Schedule Control - aspects that are deficient and leads to increased durations of projects within ESKOM.	IT	
8	Increased Costs	All costs of the Projects, whether increased or decreased, or budget constraints.	IC	
9	World View	Comparison of a specific phase of the Project during the interview against another company overseas. Also an overall opinion from the Interviewee. (In the interview	WV	

		analysis section)		
10	Best Practice	Best Practice - comparison of a method in ESKOM against what can be considered a best practice method regardless of the origin of the best practice method. Origin could be dependent on theoretical knowledge or through experimental knowledge.	BP	
11	Variation	Variation in processes, which leads to confusion and loss of control, and affects time, cost and quality.	VAR	DQ, IT, IC
12	No Comment	When the interviewee gave an answer in which it could not be categorised into any of the above emergent themes.	NC	

Table 21: Description of Codes used in Analysis extended.

Item No.	***Code ABB***	***Code Full Text***	***Description***
1	RR	Roles and Responsibilities	The interviewee describes their roles and responsibilities pertaining to their job.
2	OP	Outage Philosophy	Outage Philosophy - Person describes the types of outages and durations of the outages.
3	VIB	Vibration	Reference to vibration of a unit, must be used in context - causing extra duration, shutdown of unit, etc.
4	FO	Forced Outage	An Outage that exists because a component or system has run passed its time duration of operating hours, and the unit will need to be shutdown, as this will threaten the overall health of the unit.
5	PLO	Planned Outage	Planned Outages as described in the Outage Philosophies.
6	IR	Interim Inspection	IR as described in the Outage Philosophies.
7	DUR	Duration of Outages	A timeline presented by the interviewee in correlation to a question.
8	HIS	History	Related to the Interviewee's own personal history of career or history of past event - related to experience.
9	TR	Training	Relevant to many aspects of training which correlates to the question.

10	JP	Job Profile	Linked to Roles and Responsibilities, minimum requirements as outlined by the company for a job profile.
11	TA	Technical Aspects	Any Technical aspect related to a specific question.
12	FT	Further Training	Required based on question by the Interviewer.
13	Q	Quality	Quality of a Project as per PMBOK.
14	C	Cost	Cost of a Project.
15	T	Time/Schedule	Time relating to a Project.
16	B	Budget	Budget linked to a project, money estimated for the completion of the Project.
17	EM	Earning Money	In relation to earned value, or earning money by performing a service. If no service is provided, no money will be earned.
18	LS	Load Shedding	When the Grid is demanding more capacity then ESKOM can supply, certain areas are shutdown, so that other critical areas in SA can be sustained with electricity. In reference to the Interviewer's question.
19	O	Outage	Outage can refer to any type of outage.
20	PP	Procurement Processes	Procurement processes based on the Interviewer's Question.
21	UP	Understanding Processes	Processes that are understood, however there are some instances in which clarity is still needed amongst individuals.
22	VAR	Variation in Processes	Variation that is considered regardless of the disruption the variation might cause.
23	NC	No Comment	No information obtained.
24	SOW	Scope of Work	Reference to the scope of work of a particular outage.
25	PMBOKP	PMBOK Phases	Reference to project phases/stages in PMBOK.
26	PER	Performance	Performance in relation to employees.
27	TRK	Tracking	Tracking cannot be controlled because there is too little information, or information is just not available.
28	POP	Poor Planning	Poor planning methods by the organisation in general.
29	AW	Awareness	Relates to awareness needed amongst employees in specific processes.
30	OT	Overtime	Earned value outside of normal working hours.
31	LE	Lean	Reference to Lean Training.
32	GE	General Electric Power Industries	Refers to GE as an organisation specific to relevant processes.

33	EX	Expectations	Expectations outlined by individuals working for ESKOM, either temporary staff or permanent staff.
34	COM	Components	Having components in time - also refers to Spares.
35	PREP	Preparation work	Refers to Preparation Work before an outage can begin.
36	SIE	Siemens	Refers to Siemens as an organisation specific to relevant processes.
37	CUL	Culture	Reference to the culture of an organisation.
38	MAN	Management	Reference to Management within ESKOM.
39	DOCS	Document System	The current document system at ESKOM and .
40	SDR	System Deficiency Report	Current process outlined by that flags defects in a process and corrective action is required.
41	LB	Labour Brokers	Labour Brokers that supply temporary labour on outages by following the Procurement process.
42	RF	Right First	Refers to a Lean Practice, achievement of activities successfully the first time.
43	PREF	Preference	Individuals choosing a preference over what should be used.
44	SF	Safety	Safety related issues.
45	MI	More Interactive	Call on individuals to be more interactive in terms of processes or management.
46	OEMT	Original Equipment Manufacturer Training	Specific personnel were selected to complete training with various OEM's.
47	TT	Trade Tests	When a person undergoes a study and test process to obtain a trade test, this is working physically with equipment, as outlined in that trade tests.
48	MOV	Motivation	when an individual shows motivation in answering a question, relevant to any topic.
49	SL	Spares Late	Spares that are late for an outage, and thus the outage duration increases.
50	NA	No Accountability	Employees that do not perform well, and there are no consequences for actions.
51	PE	Political Environment	When an individual refers to the ESKOM environment as being heavily influenced by the government.
52	CORR	Corruption	When an individual refers to corrupt practices within the ESKOM environment in any division.
53	SUPP	Suppliers	When an individual refers to the suppliers that are contracted to ESKOM, or another party.

54	BES	BBBEE Status	When an individual refers to the BBBEE Status of a company.
55	VL	Vendors List	When an individual refers to the suppliers that are approved by ESKOM and to be contracted and supply items to ESKOM.
56	TOO	Tools	Tools, when an individual refers to tools used for performing tasks.
57	WR	Works Rosherville	The Works Section in Rosherville where refurbishment work is completed on equipment. The Works falls under TGS and refurbishment work is completed on turbines and generators.
58	GS	Generator Supervisor	Supervisor that works on Generators both in the Works Section in Rosherville and at different sites.
59	WI	Works Instruction	A procedure showing an individual how a specific activity or task is completed.
60	PQP	Process quality Plan	A series of steps followed by the Team to ensure that the activities that are completed are within the required specifications based on engineering design. This process is audited and checked by at least 2 levels of security.
61	VH	Vehicle Hire	The system of hiring vehicles for staff to travel to sites.
62	PRP	Project Program	The Programme or schedule that is completed for a project based on the SOW for the outage. This is the planner's responsibility.
63	COMM	Communication	When an individual refers to good communication habits, or alternatively poor communication.
64	ST	Standing Time	When a contracted company charges for resources that are standing on site and not being utilised during execution of the project, while waiting for equipment or services to be supplied by the Employer.
65	SR	Service Report	A report completed by the technician stating what occurred on an outage, the necessary steps that were taken, and the results. This report gets reviewed by the assigned project engineer.
66	TN	Technical Notification Process	The TN Process is where deviations from the scope of work is outlined, risks are outlined and the possible technical solutions are outlined. This will be submitted to the ESKOM Engineering Dept. for approval.
67	EP	Escalation Process	When the site engineers cannot agree on a solution, then the problem is escalated to the senior engineer, to solve, if this cannot be solved on a senior level, then it is escalated further to the chief engineer for resolution.

7.3 APPENDIX C - INTERVIEW QUESTIONS

"Official Memo"
Name: Shanelle Mahas
Designation: Project Manager

To:	All Potential Participants (Interviews for the Research Project - Reduction in Outage Durations at ESKOM Power Plants in South Africa.)
Copy to:	Shanelle Mahas, and Direct Participant

Research Topic:	Reduction in Outage Durations at ESKOM Power Plants in South Africa
Institution:	University of Witwatersrand – School of Mechanical, Industrial and Aeronautical Engineering.
Supervisor's Name:	Miss Bernadette Sunjka (Head of Stream Industrial Engineering, Senior Lecturer)
Duration of Research Project:	29 August 2018 – 28 April 2019

List of Interview Questions:

Section A – General Questions
1. Is there anything you would like to declare before the interview process starts?
2. Can you please describe your current role in ESKOM, and your current role in performing outages on ESKOM Power plants?
3. Can you please provide your history of work experience since the start of your working career? (This answer would include start date at ESKOM till present.)

Section B – Technical Questions
1. Did you receive training to perform your duties in your role, can you please describe the training received.
2. Were there minimum requirements outlined in your job profile, if so can you please describe the requirements associated with the job profile?
3. Do you fully understand all technical aspects of performing your duties?
4. Do you feel that further technical training is required for you to be more effective in performing your duties?
5. Do you understand how performing your duties, fits into the bigger aspect of the successful completion of the outage and can you describe this?
Section C – Procurement Questions
1. Do you deal with procurement processes in your job profile? If so, which processes in particular?
2. Do you understand the processes that you deal with clearly?
3. How often do you refer to the procurement procedure/ policy associated with your process?
4. Does the process change often?
5. Do you deal with the purchasing of spares? If so, what spares in particular?
6. Do you receive spares in time for the outage? If not can you describe why?
7. Do the procurement processes help you in achieving the successful completion of the outage? Can you provide an overall description of the procurement process and how it either constrains or helps you in achieving successful completion of the outage?
8. Are Procurement processes similar for all outages?
9. Is the same documentation used for all outages? Is this documentation specific to ESKOM or other companies?
10. Is pricing amongst suppliers competitive, and do you consider ESKOM saving costs in the procurement process? If costs are not being saved in the procurement process can you describe why?
Section D – Project Management Questions

1. Are you involved with Project Management on the outage? If so can you describe your involvement?
2. Are you involved with the scheduling of the outage project? If so can you describe how you would schedule a project and based on what documentation?
3. Do you think projects are constrained to be completed within a timeframe and is this associated to a Scope of Work (SOW)? If so can you describe what the constraints are?
4. Does the outage project have defined phases as per the PMBOK (Project Management Body of Knowledge) -defined phases would be "Conception, Feasibility, Implementation, Operation and Termination"? What are the phases of an outage project in ESKOM?
5. What are the critical aspects you would say in performing outages? Can you please explain?
6. How is costing achieved on the outage, are you involved with costing? What documentation do you follow?
7. What factors lead to increased costs on an outage? Can you please explain further?
8. Would you say cost is related to time and quality on the outage? How would these factors be influenced on an outage?
9. Are roles and responsibilities clearly defined in the outages and are personnel aware of this?
10. What resources are used on the outage in terms of labour? Can you describe the labour and issues experienced, if any with the labour resources?
11. Do outages start as per the agreed start dates?
12. What does outage due date performance mean? Is ESKOM successful in achieving due date performance?
13. Would you say that ESKOM performs outages like a world class organisation? Can you compare ESKOM to an organisation overseas that performs outages, are there similarities or differences?
Section E – Business Questions:
1. Is ESKOM successful in the way they perform outages? Can you please explain your answer?
2. Is ESKOM subsidiaries' successful in the way they perform outages? Can you please explain your answer?
3. Do you think the external environment influences the success of performing outages on power plants in South Africa?
4. Does ESKOM have sufficient capacity to supply South Africa and neighbouring countries, whilst performing successful outages?
5. What best practices can be adopted at ESKOM and its subsidiaries when

performing outages?
6. How would ESKOM and its subsidiaries reduce cost on an outage whilst still being successful in performing the outage?
7. What do you think are the greatest challenges experienced in ESKOM and its subsidiaries in general?
8. What improvements would you make in the management of outages at both ESKOM and its subsidiaries?

----------End of Interview----------

7.3.1 Percentage Results of Emergent Themes in the Interview Analysis.

Table 22 below shows the descriptions of the codes used in the interview analysis, and codes are similar as the previous ones used in the other phases.

Table 22: Percentage Results of Emergent Themes in the Interview Analysis.

Codes	***Sum of Responses***	***Corresp. %***
VCEF - Related to the Macro Environment, PEST factors. Varying, volatile, environment.	**32**	**7**
SL - Related to the management of spares in ESKOM, experiences in delays of receiving spares on outages due to many factors.	22	5
TRN - Related to Training within the ESKOM Environment, training that is needed for a specific task, or an individual who has these core skills that need to be transferred or utilised on the job.	**36**	**8**
IPRO - Related to all Procurement Processes, delays experienced in the project environment.	24	5
GMP - Related to all General Management Processes, also inclusive of Management of Information - Document Systems, and Poor Planning.	**82**	**17**
DQ - Related to all Quality Control aspects that are deficient, and leads to decreased quality in the project environment.	26	5
IT - Related to all Time/Schedule Control aspects that are deficient and leads to increased durations of projects within	**34**	**7**

ESKOM.		
IC - Related to all costs of the Projects, whether increased or decreased, or budget constraints.	25	5
WV - World View - comparison of a specific phase of the Project during the interview against another company overseas. Also an overall opinion from the Interviewee.	14	3
BP - Best Practice - comparison of a method in ESKOM against what can be considered a best practice method regardless of the origin of the best practice method. Origin could be dependent on theoretical knowledge or through experimental knowledge.	10	2
VAR - Variation in processes, which leads to confusion and loss of control, and affects time, cost and quality.	**44**	**9**
NC - No information obtained.	129	27
TOTAL AMOUNT OF OCCURENCES	***478***	***100***

7.3.2 Transcribed Interviews

Table 23 below shows the intelligent method of transcribing one of the interviews.

Table 23: Interview No. 1 – Example Provided – Intelligent Verbatim Transcribed Interview.

Section A – General Questions	***Answers***	***Codes***	***Codes/ Category***	***Additional Questions***	***Additional Answers***
1. Is there anything you would like to declare before the interview process starts?	No.	NC	NC	N/A	N/A
2. Can you please describe your current role in Eskom Rotek Industries, and your current role in performing outages on Eskom Power plants?	My role is a project planner, planning the outage, and breakdowns, forced outage, so that investigations can occur.	RR, OP, VIB, FO, PLO, IR, DUR	GMP	1. Explain what is a Forced Outage? 2. Do you know of durations of these types of outages.	Forced Outage when a component or system has vibration and needs to be shut down for maintenance. Planned outages are planned, inspections and checks incorporated into this, when the

					units starts up and then when the unit needs to undergo regular maintenance.
3. Can you please provide your history of work experience since the start of your working career? (This answer would include start date at Eskom Rotek Industries till present.)	Started work in Eskom in 2015, worked at Iskor Eng. Junior Technician. Technical Background. Was previously assigned as an Outage Planner based at a particular Power Station.	HIS	NC	1. Was it difficult to work as a planner for the Outage?	No it was not difficult working as an outage planner.
Section B – Technical Questions					
1. Did you receive training to perform your duties in your role, can you please describe the training received.	Yes.	TR	TRN	1. What training did you receive? 2. How long was the training? 3. Was the training good?	Basic Intro to Project Management, Primavera, and Microsoft Project, provided by an external provider. 4 months of training. Training good and informative.
2. Were there minimum requirements outlined in your job profile, if so can you please describe the requirements associated with the job profile?	Yes, as described in roles and responsibilities.	JP	TRN	1. Do you feel that you need additional Training?	NEC Training, Technical training is not necessary due to the assistance from Project Technicians and Engineers.
3. Do you fully understand all technical aspects of performing your duties?	Yes.	TA	NC	N/A	N/A
4. Do you feel that further technical training is required for you to be more effective in performing your duties?	No.	FT	TRN	N/A	N/A

5. Do you understand how performing your duties, fits into the bigger aspect of the successful completion of the outage and can you describe this?	As a planner it's understood that project management is based on quality, cost and time, and when given a duration it's important to execute that project within the duration. Thus it's important to control cost and budget, and if you don't, Eskom will not be earning money, and also load shedding will be caused. Reference to the fact that Eskom is not generating money whilst performing the outages.	Q, C, T, B, EM, LS, O.	IC, IT, Q	N/A	N/A
Section C – Procurement Questions					
1. Do you deal with procurement processes in your job profile? If so, which processes in particular?	No.	PP	IPRO, IT, IC	N/A	Procurement - they work with what they have, instead of prioritising the urgency of work.
2. Do you understand the processes that you deal with clearly?	Yes.	UP	NC	N/A	N/A

3. How often do you refer to the procurement procedure/ policy associated with your process?	Sometimes, but not often, mostly the expeditors work with procurement processes. They need to know the processes. Interactions with expeditors gives me an understandin g.	PP	IPRO	Do you have comments about documentati on in Eskom.	There is a document centre however the documents are not stored properly. For example this outage, not all the history of the documentation was present, and not all the same people were working in the same positions, thus there is a risk on performing the job.
4. Does the process change often?	Yes, I have experienced changes in the project execution on a daily basis, and changes in the procurement process.	VAR	VAR	N/A	N/A
5. Do you deal with the purchasing of spares? If so, what spares in particular?	No.	NC	NC	N/A	N/A
6. Do you receive spares in time for the outage? If not can you describe why?	No. Spares are often a problem on many outages because the client does not provide the spares in time.	T	SL	N/A	N/A
7. Do the procurement processes help you in achieving the successful completion of the outage? Can you provide an overall description of the procurement process and how it either constrains or helps you in achieving successful completion of the outage?	Most of the time it takes too long and puts the outage at risk.	T	IT, IPRO	N/A	N/A

8. Are Procurement processes similar for all outages?	No comment.	NC	NC	N/A	N/A
9. Is the same documentation used for all outages? Is this documentation specific to Eskom or Eskom Rotek Industries?	No comment.	NC	NC	N/A	N/A
10. Is pricing amongst suppliers competitive, and do you consider Eskom saving costs in the procurement process? If costs are not being saved in the procurement process can you describe why?	No comment.	NC	NC	N/A	N/A
Section D – Project Management Questions					
1. Are you involved with Project Management on the outage? If so can you describe your involvement?	Yes, I'm a Planner, as described before.	NC	NC	N/A	N/A
2. Are you involved with the scheduling of the outage project? If so can you describe how you would schedule a project and based on what documentation?	Yes, I'm a Planner, as described before.	NC	NC	N/A	N/A
3. Do you think projects are constrained to be completed within a timeframe and is this associated to a Scope of Work (SOW)? If so can you describe what the constraints are?	Yes, The SOW is a problem because it is not received on time, and it is not complete when received, there is no clarity on some aspects of the SOW. SOW also depends on the condition of the components when you open the machines. This is outlined as	SOW	IT	N/A	N/A

	additional scope of work.				
4. Does the outage project have defined phases as per the PMBOK (Project Management Body of Knowledge) -defined phases would be "Conception, Feasibility, Implementation, Operation and Termination"? What are the phases of an outage project in Eskom Rotek Industries?	Yes, planning, Costing, and Execution mainly.	PMBOKP	GMP	N/A	N/A
5. What are the critical aspects you would say in performing outages? Can you please explain?	Focus should be on Scope of Work and Performance of Employees	PER	GMP	N/A	N/A
6. How is costing achieved on the outage, are you involved with costing? What documentation do you follow?	Costing can be achieved by tracking planned costs against actual costs. The organisation needs to plan properly, the system doesn't show clear indication of planned costs vs actual costs. Information on SAP is not accurate. Contingency on projects is not planned properly for unexpected events.	TRK, C, B	IC, VAR, GMP	1. Putting together the Cost breakdown, do you have all the required information needed when you plan. 2. what percentage of projects run over its initially planned costs.	Yes we do have enough information. I believe at least 70% of project run over initial costs. Clear understanding is needed with regards to the information on SAP. The costing is like a balloon, with all the costs combined and not knowing where the actual costs fall under. This is a major concern when you want to track costs.
7. What factors lead to increased costs on an outage? Can you please explain further?	Poor Planning, Poor Management, and Poor	POP	GMP	Poor Control	Poor Tracking methods.

	Communication, no control.				
8. Would you say cost is related to time and quality on the outage? How would these factors be influenced on an outage?	Yes, poor quality leads to rework which leads to increased costs.	Q, C	DQ, IC	N/A	N/A
9. Are roles and responsibilities clearly defined in the outages and are personnel aware of this?	Yes clearly defined but awareness needs to happen every day.	AW	GMP	N/A	N/A
10. What resources are used on the outage in terms of labour? Can you describe the labour and issues experienced, if any with the labour resources?	Our labour - expectations differ between companies and labour. People have their own agendas of earning money, due to longer durations on outages and the company needs to complete outages in time.	OT	IC, IT	Difference between temporary labour and permanent resources. Skills?	No comment, Skills the employee might be qualified but does not have experience. So you have to train the employee.
11. Do outages start as per the agreed start dates?	No, definitely not.	T	GMP	N/A	N/A
12. What does outage due date performance mean? Is Eskom Rotek Industries successful in achieving due date performance?	No, because of all these factors. Issues between Eskom and the sub-contractor.	T	IT	N/A	N/A
13. Would you say that Eskom Rotek Industries performs outages like a world class organisation? Can you compare Eskom Rotek Industries to an organisation overseas that	TFAs training, lean - how to change our processes. Examples -	LE, GE, EX, COM, PREP	WV, BP	N/A	N/A

performs outages, are there similarities or differences?	other outages are completed in planned times. GE is more efficient. Expectations are clear, everyone is aware of the understandin g on what needs to be done. And they have trolleys that move around with them with their work areas, and they have all the components in order to perform the work. Discussions of what needs to be arranged for that day - prep work. Improvemen t needs to happen, everyone needs to be aware. Upon shutdown already everything that is needed is already available.				
Section E – Business Questions:					
1. Is Eskom successful in the way they perform outages? Can you please explain your answer?	No, there needs to be improvemen t.	VAR	GMP	N/A	N/A

2. Is Eskom Rotek Industries successful in the way they perform outages? Can you please explain your answer?	No, due to what I have described.	VAR	GMP	N/A	N/A
3. Do you think the external environment influences the success of performing outages on power plants in South Africa?	Yes social, or culture influences the organisation. The culture is bad, culture of don't care attitude.	CUL	VCEF	LOA	LOA is linked to accommodation and this money is budgeted. Increased costs due to LOA, people will be booked on further if outage over-runs. Savings - people must work within their town, home based plants.
4. Does Eskom have sufficient capacity to supply South Africa and neighbouring countries, whilst performing successful outages?	Yes I do believe so, but because of the inefficiency that's why we don't perform well. There is also a culture of the external customers come second to Eskom.	CUL	VCEF, GMP	N/A	N/A
5. What best practices can be adopted at Eskom and Eskom Rotek Industries when performing outages?	Lean Training.	LE, GE	BP, WV, GMP	N/A	N/A
6. How would Eskom and Eskom Rotek Industries reduce cost on an outage whilst still being successful in performing the outage?	Resolve these issues that I have mentioned before and improvemen t will be seen.	NC	NC	N/A	N/A
7. What do you think are the greatest challenges experienced in Eskom and Eskom Rotek Industries in general?	SOW, Culture, Managemen t.	MAN	GMP	N/A	N/A

8. What improvements would you make in the management of outages at both Eskom and Eskom Rotek Industries?	Planning needs to improve, go back to philosophies of the machines, and each and every component must be refurbished based on this. We will improve when we stick to the process. And the documentation needs to be accessible. If the philosophies need to be changed then Management must change these philosophies and procedures.	POP, OP, DOCS, MAN	GMP	Other Comments	Need to change the culture. Everyone is allowed to ask questions. Don't have a bigger picture of the impact on the economy. It must be explained to all employees affect SA. Improve the attitude of the management team.

7.4 APPENDIX D - Document Analysis – Section A - Full Text.

Documents from various sources were retrieved for the review, and were categorised based on the PMBOK areas of knowledge. A coding system was used to classify all documents. A total of 40 documents were reviewed across ESKOM. Table 24 below shows the coding category.

Table 24: Coding System for Categorisation of Documents.

Item No.	*Description - Areas of Knowledge in PMBOK*	*Code*
1	Project Management Processes	MP
2	Project Integration Management	IM
3	Project Scope Management	SM
4	Project Time Management	TM
5	Project Cost Management	CM
6	Project Quality Management	QM
7	Project Human Resource Management	HRM
8	Project Communications Management	COMM
9	Project Risk Management	RM
10	Project Procurement Management	PRM
11	Project Stakeholder Management	STKM

After the documents were categorised as stated in Table 24 above, a process flow of the documents that were relevant to managing the project was completed. Documents from each group were reviewed.

7.4.1 Project Process Flow – Document P131

Projects conducted in ESKOM are based on the document P131, which is described as the Project Management Process/ Product Quality Plan. It describes the project process, planning and control as well as reporting. This document is the foundation for conducting projects in ESKOM. It describes the system requirements of a project, and references other forms and procedures that one must review. The document also specifies time limits on activities' that need to be completed to lead to the successful completion of the project, within time, and having met all standards of quality. A brief description of the process is shown in Figures 51 and 52 below.

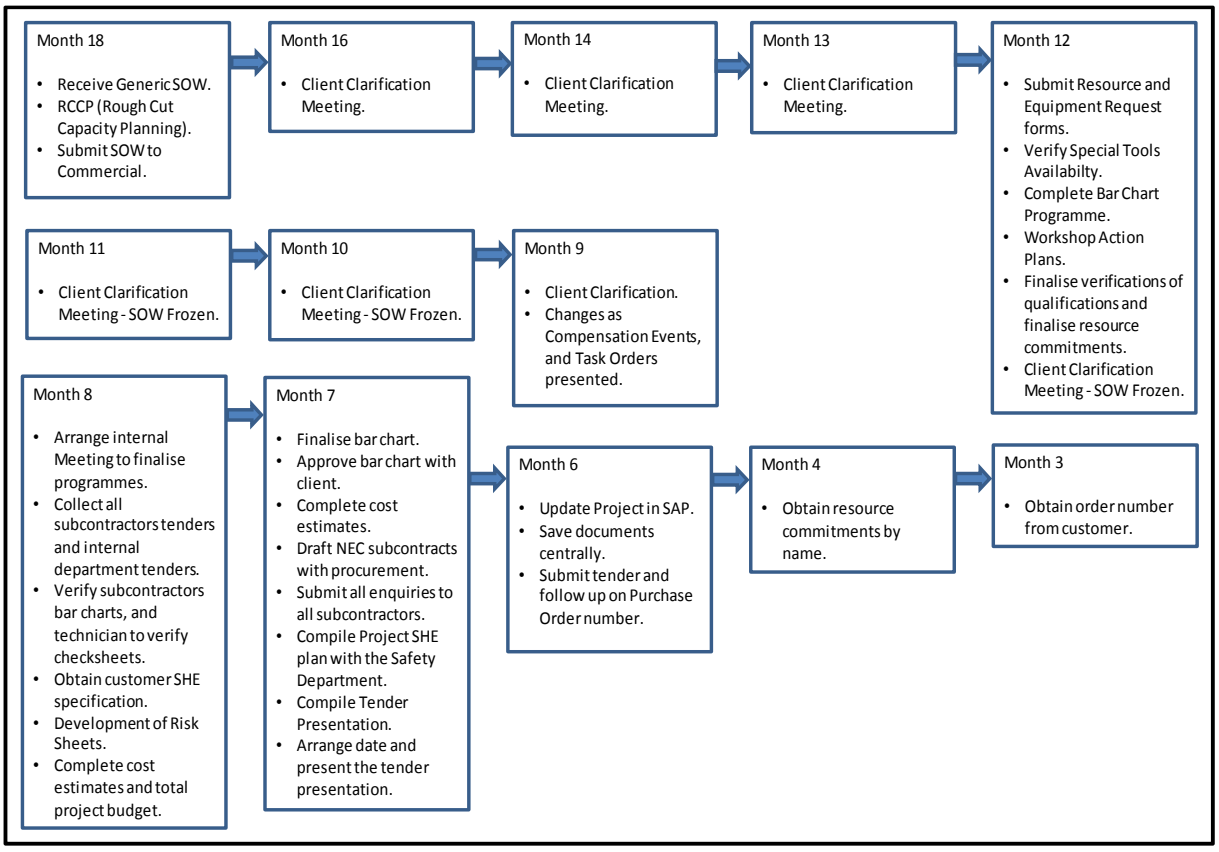


Figure 51: Part 1 of P131 - Process Flow of Document.

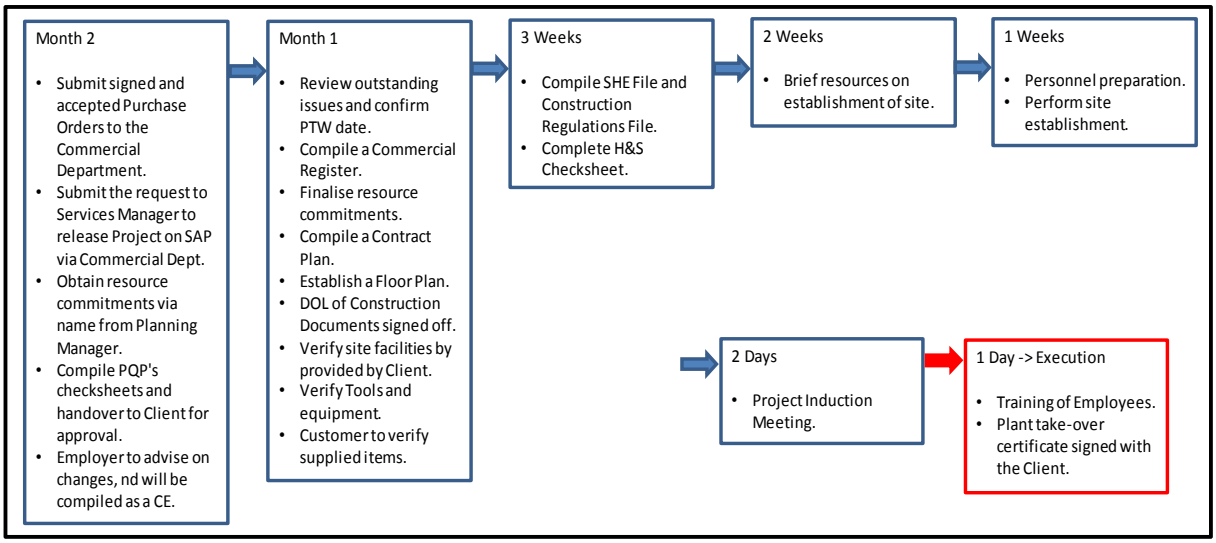


Figure 52: Part 2 of P131 Process Flow of document.

7.4.2 Outage Readiness Indicator (ORI)

A current key practice in ESKOM is the Outage Readiness Indicator (ORI) documents that are presented at many meetings within ESKOM, before the commencement of any outage. An example of the ORI is displayed in the Figure 53 below.

Power Station	Scope Frozen	Approved Plan	Components	Client Free Issue Spares	Works Capacity Constraints	Tender	Eskom PO
Kriel U3 IN 14/09/18-02/11/18	OT	OT	W	IP	NPOC	OT	IP
Koeberg U2 GO 17/09/18-12/12/18	OT	OT	OT	OT	N/A	OT	IP
Duvha U6 GO 27/09/18-24/01/19	OT	OT	MS & W	IP	NPOC	OT	OT
Kendal U1 Ext IR 12/10/18-19/01/19	R	OT	MS & W	IP	NPOC	OT	OT
Majuba U3 MGO 09/11/18-28/12/18	R	OT	W	IP	PCC	OT	IP
Tutuka U5 GO 09/11/18-27/01/19	OT	OT	W	IP	PCC	OT	IP
Lethabo U4 GO 28/11/18-19/02/19	OT	OT	W	IP	PCC	OT	IP
Duvha U1 IR 14/12/18-17/01/19	OT	IP	W	IP	NPOC	IP	IP

Figure 53: Outage Readiness Indicator (ORI) Visual Representation. (Eskom , 2019)

7.4.3 Outage Philosophies

Outage Philosophies are controlled documents written for every power plant specific to that power plant. This document highlights the method to be used to achieve and sustain ESKOM's planned outage requirements. Scope of Work (SOW) for outages specific to a power plant is most often based on 3 conditions as stated below:

- Condition Based
- Time Based
- Running hour conditions

Each of the outage philosophy documents states that outage durations are based on the maintenance requirements for the major components and the outage will be measured

from breaker open to breaker close. Unit Capability Factors (UCF's) are stated from 70 – 80% for each unit, this is the basic percentage of efficiency that the unit should be operating at.

Unplanned Capability Loss Factor (UCLF) averages from 7 – 10%, and Planned Capability Loss Factor (PCLF) averages from 7 – 10%. UCLF is the basic percentage of loss during operation due to unforeseen circumstances like breakdowns, mechanical failure and other reasons for shutting down a unit. PCLF refers to shutting down a unit to perform regular maintenance.

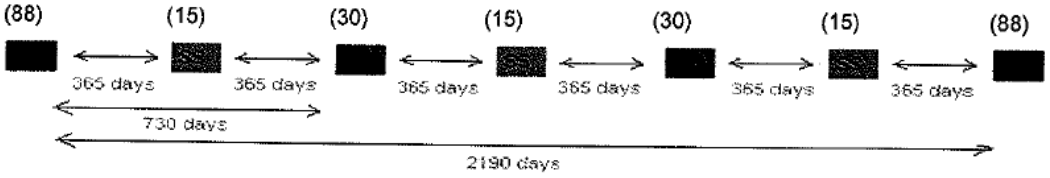
Specific to the outage project in this research document, are summary points stated below. Figures 54, 55 and 56 below, shows the definitions of the different types of maintenance categories performed in the power plant.

- Each unit in the power plant undergoes one outage per annum.
- Half power plant shutdowns on a 15 year cycle.
- Scope Freeze - 6 months before the outage start date. No additional work will be considered, and if needed, the change approval process must be followed.
- Bill of Materials (BOM) must be given to Materials Management 12 months before the start of the outage.
- 55 or 65 day GO - specification of work to be done in the document.
- 35 day IR - specification of work to be done in the document.
- 15 day boiler tube inspections.
- GO's and Mini GO's (MGO's) are not to be more than 72 months apart.
- Inspection Outage (IN) - 14 days.

GO	> 6 weeks	GENERAL OVERHAUL: This is a full turbine centreline outage Boiler statutory inspection/tests and refurbishment Boiler & turbine auxiliary plant refurbishment
IN	1 - 2 weeks	INSPECTION: For inspection purposes only to determine scope of work or obtain history; i.e. fans, boiler, ducting, air heaters and precipitators.
IR	2 - 6 weeks	INTERIM REPAIRS: This is done between a GO and BTI/ SS (Boiler Tube Inspections/ Short Service) Scheduled to perform critical repairs to prevent plant failures until the next scheduled outage like boiler tube leak prevention, air heater- and precipitators repairs/washing.
ST	As required	SHORT TERM PLANNED REPAIRS: Any planned work required outside of the normal outage philosophy. Planned and requested 28 days in advance Readiness indicator and ORC Risk Report to be submitted with the request.

Figure 54: Outage Definitions sourced from a particular Outage Philosophy document. (Eskom, 2014 -2017)

This diagram summarises a typical outage philosophy cycle from one GO to the next GO:



Outage type	Interval Years	Duration (days)	Main activities
GO	6	88	General Overhaul **(GO)** every **6 years** with a duration of • HP and IP cylinders every 12 years and LPs every 6 years
IR	2	30	Interim repair **(IR)** every **2 years** between GO • Boiler SOW inclusion of HP pipework inspections=7days
SS	1	15	Boiler tubes inspection **(BTI)** including electrostatic precipitator washing and HP pipework inspection every **12 months** between IR

Figure 55: Cycle showing periods in which maintenance repairs is done on a unit. (Eskom, 2014 -2017)

2014 – 2018 PCLF from the revised 5 year outage plan.

YEAR	PCLF %	DAYS
2014	11.98	263
2015	8.25	181
2016	7.87	174
2017	6.08	134
2018		

Figure 56: Example of PCLF values from 2014 till 2017. (Eskom, 2014 -2017)

Outage Philosophies amongst all power plants across the ESKOM fleet was reviewed. Ten documents were reviewed for ten power plants in total. A comparison of the ten documents were based on definitions and planned durations of outages. The average percentage for UCF, PCLF and UCLF amongst the ten power plants was calculated. Figure 57 below, shows that the average number of days that a GO should take amongst the ten power plants, which is approximately 77.4 days.

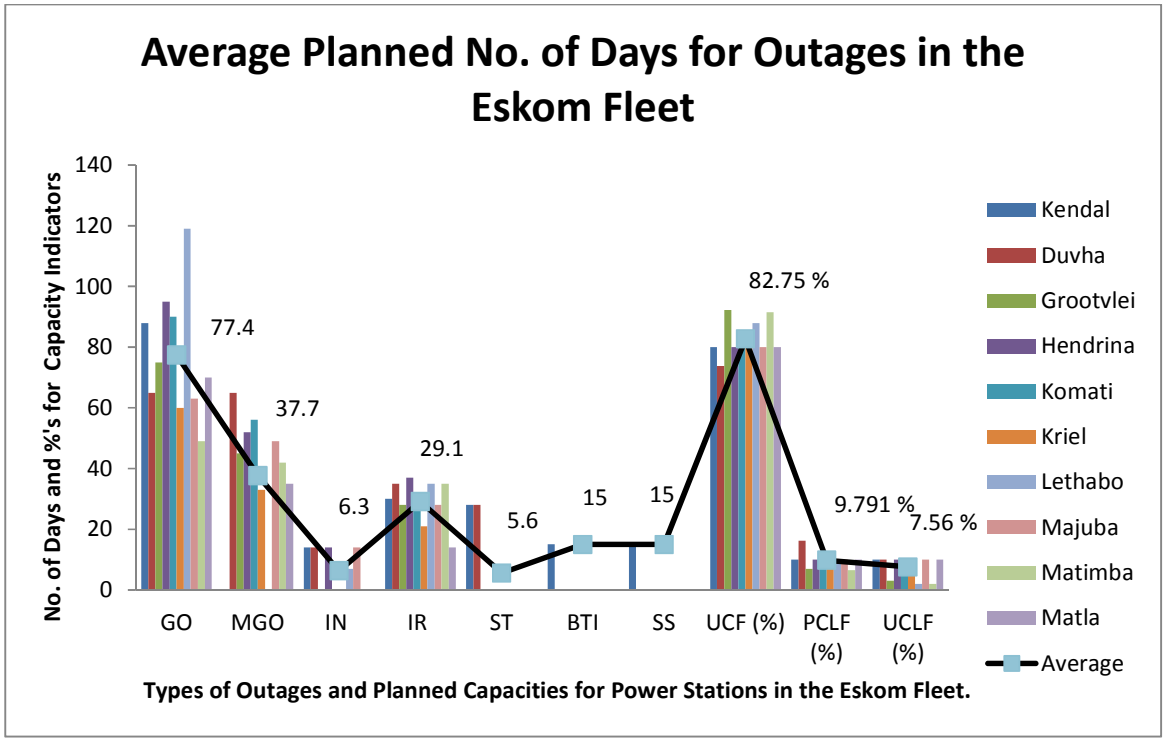


Figure 57: Graph showing average planned amount of days for outages and average efficiencies for units amongst the 10 stations.

7.4.4 Operational Plans

Table 25 below shows the operational plan for the organisation with focus on international standards that applies to the organisation. The company also has a vision that believes in zero harm, integrity, innovation, 'sinobuntu', customer satisfaction and excellence. Some of the focus goals are achieving growth both locally, and across borders, reducing planned capital expenditure, driving efficiencies through digitisation, and advanced analytics, and releasing government guarantees.

Objectives and Targets of the organisation is based on achieving acceptable standards in ISO 9001 certification, improvement of compliance to organisational systems, improve customer satisfaction, improvement on due-date performance on outage projects, improve debtors days, reduce rework, improve invoicing, provide administrative support to projects, provide all tools and equipment for outage projects, and improve on safety performance.

Stakeholder Analysis is present for both external and internal stakeholders, as represented in Tables 26 and 27 below. A Strength's, Weakness's, Opportunities' and Threats (SWOT) analysis is also present for the company and is stated below in Table 28.

Table 25: Operational Plan for the Organisation (Eskom Business Management Document, 2010)

1. ISO 9001	Quality Systems Standard
2. ISO14001	Environmental Management Standard
3. ISO 31000	Risk Management – Principles and guidelines on implementation
4. Corporate Plan	Corporate Plan 2018/19 to 2022/23

Table 26: External Stakeholder Analysis. (Eskom Business Management Document, 2010)

Key External Stakeholders	Impact/Influence on the Business	The Stakeholder expectations	Communication and consultation needs
Customers	Revenue and sustainability	Professional service Value for money Efficient and quality service Positive financial returns Compliance to Environmental legislation Prevention of Injuries	Commercial documentation, contracts , agreements an PO's Service reports
Suppliers & OEM's, (creditors)	Capacitation through supply of services, resources, materials and IP	Business opportunity Timeous payments	Commercial documentation, contracts, agreements and PO's
Communities	Source of labour and other services	Business and employment opportunities	Frequent engagement
Competitors	Potential loss of business, Potential partnerships and collaboration	Fair trading, Protection of market share Positive financial returns	MOU's Partnership agreements

Table 27: Key Internal Stakeholders. (Eskom Business Management Document, 2010)

Key Internal Stakeholders	Impact/Influence on the Business	The Stakeholder expectations	Communication and consultation needs
Organised Labour	Stability of labour environment Delays, industrial action	Responsible management of relationships Fair application of processes and procedures	SRF, Local forum, Departmental forums, Individual engagement
Support Services	Delivery of internal services to ensure the company achieves its mandate	Compliance to policies and processes, Efficient support to enable operational activities	SLA's, Meetings
Governance and Compliance dept.	Assurance to management on governance and internal controls	Compliance and availing of resources during reviews	Review and Audit Plans Engagement meetings Reports

Table 28: SWOT Analysis. (Eskom Business Management Document, 2010)

Strengths (Internal) – to leverage	Weaknesses (Internal) – to overcome
• Strategic Facilities, Assets, Tools and Equipment • Integrated Basket of Services / Diversity of Products and Services • SHEQ Systems and Process are in place • 5 year Service Agreement, On-site service operating in customers arena • Good operational processes • Strategic Supplier • Outage planning and readiness • Responsiveness to requirements • Maintenance of plant beyond designed life	• Lack of ownership and accountability • Poor communication • Inadequate training • Skills and experience of majority of staff • Rework and sub-standard quality • Due date performance • Discipline in compliance to the application of policies, processes and procedures • No punitive measure taken to address poor performance • Not keeping abreast and setting benchmarks of duration, technology, training, legislation, etc. • Business performance review, monitoring and management not executed on departmental level • Lack of rates and pricing model specific to External tendering • Poor management of tools and equipment's • Poor management of human resources leading to extended task duration • Inability to perform financial measurement directly from SAP
Opportunities (External) – to take advantage of	**Threats (External) – to treat/mitigate/accept**
• Skills transfer from OEM's during the new build programmes and turbine and generator overhauls • Cooperation and exchange programs with OEM's • Technology investment and improvement • Core competency capitalisation • Clever and agile tendering into the External market • Aging customer plant- new business • Gas and hydro turbine maintenance • Maintenance agreements with IPP companies • Selling of "a service" instead of selling of "hours" • Adopting and implementing the LEAN philosophy • Strategically positioned to manage and warehouse all modular strategic spares for ESKOM • Expanding the modular strategy to include ESV and Governor Valves	• ESKOM Holding's Financial sustainability • OEM's maintenance drive • Lack of turbine specialist skills in the External market • Loss of skills and skill shortages • Loss of ENK causing open competition • Support processes are inadequate • ESKOM more inclined to get OEM opinion and solution rather that TGS's • Future ESKOM budget not including the RF strategy • Adoption of National Treasury influenced Procurement Policy impact on TGS response time to potential tenders • End of life cycle of plant

7.4.5 Document Management System

Document management is completed through the quality department. Tracking of documents is completed manually on an excel template. An example of the documents' that are being monitored on a regular basis is listed below. Each department gets informed of the quantity of documents, per current status, as shown in Figure 58 below.

Authorised/Approved	Draft	Out for comment	To be revised	Grand Total
183	11	21	125	340
119	15	39	80	253
61	16	43	103	223
76	3	30	50	159
21	1	6	9	37
4	1	3	6	14
5			5	10
			5	5
2			2	4
2		1	1	4
2	1		1	4
3				3
	1	2		3
3				3
481	**49**	**145**	**387**	**1062**

Figure 58: Document Control. (Eskom Rotek Industries Business Management Document, 2010)

7.4.6 Quality Risk Management Document

The company has reviewed risks associated with the business activities and the following treatment plan has been extracted from the risk model:

- Streamlining internal processes to ensure flexibility when pursuing external revenue.
- Optimise the current business model to deliver more efficiently and competitively.
- Benchmarking with competitors on how they do business and ensure that the procurement system aligns with the external customer processes in terms of agility.
- Development of a pricing model in order to be more competitive.

7.5 APPENDIX E - Additional ESKOM statistics – produced by the organisation. (Data Set 1, Part 1)

In most projects in the power industry, the quality of the project must never be compromised, thus all technical aspects of running outages in the power industry is of critical importance. (Brown, 2004)

Thus management of outages relies heavily on the project management techniques described in the PMBOK, as well as a strong focus on technical aspects. Sethusa (2016) in completion of a dissertation; based on power delivery in ESKOM shows analysis on completion of a refurbishment project, at the Matla Power Plant. The main aim of the dissertation was to focus on implementing outage projects, in a better way and thereby reduce late delivery, over expenditure and still deliver projects of quality. (Sethusa, 2016) Strong emphasis was based on the full scope of work of the outage, as well as scope changes during the outage that led to changes in the project management style. [VAR]

After analysis of surveys Sethusa (2016) explained that there was a need for improvement in addressing scoping, planning, costing and contracting; and it was also stated that the appointed people were skilled, competent and had the relevant levels of competence to execute the type of project. [POP]

ESKOM has a dedicated department called the “Centre of Excellence” that monitors outage projects across the ESKOM fleet. Investigations are done on outage durations and outage costs. Figure 59 below shows a Pareto graph – count from 1231 x Outage Slip investigation findings. The first bar on the graph is attributed to one of ESKOM’s subsidiary. Bar’s 2 and 3 is attributed to Outage Management which is ESKOM’s Outage Management Teams’ based at the various stations as well as engineering respectively. This data was drawn over a period of time from January 2014 until January 2018. [HPA, TDL, POP]

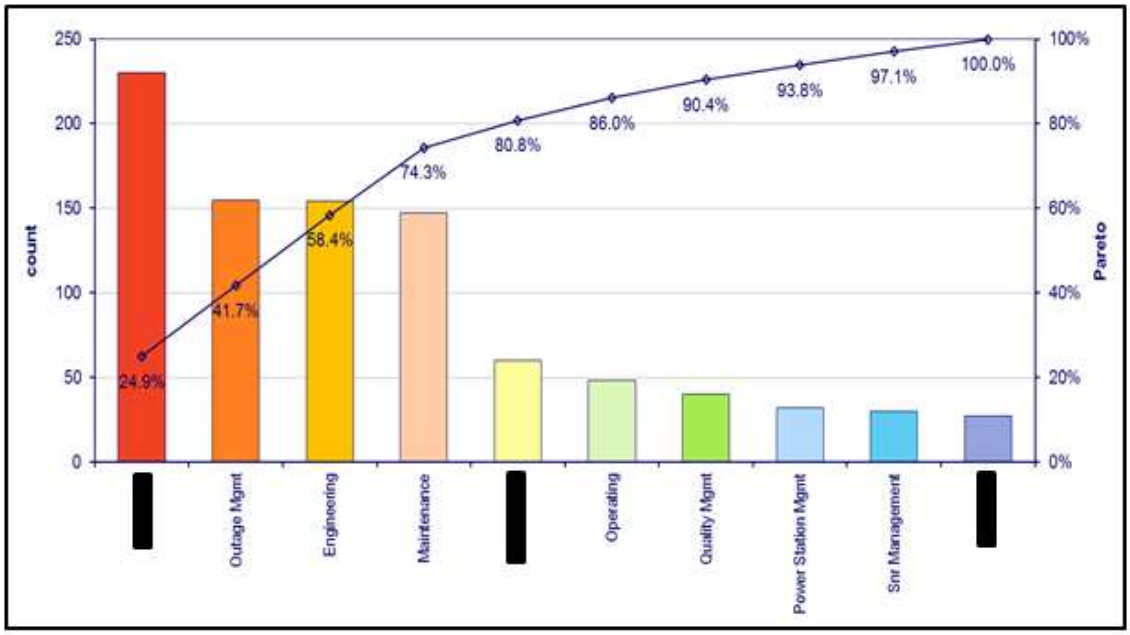


Figure 59: Data from 64 × Outage Slip Investigation reports from Jan 2014 → Jan 2018.

(Eskom - Centre of Excellence (COE), 2019)

The Outage Requests Committee (ORC) is a committee established where power plant managers present their outage projects, provide feedback on ongoing outages, as well as request for extensions on outages, if they foresee that outages will not be completed in the allocated time, as per the initial agreed completion dates.

Figure 60 below shows the number of days that was requested for by the power plants over a period of time from June 2016 until March 2018. The top ten power plants that have requested for the most amount of time in outage extension periods are emphasised in the Pareto graph in Figure 60 below. [IT, IC]

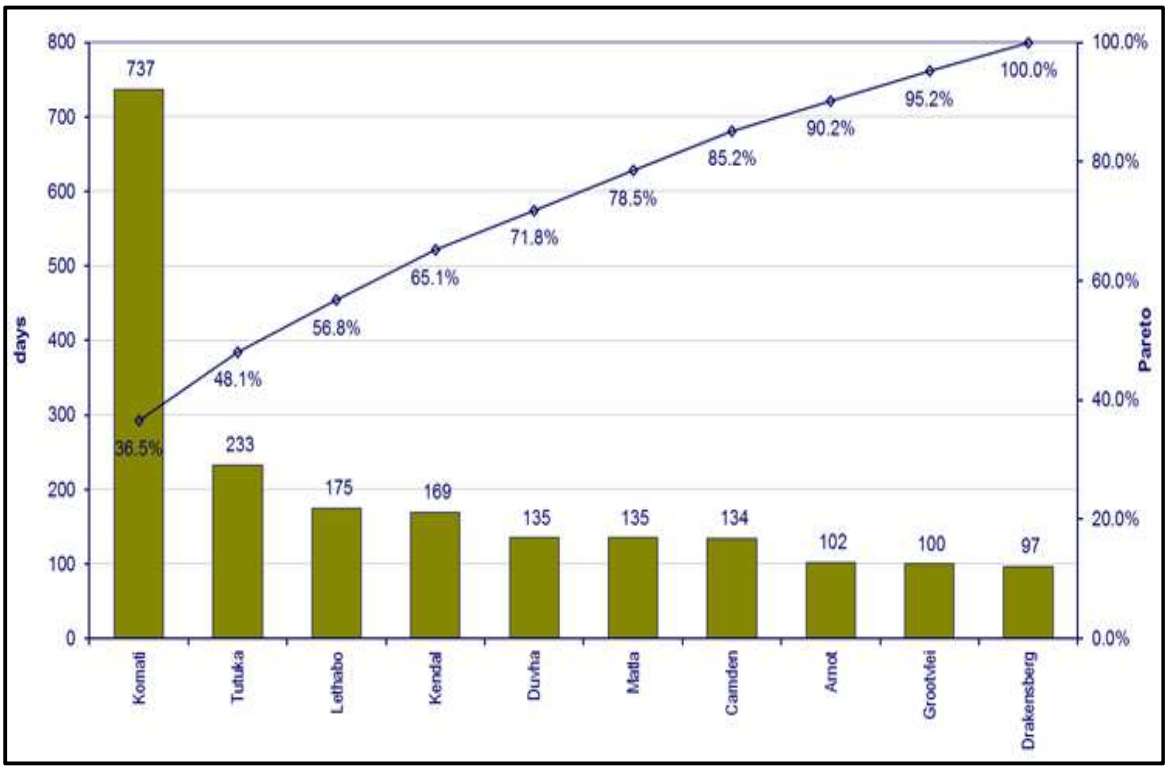


Figure 60: No. of Days of Slip on Outages per station from June 2016 until March 2018.

(Eskom - Centre of Excellence (COE), 2019)

Figure 61 below shows tracking of outages over a period of time between August 2018 and March 2019. Outage extensions have been categorised as stated below.

- Pre-outage extensions – is usually done before an outage can start, thus actually should be considered as postponement of the start date of an outage – usually due to capacity constraints on the national grid. [POE]
- In-outage extensions – is usually done while an outage is in execution, and the extension is justifiable. [IOE]
- Outage Slips – The outage has been extended because of the perception that personnel have failed to control the outage original duration. [OS] Table 29 below shows the total number of days for outage slips and planned extensions.

Table 29: No. Days of outage extensions across the ESKOM Fleet. (ESKOM - Centre of Excellence (COE), 2019)

outages returned to service between 30 Aug 2018 → 30 Mar 2019	
number of outages:	50×
planned duration excl. extensions (days):	1 148.15
number of pre-outage extensions:	21×
total duration of pre-outage extensions (days):	186.91
number of in-outage extensions:	10×
total duration of in-outage extensions (days):	147.84
number of outage slips:	29×
slip duration (days):	258.88

Figure 61 below also shows the top 10 power plants, that have requested for extensions on outages between a period from October 2018 until March 2019. [IT]

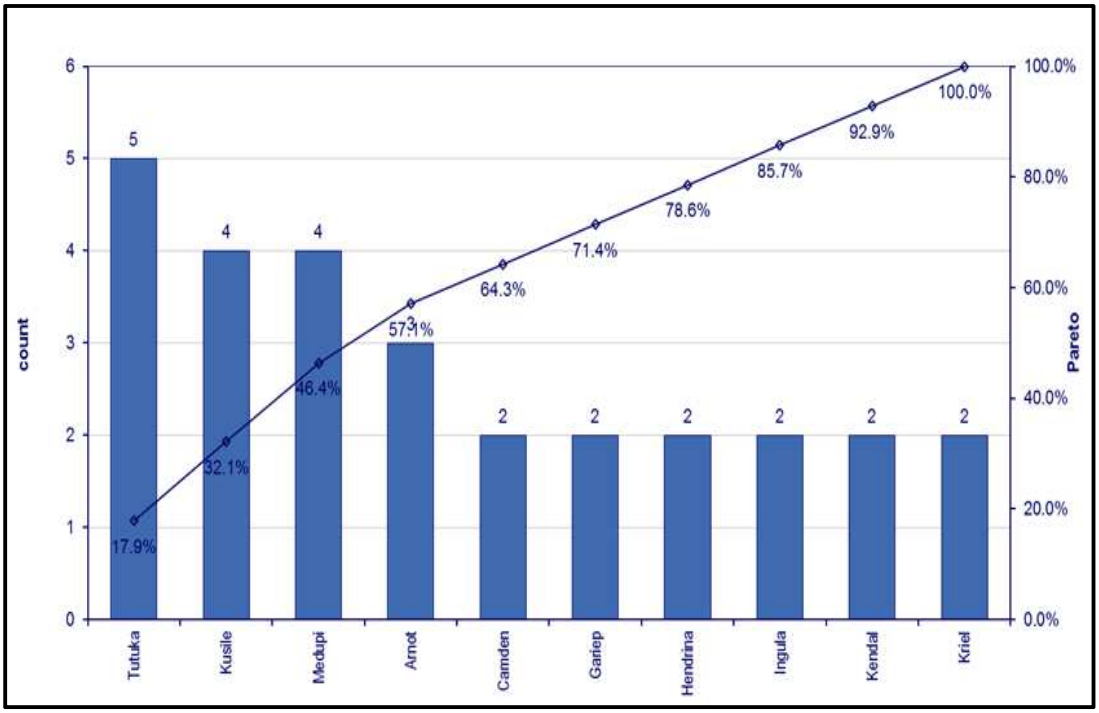


Figure 61: Top 10 Power stations over the last 50 outages requesting for extensions, from October 2018 until March 2019. (Eskom - Centre of Excellence (COE), 2019)

Table 30 below shows a numerical analysis of the amount of money that can be saved if ESKOM were to achieve zero extensions of outages, over a period from August 2018 until March 2019. Thus a total of R 6, 074, 503.33 can be saved in an 8 month period. This is an estimated saving of approximately R 759, 312.92 per month. (Please note these are estimated values only.) [IC]

Table 30: Analysis of the amount of money lost due to extensions and slips in outages. (Eskom - Centre of Excellence (COE), 2019)

	extensions	slips	Total
days	334.75	258.88	593.63
MWh	3 979 668.96	2 845 615.68	6 825 284.64
R (at R0.89 / kWh sales price)	R3,541,905,374.40	R2,532,597,955.20	R 6,074,503.33

Figure 62 below shows a Pareto graph of where the most amount of issues are experienced in terms of the actual physical plant equipment. Most of the issues experienced during outages are turbine and generator related. [TGPH]

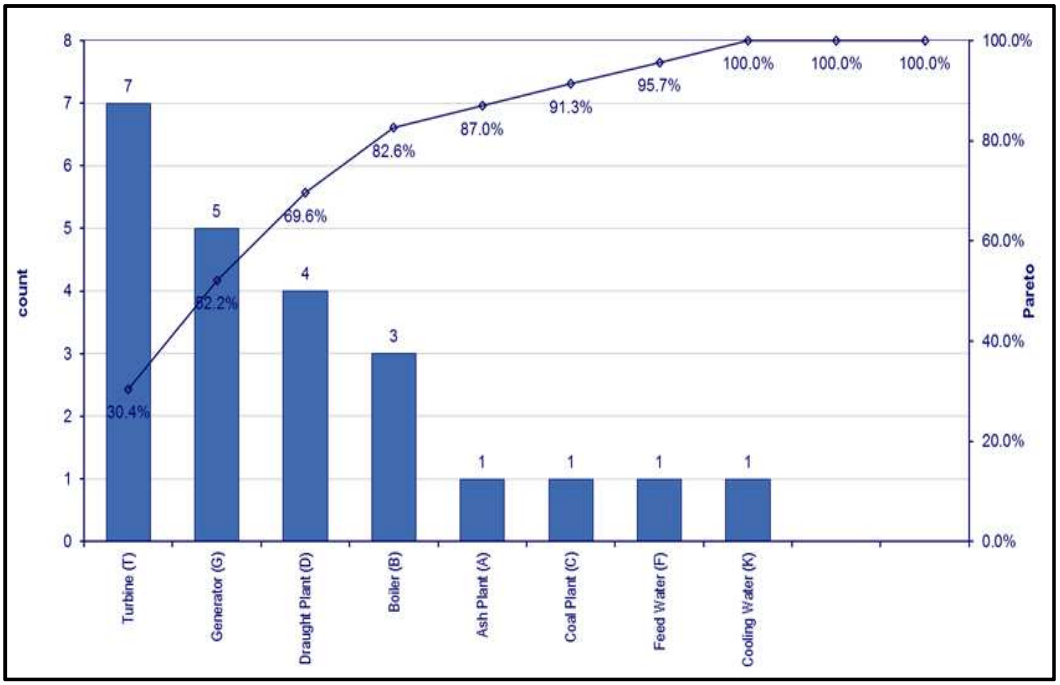


Figure 62: Physical Plant areas where most issues are experienced during Outages. (Eskom - Centre of Excellence (COE), 2019)

7.5.1 Coding of Post Mortems of some randomly selected Outages from 2019 to 2020. (Data Set 2)

Table 31 below shows the investigation analysis on problems experienced on outages from 2019 until 2020.

Table 31: Post Mortems on outages.

Post Mortems Conduction in the Projects Environment (2019-2020, Data Set 2)								
Item No.	**Power Station**	**Unit**	**Outage Description**	**Presentation Completed (Yes/No)**	**Date**	**Lessons Learnt**	**Recommendations/ Comments**	**Category**
1	Duvha	2	IN Last blade Inspection	Yes	March - April 2020	Manual Cleaning Of The last Stage Blades	Works Supervisor to be present all the time to show the workers where to clean and how to clean.	Workmanship
2	A power station	2	IR - LP Rotors Swap, Control and Protection, Generator Inspections.	Yes	June - October 2019	Spares	Spares to be prepared and quality checked before commencement of the outage. Spares to be available in time.	Spares
						Equipment	Equipment, machines, and Tools to be reviewed before the start of the outage.	Equipment and Services
						Lessons Learnt from previous outages	Consider all lesson learned from the previous outage and	History

							implement the corrective action on future outages.	
						Quality Checks at Works	Ensure all components sent to works are quality checked prior to dispatch to site. (Rotors, Bearings, Baffles etc.)	Process Control
						Engineering Review	Engineering review on methods used to perform alignment and documented conditions on performing alignment during the outage.	Technological Advancement
3	A power station	5	IR - Steam leak repair, Oil baffles inspections and Generator Inspections.	Yes	September - October 2019	Spares	Spares to be prepared and quality checked before commencement of the outage. Spares to be available in time.	Spares
						Equipment	Equipment, machines, and Tools to be reviewed before the start of the outage.	Equipment and Services

						Lessons Learnt from previous outages	Consider all lesson learned from the previous outage and implement the corrective action on future outages.	History
						Quality Checks at Works	Ensure all components sent to works are quality checked prior to dispatch to site. (Rotors, Bearings, Baffles etc.)	Process Control
						Subcontracted Costs	Ensure all subcontracts required for works are in place and ready to commence with execution.	Equipment and Services
4	Matimba	4	BD - last blade inspections on both LP1 and LP2 rotors.	Yes	Apr-20	Stakeholders	The support we received from our stakeholders both internally and externally and how flexible they were in offering their assistance when required.	Decision Making
						Decision Making	The technical decisions that were made were prompt and	Decision Making

							time effective.	
						Shift Working Arrangement	The 3 shift working arrangement was well planned and managed given the fact in was our first time implementing such a process on site and as a result we managed to comply with regards to the overtime restrictions.	Shifts
5	Matimba	5	HP, LP, Loop Pipe Inspection, Turbine Centreline and Inspection and Repairs, Auxiliaries, and Control and Protection.	Yes	October - December 2019	Rotek not working according to agreement	NCR raised to Rotek to come up with CA	Process Control
						Bolt heating machine breaking down	NCR raised to Rotek to come up with CA	Equipment and Services
						Damage of property	NCR raised to Rotek to come up with CA	Workmanship
						FRF oil spillage and Lube oil	NCR raised to Rotek to come up with CA	Workmanship
						NDT report not signed on time by ERI	NCR raise to Rotek to come up with CA	Process Control

6	Matimba	5	Breaker poles contact inspection, Breaker receivers inspection, Breaker earth switches service, Clean breaker and surrounding area, Function check Isolated Phase Bar pressuring system	Yes	Feb-20	Premature failure of insulation tubes	Purchase excess tubes , batch of tubes has been identified and need to be replaced.	History
7	Matimba	5	Unit & Service transformers .	Yes	Feb-20	Spares and Equipment	Cleaning contract manager to ensure the cleaning chemicals are reserved for MM to plan accordingly.	Equipment and Services
						Decision Making	Engineer to play a role on Scaffolding planning to avoid unnecessary delays caused by modifications	Decision Making
						Spares	Winding temperature device: Engineer to include all spares to be needed by EMD and PTM during the unit	Spares

							execution to be planned on time.	
						Decision Making	Engineer's involvement to be improved for progress and decision making to be done immediately.	Decision Making
8	Arnot	1	Bearing 1,2 and 3 inspections or replacement, BFPT bearings replacement and alignment correction. HP and IP Turbines heat shield replacement Turbine drains replacement & Functional test.	Yes	November - December 2019	Change in Process.	Pressure test on seal oil coolers done with oil instead of water decreased duration for oil purification on seal oil tank.	Technological Advancement
						Engineering Review	Stroking to be improved on dump valve (CI and Rotek)	History
						Spares	All spares to be replaced when stripping components (CI and Rotek)	Spares
						Process Control	Sequence to be followed when running up machine (operating)	Process Control

7.5.2 Other Improvement Initiatives' within ESKOM (Data Set 1, Part 2)

After a quality drive was held within ESKOM, the results displayed that most concerns revolve around poor workmanship [PWM], as a result of lack of skills in the organisation [TRN]; inadequate planning [POP], and the Technical Notification (TN) process – decisions that take too long [TDL].

With regards to planning, the ORI system gives a visual display and percentage output based on all the factors that need to be in place before the start of the outage, which was depicted in section 7.4.2 above and currently is not aiding in effective planning. With regards to the TN process, which is used by the engineers to communicate technical decisions on outages, and has to be approved by relevant parties before further work can continue, it has been highlighted that this causes delays in outages [IT, IC].

Modular spares also forms a significant problem as this is a new initiative that has been implemented by ESKOM. New spares have been bought and stored, as a hope to prepare these spares for the upcoming outages, so effectively having a "plug and play" scenario during the execution of the outage. There have been cases of modular spares not being ready in time and rework incidents. [IT, PWM]

Figure 63 below shows the development of a 'work package', which is one of the major drives to try and improve the workmanship within ESKOM. The packages provide a detailed description of how to perform tasks and subsequent approval on the documentation is required by relevant parties. It has been documented that although the packages have been implemented, personnel on the turbine floor have not been using it, thus it's not being managed well. In addition there is duplication in completed the SAP Work Packages' as well as checksheets that deliver the same output, thus making processes less efficient and adding time in the outage. [IPR, CPR]

Business Productivity Plan (BPP) and Maintenance Strategy (MS) as well as Maintenance Work (MW) is a project, that aims to improve the efficiency of power plants, by optimising the way in which maintenance strategies, and work packages are

completed. Simultaneously, this is also manual process that requires all documents to be completed, such as the checksheets process under the process quality plan. [CPR]

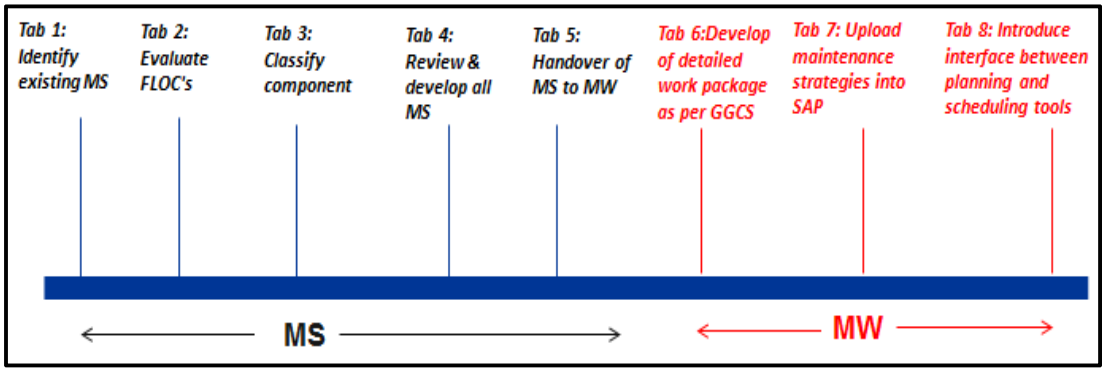


Figure 63: Maintenance Work Packages to improve workmanship. (Quality Drive, 2018)

Figure 64 below shows the results of a survey completed amongst ESKOM employees, which is based on the perception/opinions of the employees. "Lack of skills, lack of training and lack of resources", [TRN] forms the highest trending reasons' linked to quality issues.

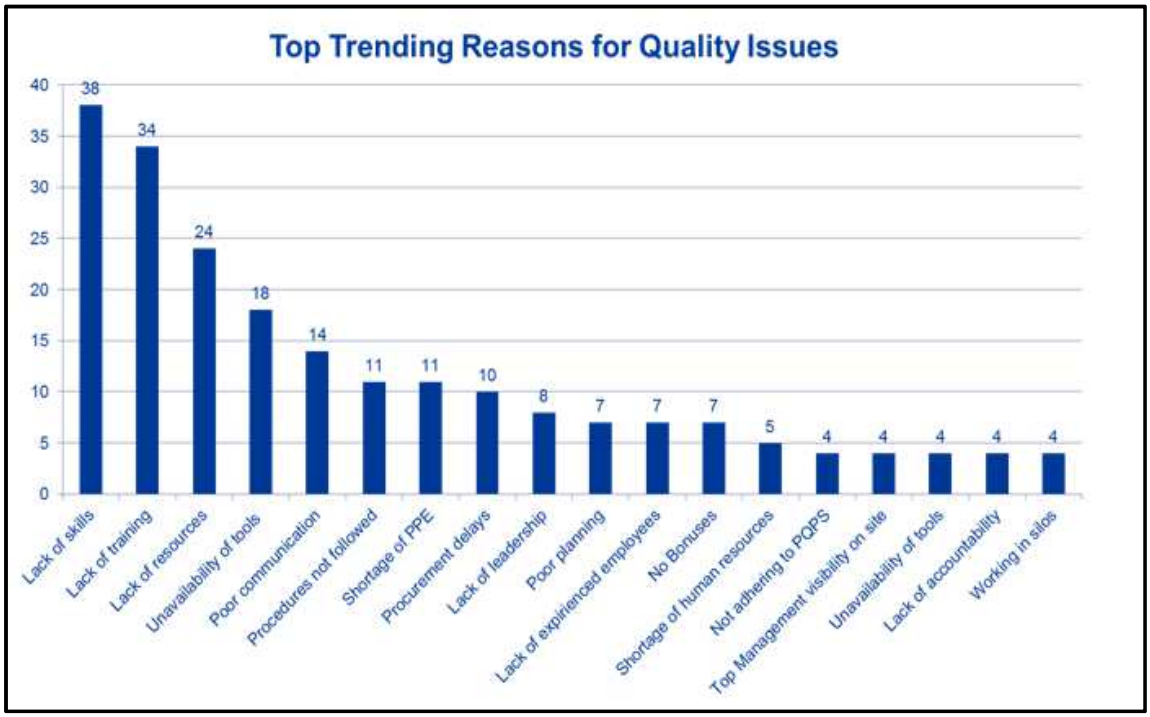


Figure 64: Graph showing the statistics of a survey done amongst ESKOM employees relevant to quality. (Quality Drive, 2018)

7.6 APPENDIX F - Additional information, supporting Chapters 3 & 4 (Research Method and Results)

Figures 65 and 66 below, is an in depth fishbone analysis of problems experienced on outage projects, as well as problems experienced with regards to training programmes. (Business, 2017)

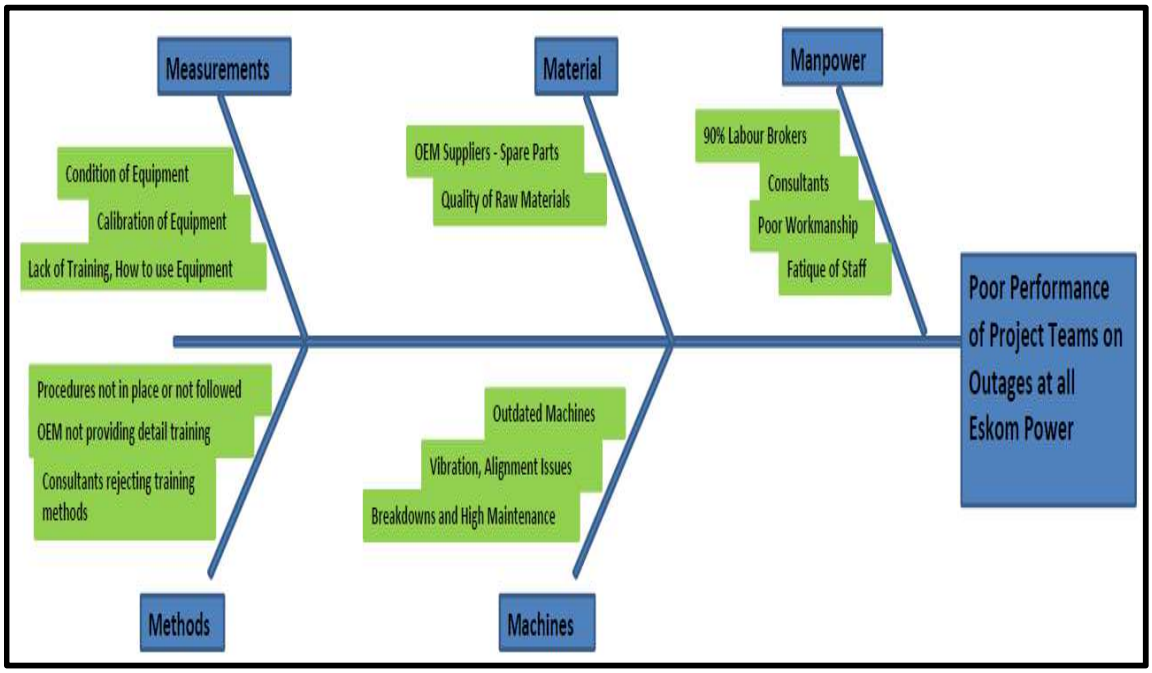


Figure 65: Fishbone Analysis of problems experienced in ESKOM. (Business, 2017)

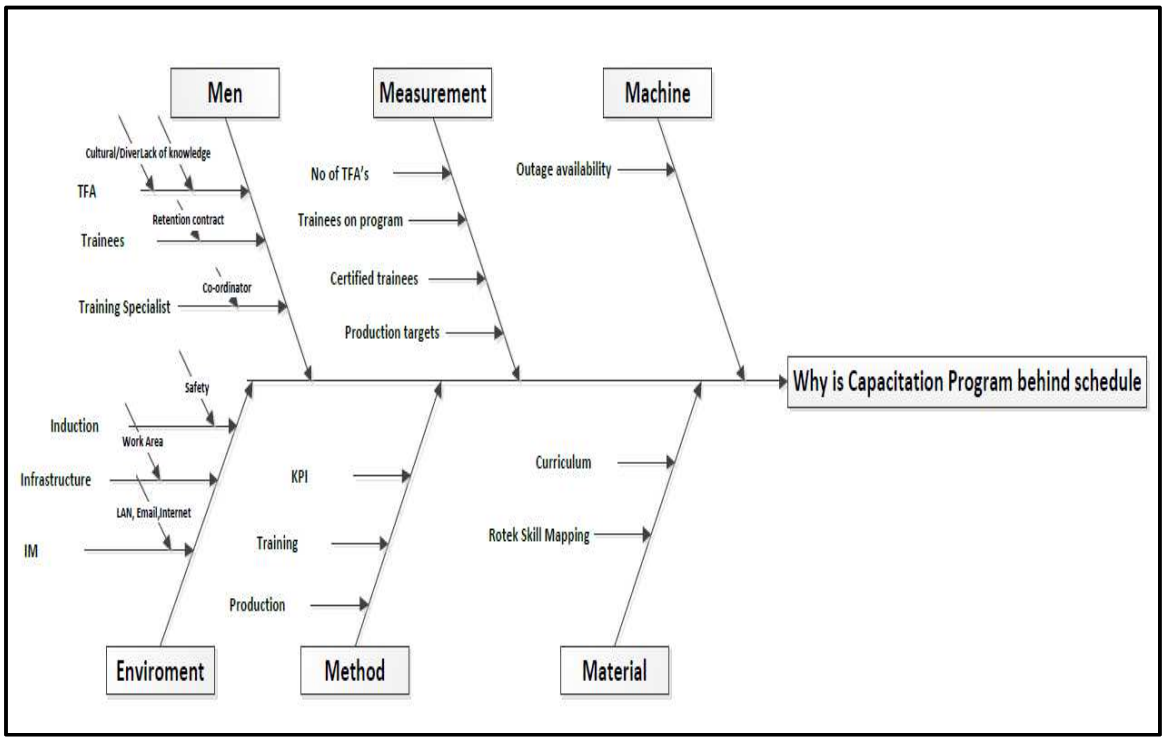


Figure 66: Training Program at ESKOM. (Business, 2017)

Table 32 below outlines the steps of the TN process according to SIPOC. Some of the failure points that were highlighted in the TN process through work performed by other students are documented below. (Business, 2017) [CPR, IT]

- Manual checksheets are hand-written and submitted for approval to many levels sometimes resulting in late submission.
- Sometimes submissions occur without third party consultation, and thus there might be rework required on TN's if disagreement exists.

Table 32: Display of SIPOC for the TN Process. (Business, 2017)

Suppliers	Inputs	Process	Outputs	Customers
Technical Department Quality Department	Compile Check sheet Approve Check sheet	Check Sheet Approved ↓ Assessment of out of Specification conditions ↓ Raise TN with recommendations ↓ Eskom Engineering approval of TN ↓ Eskom Outage Management approval of TN, Project Plan and Budget	Approved TN Approved budget and time extension Execute scope of work Statuary compliance achieved	Eskom Engineering Department Eskom Outage Management Department Finance Department Outage Review Committee
Transforming Resources				

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