Cape Peninsula
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IMPROVING OUTAGE PROCESS MATURITY LEVEL USING A PROCESS MATURITY MODEL

by

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DECLARATION

I, Mervyn Petersen, declare that the contents of this dissertation represent my own unaided work, and that the dissertation has not previously been submitted for academic examination towards any qualification. Furthermore, it represents my own opinions and not necessarily those of the Cape Peninsula University of Technology or Eskom.

Signed   Date

ABSTRACT

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The research study establishes the maturity level of the outage process of the Outage Management Department at Eskom. The outage process started in 2012 to contribute to the effective planning and execution of outages. The successful completion of outages depends on effective planning and execution of an outage. At the time of the research study, poor outage performance at Eskom's power stations contributed to load shedding of electricity in South Africa.

The research problem statement reads as follows: The absence of an outage process maturity indicator diminishes the ability of the Outage Management Department (OMD) to comprehend the current process maturity level. The research question: Will the Outage Management Department be able to identify improvement opportunities if the maturity level of the outage process is established?

The key research objectives are:

- To consider how process maturity enables improvement.
- To identify critical elements in an outage process.
- To determine what is included in outage planning, control and improvement.
- To identify a suitable process maturity model.
- To identify a measurement instrument to determine the maturity level of Eskom's outage process

The research study uses a descriptive research design and applies the survey research method. Greener and Martelli's (2015: **Online**) Business Research Process (Sources: Greener & Martelli, 2015: Online) is used together with Farooq's Research Steps for Survey Research (2015, **Online**). The survey questionnaire adopted from Smith's Maintenance Planning and Scheduling Maturity Matrix (2013: **Online**) was used to develop the survey questionnaire. The author developed the Outage Management Maturity Framework by combining Business Process Management Maturity model and a Maintenance Planning and Scheduling Maturity Matrix.

The research finding is that a process maturity model can determine the maturity level of the outage process and is useful as a process improvement tool. The research findings rank the maturity level of the outage process at Level 2, Experimenting.

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Firstly, I thank my heavenly Father God, Jesus Christ my savior and our sweet Holy Spirit for opening this door of opportunity and giving me the strength and insight to see it to its completion.

I thank the following people for the support and encouragement during this journey. Emerson said that *Life is a journey, not a destination*. What a journey it's been.

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GLOSSARY TERMS

Outage:	A predetermined repair, overhaul or maintenance endeavor undertaken during a power station life cycle to ensure optimal production (Eskom Internal Document 32-1312, 2015: 5)
Outage Management:	A complicated task involving the co-ordination of available resource, regulatory, technical and safety requirements, together with all activities and work prior and during the outage (IAEA, 2002: **Online**).
Outage Slip:	Outage taking longer than scheduled (Eskom Internal Document 32-1312, 015).
Outage Readiness Index:	Outage Readiness Index (ORI) is a standard approach to evaluate the readiness of an outage at predetermined stages prior before it start (Eskom Internal Standard 240-47532542: 2013:4).

CHAPTER 1: SCOPE OF THE DISSERTATION

1.1. INTRODUCTION

In 2012 Eskom's Outage Management Department implemented a quality management system certified to ISO 9001: 2008. According to SANS 9004 standard continued success is achieved by implementing a quality management system (SANS 9004: **Online**). Quality improvement is a planned approach explained by the Plan-Do-Check-Act (PDCA) model (SANS 9004: **Online**).

The aim of the research study is to establish the maturity level of the outage process at Eskom's Outage Management process. This would enable the Outage Management Department to establish a baseline maturity level for the outage process. The baseline maturity level should include all power stations and enable benchmarking across the fleet.

1.2. MOTIVATION

In 2012, Eskom adopted a process approach to outage planning and execution. Boutros and Purdie (2014: **Online**), point out that it is vital to monitor and measure organisational process maturity. Organisations are able to find improvement opportunities and identify crucial tasks that may put the organisation at risk if the processes are not at the suitable maturity level (Boutros & Purdie, 2014: **Online**).

Improving the planning and execution of outages contributes to improved electricity supply to South Africa. The use of a process management maturity instrument enables the Outage Management Department to identify opportunities for process improvement and possible risk during planning and execution of outages.

1.3 BACKGROUND TO THE RESEARCH PROBLEM

The research environment is Eskom's Outage Management Department. At the time of this research study Eskom was working to reduce load shedding of electricity in South Africa. Eskom established an Outage Management Department in 2012 to focus on the planning and execution of outages of its generation fleet. During the year of April 2014 to May 2015 Eskom's outage readiness showed an average readiness of 33 percent (see figure 2.7).

1.4 STATEMENT OF THE RESEARCH PROBLEM

The research problem statement in the ambit of the research study reads as follow: The absence of an outage process maturity indicator diminishes the ability of the Outage Management Department (OMD) to comprehend the current process maturity level.

1.5 RESEARCH QUESTION

The primary research question for this research study reads as follows: Will the Outage Management Department be able to identify improvement opportunities if the maturity level of the outage process is established?

1.6 RESEARCH INVESTIGATIVE QUESTIONS

The research investigative questions are listed below:

- How would process maturity enable improvement?
- What are the critical elements in an outage process?
- What is included in outage planning, control and improvement?
- What measurement instrument is able to determine the outage process maturity level?
- What is the current maturity level of the outage process at Eskom?

By answering the research questions and investigative questions the researcher seeked to determine if a process maturity model can be used as an instrument to enable quality improvement.

1.7 PRIMARY RESEARCH OBJECTIVE

The primary research objective in the ambit of the research study reads as follows:

- **Primary Research Objective:** The primary research objective is to establish the maturity level of Eskom's outage process using a process maturity model.
- **Secondary Research Objectives:** The secondary research objectives read as follows:
  - To consider how process maturity enables improvement.
  - To identify critical elements in an outage process.
  - To determine what is included in outage planning, control and improvement.
  - To identify a measurement instrument to determine the maturity level of Eskom's outage process
  - To establish the current maturity level of the outage process at Eskom.

1.8 THE RESEARCH PROCESS

The research study adopted the approach by Greener and Martelli (2015: **Online**). The research commenced with a review of the Outage Management Department's performance. The Outage Management Department's performance was analysed and the research problem statement identified.

The research design followed the descriptive research design. Research questions and objectives were developed. The survey questionnaire was developed and sent out to the staff in the Outage Management Department. The duration of the data collection started in April 2016 and ended in May 2016.

The research study used descriptive statistics to analyse the research data. Descriptive statistics was used to describe the current maturity level of the outage process. The data interpretation determined the maturity level of the outage process. The research study makes recommendations to assist with the improvement of the outage process.

1.9 RESEARCH DESIGN AND METHODOLOGY

Mouton (2001: 55) points out that the research design as a blueprint or plan explains the process to follow when conducting research. The research study adopted a quantitative research approach. The research design chosen for the research study is a descriptive research design. The research study employed the survey research method and used Greener and Martelli's (2015: **Online**) Business Research Process.

1.10 DATA COLLECTION DESIGN AND METHODOLOGY

The data collection method used was a survey. Survey questions developed for the research study is based on the Maintenance Planning and Scheduling Maturity Matrix (Smith, 2013: **Online**). Kwiksurveys online survey was used to create the survey questionnaire.

An electronic survey was disseminated via email using the Kwiksurveys online tool to all the employees in the Outage Management Department. Employees had the option to respond or refrain from responding to the survey. Employees had one month to respond to the survey. Kwiksurveys online tool provided basic descriptive statistics.

1.11 ETHICS STATEMENT

According to Greener and Martelli (2015: **Online**), ethics is concerned with moral choices influencing decisions, behavior and standards. Mouton (2001: 238) found that ethics in science is concerned with the wrong and right when conducting research. Mouton (2001: 238) further mentions that scientists hold the right to search the truth, while not to the detriment of others. Research involves the study of some being (Mouton, 2001: 243). Mouton (2001: 243) asserts that research subjects have basic rights and these include:

- The right to confidentiality and the right to decline to take part in research.
- The right to anonymity and confidentiality.
- The right to full disclosure about the research (informed consent).
- The right not to be harmed in any manner (physical, psychological or emotional).

Trochim (2006: **Online**), points out that the rule of voluntary involvement in research is essential when people take part in the research. Greener and Martelli (2015: **Online**), refer to some ethical criteria used in higher education:

- Avoid deception and be honest.
- Follow an ethical code of a professional body as appropriate.
- Fully disclose information about the study and the author's role and status.
- Do not cause harm by an act or omission of the research study.
- Obtain informed permission to take part in the research.
- Respecting the right to refuse to take part.
- Respect the need for anonymity and confidentiality.
- Clarify to the participants and gatekeepers potential limitations in confidentiality and anonymity.

The criteria mentioned by Greener and Martelli (2015: **Online**) along with the basic rights as mentioned by Mouton (2001: 243) are recommendations to be considered for inclusion in the ethics statement for the research.

When the data is presented the names of power station will be renamed as Power Station -1 and the support departments will be renamed as Support Departments.

1.12 RESEARCH CONSTRAINTS

The following research limitations and delimitations are relevant to this study. Research constraints listed below:

- Limitations related to the research are:
    - The Outage Management Department makes up the population selected for the research study.
    - Not all power stations will respond to the survey.
    - The level of skill and experience of participants in planning and execution of outages may vary, affecting the outcome of the maturity level.
- De-limitations related to the research are:
    - The research outcome may have a generalised application in the planning and execution of outages and online maintenance processes.

1.13 SIGNIFICANCE OF THE RESEARCH

The research study assumptions and limitations identified provide a method to determine the maturity level of the outage process. The research establishes a baseline maturity level of the outage process. Great understanding of the process maturity level could enable the Outage Management Department to identify improvement opportunities and enable benchmarking across the fleet.

Possible future research opportunities include the development of a maturity model for the online maintenance or work management process within the Eskom power station fleet and facilitate a structured improvement approach for the outage processes.

1.14 CHAPTER AND CONTENT OUTLINE

The literature review investigates the research question in the next chapter:

- **Chapter 1:** This chapter introduces the research subject and provides the motivation for the research.
- **Chapter 2:** A background of the research environment is presented in this chapter. The background leads the reader to understanding the research environment and identifies the research problem statement.
- **Chapter 3:** The chapter's primary focus is to understand process maturity models and the outage process. The author explores the applicable literature concentrated on the primary theme of the research study. The literature identifies an instrument to measure the outage process maturity level. The literature provides the context to answer the research questions.
- **Chapter 4:** The research process presents a structured research approach. The chapter looks at the research approach, the research design, methodology, assumptions and constraints.
- **Chapter 5:** Data collection, analysis and interpretation of results forming the central part of this chapter and will facilitate the arrival to a conclusion.
- **Chapter 6:** The author revisits the research questions and key objectives, ensuring the research has effectively addressed its objectives. Conclusions are drawn from the result and recommendations to mitigate the research problem that could proof beneficial to the organisation.

1.15 CONCLUSION

The research study creates an opportunity for the Outage Management Department to establish a baseline maturity level, identify best practice within the fleet to recognise improvement opportunities. The chapter:

- Reviews the motivation and background to the research environment.
- Determines the research problem statement and research questions.
- Establishes the research objectives.
- Reviews the research process, design and methodology.
- Reviews the data collection design and methodology.
- Discusses the research ethics statement.
- Reviews the research constraints.
- Discusses the significance of the research.
- Provides a chapter and content outline.

Chapter 2 reviews the background to the research environment.

CHAPTER 2: BACKGROUND TO THE RESEARCH ENVIRONMENT: A GENERAL PERSPECTIVE OF ESKOM'S OUTAGE MANAGEMENT DEPARTMENT

2.1 INTRODUCTION

The research environment is Eskom Holdings State Owned Company (SOC) Ltd, South Africa's primary supplier of electricity owned by the South African Government (Eskom Internal Document 240-56927206, 2015: 2). Eskom distributes, transmits and generates electricity to the mines, residential, industrial, commercial and agricultural customers (Eskom Internal Document 240-56927206, 2015: 2). Eskom owns and operates 27 power stations in South Africa (Eskom Internal Document 240-56927206, 2015: 2). Eskom contributes to around 95% of the electricity consumed in South Africa (Eskom Intranet, **s.a.**, **Online**).

The research focuses on Eskom's Outage Management Department and the outage process. The author is part of the Outage Management Department that focus on planning and scheduling of outages for Peaking power stations. This chapter presents:

- The challenges Eskom faced during April 2014 to May 2015.
- An overview of Eskom's Outage Management Department.
- An outage in context of power stations.
- The Eskom outage process.
- The research problem statement.

The background to the research study starts by presenting the challenges Eskom faced during April 2014 and May 2015.

2.2 THE CHALLENGES FACING ESKOM'S OUTAGE MANAGEMENT DEPARTMENT

This section presents the challenges Eskom faced from April 2014 to May 2015. In the internal report (Eskom Internal Document 240-56927206, 2015: 4), Eskom acknowledged that it faces a number of challenges, most notably load shedding. In an attempt to comprehend possible reasons for load shedding, a Five Why analysis was completed to assist in determining the possible contributing factors to load shedding. Table 2.1 captures the results of the Five Why analysis.

Table 2.1: 5 Why Analysis for possible contributing factors to Load Shedding (**Source:** Own Source adapted from Eskom Integrated Report, 2015: **Online**)

5 Why Analysis for Load Shedding	
Performance Categories	Possible Contributing Factors
Plant Availability Low	Unplanned Outages Planned Outages Outages slip / not completed on time/ Increased breakdowns on completion of outages
Maintenance Execution	Plant Breakdowns Increased Maintenance to reduce the Maintenance Backlog
Plant Failures	Lack of Maintenance Keeping the lights on in 2010 Soccer World Cup Increase in deferred maintenance
Outages Slip	Scope Increase Rework Poor Outage Readiness Poor Outage scoping development
Increased Outage Scope	Flawed Maintenance Execution Programmes Scope Growth – Work included late

The Five Why analysis found possible contributing factors and observed the following important contributing factors:

- **A lack of maintenance**: Increase in equipment breakdowns contributing to poor performance and a decrease in the plant availability to produce electricity.
- **Poor outage readiness and poor outage scope development**: Outage is executed even when the plants prepared. The scope is not accurate resulting in scope increase based on the as found inspections at the start of the outage.

- **Flawed maintenance execution programs**: The maintenance programmes are incomplete or out dated therefore accurate outage execution scopes cannot be developed.
- **A decline in the plant performance of its power stations resulting in an increase in unplanned breakdowns**: The power stations are operated beyond its recommended maintenance times to keep the lights on placing more strain of already stressed power stations. This increased the unplanned breakdowns as equipment failure surge under these conditions.
- **Limited opportunities to execute planned maintenance, leading to increased unplanned maintenance**: With limited maintenance opportunities contributes to increased equipment failure.
- **The deferment of maintenance and urgent repairs results in an increase in cost and the risk for load shedding**: Delaying maintenance increase the equipment failure and unplanned maintenance cost.

The main causes of these challenges are the result of a practice adopted by Eskom in 2010, committed to *keeping the lights on* in support of the Soccer World Cup (eNCA, 2015: **Online**). The Eskom Integrated Report (2015: **Online**) mentions deferment of maintenance, resulting in delays of critical maintenance and refurbishment of generating equipment and contributing to an escalation in breakdowns of generation plants (Eskom Integrated Report, 2015: **Online**). The risk captured in the Eskom Integrated Report (2015: **Online**) refer to the decrease in generating capacity caused by maintenance backlog and a decline in the generating plant's technical performance.

Figure 2.1 provides an overview of the impact of the approach adopted by Eskom that spirals into a cycle starting with *keeping the lights on* followed by deferring critical maintenance, resulting in an increase in maintenance backlog. The lack of maintenance increases the plant breakdowns, reducing plant availability, placing strain on the electricity supplier that results in load shedding to prevent a grid collapse. Eskom implemented controlled load shedding and scheduled power cuts by rotating load shedding between all consumers when demand is high to avoid total blackouts in the supply area (Eskom Internal Document 240-56927206, 2015:258).

In an attempt to address the cycle in Figure 2.1, Eskom has placed great focus on improving plant performance and executing critical outages to improve electricity supply and reduce load shedding (Eskom Integrated Report, 2015: **Online**).

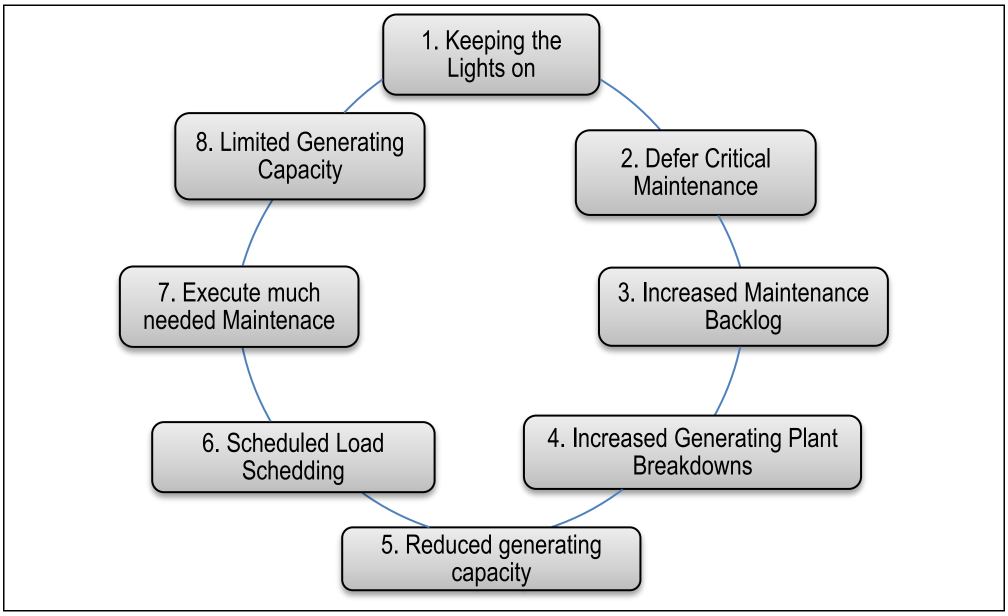


Figure 2.1: Impact of keeping the light on approach adopted by Eskom (**Source:** Own Source adopted from the Eskom Integrated report, 2015: **Online**)

Eskom maintained focus on its Corporate Plan to achieve its mission: *to provide sustainable electricity solutions to grow the economy and improve the quality of life of the people in South Africa and the region* (Eskom Internal Document 240-56927206, 2015: 22). In addition to its Corporate Plan, Eskom implemented a structured approach to enable further improvement by adopting a quality management system certified to ISO 9001: 2008 on 31 March 2013 (Eskom Integrated Report, 2015: **Online**). In 2012, Eskom established an Outage Management Department.

The implementation of an ISO 9001: 2008 management system, along with the establishment of a department focused on outage planning and execution is a clear indication of Eskom's commitment to improve and realise its business objectives. An overview of the Outage Management Department is discussed in the following section.

2.3 AN OVERVIEW OF ESKOM'S OUTAGE MANAGEMENT DEPARTMENT

This section provides an overview of the Outage Management Department. The Outage Management Department is accountable for the outage planning and execution.

This section provides a briefly overview of the Outage Management Department, and describes its primary mandate.

The Outage Management Department forms part of the Technology Division and consists of four primary operating units (OU) seen in Figure 2.2 (Eskom Intranet, **s.a.**: **Online**).

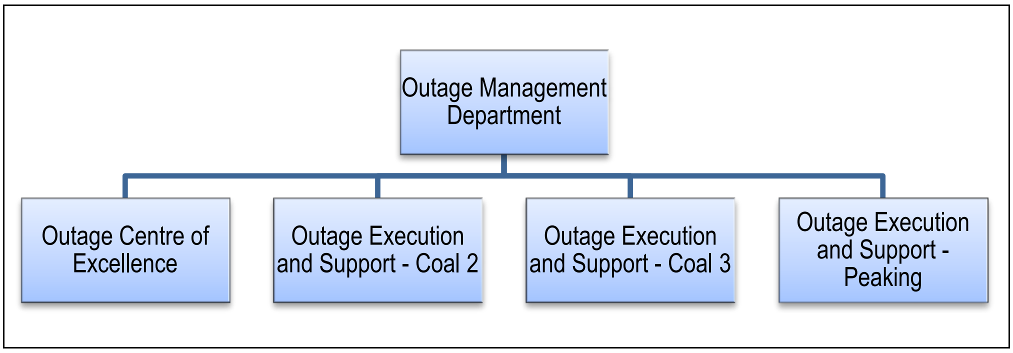


Figure 2.2: Outage Management Department (**Source:** Own Source adopted from Eskom Intranet s.a.: **Online**)

Each OU is responsible for the planning and execution of outages for a number of power stations in the OU. Coal 2 has seven power stations, which includes some of the mid aged power station. Coal 3 has six power stations and includes the oldest in the fleet as well as return to service power stations. Peaking OU have nine power stations consisting gas and hydro power stations.

The Nuclear OU is not included in the Outage Management Department but has its own Outage Management Department managed with in the Nuclear OU.

The mandate for the Outage Management Department including the Nuclear OU is to provide an end-to-end outage management service standardising outages across the fleet of power stations with the focus on high quality and timely completion of outages (Eskom Intranet, **s.a.**, **Online**). The mandate includes the outage planning, execution and close phases discussed in the following section.

The following section turns to an outage in a power station context to establish the basic outage process.

2.4 OUTAGES DEFINED IN POWER STATIONS CONTEXT

The technology categories under consideration include fossil fuel, hydro, gas, nuclear and renewable energy and focus on the following:

- Define an outage within power station context.
- Identify the challenges experienced by the Outage Management Department.

The following section defines an outage to create a uniform understanding of an outage.

2.4.1 Definition of term outage

This section presents definitions for an outage by considering recognised international bodies involved in power generation. It includes Eskom's definition on an outage.

The United States Nuclear Regulatory Commission (USNRC) (2015: **Online**) defines outages as a time when *a generating unit, transmission line, or other facility is out of service*. The Eskom definition of outages is a predetermined repair/overhaul/maintenance endeavour undertaken during a power station life cycle to ensure optimal production (Eskom Internal Document 32-1312, 2015: 5).

The following section presents the basic outage process and identifies the phases that make up the outage process.

2.4.2 Challenges in the Outage Management Department

The challenges facing the Outage Management Department have an adverse consequence on the consistent electricity supply to the South African economy. This section presents:

- The contributing causes to Outage slips.
- The Outage Readiness Performance.

The following section reveals the contributing cause to outage slips, quantify, and categorise the identified causes.

2.4.2.1 Contributing causes to outage slips

This section present the contributing causes to outage slips in an attempt to contextualise the challenges facing the Outage Management Department.

The International Atomic Energy Agency (IAEA) (2002: **Online**), mention some causes for outage extensions or slips included in Table 2.2.

Table 2.2: Causes for Outage Extension / Slips as found by IAEA (**Source:** Adopted from IAEA, 2002: **Online**)

Category	Sub-Category
Non identification of system, equipment and component defects	Deficiency in plant condition monitoring and trending Equipment breakdown in the course of outage execution
Quality of work completed	Absence of quality awareness and procedure use Poor material quality Deficiency in skills or trained staff Inappropriate control of work execution Unconcerned attitude to work execution causing in waste of working time
Lack of outage management	Deficiency of leadership and control over the planned activities Lack of motivation Deficiency of budgeting Equipment, material and spares are ordered late Inadequate collaboration among the stakeholders
Deficient outage planning	Under estimation of activity durations and labour Inappropriate scheduling of work activities Supporting activities (scaffolding, rigging, etc.), materials, tools are not well-defined. Plant isolations, permit to work and approvals not defined. Lessons learnt and operational experience feedback not considered or effectively implemented.

The primary and secondary causes to outage slips are presented using Histograms and Pareto diagrams. Eskom's Outage Management Department investigated the reasons for the outage slips using pre-determine barriers. The pre-determined barriers are Organisational Effectiveness and Operational Effectiveness barriers (Eskom Internal Report, 2015: 20150815). The Eskom Organisational Effectiveness is primary barriers are:

- Engineering Control.
- Formal Controls.
- Management, Assurance and Oversight Controls.
- Cultural Controls.

Figure 2.3 identified the major contributor to the outage slips as 390 failures in the Organisational Effectiveness controls (Eskom Internal Report, 2015: 20150815).

The Operational Effectiveness contributes to 211 failures. The Pareto analysis determined the causes within the seven sub-categories identified in Figure 2.3.

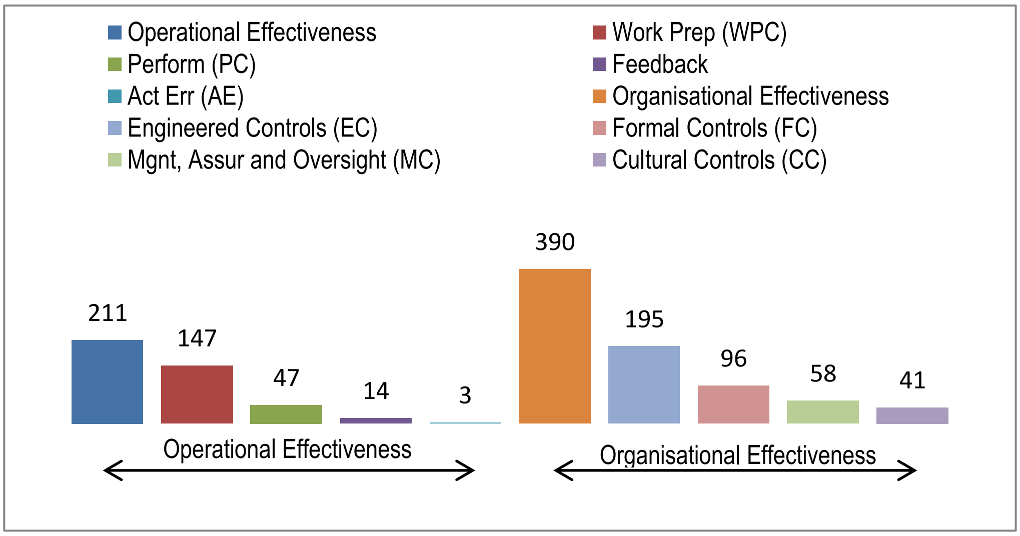


Figure 2.3: Histogram of Causes categorised into Operational and Organisation Effectiveness (**Source:** Own source adopted from Eskom Internal Report 20150805)

The Pareto analysis in Figure 2.3 combines the organisational and operational causes to find the primary contributing causes and identifies the major contributing cause was the 390 failures in the organisation effectiveness barrier (Eskom Internal Report, 2015: 20150815).

Figure 2.4 identifies Engineering controls as the main contributing cause followed by Work Preparation and Formal Controls.

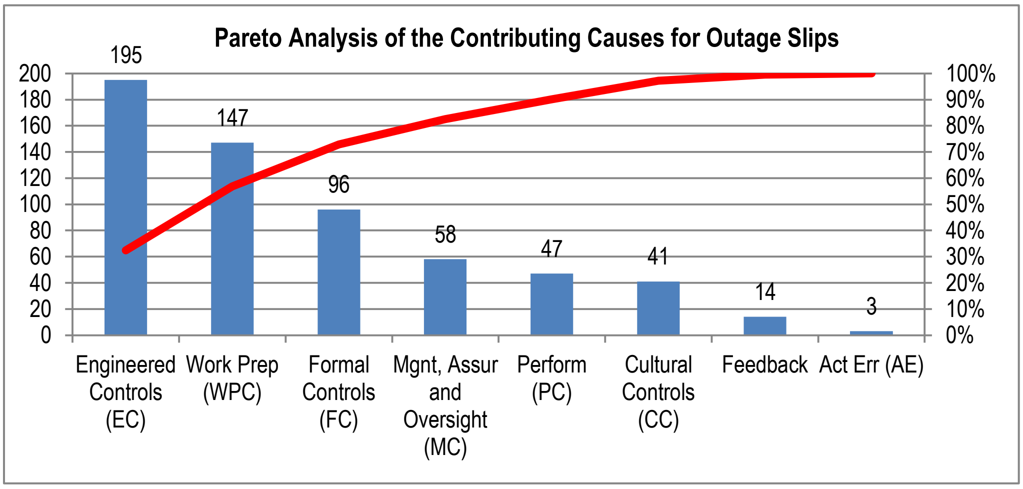


Figure 2.4: Pareto Analysis of the Contributing Causes for Outage Slips **(Source:** Own source adopted from Eskom Internal Report 20150805)

The Pareto analysis shows the 20 percent of the contributing causes that contribute to 80 percent of the outage slips are Engineered Controls, Work Preparation, Formal Control and Management Assurance and Oversight. Figure 2.4 indicates that the primary cause of outage slips are the failure of Organisational controls.

The analysis in Figure 2.5 further identifies the sub-categories enabling a better understanding of the failures within the Engineered Controls, Work Preparation Controls, Formal Control and Management Assurance and Oversight Controls (Eskom Internal Report, 2015: 20150815).

Figure 2.5 identifies failures in 11 sub-categories (Eskom Internal Report, 2015: 20150815). Work Planning and Scheduling and Work Co-Ordination account for 143 failures. Equipment Failures, Equipment Conditions and Maintenance Programs account for 150 failures.

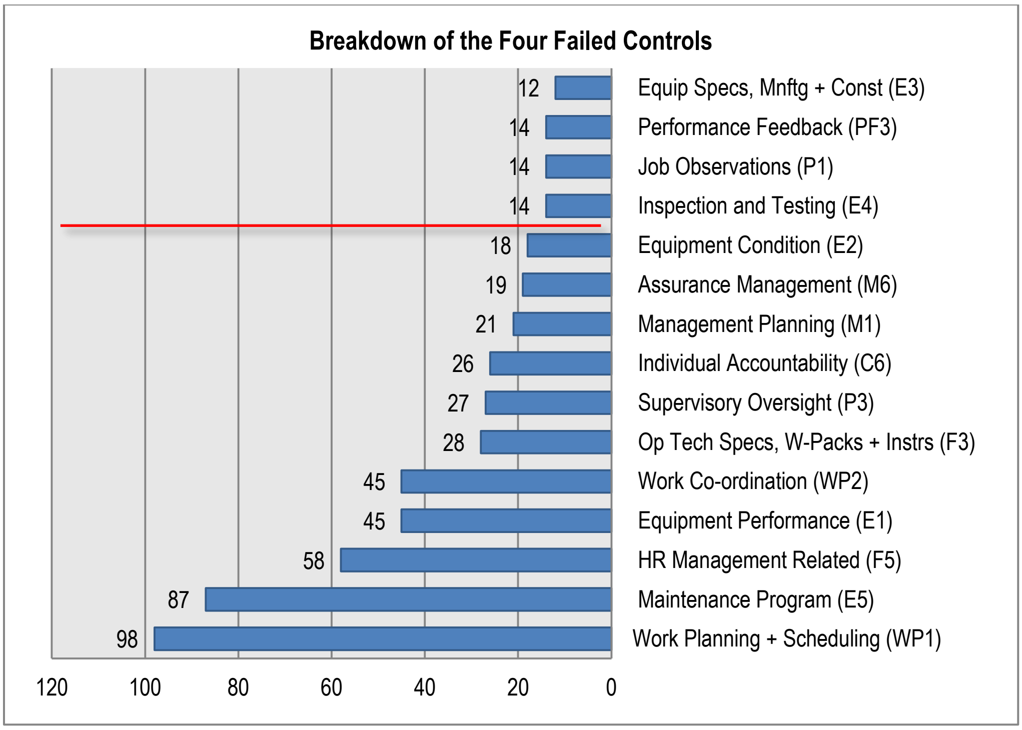


Figure 2.5: Breakdown of the Failed Controls (**Source:** Own source adopted from Eskom Internal Report 20150805)

Human Resources Management Related, Operational Technical Specifications and work packages and instructions account for 86 failures. The areas of Supervisory oversight, Management Planning and Assurance account for 67 failures.

Gryna (2001: 27) uses an Iceberg model to show the effects of the cost of poor quality. In Figure 2.6, the author uses the Iceberg model to show a number of factors that have an effect on the effectiveness of the outage process, including outage readiness.

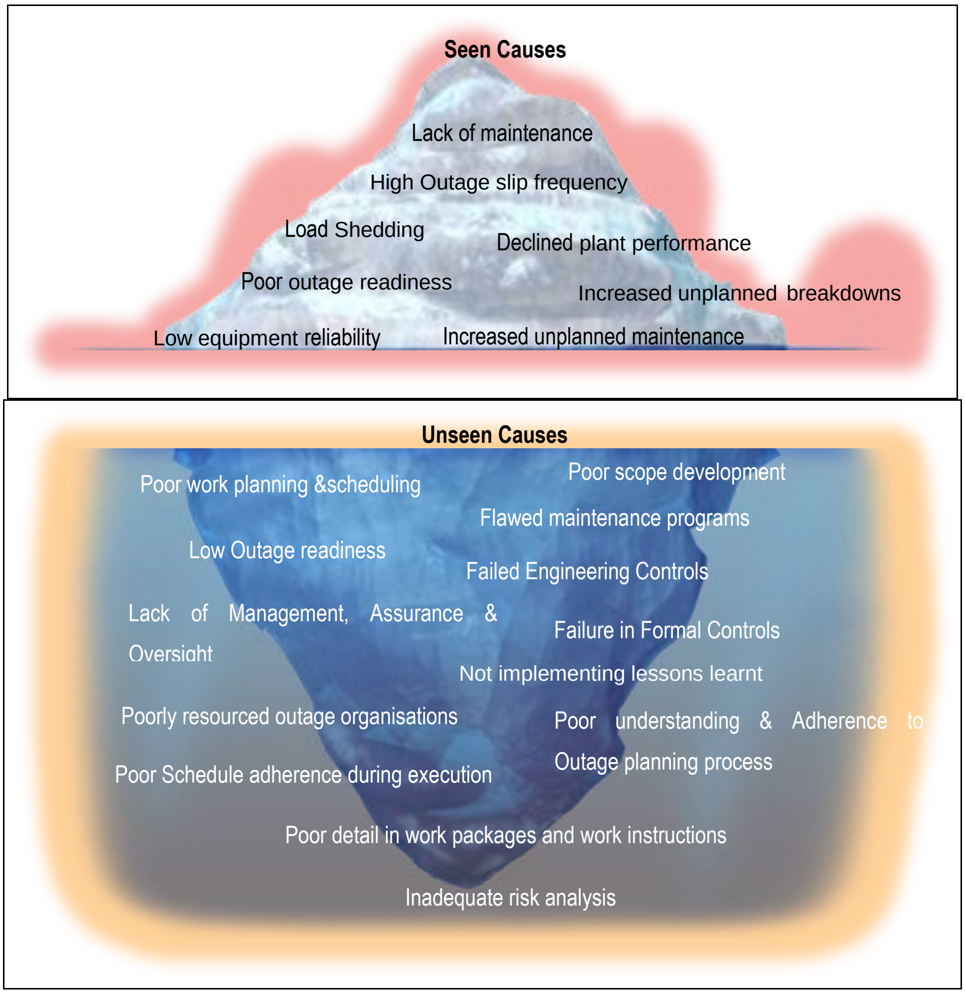


Figure 2.6: Iceberg Effect on Outage Management (**Source:** Own Source adopted from Gryna, 2001: 27)

The Outage Management Department uses the Outage Readiness Indicator (ORI) as a measure to determine outage readiness. It is a control and documented process and is discussed in the following section.

2.4.2.2 Review Eskom's outage readiness

The section reviews the Outage Readiness Index results from April 2014 to April 2015 to determine the status of outage planning. Outage Readiness Index (ORI) is a standard approach used by Eskom to evaluate the readiness of an outage at predetermined stages prior to its start (Eskom Internal Standard 240-47532542: 2013:4):

- **The detail captured in the ORI:** The outage planning process starts 24 months prior to the start of an outage and readiness outage readiness reviews are complete at pre-determine intervals (Eskom Internal Standard 240-47532542: 2013:4). The ORI standard further establishes a 90 percent ORI readiness score prior outage execution (Eskom Internal Standard 240-47532542: 2013:4).
- **Evaluation of the ORI readiness:** A review of the ORI scores from April 2014 to April 2015 in Figure 2.7, show an average ORI readiness 33 percent compared to an internal target of 80 percent. The target used by the Outage Management Department is ten percent less than the required 90 percent specified in the ORI standard (Eskom Internal Standard 240-47532542: 2013:5). The Outage Management Department does not include a minimum ORI score in any procedure, which can be used as a guide to delay the start of an outage. The 33 percent Outage readiness is an indication of outage poor planning and readiness and is therefore best captured by Baumler (2010: **Online**), considers Winston Churchill's comment; the one that fails to plan, plans to fail. The use of a lower readiness target could assist in determining the minimum readiness for an outage to continue. With a known upper and lower-limit, creates an opportunity to apply statistical process control (SPC).
- **Consider the use of Statistical Process Control:** The use of SPC could prove valuable in the monitoring of outage readiness. Early identification of process variance can lead to an investigation and resolution of causes early in the process.

Gryna (2001:495) describes SPC as the application of statistical methods to the measure and analysis process variation. The control chart in Figure 2.7 includes an upper control limit of 80 percent and no lower control limit. The ORI score process control chart show an average readiness of 33 percent at the time of the research.

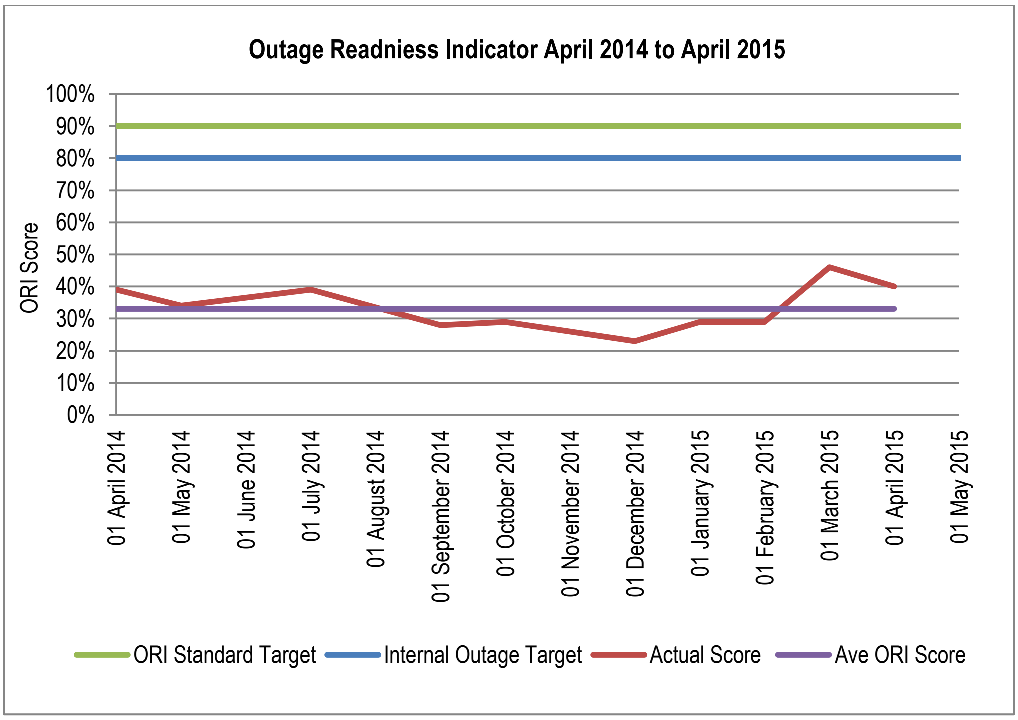


Figure 2.7: Outage Readiness Index Scores (**Source:** Own Source adopted from Eskom Internal Report, 20150805: GEXCO)

The low ORI scores point to problems in the outage planning resulting in process variation. With the gap between the actual score and target score the variations and problems will persist. The ORI scores in Figure 2.7 are an indication that the ORI planning process is out of control. The failure to understand the underlying causes have a negative impact on the ORI score and results in continued poor outage readiness. The use of SPC may well prove to be a valuable tool to identify process variance and assist with maintaining internal process controls.

Mauch (2010, **Online**) found that the last phase in process quality planning is to establish the internal controls that would stabilise the process. Defeo and Juran (2014: **Online**) explain that a strategic plan is the logical method to define a long-term goal and planning ways to achieve them. Boutros and Purdie (2014: **Online**) found that simultaneous change are required in the process system, technical systems, management and behavioral system when pursuing process improvement.

Boutros and Purdie (2014: **online**) explain that the pursuit of process improvement is a continuous and long-term goal. Knowles (2012: **Online**) states that if quality management focuses on anything, it is focused on change, and change for the better, while emphasising that learning is essential if a company wants to achieve a degree of excellence.

The research problem statement follows in the next section.

2.5 RESEARCH PROBLEM IDENTIFICATION

The aim of this section is to identify the research problem. The outage process uses Organisational Effectiveness and Operational Effectiveness codes to categorise failures when investigating outage slips. The Eskom Internal Report (Eskom Internal Report, 2015: 20150805) indicates a failure in the sub-categories, but omits to report which major category (Organisational Effectiveness or Operational Effectiveness) is the main contributor. The major contributor to outage slips is failures in the Organisational Effectiveness as shown in Figure 2.3.

A secondary consideration in the Eskom Report (Eskom Internal Report, 2015: 20150805) is the outage readiness indicator. The low ORI scores shown in Figure 2.7 provide evidence of outage processes are not in a state of control.

The lack of organisational effectiveness is the primary contributor to outage slips, followed by failures in certain operational controls.

The research problem statement reads as follow; the absence of an The absence of an outage process maturity indicator diminishes the ability of the Outage Management Department (OMD) to comprehend the current process maturity level.

2.6 CONCLUSION

The Outage Management Department captures and communicates data and figures in reports on the ORI scores and outage slips, but do not provide the methods to improve the current process performance. According to Deming (2000:15), figures indicate how processes are performing, but it does not demonstration how to improve processes. The Outage Management Department has many figures indicating how the process outage process performs, but these figures do not show how to improve the outage process.

This chapter provided the background to the research environment and included:

- The challenges Eskom faced.
- An Over view of Eskom's Outage Management Department.
- Outage Defined in the power station context.
- Identification of the research problem.

In Chapter 3 the literature review focuses on the use of the Process Maturity Model as a Quality Improvement approach.

CHAPTER 3: LITERATURE REVIEW – THE PROCESS MATURITY MODEL AS A QUALITY IMPROVEMENT APPROACH

3.1 INTRODUCTION

The aim of the literature review was to find an academic point of view to answer the research questions. According to Leedy and Ormrod (2014:51), the literature reviews the theoretical perspective and considers former research relating to the research problems. The literature review attempts to provide a comprehensive explanation of a process maturity model, the outage process that includes its planning, execution and improvement.

The approach to the literature review is a structured approach and follows the literature review model seen in Figure 3.1 developed by author and the research supervisor. The Literature Review Model has three phases. The review focuses on the theory of process maturity.

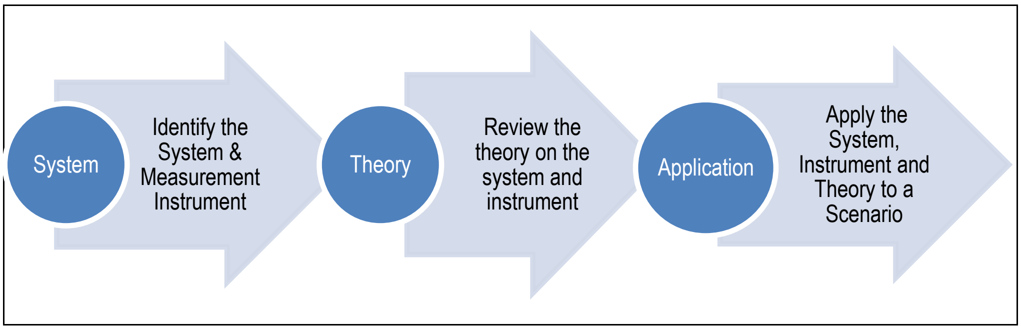


Figure 3.1: Literature Review Model (**Source:** Own Source)

The detailed literature review will focus on:

- Review Process Maturity.
- Review the Outage Process.
- Review Outage Planning Process.
- Review Outage Control Process.
- Review Outage Improvement Process.
- Review the measurement instrument to determine outage maturity level.

3.2 PROCESS MATURITY

This section reviews the process maturity and focuses on:

- The history of maturity models.
- Crosby's Quality Management Maturity Grid.
- Process Maturity.
- Continuous and Staged representation of process maturity.

3.2.1 History of maturity models

The aim is to look at the history of maturity models and to gain an understanding of how maturity models evolved focusing on:

- Nolan's Stages of Growth Model.
- The evolution to the process maturity framework.
- History summary of maturity models.

3.2.1.1 Nolan's Stages of Growth Model

According to Prananto, McKay and Marshall (2003: **Online**), the Nolan's stage hypothesis first appeared in the 1970's. Hollyhead and Robson (2012: **Online**) found that Richard L. Nolan designed the Stages of Growth Model for IT systems in the 1970. Gibson and Nolan (1979: **Online**) explain the purpose of the Stages of Growth Model is to describes each stage, listing key characteristics for each stage and explains the underlying organisational forces at work in each.

Gibson and Nolan (1974: **Online**) introduce a Four Stage Growth Model and point out that three types of growth would be required as maturity increases:

- A growth in computer application.
- A growth in specialisation of staff.
- A growth in formal management techniques and organisation.

Thakur (**s.a.**: **Online**) return that Nolan's model helps organisations understand the role of information systems and the models evolutionary route has six-stages as shown in Figure 3.2.

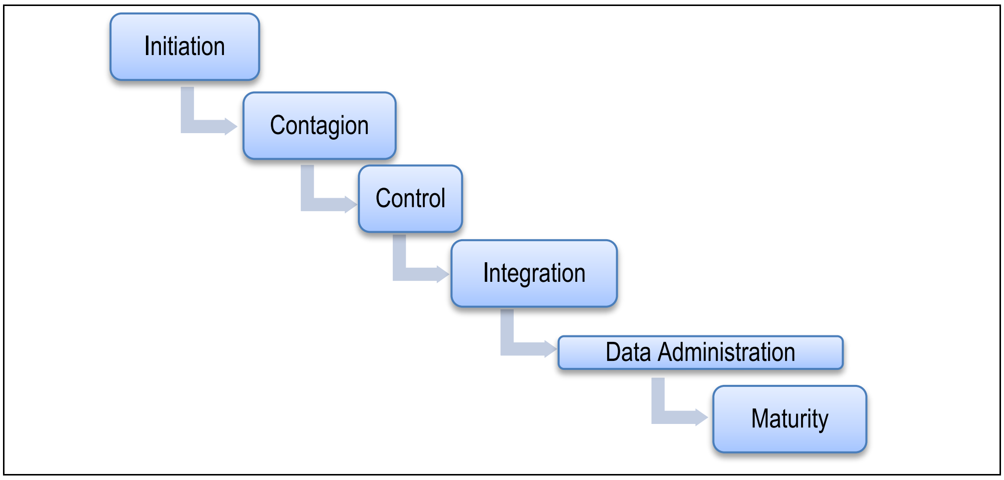


Figure 3.2: Nolan's Stages of Growth Model: (**Source:** Thakur, **s.a.**: **Online**)

Hollyhead and Robson (2012: **Online**) explain that other models have been created founded on Nolan's Stages of Growth model. Hollyhead and Robson (2012: **Online**) found that Nolan's Stages of Growth model is a useful tool to assist with identifying long-term strategic plans and find improvement opportunities.

A brief discussion of the evolution to the Process Maturity Framework follows in the next section.

3.2.1.2 Evolution to the process maturity model

The evolution from Nolan's Growth Model includes a number of contributions from various individuals and organisations. Two contributors include Crosby (1979: 25) and Humphrey (1987: **Online**).

In 1979, Crosby (1979: 25) proposed the Quality Management Maturity Grid (QMMG) with five maturity stages and six management groups. Humphrey's (1987: **Online**) contribution was during his time at Software Engineering Institute (SEI) and this contribution resulted in the development of the Process Maturity Framework, which provided a way of characterising the capabilities of software developers.

Humphrey (1987: **Online**), supported by Van Dyk & Schutte (2012: **Online)**, explain that the process maturity framework can be used to assess the process capability of a given organisation and identify important areas for improvement. Alden and Curtis (2006: **Online**) describe the history of maturity models in Figure 3.3. They acknowledge the contribution made by Shewart's Statistical Process Control approach, Deming PDCA model and Crosby's Quality Management Grid as contributors to the development of Humphrey's Process Maturity Framework.

Figure 3.3 shows that Humphrey's Process Maturity Framework contributed to the Capability Maturity Model with its variations leading to the development of the Business Process Maturity Model.

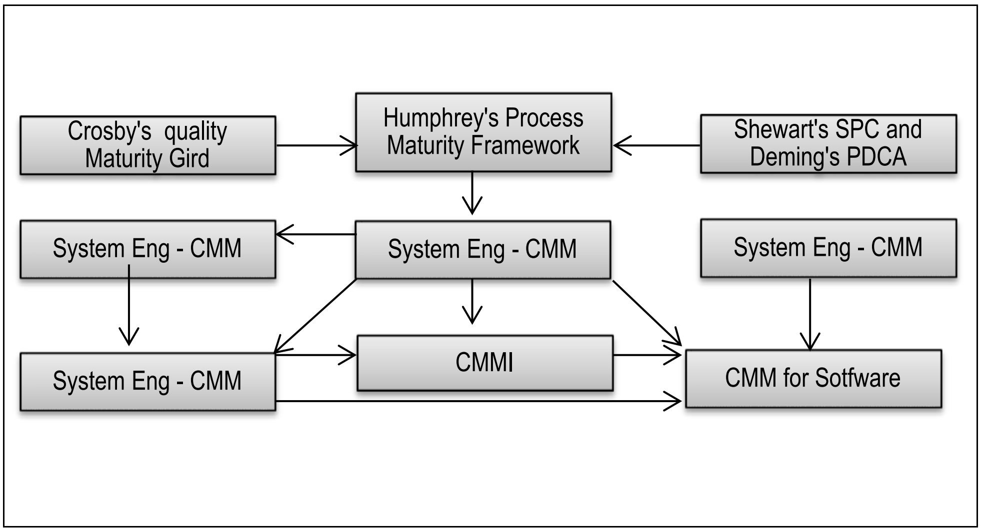


Figure 3.3: History of Maturity Models (**Source:** Alden & Curtis, 2006: **Online**)

The history of the maturity models seen in Figure 3.3 was not the end of the evolution of the maturity models. The next section provides an overview of various maturity models.

3.2.2 Crosby's Quality Management Maturity Grid

According to Crosby (1979:23), the Quality Management Maturity Grid (QMMG) enables any manager to determine the maturity level of any operation in terms of quality concepts. The review focuses on:

- The background to the QMMG.
- Using the QMMG as an Improvement Tool.
- Description of the QMMG.
- The working of the QMMG.

3.2.2.1 Background to the Quality Management Maturoty Grid

According to Maier, Moultrie and Clarkson (2012: **Online**), Crosby's Quality Management Maturity Grid is a pioneering example, promoting progress across five stages: uncertainty, awakening, enlightenment, wisdom and certainty. Wilson (2013: **Online**) developed a Quality Maturity Model closely founded on the Capability Maturity Model (CMM) used in software development. The five stages in the maturity model by Wilson (2013: **Online**) are similar to the Capability Maturity Model: Initial, repeatable, defined, managed and optimising.

3.2.2.2 Quality Management Maturoty Grid as an improvement tool

According to Maier, Moultrie and Clarkson (2012: **Online**), a maturity grid can be used as an assessment or improvement tool. Crosby (1979:25) point out that the Quality Management Maturity Grid is used to pinpoint the "as is" state of a process and enable improvement by referring to the next stages to identify actions to be taken for improvement. The grid can help identify the last success point and reading backwards to determine where established programs deteriorated.

De Bruin, Freeze, Kaulkarni and Rosemann (2005: **Online**) mention that maturity models are used to assess the maturity level of selected processes based on a comprehensive set of criteria.

De Paula, Fogliatto and Cristofari (2012: **Online**) maintain that the maturity grid method provides a qualitative description of each process area. Pöppelbuß and Roglinger (2011: **Online**) found that maturity models are expected to make known the current and desired maturity levels and to include relevant improvement measures.

3.2.2.3 Explanation of the Quality Management Maturoty Grid

De Paula, Fogliatto and Cristofari (2012: **Online**) explain that the grid cell has text descriptions of typical performance expected at various maturity levels. The detail of the Quality Management Maturity Grid developed by Crosby (1979: 32-33) is provided in Table 3.1.

Maier, Moultrie and Clarkson (2012: **Online**) explain the process for determining maturity uses a matrix or grid design seen in the QMMG shown in Table 3.1. The maturity level is assigned against key performance characteristics thereby creating a series of cells.

Crosby's QMMG shown in Table 3.1 clearly define six measurement categories and five stages ranging from uncertainty to certainty. Table 3.1 of Crosby's QMMG has a clearly defined requirement for each measurement category and the corresponding stage.

Table 3.1: Quality Management Maturity Grid (QMMG) (**Source:** Crosby, 1979: 32-33)

Quality Management Maturity Grid					
Measurement Categories	**Stage 1: Uncertainty**	**Stage 2: Awakening**	**Stage 3: Enlightenment**	**Stage 4: Wisdom**	**Stage 5: Certainty**
Management understanding and attitude	Do not comprehend quality as a management tool. Tend to blame quality department for quality problems	Recognise the value of quality management, but will not provide time of money to make it happen	While going through quality improvement, learn more about quality management and become supportive and helpful	Participate. Understand the absolutes of quality management and recognise their role continuing emphasis	Consider quality management as a vital part of the company system
Quality Organisation Status	Quality is hidden in manufacturing and engineering department. Inspection probably not part of organisation. Emphasis on assessment and sorting.	A strong quality leader is appointed but the main emphasis is still on assessment and moving production. Still part of manufacturing and others.	Quality Department reports to top management, all assessment is incorporated and manager has role in management of company.	Quality manager is an officer of company; effective status reporting and preventive action. Involved with consumer affairs and special assignments.	Quality manager on board of directors. Prevention is main concern. Quality is a thought leader.
Problem Handling	Problems are fought as they occur; no resolution, inadequate definition, lots of yelling and accusation	Teams are set up to attack major problems. Long range solutions are not solicited	Corrective action communication established. Problems are faced openly and resolved in an orderly way	Problems are identified early in their development. All functions are open to suggestions and improvement.	Except in the most unusual cases, problems are prevented.
Cost of Quality as % of sales	Reported: Unknown. Actual: 20%	Reported: 3% Actual: 18%	Reported: 8%. Actual: 12%	Reported: 6.5% Actual: 8%	Reported: 2.5% Actual: 2.5%
Quality Improvement Actions	No Organised activities. No understanding of such activities.	Truing obvious "motivational" short-range efforts.	Implementation of the 14 step program with thorough understanding and establishment of each step	Continuing the 14 step program and starting Make Certain	Quality Improvement is normal and continued activity.
Summation of company quality posture	"We don't know why we have problems with quality."	"Is it absolutely necessary to always have problems with quality?"	"Through management commitment and quality improvement we are identifying and resolving our problems."	"Defects prevention is a routine part of our operations."	"We know why we do not have problems with quality."

The working of the QMMG is discussed in the following section.

3.2.2.4 The working of the Quality Management Maturity Grid

The use of the QMMG to determine the quality maturity level is explained by Crosby (1979: 31) finding that the correct use of the Grid's assessment result could encourage quality improvement.

According to Crosby (1979: 31), the first step is to ask the managers to check the stage they think their operation is in for each of the six measurement categories, and score it in accordance with Table 3.2. The managers add up the score and obtain a result out of 25 providing a quantifiable measure that represents a certain maturity level.

Table 3.2: Quality Management Maturity Grid Points Guide. (**Source:** Own Source Adopted from Crosby, 1979: 31)

Quality Management Maturity Grid Point Grid					
Measurement Categories	**Stage 1: Uncertainty**	**Stage 2: Awakening**	**Stage 3: Enlightenment**	**Stage 4: Wisdom**	**Stage 5: Certainty**
Points Allocation	1 Point	2 Points	3 Points	4 Points	5 Points

The following section describes process maturity and shows at how it is utilised.

3.2.3 Process maturity

The author seeks to understand a Process Maturity Model and consulted literature on the subject that includes:

- ➢ The description of the process maturity models.
- ➢ Identifying the basic levels observed in a process maturity model.
- ➢ Three ways to utilise maturity models.

3.2.3.1 Description of the Process Maturity Model

This section describes the Process Maturity Model. Paulk, Curtis, Chrissis and Weber (**s.a., Online**) defines process maturity as: Process maturity is the degree to which a particular process is well defined, controlled, evaluated and successful.

According to Boutros and Purdie (2014: **Online**), a process maturity model is a set of well-defined structured stages that explain how well the practice, behavior and process of an organisation can consistently produce the predetermined outcome. Jochem, Geers and Heinze (2011: **Online**) consider the maturity model as a specific competency model that point out various degrees of maturity.

Dijkman, Lammers, and De Jong (2015, **Online**) explain that Business Process Management (BPM) is a contemporary management practice centered on managing the organisations 'business processes'. Pešić, Milić and Anđelković (2012, **Online**), citing Oliveira, Ladeira and McCormack (2012), describe BPM as a complete management approach focused on identifying, defining, implementing, measuring monitoring, analysing and continual improvement of business processes. Maier, Moultrie and Clarkson (2012: **Online**) found that the focus on quality management and process improvement programs often encourage the organisations to assess their capability against improvement frameworks.

3.2.3.2 The basic levels of process maturity models

Paulk, Curtis, Chrissis and Weber (**s.a.**, **Online**), Song, Zhu, Danilovic and Hoveskog (2011, **Online)** and Boutros and Purdie (2014: **Online**), support the view of Humphrey (1987: **Online**), that the process maturity model has five levels.

Figure 3.4 presents the basic process maturity levels. Pešić, Milić and Anđelković (2012, **Online**) find that the models developed by Rosemann and De Bruin (2004) include five factors influencing five phases that an enterprise has to go through to improve the maturity of the Business Process Management.

According to Rosemann and De Bruin (2005: **Online**), the BPM have five maturity levels which is similar to Capability Maturity Model (CMM) and are:

- Initial Stage,
- defined,
- repeatable,
- managed; and
- optimised.

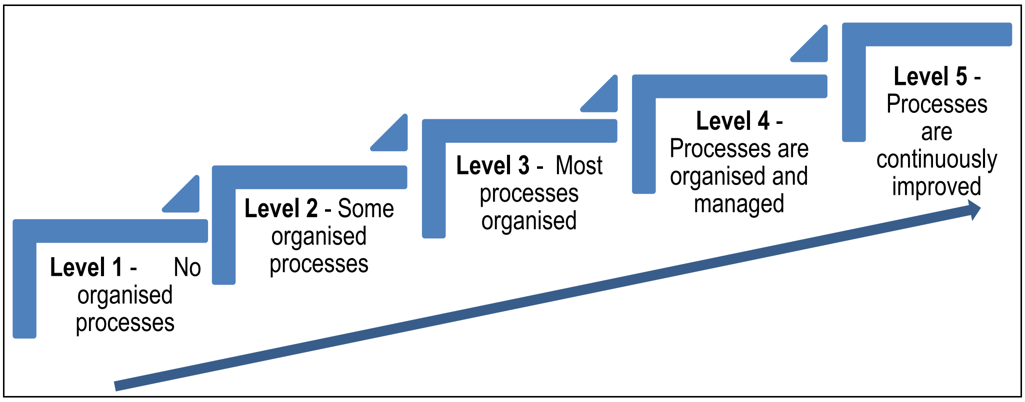


Figure 3.4: Five Levels of Process Maturity (**Source:** Own Source adopted from Humphrey 1987: **Online**)

Figure 3.4 presents Humphrey's (1987: **Online**) detailed description of the five levels of a process maturity model are:

- **Initial:** The process is not under statistical control; therefore, no systematic process improvement is likely.
- **Repeatable:** To achieve a process that is stable and repeatable, statistical controlled; introduce accurate project management of responsibilities, cost, schedule and changes.
- **Defined:** The process definition is essential to assure consistent implementation and to provide a foundation for better comprehension of the process.
- **Managed:** Subsequent to the defined phase, it is possible to start process measurement. At this phase significant quality improvement begins to emerge
- **Optimise:** The measured process is the foundation for continuing improvement and process Optimisation.

With a basic understanding of the Quality Management Maturity Grid and a Process Maturity Model, the following section focuses on the three approaches used to utilise maturity models.

3.2.3.3 Three ways to utilise maturity models

De Bruin, Freeze, Kaulkarni and Rosemann (2005: **Online**) mention that maturity models can be used as a descriptive, prescriptive or comparative nature briefly described in the following text.

Descriptive Approach: According to De Bruin, Freeze, Kaulkarni and Rosemann (2005: **Online**), the descriptive approach assists to determine the current state of a process and makes no provision for improvement. De Bruin, Freeze, Kaulkarni and Rosemann (2005: **Online**) explain that a model is descriptive to gain a deeper understanding of the current situation.

Prescriptive Approach: De Bruin, Freeze, Kaulkarni and Rosemann (2005: **Online**) found that the prescriptive approach enables the development of a roadmap for improvement. The prescriptive approach enables repeatable improvement and with the understanding of the current, "as is" situation (De Bruin, Freeze, Kaulkarni & Rosemann, 2005: **Online**).

Comparative Approach: De Bruin, Freeze, Kaulkarni and Rosemann (2005: **Online**) explain that the comparative approach permits benchmarking across industries, comparing similar practices across various originations.

3.2.4 Continuous and Stage Representation of maturity models

This section review differences between two types of representations of maturity models and present the advantages for each representation. Shrum (1999: **Online**) mention continuous and staged representations as two representation applied in the Capability Maturity Model (CMM).

3.2.4.1 Continuous Representation

According to Cepeda (2005: **Online**), continuous representation uses capability levels to measure an organisation's process improvement. Shrum (1999: **Online**) summarises the continuous representation as a capability level applied to achieve process improvement in a specific organisational process. Rungta (2007: **Online**) mention that continuous representation is used by organisations that want to improve processes most important to the need of the organisation. Rungta (2007: **Online**) offers a second use of continuous representation stating that allows organisations to improve the maturity of processes at different rates. Rungta (2007: **Online**) point out that an organisation gains the best value from selecting the continuous representation approach if they know which processes require improvement.

According to Shrum (1999: **Online**), continuous representation has specific process areas as summary component as shown in Figure 3.5. The processes need specific practices to achieve predetermined goals and generic practices that achieve generic goals. Each goal and practice is linked to a specific capability level as seen in Figure 3.5 (Bourne & Tuffley, 2007: **Online**). Rungta (2007: **Online**) explains that continuous representation enables an organisation to prove process capability.

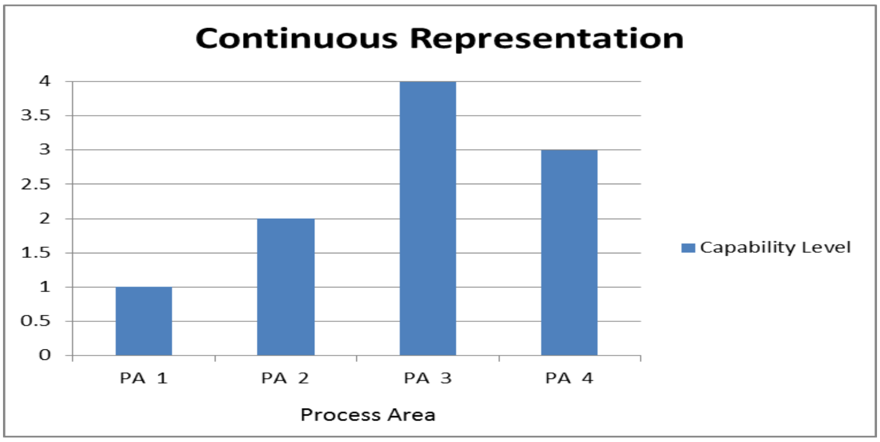


Figure 3.5: Maturity Models – Continuous Representation Vs Staged Representation (**Source:** Bourne & Tuffley, 2007: **Online**)

3.2.4.2 Staged Representation

Shrum (1999: **Online**) found that the staged representation is chosen when an organisation needs to enhance the complete process capability and observed several integrated process parts that require improvement. Cepeda (2005: **Online**) mention that stage representation makes use of maturity levels to measure an organisation's process improvement. Shrum (1999: **Online**) summarises the staged representation as an approach to determine process maturity level focus on the overall organisational process improvement. Cepeda (2005: **Online**) explains that this approach uses pre-determined process areas to define an organisation's improvement path.

According to Rungta (2007: **Online**), the stage representation matures an organisation as a whole. Shrum (1999: **Online**) found that in staged representation the summary elements are maturity levels with each maturity level having its own process areas, goals and practices as seen in Figure 3.6. Shrum (1999: **Online**) mention that the practices are guides on what to do to achieve the goals for those specific process areas.

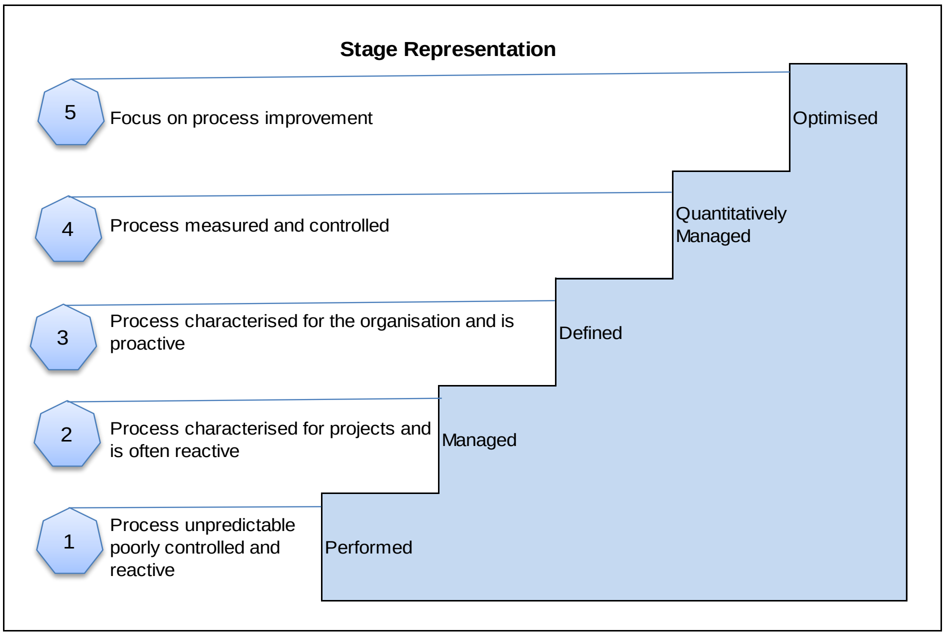


Figure 3.6: Maturity Models – Staged Representation (**Source:** Bourne & Tuffley, 2007: **Online**)

The last part of this section reviews the advantages of the two representations.

3.2.4.3 Advantages of Continuous and Staged Representations

Shrum (1999: **Online**) and Cepeda (2005: **Online**) find that each representation has its advantages. Table 3.3 provides a combined list of advantages for each representation as found by Shrum (1999: **Online**) and Cepeda (2005: **Online**).

Table 3.3: Advantage of using each Model Representation (**Source:** Own Source adopted from Shrum: 1999: **Online** & Cepeda, 2005: **Online**)

Continuous Representation	Staged Representation
Grants explicit freedom to select the order of improvement that best meets the organisation's business objectives	Enables organisations to have a predefined and proven path
Enables increased visibility into the capability achieved within each individual process area.	Builds on a relatively long history of use
Supports a focus on risks specific to individual process areas.	Case studies and data exist that show return on investment.
Affords a more direct comparison of process improvement to ISO 15504 because the organisation of process areas is derived from 15504.	Permits comparisons across and among organisations.
Allows the generic practices from higher capability levels to be more evenly and completely applied to all of the process areas.	Introduces a sequence of improvements, beginning with basic management practices and progressing through successive levels, each serving as a foundation for the next
Maximum flexibility for prioritising process improvement and aligning it with the business objectives.	Predefined and proven path with case study – reduce guesswork.
Enable increased visibility of improvement within process areas Quick wins can be easily defined to increase buy-in. Increases focus on risk specific to each process area	Focuses on organisational improvement
Improvement of processes can occur in different rates Less upfront investment required	Overall results summarised in a Maturity Level Provides familiar benchmarking capability

Considering the literature reviewed in this section, the author is of the opinion that capability precedes maturity.

3.3 OUTAGE PROCESS

This section examines the basic outage process within the context of a power station and:

- Review the outage process.
- Identify the critical elements of the outage process.

3.3.1 Define the outage process

The objective of this section is to understand the basic outage process in the context of power station. The review of the basic outage process seeks to:

- explains the basic outage phases; and
- reviews the Eskom outage process.

3.3.1.1 The universal outage process

The review of the basic outage process is derived from recognised international bodies involved in power generation, and includes Eskom’s definition on an outage.

Electric Power Research Institute (EPRI) (2006: **Online**), find that an outage process consists of three phases and starts long before the outage start date, and includes both budget and resource planning. Outage improvement is greatly depended on attention paid to the manner and timeliness of achieving set goals and objectives (EPRI 2006: **Online**).

The International Atomic Energy Agency (IAEA) (IAEA, 2002: **Online**) supports the view of EPRI (2006: **Online**), acknowledging that the outage process has three phases.

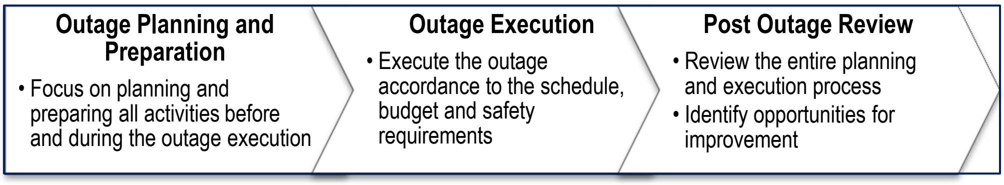


Figure 3.7: Universal outage process (**Source:** Own Source adopted from IAEA, 2002: **Online**)

The Eskom Outage process are in line with the IAEA (2002: **Online**) outage process and includes the three phase of an outage as illustrate in Figure 3.7. The review of the Eskom outage process follows.

3.3.1.2 Eskom outage process

This section briefly looks at the Eskom outage process and includes a summary of the process.

The Eskom outage process represented Figure 3.8, consists of the Planning phase, Execution Phase and the Post Outage Review phase (Eskom Internal PCM 32-1312). The Eskom Outage Management Department documented the outage processes in the Process Control Manuals (PCM). The PCM's documents the Outage planning, execution and post outage review. The PCM focus on the planning and execution of outages is the Conduct Planned Outages PCM (Eskom Internal Document, 2015: 32-1312).

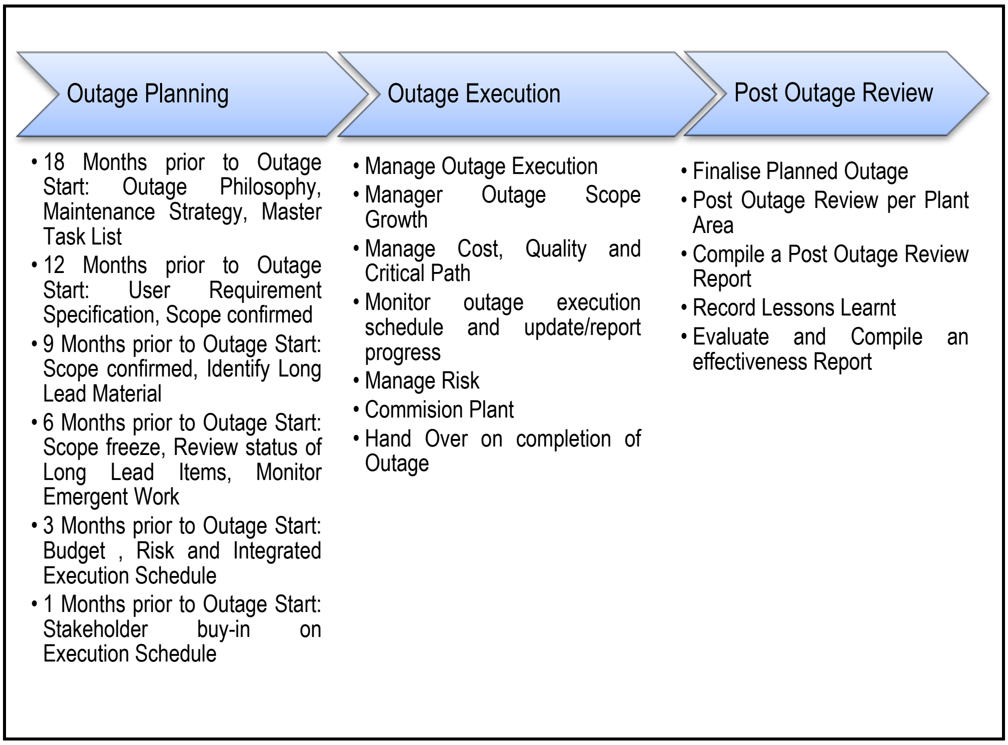


Figure 3.8: Eskom Outage Process (**Source:** Own Source adopted from Eskom Internal PCM 32-1312)

The planning phase includes Outage Readiness Reviews (refer to Chapter 2, section 2.4.2.2). Figure 3.8 indicate the pre-determined outage readiness reviews required by the Outage Planning PCM. Outage readiness reviews are conducted 18 Months prior to the start of the outage. Then again at twelve months, nine months, six months, three months and one month prior to the start of the outage.

The execution phase clearly state what should be managed during the execution of an outage and includes scope growth, managing the cost, quality and the critical path, monitoring outage execution and reporting on progress, risk management and commissioning.

The post outage review phase focuses on post outage reviews for each plan area, compile a post outage review reports, capture lessons learnt and compile an effectiveness report.

The following section identifies characteristics of a good outage process.

3.3.2 Critical elements in outage processes

This sections search for the characteristics for a good outage process, and look over literature commencing with the basic planning process.

According to Mauch (2010: **Online**), the planning process offers uniformity of purpose and direction of the actions required to accomplish the department goals. Holpp (1999: **Online**) mention that the guidelines for success in planning requires some measurement of the progress, identify difficulties, goal setting, decisions concerning actions, put the plans to work continuous evaluation of the situation and a focus on success.

Boutros and Purdie (2014: **Online**) found that advancing the objectives of an organisation requires some sort of structure plan, called strategic planning. The senior leaders, managers, and required process owners determine the strengths, weaknesses, opportunities and threats (Boutros & Purdie, 2014: **Online**).

The IAEA (IAEA, 2002: **Online**) provides a detailed description of the three phases of outages in some detail:

- **Outage Planning and Preparation:** Consists of all activities before and during outage execution and includes co-ordination of resource, regulatory, safety and technical requirements and scheduling.
- **Outage Execution:** Execute the outage accordance to the schedule, budget and good industrial safety performance, to ensure the next cycle is disturbance free.
- **Post Outage Review:** Review the entire process to evaluate the completed work and provide feedback to improve the next outages.

According to the IAEA (IAEA, 2006: **Online**), an outage is part of the normal operation of a power station and are integrated into the power station business processes.

The IAEA (IAEA, 2006: **Online**) recommend that a monitoring method for outages be used that tracks all critical and fundamental activities and due dates in every phase of the outage.

The outage process should meet the required business objectives if these characteristics are included. The following section focuses on outage planning.

3.4 OUTAGE PLANNING

The Outage Planning section focuses on the planning phase of the outage process and assimilates to the Juran's Quality Planning Phase, which is to define the scope, goals, objectives, processes and improvement actions. Say what you are doing to do. This section goes through:

- Quality planning.
- Outage organistion.
- Outage process readiness.
- Outage planning.
- Outage management plan.
- Scope development.

3.4.1 Quality planning

The objective of this section is to understand the quality planning process and identify the phases that enable quality improvement. The approach reviews various improvement approaches, identify, and compare similarities within the improvement phases. The review includes:

- Brief definition of Quality Improvement.
- Juran Trilogy.
- Quality Improvement by Plan, Do, Study, Act (PDSA) and Plan, Do, Check, Act (PDCA) Models.
- The Six Sigma (DMAIC) approach.
- Comparison of the above mentioned approaches.

3.4.1.1 Define quality improvement

This section briefly seeks definitions for quality improvement. The review considers definitions by a few authors starting with a view expressed by Juran and De Feo (2010: **Online**).

According to Juran and De Feo (2010: **Online**), defining and agreeing on the meaning of the word quality within an organisation assists in knowing how to manage "it". They further point out that if one can manage it, one can fulfill the customer requirements. The organisation cannot manage quality if it does not share a common meaning of the quality term (Juran and De Feo, 2010: **Online**).

Boutros and Purdie (2014: **Online**) explain that process or quality improvement is a continuous effort to enhance services, products and processes with the aim of meeting new goals and objectives. Grutter (2010: 285) defines process improvement as a systematic identification and removal of waste in a process. Gryna (2001: 51) describes quality improvement as verifying the need and mission of the improvement project, diagnosing the causes, and a providing solution. Juran and De Feo (2010: **Online**) mention that quality is a moving target with aim to the improvement process driven by a business plan which includes goals for improvement.

Boutros and Purdie (2014: **Online**) assert that the most vital element to successful process improvement is to ensure that participants are trained in their discipline, they understand the critical interfaces with other departments and understand the basic terminology. This approach helps in reducing communication gaps, while speeding up execution efforts. The World Health Organisation (2009: **Online**) found that the important principle underpinning quality improvement focused on quality throughout the entire process and not as something completed at the end of the line.

Grutter (2010: 288) identifies helpful techniques for process improvement and includes:

- Collection of information concerning what is really happening.
- Analysis of the information collected to comprehend the root causes.
- Recommends actions to correct causes.

The following section focuses on various quality improvement approaches starting with the review of the Juran Trilogy and its contribution to quality improvement.

3.4.1.2 Juran Trilogy

The focus in this section is on the Juran Trilogy. The review provides an overview of the Juran Trilogy and seeks to identify the elements included in the improvement phase.

Tcherpokov and Foster (2006: **Online)** found that the Juran Trilogy is a universal, systematic approach to quality. Tcherpokov and Foster (2006: **Online**) point out that the Trilogy has a universal application to any process and consists of three consecutive and logical activity groups, quality planning, quality control and quality improvement.

According to Juran (1999: **Online**), a number of projects executed during the 1980's and 1990's prove that quality improvement is applicable to the service industry, manufacturing industry, business and manufacturing processes, support activities and software and hardware industries. The quality improvement process is a structured approach and should be executed as improvement projects. The organisation will select a team to execute the projects. The project team should be suitably trained and have the required resources and equipment to execute the project.

De Feo and Juran (2014: **Online**) suggest that the Juran Trilogy holds the core managerial processes that an organisation requires to manage quality; planning, control and improvement. Tcherpokov and Foster

(2006: **Online**) support the view expressed by De Feo and Juran (2014: **Online**) and point out that the processes in the Juran Trilogy are performed by top and middle management.

Juran's Trilogy shown in Table 3.4 provides the details in the quality planning, control and improvement phases.

Table 3.4: Managing for Quality (**Source**: Defeo & Juran, 2014: **Online**)

Quality Planning	**Quality Control**	**Quality Improvement**
Establish Goals	Determine the control subjects	Prove the need with a business case
Identify who the customers are	Measure actual performance	Establish a project infrastructure
Determine the needs of the customer	Compare actual performance to targets and goals	Identify the improvement projects
Develop features which respond to customers' needs	Take action on the difference	Establish the project team
Develop process able to produce the product	Continue to measure and maintain performance	Provide the team with resources, training and motivation to Diagnose the causes and Stimulate remedies
Establish process controls		Establish controls to hold the gains
Transfer the plan to operating forces		

Tcherpokov and Foster (2006: **Online**), citing Juran and Gibbons further explain the Juran Trilogy:

- **Quality Planning:** Creating a process with the ability to meet the well-known objectives and to do so under operating conditions.
- **Quality Control:** The management process used to assess factual performance, comparing real performance to objectives and take action on the difference.
- **Quality Improvement:** Is a well thought out formation of positive adjustment, the realisation of unparalleled levels of performance.

The final task is to institute controls to maintain the gains. Juran (1999: **Online**) find that there is no mention of general improvement and pointed out that improvements take place project by project. Tcherpokov and Foster (2006: **Online**) emphasise the importance of the control phase and ascribe this responsibility to top and middle management.

The following section considers the Plan, DO, Check, Act (PDCA) cycle developed by Deming.

3.4.1.3 Plan, Do, Check Act (PDCA) Model

The review focuses on the PDCA model then evaluates and describes each phase the models.

Grutter (2010: 285) refers to Walter Shewhart as the one who originally proposed the Plan, Do, Check and Act (PDCA) cycle and Edward Deming is responsible for its further development. Many process improvement methods are based on the PDCA model. The South African National Standard (SANS 9001: 2008: **Online**) suggest the implementation of a process approach to develop, implement and improve quality management systems. The model for process-based quality management is the Plan-Do-Check-Act (PDCA) model (SANS 9001: 2008, **Online**).

The SANS 9001: 2008 (SANS 9001: 2008: **Online**) describe process steps of the PDCA model include:

- **Plan:** Establish the required processes and goals.
- **Do:** Carry out the process.
- **Check:** Measure and keep an eye on the process and product and assess it against the policy, objective and product requirement and report the result.
- **Act:** Take action that would continuously improve the process performance.

Wilson (2015: **Online**) agrees with Knowles (2012: **Online**), and contend that the Plan, Do, Check portion of the PDCA model adopts a scientific approach and enables continuous improvement when going into the Act stage of the model. Wilson (2015: **Online**) further explains that Act means a *thoughtful action* which includes careful consideration to act or not to act.

Wilson (2015: **Online**) conclude that the Act stage could focus on the results of the Plan, Do, Check stages or focus on the means (skills, techniques and tactics) used to achieve the results.

The following quality improvement approach also follows a structured approach and includes planning or defining, measurement, analysis and control to achieve quality improvement. The following section discusses the Six Sigma or DMAIC approach to quality improvement.

3.4.1.4 The Six Sigma (DMAIC) approach

The Six Sigma approach, like the Juran Trilogy and the PDCA model follows a structured approach to achieve improvement. The section reviews the Six Sigma approach and unpacks the DMAIC phases.

According to Cavinato, Flynn and Kauffman (2006: **Online**), the implementation of Six Sigma projects are called DMAIC; define, measure, analyse, improve and control. Grutter (2010: 278) explains that Six Sigma derive its name from the goal to achieve a high enough process capability so that the process variability is low enough for three standard deviations on both sides of the target value. Table 3.5 provides the requirements and brief explanation for each of the DMAIC phases.

Table 3.5: DMAIC Project Structure (**Source:** Own Source adopted from Cavinato, Flynn & Kauffman, 2006: **Online**)

DMAIC Phase	Phase Requirement
Define	Clearly define what needs to be improved
Measure	Measure the baseline performance of the process. Define the process flow Measure the process capability Evaluate the measurement system
Analysis	Analysis the data Development of an improvement plan
Improve	Improvement are made to the current process and measured for success
Control	A control plan is put in place to sustain improvements

The measurement phase in Table 3.5 in the Six Sigma approach enables the measurement of the process capability. According to Juran and De Feo (2010: **Online**), measurements were developed to enable senior managers to monitor the organisations ability to meet customer requirements and quality improvement. Juran and De Feo (2010, **Online**) resolve that managing for quality is the senior managers responsibility and certain responsibilities were not delegated.

Table 3.5 shows the analysis phase to include data analysis and the development of an improvement plan. This means that improvement requires planning and supports Wilson's (2015: **Online**) view of the requirement of *thoughtful action*. The last two phases of the DMAIC approach are the Improve and Control phases. The Improvement phase focuses on improvement of current processes and the measurement of success. The Control phase is developed and put in place to ensure that the improvements are sustained.

The review of the Six Sigma approach to quality improvement follows a structured approach much similar to the Juran Trilogy and PDCA model. The following section considers the Six Sigma (DMAIC), Juran Trilogy, and PDCA approaches described in ISO 9001:2008 and compares the models to identify similarities.

3.4.1.5 Comparison of the above mentioned approached

This section compares the quality improvement approaches discussed in the previous sections to identify the phases of quality improvement.

The review identifies the phases of each approach and draws comparisons and similarities of the three approaches. Table 3.6 identifies and compares phases for quality improvement to identify any common elements to quality improvements.

Table 3.6: Comparing Quality Improvement Phases (**Source:** Own Source)

Improvement Approach	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5
Juran Trilogy	Motivate the need for a project & define scope	Diagnose the causes	Simulate the remedy	Establish the controls to maintain the gains	
Six Sigma (DMAIC)	**Define** Clearly define what needs to be improved	**Measure** Measure process baseline performance Define process flow Measure process capability Evaluate measurement system	**Analysis** Analysis data Develop an improvement plan	**Improve** Improvement are made to the current process and measured for success	**Control** Put a control plan in place to sustain the improvement
PDCA	**Plan** Establish required processes & objectives	**Do** Implement the process	**Check** Monitor & measure against requirements Report results	**Act** Take action to continuously improve the process performance	

The improvement approaches in Table 3.6 identified a common theme of Plan, Do, Check and Improve in the three approaches. Table 3.7 summarises the general theme of Juran Trilogy, Six Sigma and PDCA approaches. The Plan, Do, Check, Improvement approach is shown in Table 3.7.

Table 3.7: Plan-Do-Check-Improve Model (**Source:** Own Source)

Improvement Approach	Plan	Do	Check	Improve
PDCI	Define the scope, goals, objectives, process and actions	Implement the predetermined actions and record outcome against goals and objectives	Analyse the results, determine the effectiveness against of the action compared to the goals and objectives	Establish suitable controls to sustain the improvement gained while seeking new improvements opportunities.

Goldstein's (2006: **Online**) statement state; say what you going to do, do what you said you will do, prove that you did it and then improve it.

The author's rendition of Goldstein's statement in the PDCI context reads:

- **Plan:** Say what you going to do.
- **Do:** Do what you said you going to do.
- **Check:** Prove that you did it.
- **Improve:** Improve it.

The important elements required to achieve process improvement follows a structured approach, have clean goals and objectives, measure and analyse the results, identify, establish and implement control to maintain the improvement.

3.4.2 Outage organisation

The literature published on the outage process is limited. From the literature that was sourced the following significant conclusions can be drawn.

Feigenbaum (**s.a.**, **Online**), states that an organisational structures within a company defines the roles and departments that make up the function and show how the organisations fit together. Feigenbaum (**s.a.**, **Online**) find that understanding the organisational structure allows staff to perform their roles, feel secure and enable people to work together. Feigenbaum (**s.a.**, **Online**) mention that job descriptions help staff identify the scope, limits and functions of their roles and clearly indicate what tasks and outcomes are their responsibilities. Organisation structures aim to ensure that every function and task has someone allocated to perform the task, minimising the possibility of duplication and unnecessary overlap (Feigenbaum, **s.a.**: **Online**).

Bashir (2011: **Online**), mentions that an organisation should have administrative procedures that define the organisation, responsibilities and processes for preparing, executing and cost of outages. Kovan (2005: **Online**) found a number of people and organisations within the power station working together to plan an outage. Bashir (2011,

Online) mention that the required interfaces between the different groups and contractors be defined to ensure focus on safety, quality, scheduling activities and coordination is maintained between the applicable stakeholders.

Bashir (2011: **Online**) suggests that the key outage management staff be identified and appoint 11 months prior to the start of an outage.

Kovan (2005, **online**) mentions that the groups that form part of the outage organisation range from and include support groups that include the unit managers and specialists, outage control and coordination, operating, training, modifications, quality control, maintenance planning, projects and design, mechanical, instrumentation and control and electrical maintenance and area services and logistics. Bashir (2011: **Online**) explains that the Outage execution organisation should be established five to six months before the start of the outage.

Kovan (2005: **Online**), emphasise that the planning, coordinating and monitoring of outages are the responsibility of the plant personnel. Kovan (2005: **Online**) provides a detailed diagram known as the *Controlling model* that provides person's responsible and their area of responsibility along with an organisational chart with the same details as the *Controlling model*. Kovan (2005: **Online**) explains that the outage meetings are chaired by the Outage and Project Group that involves about 25 to 30 people. These people represent technology, safety, operations, maintenance and security.

The important element of an organisation is that every person should understand their role and responsibility. Hessler (2011: **Online**) point out that management personnel with solid outage experience are in short supply and mentioned two reasons. The first is due to the retirement of older managers along with a lack of successors to create a new pipeline of possible replacement for older manager. The second reason is the short supply is due to experienced staff moving on to seek greener pastures.

Hessler (2011: **Online**) maintain that the organisation should ensure that the person charged with executing the outage should have the skill level.

3.4.3 Outage process readiness

As stated by Boutros and Purdie (2014: **Online**), a process is set of activities that uses people, tools and systems to convert inputs into value-added outputs. Gryna (2001:143) defines a process as a group of actions that transforms inputs into results or outputs. Singh and Singh (2015: **Online**) observe that a process approach is when the desired result or outcome is realised more effectively when related actions and resources are managed as a process. Defoe and Juran (2014: **Online**) explain that a business process includes the logical organisation of information, equipment, energy, materials and people into work actions intended to yield a necessary product or service.

3.4.3.1 International outage readiness practice

This section briefly explores Outage Readiness practice, identifies when outage planning should comment and determine the purpose of the Outage Readiness Index.

Drew (2015: **Online**) point to an Outage Readiness Index (ORI) as a instrument to examine the readiness and progress of the outage one year prior to when the outage starts. Hessler (2011: **Online**) refers to an approach to determine outage readiness by scoring a process to aid in establishing the potential success. Hessler (2011: **Online**) continues by stating that this is done by identifying the items critical to the outage start and rating its preparedness. The items are weighted according to importance and their impact on the outage readiness is calculated based on the individual rating with a ORI target score is 84% (Hessler ,2011: **Online**). Sanders and Cook (**s.a**. **Online**) see the readiness review as an effective method to ensure that all employees involved in outage planning and execution understand the outage goals and the plan set out to achieve the goals. Drew (2015: **Online**) point out that a good ORI process reduces the number of surprises by ensuring that actions are complete on time and during discussions the identified risk is evaluated.

Sanders and Cook (**s.a**. **Online**) recommend that the supervisors and the contractors be included in the readiness reviews as it lays the foundation for a successful outage. Drew (2015: **Online**) point out that progress meetings should be planned, responsibilities should be assigned and the delivery schedule should be reviewed.

3.4.3.2 Eskom's outage readiness approach

The Outage Readiness Indicator (ORI) is a standard approach to evaluate the readiness of an outage at predetermined stages prior to its start (Eskom Internal Standard 240-47532542: 2013:4).

According to the Eskom Outage Readiness Standard (Eskom Internal Standard 240-47532542: 2013:4), the ORI is defined as the standard approach to evaluate the readiness of an outage at predetermined stages prior to its start. The outage planning process starts 24 months prior to the start of an outage (Eskom Internal Standard 240-47532542: 2013:4). The ORI standard further establishes a 90 percent ORI readiness score prior outage execution (Eskom Internal Standard 240-47532542: 2013:4). Hessler (2011: **Online**), concludes that a good outage readiness is the key to achieving a successful outage.

3.4.4 Outage planning

According to the IAEA (2006: **Online**), an outage management indicator should be used to continuously monitor and evaluate the outage planning and execution processes. IAEA (2006: **Online**) found that a planned outage are effective when it meets amongst other requirements: no significant unscheduled events, least impact on personnel, optimising the work scope, adherence to the schedule, no re-work, and effective usage of material, human and financial resources.

McMahon (2015: **Online**) found that experienced contractors could assist in pre-outage planning to ensure that activities are managed well.

McMahon (2015: **Online**) point out that contractors can add further value to the pre-outage planning if they are thorough and develop predictable work plans.

When considering the planning of outage activities Bashir (2011: **Online**) recommends that the following assessment be made. Assess the required manpower, the activity duration, spares and materials or consumables required for the task, cost, procedures, training, special tools and equipment as well as pre- and post-maintenance testing, foreign material exclusion (FME) and temporary services and facilities. Bashir (2011: **Online**) also mentions the importance of Quality Assurance audits and surveillance activities.

Kovan (2005: **Online**) mentions monthly outage meetings which starts ten months prior to the start of the outage. These meeting are chaired by the head of Outages and Projects and involves about thirty people representing the main units, technology or engineering, safety, operating, maintenance and security. The content of these meetings include:

- Discuss the main work with the people in charge.
- The planning in all maintenance groups and the degree of readiness of the design work.
- Status of the manufactured spare parts.
- Special tools and equipment.
- Selection and availability of contractors.
- New work orders pertaining to the critical path or activities affecting the total outage duration.
- The following year’s outages.

Spring (2010: **Online**) supports the view of Drew (2010: **Online**), finding that the site team and its internal support should start with outage planning a least 12 months in advance. Spring (2010: **Online**), mentioned that some outages types may require outage planning to start up to 24 months prior to the execution date. Bashir (2011: **Online**), expresses the opinion that outage preparation work should start 12 months before the outage starts. The IAEA (2006: **Online**), found that an important element of outage planning is identifying and monitoring pre-outage indicators.

3.4.5 Outage management plan

Hessler (2011: **Online**) highlight the following challenges experienced during the outage planning process:

- **Pre-Outage Milestones:** The milestone verifies if the scope cut-off dates were established and adhered to, if the budget is approved, if lessons from previous outages were reviewed, does the schedule include resources and are the activity logic ties completed and were the outage readiness reviews completed.
- **Labour Resources:** The labour forming the heart of an outage in fossil and nuclear power station outages and requires very specialised skills.

3.4.6 Scope development

EPRI (2006: **Online**) explains that the anticipated scope for inclusion into an outage ranges from inspections, testing and operations date collection, monitoring the performance of equipment, corrective action, cost and follow up reports, retaining and accessing historical data and the initial planning steps for the coming outage.

Bashir (2011: **Online**) and Shahi (**s.a.**: **Online**) share the view that the outage scope should be frozen six months prior to the start of the outage. Drew (2015: **Online**), also mentions a best practice; where every year starts with a Maintenance Technology Meeting where the outage scope of 43 power plants are discussed for the outages due in the next year and a budget allocated.

Sanders and Cook (**s.**a., **Online**) say that effective, data-driven preventative maintenance (PM) programs leads to more reliable plant performance and reduces emergent work that requires repairs. Shahi (**s.a.**: **Online**) find that the scope which should be derived from the Work Orders with Task List, ought to clearly define the labor, material, equipment and permit that would be required. IAEA (2006: **Online**) point to scope of outage work as a possible indictor to measure during the planning phase and includes work requests, work orders and packages and permits to complete the work. (Shahi, **s.a.**: **Online**) observes that the collections of Work Orders and Task Lists are used to calculate the budget. Shahi (**s.a.**: **Online**) recommend that all stakeholders be involved early in the process to minimise any risk while reducing changes to the scope.

3.5 OUTAGE CONTROL

The Outage control section focuses on the execution phase of the outage process and assimilates to the Juran's Quality-Control Phase. Do Phase focuses on implementing the predetermined actions and measurement of the outcome. Do what you said you going to do and prove it.

McMahon (2015: **Online**) contest that effective execution of outages is challenging and requires years of experience and the proper resources ensure that the outage work stay within budget and on schedule. The IAEA (2006: **Online**) emphasise the importance of tight controls of the work and good communication between the team member when an outage starts. The section reviews:

- Outage schedule.
- Scope management.
- Outage progress monitoring.
- Outage work orders.

3.5.1 Outage schedule

McMahon (2015: **Online**) point to an old project management adage that says '*plan the work and work the plan*'. This approach to *plan the work* then *work the plan* is important to ensure an outage is completed on time. McMahon (2015: **Online**), finds the practice simple but difficult.

Bashir (2011: **Online**) point out that the level 1 and 2 outage execution schedule should be developed one month prior the start of the outage. The Level 1 schedule provides the detailed sub-activities for the critical path while the Level 2 schedule provides the implementation schedule for all the outage jobs, which includes all the maintenance activities, modifications and tests. The required pre-outage work should be completed 15 days prior the start of the outage (Bashir, 2011: **Online**).

According to Canada's Nuclear Regulator's Maintenance Program for Nuclear Power Plants (NPP) of 2012 (2012: **Online**), all the groups are required to review the outage plan in the areas they are responsible for. McMahon (2015: **Online**) supports the view by Canada's Nuclear Regulator's Maintenance Program for NPP highlighting the importance of effective partnerships between the plant team and the contractor.

Kovan (2005: **Online**) considers process logic as a basic priority of outage planning. The process logic is used to devise effective overall outage duration. The process logic diagram shows the outage process with all the outage activities and can assist staff to see that the work is completed at an appropriate time.

3.5.2 Scope management

According to the IAEA (2006: **Online**), work scope stability is a metric to measure work planning effectiveness. Kovan (2005: **Online**) presents a practice used in Loviisa Power Plant (USA) when problems occur.

If a problem poses a threat to the outage or is so significant that the line organisation cannot resolve it, the Outage Support Group gets involved. This is a multi-disciplined group focused on problem solving.

3.5.3 Outage progress monitoring

According to EPRI (2004: **Online**), *How smoothly the outage progress will be a reflection of how well it was planned*. The outage execution indicators assess the outage progress and monitor the schedule adherence while this technique enables effective outage management and decision-making (IAEA, 2006: **Online**).

Bashir (2011: **Online**) point out that measuring outage progress should include:

- Daily outage coordination meetings.
- Daily planning meetings.
- Daily progress meetings.
- Weekly progress meetings.

Canada's Nuclear Regulator's Maintenance Program for Nuclear Power Plants of 2012 (2012: **Online**), recommends that the organisation ensure that effective communication is exercised between the work groups. The IAEA (2004: **Online**) propose daily meetings and action lists as a means to coordinate work. The outage manager should conduct the meeting and the planning group should maintain the action list (IAEA, 2004: **Online**).

Kovan (2005: **Online**) shares a practice used at Loviisa Power Plant; meetings are held twice a week and involve the same people that were involved in the outage-planning phase. During the meetings the actual conditions on the plant are compared to the outage process logic and the main work progress is reviewed. The line managers which include operations, mechanical maintenance, instrumentation and control and electrical provide short explanations in response to the outage process logic and an update of the progress of the work orders that have been issued, finished and not started. Allowance are made for the review of the work and schedules.

Bashir (2011: **Online**) also recommends that the outage schedule should be updated on a daily basis and a three day rolling schedule be issued daily. Kovan (2005: **Online**) mention that all preventative and corrective maintenance as well as periodic testing should be completed within a specific scheduled period.

3.5.4 Outage work orders

According to the Canada's Nuclear Regulator's Maintenance Program for Nuclear Power Plants (2012: **Online**), maintenance activities should be evaluated to ensure that the relevant maintenance activities are complete and that the work is completed by appropriately qualified staff.

Kovan (2005: **Online**) found that the main activities in an outage are made up of work packages. Time information in the work packages is transferred to the work order system; this ensures that all outage activities have planned start and finish dates. When the work packages are completed, filed in the computerised maintenance management system. Kovan (2005: **Online**) explains that all work orders are checked and printed along with the work package isolation requirements.

3.6 OUTAGE IMPROVEMENT

The Outage Improvement section focuses on the improvement phase of the outage process and assimilates to the Juran's Quality-Improvement Phase. The Improvement Phase focuses on the analysis the results to determine its effectiveness and the establishment suitable controls to sustain the improvement gains while seeking new improvement opportunities. The review focuses on:

- Post outage reviews.
- Outage risk.

3.6.1 Post outage review

According to the IAEA (2006: **Online**), the post-outage reviews are applied to the entire outage process with the aim to recognise and consider likely risks in future outages.

Bashir (2011: **Online**) put emphasis on outage follow-up experience feedback reports from the work organisations and the contractors, critique meetings that captured problems encountered and lessons learnt. McMahon (2015: **Online**) found the benefits from a post outage review on completion of the outage when the contractor and the outage team reviews the performance indicators and identify good practices and areas for improvement. McMahon (2015: **Online**) explains that both parties will gain a significant advantage in future outages when they incorporate good practices and address the areas for improvement.

Bashir (2011: **Online**) point out information that should be included in an outage report and includes:

- The outage preparation and execution,
- outage job statistics, major work completed, compare planned versus achieved outage goals,
- objectives, critical path milestone,
- major problems experienced and the corrective actions taken; and
- any good practices and lessons learned.

Kovan (2005: **Online**) recommends that the experience and lessons learned are collected and captured in a report directly after every outage to provide information and feedback required to update the Computerised Maintenance Management System (CMMS).

Canada's Nuclear Regulator's Maintenance Program for Nuclear Power Plants (2012: **Online**) assert that the organisation should establish an assessment process to review and continuously improve the maintenance program to ensure effectiveness of the maintenance strategy and integrate any improvement into the maintenance-training program.

3.6.2 Outage risk

According to Canada's Nuclear Regulator's Maintenance Program for Nuclear Power Plants (2012: **Online**), activities that form part of the outage planning include developing written contingency plans to manage recall times. According to Hessler (2011: **Online**), outage risk assessment is not only an improvement tool but can be used as an outage readiness indicator.

Hessler (2011: **Online**) employ a formal, documented question and answer process. The team meets several months prior to the start of the outage for a period of up to two days to consider a generic list of outage risks or obstacles. With the assistance of a trained facilitator, the team considers the outage risk and brainstorm to identify possible issues and then capture the risks and issues in a document, considers its impact, and completes a severity and probability analysis raking the issues. The issues are identified during the team meeting is addressed one at a time.

A mitigation plan is developed detailing each issue and a specific person selected to take ownership for resolving the issue. The owner provides a target date for resolution of the issue. The team repeats the assessment process before the outage starts verifying that the identified issues were resolved or that the issues have a workable mitigation plan.

3.7 MEASUREMENT INSTRUMENT TO DETERMINE OUTAGE MATURITY LEVEL

This section concentrates identifying a measurement instrument to determine the outage process maturity and focus on:

- the Business Process Management Maturity Model,
- the Maintenance Planning and Scheduling Maturity Matrix; and
- Outage Management Maturity Framework.

3.7.1 Business Process Maturity Model

The Business Process Management Maturity Model in Figure 3.9 has five maturity levels known as the Stage and six elements known as the Factor and Scope (Rosemann and de Bruin: **s.a.**, **Online**). The Stage describes the process maturity levels and the Scope comprises the information on the organisation, its divisions and a time element. This model permits for analysis across the models factors and the stages as well as the scope. Therefore, the maturity level of each element can be presented individually, or per division within the organisation and at a particular point in time. The Scope of the model focuses on Strategic Alignment, Governance, Methods, Information Technology or Information Systems, People and Culture. The Business Process Management Maturity Model then presents the maturity level of the organisation based on the models Scope.

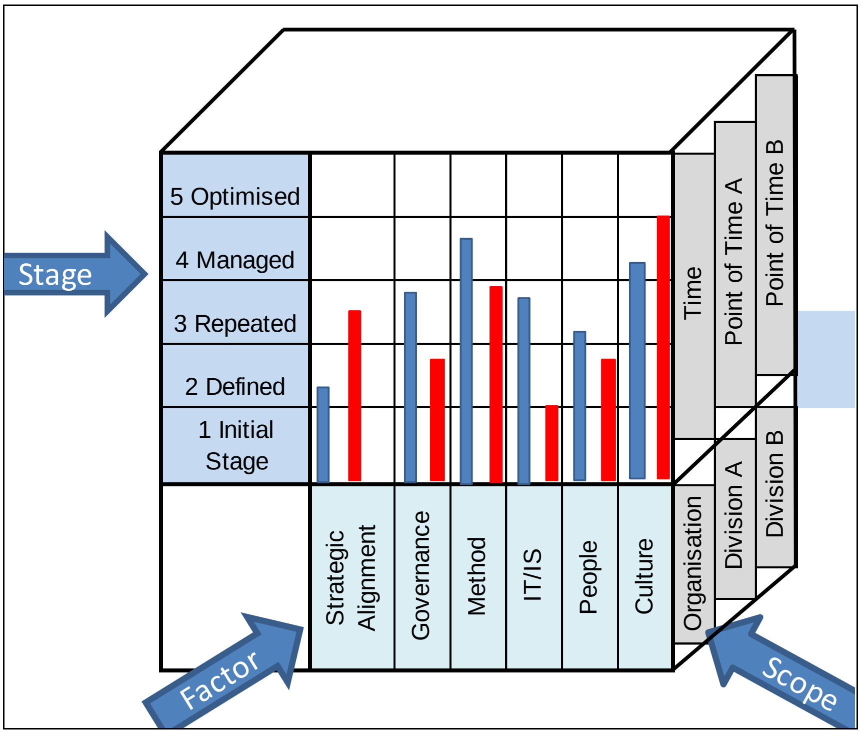


Figure 3.9: Business Process Management Maturity Model (Source: Rosemann and de Bruin **(s.a., Online)**

While the scope of the Business Process Management Maturity Model does not address an outage process, the model's structure proves valuable as it presents the maturity level across various departments at a specific point in time.

3.7.2 Maintenance Planning and Scheduling Maturity Matrix

Smith (2013: **Online**) developed the Maintenance Planning and Scheduling Maturity Matrix, a grid type maturity model when applied to determine the Planning and Scheduling maturity. The Maintenance Planning and Scheduling Maturity Matrix have five levels and three main elements (See Appendix C):

- Outage planning
- work control; and
- metrics / scorecards.

The three main elements have sub-elements as shown in Table 3.8. The Outage Planning element is divided into four sub-elements; the Work Control and the Metrics/Scorecard element both have six sub-elements. A detail of the Planning and Scheduling Maturity Matrix is in Appendix B.

Table 3.8: Maintenance Planning and Scheduling Maturity Matrix (**Source:** Own Source adopted from Smith, 2013: **Online**)

Main Element	Outage Planning	Work Control	Metrics/Scorecard
Sub-Elements	➢ Outage Organisation. ➢ Single Outage Plan. ➢ Risk Analysis. ➢ Outage Processes.	➢ Work Requests. ➢ Work Order Prioritisation. ➢ Work Order Usage. ➢ Work Order Status. ➢ Work Order Close Out. ➢ Backlog Management and Measurement. ➢ Work Order History.	➢ % Planned vs Unplanned ➢ Ready Backlog ➢ Wrench/Tool Time ➢ % Estimated vs Actual Hours ➢ % Available Labor Scheduled ➢ Schedule Compliance

The Maintenance Planning and Scheduling Maturity Matrix developed by Smith (2013: **Online**), focuses on the elements seen in Table 3.8.

The literature review identified additional characteristics important to outage planning as found by Kister (2009: **Online**), Shahi (**s.a.**: **Online**), Spring (2010, **Online**), Drew (2015: **Online**) and Sanders and Cook (**s.a**., **Online**). The following section includes the findings from the literature review as inputs to developing an Outage Management Maturity Framework.

3.7.3 Outage Management Maturity Framework

The aim of this section is to develop an Outage Management Maturity Framework (OMMF). The framework is based on Smith's (2013: **Online**) Maintenance Planning and Scheduling Maturity Matrix and the Business Process Management Maturity Rosemann and de Bruin (**s.a.**, **Online**).

The author expands on Smith's framework by including the outage characteristics seen as important by Kister (2009: **Online**), Shahi (**s.a.**: **Online**), Spring (2010, **Online**), Drew (2015: **Online**) and Sanders and Cook (**s.a**., **Online**). The Outage Management Maturity Framework seen in Figure 3.10 has five levels of maturity and twelve elements.

Each element has a detailed description at each level of maturity (see Appendix A).

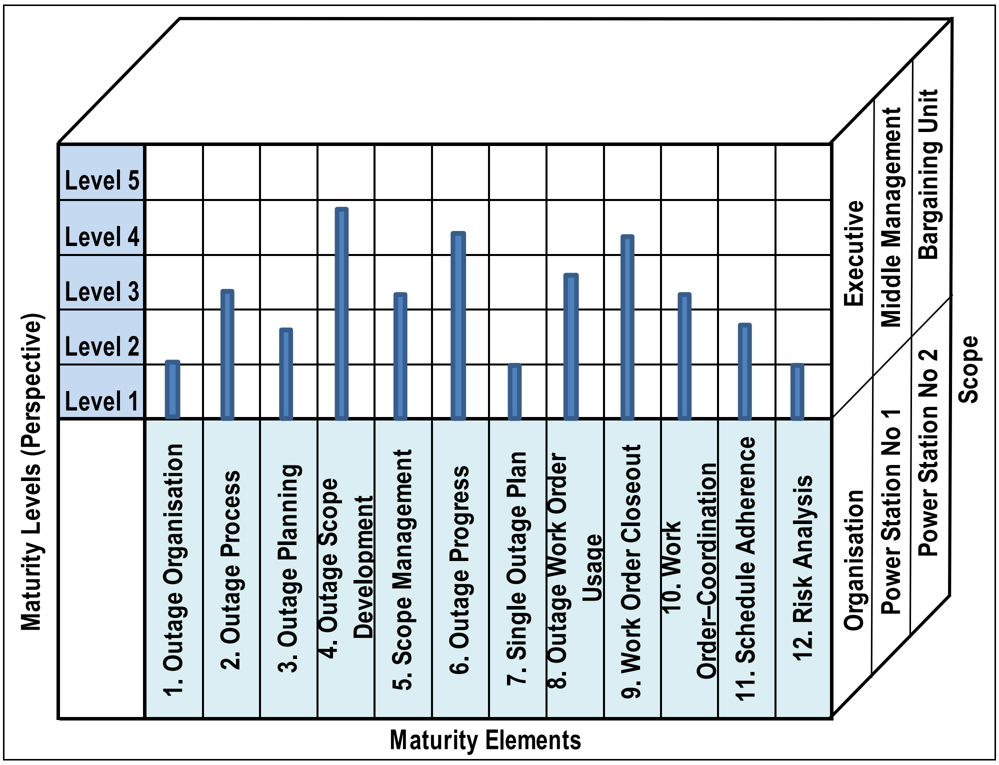


Figure 3.10: Outage Management Maturity Framework (**Source:** Own Source adopted from Rosemann and de Bruin (**s.a.**, **Online**) and Smith, 2013: **Online**)

The Outage Management Maturity Framework is made up of three sections. The Framework presented in Figure 3.10 is the first part. The second section is the Outage Management Maturity Framework Criteria shown in Appendix A and the final section is the survey questionnaire with determined questions (Section 4.6) and statements based on the context of Appendix A. It is vital to state that the maturity level of the outage process is determined based on the staff's perception.

The OMMF is the instrument developed assist the outage management organisation to determine the current maturity level of the outage management process. The initial assessment will enable the Outage Management Department to determine baseline maturity level. The OMMF enables improvement of the organisation in the twelve elements by investigating the elements with low maturity levels, identify the gaps that if closed will move the process to the following maturity level, develop a corrective action plan, implement actions and reassess the element to verify increased maturity. Tables 3.9 to 3.20 provide the detail for each of the twelve maturity elements.

Table 3.9 focuses on the Outage Organisation and seeks to determine if the outage organisation is fully integrated, roles and responsibilities defined, the organisation is working as a team, adhering to processes and checks for evidence of seamless communication and decision-making.

Table 3.9: Outage Organisation (**Source:** Own Source adopted from Smith, 2013: **Online**)

Element	Level 1 – Not Engaged	Level 2 – Experimenting	Level 3 – Enlightened	Level 4 – Good Practice	Level 5 – Best Practice
1. Outage Organisation	No formal outage organisation defined. Decisions regarding outages are made by individuals, independent of the big picture.	Outage leader implied by job title, but authority and centralisation of communication and leadership not recognised. Still a high degree of individual decision making with no coordination to the big picture	Outage leadership role defined with responsibilities for communication and decision making. Organisation not further defined. Leader is tied to a high number of decision making, resulting in slow progress and independent decision making with no coordination to the big picture	Formal Outage organisation with responsibilities defined for areas such as materials management, safety, mobile equipment, contractor interface and overhaul outage leadership. Team still challenged with communication gaps, delaying decisions and progress	Fully integrated outage organisation with specific roles and responsibilities defined. Clear evidence that this team works in a cooperative manner and adhere to processes. Communication and decision making is largely seamless

Table 3.10 focuses on Outage Processes and conclude if the outage processes are established and adhered to, outage readiness review process is implemented with roles and responsibilities defined and adhered to and improvement is evident over a period of time.

Table 3.10: Outage Process (**Source:** Own Source adopted from Smith, 2013: **Online**)

Element	Level 1 – Not Engaged	Level 2 – Experimenting	Level 3 – Enlightened	Level 4 – Good Practice	Level 5 – Best Practice
2. Outage Process	No formal process for outage planning, Resources allocation as "just-in-time" immediately prior to outage. Outage readiness reviews does not form part of the planning process. Greatly diminished outage performance.	An outage process established and cut-off dates have been established, but cut-off dates are not enforced. No formal Outage readiness review process but informal reviews are completed on an adhoc basis. Outage performance is poor, organisation struggles to recover outages	Formal outage process established and routinely adhered to, covering only critical elements of outage planning process – Identification, Prepare and execute. Formal Outage Readiness review is part of the planning process and adhered too some times. The Outage Readiness Reviews only includes those directly impacted.	Level III and Formal Outage Readiness review process established, with review due dates established and adhered too. The Outage readiness review involves the entire organisation	Level IV and Heavy reliance on the Outage readiness review element with lessons learned integrated into future outages. The Outage Readiness Reviews leads to a measurable and quantitative improvements to outage performance over time. Formal Outage Readiness review process established, with responsibilities identified and review due dates established and adhered too.

Table 3.11 focuses on Outage Planning and establish if the outage planning starts 24 months prior to the outage start utilise a standard outage management plan with clear roles and responsibilities and if the organisation adheres to the outage management plan.

Table 3.11: Outage Planning (**Source:** Own Source adopted from Smith, 2013: **Online**)

Element	Level 1 – Not Engaged	Level 2 – Experimenting	Level 3 – Enlightened	Level 4 – Good Practice	Level 5 – Best Practice
3. Outage Planning	No or very little outage planning done. Outage Planning 3 months prior to the start of the outage date	Some outage planning done, but no Outage Management Plan developed or used to plan outages. Outage Planning starts 3-6 months prior to the start of the outage date	Outage planning follows a standard outage management plan (roles and responsibilities are not clearly specified). Outage planning starts 12 months prior to the start of the outage date.	Outage planning starts 18 months prior to the start of the outage date. Uses a standard outage management plan with clear roles and responsibilities for all stakeholders established, and mostly adhere too.	Outage planning starts 24 months prior to the start of the outage date. Uses a standard outage management plan with clear roles and responsibilities for all stakeholders are established and adhered too.

Table 3.12 focuses on Outage Scope Development and confirm that the scope development consider maintenance programs, corrective maintenance, inspection reports are used as part of scope development, engineering programs, modifications and lessons learnt.

Table 3.12: Outage Scope Development (**Source:** Own Source adopted from Smith, 2013: **Online**)

Element	**Level 1 – Not Engaged**	**Level 2 – Experimenting**	**Level 3 – Enlightened**	**Level 4 – Good Practice**	**Level 5 – Best Practice**
4. Outage Scope Development	No basis for outage scope	Outage scope developed based on previous outage scope.	Based on Corrective Maintenance, Preventative Maintenance Programs and Inspection Reports.	Preventative Maintenance Programs, Corrective Maintenance, Inspection Reports and Modifications Program	Input Maintenance Programs, Corrective Maintenance, Inspection Reports, Engineering Programs and Modifications Program, lessons learnt

Table 3.13 focuses on Outage Progress and establish if an Enterprise Resource Planning system is used, captures actuals, real time updates are obtained and that the schedule is used to report actual progress as well as a work control tool.

Table 3.13: Scope Management and Outage Progress (**Source:** Own Source adopted from Smith, 2013: **Online**)

Element	**Level 1 – Not Engaged**	**Level 2 – Experimenting**	**Level 3 – Enlightened**	**Level 4 – Good Practice**	**Level 5 – Best Practice**
5. Scope Management and 6. Outage Progress	Verbal feedback on Outage progress updates provided weekly. No scope management process in place.	Verbal feedback on Outage progress updates provided daily. Scope management process in place but not adhered too.	Verbal progress feedback on Outage progress provided at the end of each shift. Scope management process in place and adhered too.	Enterprise Resource Planning (ERP) systems (captures actual progress performance data i.e. cost and hours worked). Scheduling tools is used to scope and accurately capture start and finish information.	Level 3 and Real time updates per shift. Schedule is used to report actual progress and to control work.

Table 3.14 focuses on a Single Outage Plan and ascertain the level of detail in the outage plan, checks if the plan is communicated and understood across the organisation and identify schedule conflicts.

Table 3.14: Single Outage Plan (**Source:** Own Source adopted from Smith, 2013: **Online**)

Element	Level 1 – Not Engaged	Level 2 – Experimenting	Level 3 – Enlightened	Level 4 – Good Practice	Level 5 – Best Practice
7. Single Outage Pan	Outage plan not formal or published. Outage work is executed using informal lists. Multiple plans for the outage exist (maintenance, engineering, operating)	Single outage plan developed in a scheduling tool, but quality of the plan is severely lacking. Plan consists largely of simple work lists developed with inadequately detailed job plans. Knowledge of plans resides largely with maintenance leaders	Single outage plan developed cooperatively in a scheduling tool, with input and oversight from all affected disciplines and no critical path identified. All jobs are considered equal. No consistent view on priority.	Level III + critical path of the outage defined and lower priority jobs arranged around it. The schedule enjoys a higher degree of understanding across the organisation.	Level of detail on the plan is supported by hour-to-hour breakdown. Plan is communicated clearly across the organisation and universally understood. Schedule conflict between task are very rare.

Table 3.15 focuses on Work Order Usage during and Outage and verify if tasks have individual work orders and if work orders are created for emergent work additional work.

Table 3.15: Work Order Usage during Outage (**Source:** Own Source adopted from Smith, 2013: **Online**)

Element	Level 1 – Not Engaged	Level 2 – Experimenting	Level 3 – Enlightened	Level 4 – Good Practice	Level 5 – Best Practice
8. Work Order Usage During Outages	Work order rarely or never used	Task specific work orders are rarely used.	Task specific work orders are used for routine outage work. Reactive /Emergent work is covered under blanket work orders	All proactive and reactive jobs have individual work orders. Repairs/follow-up work performed under parent work order or PM work order.	All proactive and reactive jobs have individual work orders. Emergent and additional work receive a separate follow-up work order.

Table 3.16 focuses on Work Order Closeout and determine if the required detail are captured when work orders are close out, work orders are raised for follow up work, and if 90% of the work orders have some type of written feedback provided during the same shift.

Table 3.16: Work Order Closeout (**Source:** Own Source adopted from Smith, 2013: **Online**)

Element	Level 1 – Not Engaged	Level 2 – Experimenting	Level 3 – Enlightened	Level 4 – Good Practice	Level 5 – Best Practice
9. Work Order Closeout	When the work is complete, work orders remains in an open status for a long periods of time. No parts codes identified. Little or no feedback provided and no coordination delays recorded.	Work orders are closed with some part codes identified. Coordination delays know but not recorded. Verbal feedback at best, but poor performance.	Work orders are closed with part, some problems, and some reason codes identified. All coordination delays greater than 60 minutes recorded. Written feedback provided on less than 50% of work orders	Work orders closed with all part codes and some problem identified and some reason codes identified. All coordination delays over 30 minutes recorded. Written feedback on more than 50% of work	Work orders are closed with all part codes and problem identified as well as most reason codes identified. Required follow-up work is noted and new work order created. More than 90% of all work orders have some form of written feedback provided on the same shift.

Table 3.17 focuses on Outage Lessons Learnt and if the lessons learnt are captured in an information management system, shared throughout the organisation and cycled back into the planning for future outages.

Table 3.17: Outage Lessons Learnt (**Source:** Own Source adopted from Smith, 2013: **Online**)

Element	Level 1 – Not Engaged	Level 2 – Experimenting	Level 3 – Enlightened	Level 4 – Good Practice	Level 5 – Best Practice
I10 Outage Lessons Learnt	Lessons Learnt are not recorded	Discuss lessons Learnt, but are not documented or poorly documents.	Lessons Learnt are discussed and accurately documented, but not cycled into future outage planning.	Level 3 and Lessons Learnt are captured in an information management system and shares throughout the organisation	Level 4 and lessons learnt are cycled into the planning of future outage

Table 3.18 focuses on the Percentage Planned work versus Percentage Unplanned Work and indicate what percentage work is the work planned and which percentage of the work is unplanned.

Table 3.18: % Planned vs % Unplanned Work (**Source:** Own Source adopted from Smith, 2013: **Online**)

Element	Level 1 – Not Engaged	Level 2 – Experimenting	Level 3 – Enlightened	Level 4 – Good Practice	Level 5 – Best Practice
11. J. % Planned Vs Unplanned Work	0% Planned and 100% Unplanned	30% Planned and 70% Unplanned	50% Planned and 50% Unplanned	70% Planned and 30% Unplanned	90% Planned and 10% Unplanned

Table 3.19 focuses on Schedule Adherence and determine if schedule adherence is measured and what the perceived schedule adherence is.

Table 3.19: Schedule Adherence (**Source:** Own Source adopted from Smith, 2013: **Online**)

Element	Level 1 – Not Engaged	Level 2 – Experimenting	Level 3 – Enlightened	Level 4 – Good Practice	Level 5 – Best Practice
11. Schedule Adherence	Schedule adherence Unknown or not measured	Greater than 30% schedule adherence	Greater than 50% schedule adherence	Greater than 70% schedule adherence	Greater than 80% schedule adherence

Table 3.20 focuses on Risk Analysis and determine if the risk analysis is objective, if avoidance activities are identified, and how risk is managed.

Table 3.20: Risk Analysis (**Source:** Own Source adopted from Smith, 2013: **Online**)

Element	**Level 1 – Not Engaged**	**Level 2 – Experimenting**	**Level 3 – Enlightened**	**Level 4 – Good Practice**	**Level 5 – Best Practice**
12. Risk Analysis	No Risk analysis performed	Basic risk analysis performed. Some jobs are identified to be “watched more closely”.	Formal risk analysis performed but largely subjective. Level of detail do not drill down to specific recovery or avoidance actions to be taken. Largely a prioritisation exercise based on risk, little or no action taken from analysis results.	Formal objective risk analysis performed and specific factors for critical jobs defined. Organisation still struggles with execution of avoidance and recovery actions. Emergencies occur and focus is on quick recovery.	Formal objective risk analysis performed and specific factors for critical jobs defined. Both recovery and avoidance activities identified and personnel responsibilities assigned for most critical jobs. Emergencies still occur, but they are rare and organisation is well prepared for them.

The criteria listed in Tables 3.9 to 3.20 will be used to interpret the outcome when the perceived maturity of the Outage process is determined.

3.8 CONCLUSION

This section concludes the literature review chapter. The literature review shows that a process maturity model is a suitable approach to determine the maturity level of Eskom’s outage process. The literature considered the history of maturity models and found that maturity models when used can be used to determine the current state of a process, or when the processes’ current state is known, prescribe improvement path as well as compare or bench mark across similar organisations and industries.

The literature further provides an international view of the outage process. Literature on the outage process is very limited and consults no more than a few authors and found that an outage process consists of the planning, control and improvement phases with the characteristics for each phase clearly defined.

The last section of Chapter 3 presents the combined work of Rosemann and de Bruin's (**s.a.**: **Online**) Business Process Maturity Model and Smith's (2013, **Online**) Maintenance Planning and Scheduling Maturity Matrix providing a suitable maturity model for this research project. The Outage Management Maturity Framework wil be used to determine the maturity level of Eskom's outage process.

The following section is Chapter 4 and focuses on the Research design and Methodology.

CHAPTER 4: RESEARCH DESIGN AND METHODOLOGY

4.1 INTRODUCTION

The aim of the chapter is to explore the research design and methodologies that support the objective of the research project. According to Greener and Martelli (2015:**Online**), research *methods* are the specific activities used to gather data and include questionnaires, interviews, observations and focus groups while research *methodology* refers to the strategy and approach chosen to answer the research questions.

This chapter will describe the following:

- The two major research approaches.
- Research design and methodology.
- The research assumptions and constraints.
- The research questionnaire.

4.2 THE TWO MAJOR RESEARCH APPROACHES

This section discusses the two major research approaches. Greener and Martelli (2015: **Online**) support the view of Welman, Mitchell, and Kruger (2005:6), finding that the two major research approaches are the qualitative and quantitative approach.

According to Creswell (2009: 22), the difference *between qualitative and quantitative research is framed in terms of using words (qualitative) rather than numbers (quantitative), or using closed-ended questions (quantitative hypotheses) rather than open-ended questions (qualitative interview questions)*. Insightlink Communication (**s.a.**, **Online**), supports the view expressed by Creswell (2009: 22) that there are two basic methodologies for any research exercise; the quantitative and qualitative approaches.

This section explores:

- quantitative research,
- qualitative research; and
- compares of quantitative and qualitative research.

4.2.1 Quantitative research

According to Greener and Martelli (2015: **Online**), the quantitative research is associated with a deductive approach to test theories, using numbers or facts and therefore being positivist or natural science model. Greener and Martelli (2015: **Online**) explain that the deductive reasoning moves from the general theory or process to a specific theory or process.

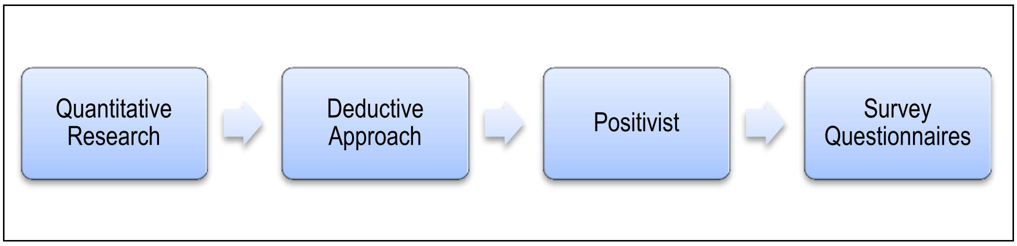


Figure 4.1: Quantitative Research Approach and Data Collection (**Source:** Own Source adopted from Greener & Martelli (2015, **Online**) and Insight Communication (**s.a.**, **Online**))

Creswell (2009:22) describes quantitative research as a method to test an objective theory by assessing the connection between variables. Jackson (2008: 88) explains that the quantitative researcher starts with the testing of a hypothesis, followed by observing and collecting data, completing statistical analysis of the data and draws conclusions. Huff (2009:348) finds that the quantitative method: draw inferences from a number of things and their relationship. According to Welman, Mitchell and Kruger (2005:8), the quantitative research evaluates objective data made up of numbers.

4.2.2 Qualitative research

According to Greener and Martelli (2015: **Online**), qualitative research is likely to be related to an inductive research that generates theories, using an interpretivist approach permitting multiple subjective perspectives focused on constructing knowledge rather than seeking facts or reality. Insightlink Communication (**s.**a., **Online**), found that qualitative research is an exploratory research approach. It makes use of non-numeric data like open-end interview, naturally occurring conversations and discussions and focus groups to identify and describe themes, norms, beliefs, patterns and decision processes and systems.

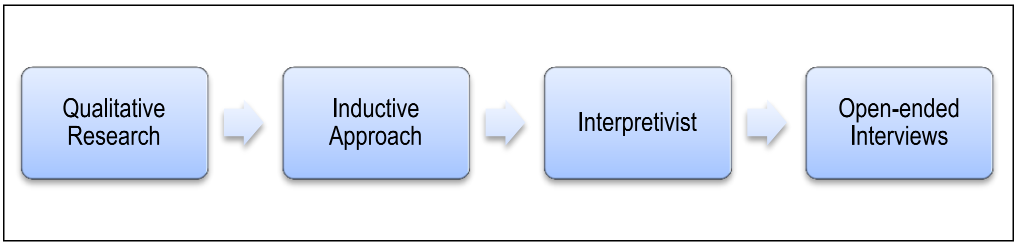


Figure 4.2: Qualitative Research Approach and Data Collection (**Source:** Own Source adopted from Greener & Martelli, (2015: **Online**) and Insight Communication,(**s.a.**, **Online**))

Creswell (2009: 125) supports the view expressed by Insightlink Communication (**s.a.**, **Online**), stating that qualitative research explores the complicated series of factors about the central occurrences and represents the diverse perspective or meanings that contributors hold.

According to Walliman (2001: 247), qualitative research makes an effort to understand a phenomenon, moving as close to the research subject as possible to collect meaningful data that enables the development of a common concept through the dynamic research process. Huff (2009:348) find that the qualitative method has a quality focus and often observes or infers relationship of things.

Welman, Mitchell, and Kruger (2005:8) found that qualitative research focuses on subjective data produced by respondents through interviews.

Jackson (2008: 88) adds that qualitative research focus on experiences in a natural environment, and the data analysis excludes statistical analysis. Coldwell and Herbst (2004: 13), expresses the opinion that qualitative research suggests that research findings are not exposed to prescribed quantification or quantitative analysis.

The following section present Leedy and Ormrod's comparison between quantitative and qualitative research approaches.

4.2.3 Comparison of quantitative and qualitative approach

Leedy and Ormrod (2014: 98), compares the distinguishing characteristics the quantitative and qualitative approaches in Table 4.1.

Table 4.1: Characteristics of the Quantitative and Qualitative Approaches (**Source:** Leedy and Ormrod, 2014: 98)

Question	Qualitative	Quantitative
Define the research purpose	Describe and explain Explore and interpret Build theory	Explain and predict Confirm and validate Test hypothesis
The nature of the research process	Holistic Unknown variables Flexible guidelines Emergent methods Context-bound Personal review	Focused Known variables Established guidelines Predetermine methods Somewhat context-free Detached view
Data collection	Textual and/or image-based data Information, small sample Loosely structured or non-standardised observations and interviews	Numeric Data Representative large sample Standardised instruments
Data analysis and interpretation	Search for themes and categories Acknowledge that analysis is subjective and potentially biased Inductive reasoning	Statistical analysis Stress on objectivity Deductive reasoning
Communicating the Outcome	Words Narratives, individual quotes Personal voice, literary style (in some disciplines)	Numbers Statistics, aggregated data Formal voice, scientific style

Table 4.1 pose five questions and are answered in light of the two approaches.

The brief comparison of the quantitative and qualitative research approaches creates the foundation for the review of the research process.

The quantitative research approach is adopted. Insightlink Communication (**s.a**., **Online**) assert that the quantitative research applies structured data collection techniques which includes closed-ended survey questions, measures the intensity and frequency and counting events to assist in determining demographic and psychographic distribution of beliefs, behaviors and opinions. This research study employs a structured data collection technique that uses statements in the form of a survey and that measured the maturity of the outage process.

4.3 RESEARCH DESIGN AND RESEARCH METHODOLOGY

The research design and methodology delve into research process. There are many research designs and methodologies with many describes for each deign and methodology. The section briefly describes:

- The research design.
- Briefly review of research methods.
- Review the survey research approach.
- The research approach.

4.3.1 Research design

Welman, Mitchell, and Kruger (2005:2) describe research as a process, which consist of finding scientific information using numerous objective approaches and procedures. Huff (2009: 348) explains that research is a meticulous and systematic examination or investigation into a subject to determine or revise facts, theories and applications. Weathington, Cunningham and Pittenger (2012: 6) define research methods as a process for gathering information.

According to Weathington, Cunningham and Pittenger (2012: 100-101), the objective when selecting a research design is to generate the best data to allow the researcher to answer the research questions. Hofstee (2006:113) notes that research design describes the general approach for testing the thesis statement. Huff (2009: 348) is of the opinion that research design is a plan for focused academic activity.

Greener and Martelli (2015: **Online**) describe each research design in detail to enhance the reader's understanding:

- **Exploratory Research:** This approach identifies or clarifies problems. The approach is often a qualitative, divergent and inductive approach resulting in a better definition or understanding of a problem.
- **Descriptive Research:** This approach tends to answer questions, which are largely factual in nature. The how, what, where, when, how much and how often are usually answered.
- **Correlation Research:** Looks for the relationship between two variables. The relationship may show a correlation in a statistical sense, meaning one variable has an effect on the other, not necessarily in the same direction.
- **Experimental Research:** The approach tests hypothesis and are designed to describe "why" something occurs.

The research design selected for the research study makes is a descriptive research design as it seeks to answer the "what" question: What is the maturity level of the outage process?

Greener and Martelli's (2015: **Online**) research approach is adopted and is seen in Figure 4.3. Greener and Martelli (2015: **Online**) describes a systematic approach to research. The process includes the analysis, design, implementation, interpretation and action stages.

This research approach has a five step, two-dimensional graphical presentation that appears to be a linear approach and should be consider as a line of best fit to business research (Greener & Martelli, 2015: **Online**).

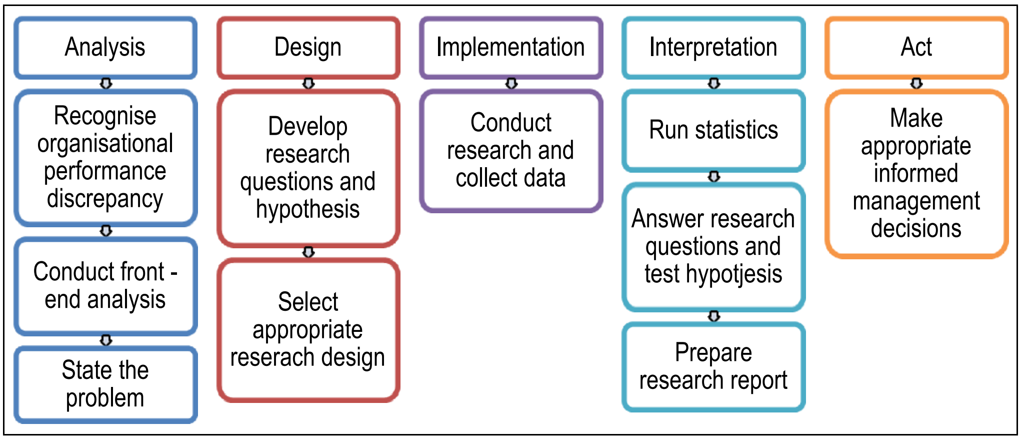


Figure 4.3: **The Business Research Process (**Sources: **Greener & Martelli, 2015:** Online**)**

Figure 4.4 describes the research process for this research study using Greener and Martelli's (2015: **Online**) Business Research Process.

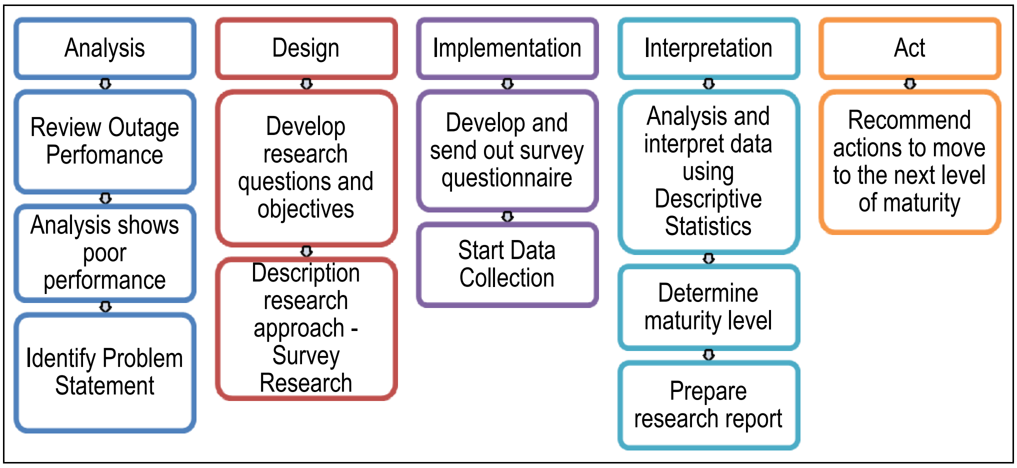


Figure 4.4: The Business Research Process (**Sources:** Adopted from Greener & Martelli, 2015: **Online**)

The following chapters in the research study deals with each phase of the research process. Chapter 2 of this research study deals with the analysis phase the research process. Chapter 1 states the research questions and objectives.

Chapter 4 describes the research approach and Chapter 3 deals with the development of the survey questionnaire. The data interpretation phase is covers in Chapter 5 and the act phase makes recommendations in Chapter 6. The following section focus on the research method.

4.3.2 Research methods

This section selects a research method for the research study, reviews the research methods and provides a brief explanation for each method. Table 4.2 lists various research methods including a brief explanation of each research method. The research methods included in the table are Creative or Experimental research, Survey research, Case Studies, Action research, Evaluation or Implementation Evaluation research, Descriptive research and Correlation research.

Table 4.2: Research Methods (**Source:** Own Source)

Research Methods	Explanation
Experimental designs/ Creative Research	Experiments – Test hypothesis or theories, or observe effects of a given intervention (Hofstee, 2006: 120-131)
	Permits researchers to define, forecast and decide whether there is a cause-and-effect connection between variables (Jackson, 2008: 19).
Survey Research	Obtains information from relevant people and the people should represent the greater population (Hofstee, 2006: 120-131)
	Questioning people on a specific topic followed by a description of their responses (Jackson, 2008: 17).
Case Study Research	The study of a specific phenomenon to determine if a general theory exist or to see if specific situations can birth to existing theories (Goddard & Melville, 2001:9)
Action Research	A small scale study in the working of the real world and a careful scrutiny of the effects of the intervention (Walliman, 2001: 115 citing Robson (1993))
Evaluation Research – Implementation Evaluation	Aimed at answering the question to determine if a process been properly implemented and if the intervention was implemented correctly (Mouton, 2001: 159)
	Systematic review of information to present useful feedback about a process, program or activity (Trochim, 2006: **Online**).
Descriptive Research	An attempt to study situations to establish the norm – Predict what can happen again under the similar circumstances (Walliman, 2001: 115).
Correlation Research	Describe the measure of relationship between two events (Walliman, 2001: 116).
	Evaluate the relationship between two measured variables. (Jackson, 2008: 18).

The research process in Figure 4.4 refers to survey research method in the design phase; therefore, the research method selected for the research study is the survey research method. Survey research questions people on a particular subject followed by a description of their response (Jackson, 2008:17).

The staff in the Outage Management Department is invited to response to a survey questionnaire on the outage process as they are assumed to have the required knowledge of the outage process.

4.3.3 Survey research method

This section looks at the survey research method, reviews the purpose of survey research and review the step to conduct survey research.

Farooq (2015: **Online**) find that survey research collects information by collecting data from a specific sample of a particular population through personal or impersonal means to research its characteristics. The personal method uses interviews and impersonal means are questionnaires via email or telephone. The findings are analysed and the outcome generalised.

Insightlink Communication (**s.a.**, **Online**) lists a number of benefits when using a systematic program of employee surveys. These benefits include:

- Demonstrating a real interest in the employees.
- Identify strengths and weaknesses in the performance of management, organisation policies, procedures and technologies, which will improve operational efficiency and improve employee satisfaction.
- Improve the retention of employees, reducing recruitment cost and making the company or department a more attractive employment proposition.
- Identify the key contributors and barriers to delivering excellence, soliciting very useful improvement opportunities.

Farooq (2015: **Online**) highlights import steps in conducting survey research. These steps:

- Define the research purpose and objective, stating the problem, specify the reason of the research, define the value of the research and clarify the research objectives.
- Define and select the target population on which the research will focus.
- Choose the technique for data collection by considering the instruments like interviews or questionnaires.
- Ensure that representative sample of the population is taken.
- The data gathering process (conducting the research), where the questionnaires or interviews are used should have pre-designed questions.
- Gather the data, analysed and interpreted then conclusions are formulated and generalising the findings.
- The entire study is presented in a survey research report.

The research study follows the steps for survey research by Farooq (2015: **Online**). Figure 4.5 provides the research method adapted from the Farooq's Research Steps for Survey Research (2015, **Online**).

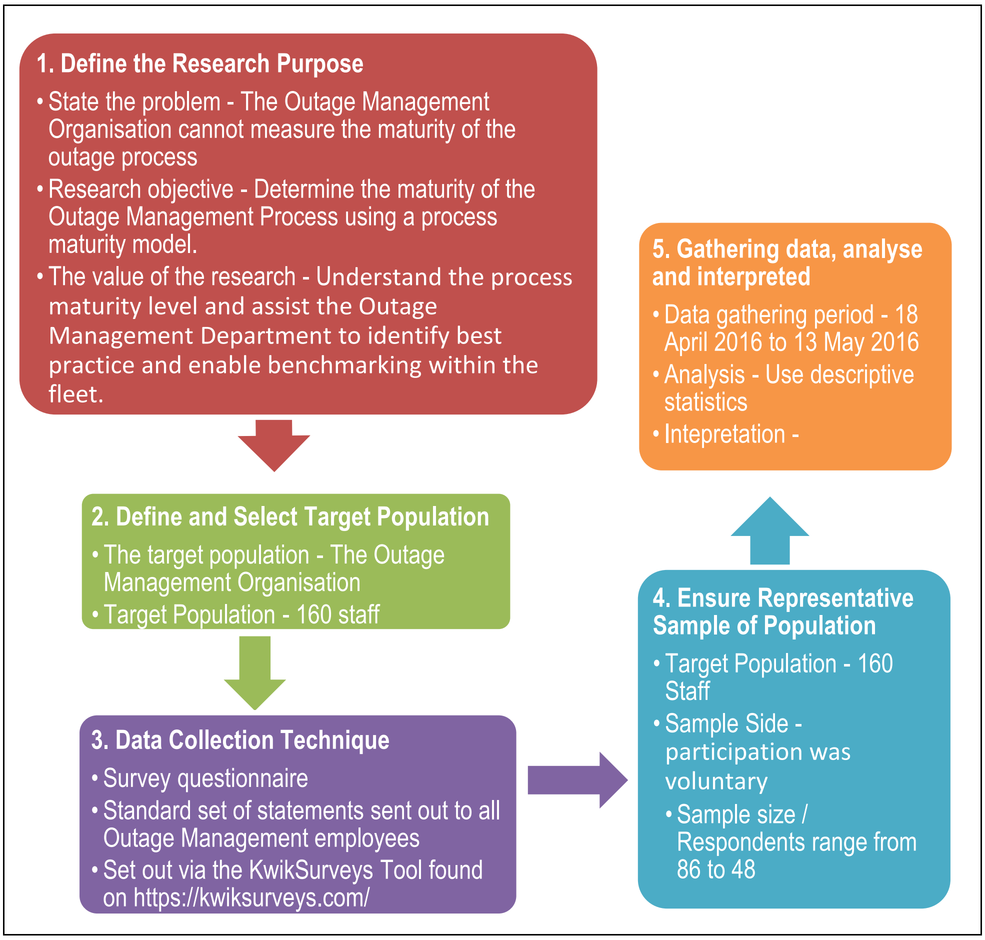


Figure 4.5: Research Approach (**Source:** Own Source adopted from Farooq, 2015: **Online**)

Summarising the research design and methodology find that the research design chosen of the research study is a descriptive research design. The research study employs the survey research method and use Greener and Martelli's (2015: **Online**) Business Research Process.

4.4 RESEARCH ASSUMPTIONS

Leedy and Ormrod (2014: 44) explained that in research, nothing is left to chance and every assumption that have an influence on the problem is clearly and entirely set forth.

The following assumptions are considered and are listed below:

- All participants received training on the outage management processes.
- Participants understand the outage processes and the interrelated processes.
- Participants have experienced in power station maintenance, engineering, operating or project management processes and practices.
- Participants will provide objective, honest feedback.
- All participants are able to read and understand English.

4.5 RESEARCH CONSTRAINTS

This section identifies research limitations and delimitations. Leedy and Ormrod (2014: 316, 318, 330), mentioned that limitations can be found in the in a number of areas including but limited to data collection and analysis, research design methodology and measurement instruments.

The research observes the constraints listed below:

- Limitations related to the research are:
  - The Outage Management Department makes up the population selected for the research study.
  - No all power stations will response to the survey.
  - The level of skill and experience of participants in planning and execution of outages may vary, affecting the outcome of the maturity level.
- De-limitations related to the research are:
  - The research outcome may have a generalised application in the planning and execution of outages and online maintenance processes.

The research outcome may form a foundation for developing other process maturity models applicable to the power generation environment.

4.6 THE RESEARCH QUESTIONNAIRE

According to Malhotra and Grover (1998: **Online**), there are three distinct characteristics identified of survey research:

- **First:** It consists of collecting data by requesting individuals for information in an arranged manner. The data can be collected using mailed questionnaires, telephone or face-to-face interviews. The people surveyed could represent themselves, their organisation, a project or their expertise, pending on the unit or analysis.
- **Second:** The survey research method is normally a quantitative method requiring stand information to define variables and its relationships.
- **Third:** The data is gathered using a sample of the greater population. The sample findings with be generalised to the population.

The purpose of the survey questionnaire is to determine the perceptions of the employees in the Outage Management department on the maturity level of the outage process. According to Weathington, Cunningham and Pittenger (2012:186) recommend the use of questionnaires if a perception is required.

The survey questionnaire uses a Likert format. Weathington, Cunningham and Pittenger (2012:191), find is a preferred option for closed-response questionnaires. The Likert scale provides a clear and unambiguous ordinal measure scale and can be used for many different questions (Weathington, Cunningham & Pittenger, 2012: 191). Weathington, Cunningham and Pittenger (2012:191) find the 5-option response as the most popular response option ranging from strongly disagrees, disagree, neutral, agree and strongly agree.

The survey questionnaire, excluding the group demographic, is based on a combination an edited version of Smith's (2013: **Online**) Maintenance Planning and Scheduling Maturity Matrix and literature review on the outage process.

4.6.1 The group demographic

The survey seeks to obtain the perception of the respondents and therefore included a request for the respondent's demographic information which includes the task grade to distinguish between management and staff (Insightlink Communication, **s.a.**, **Online**). Respondents were further asked to indicate which power station they are working at as this would allow for benchmarking across the various power stations.

Question 1	Do you work in the Outage Management Organisation?
Question 2	How many years do you have in Eskom service?
Question 3	What is your TASK grade level?
Question 4	Which Power Station do you fall under?
Question 5	What departments did you work in before joining Outage Management?

4.6.2 Outage organisation

Question 6.1	Formal outage organisation defined.
Question 6.2	Individuals make decisions regarding outages considering the big picture.
Question 6.3	The outage management leadership is recognised.
Question 6.4	The Outage leadership roles are defined with responsibilities for communication and decision-making.
Question 6.5	Outage leaders are faced with making a small number of decision.
Question 6.6	The responsibilities for areas like materials management, maintenance, engineering, operating, project management, safety and the contractor interface are defined.
Question 6.7	Fully integrated outage organisation with specific roles and responsibilities are defined.
Question 6.8	Outage teams and stakeholders work in a cooperative manner and adhere to processes.
Question 6.9	Communication and decision making is largely seamless.

4.6.3 Outage progress

Question 7.1	A formal process for outage planning is in place.
Question 7.2	The outage process identifies and adhere cut-off dates.
Question 7.3	The outage process only covers critical elements of outage planning process– Prepare and Execute.
Question 7.4	Outage Readiness Review process is established, with review due dates established and adhered too.
Question 7.5	The outage management team depends on readiness reviews and lessons learned integrated into future outages.

4.6.4 Outage planning

Question 8.1	Outage Management Plan (OMP) developed and used to add the outages planning.
Question 8.2	The Outage Management Plan clearly established roles and responsibilities for all stakeholders and the OMP is adhered too.
Question 9	Outage Planning starts 3 months prior to the start of the outage date.
	Outage Planning starts 3-6 months prior to the start of the outage date.
	Outage planning starts 12 months prior to the start of the outage date.
	Outage planning starts 18 months prior to the start of the outage date.
	Outage planning starts 24 months prior to the start of the outage date.

4.6.5 Outage scope development

Question 10.1	The outage scope considers previous outage scope.
Question 10.2	The outage scope considers Preventative Maintenance Programs.
Question 10.3	The outage scope considers Corrective Maintenance, and Inspection Reports.
Question 10.4	The outage scope considers the Modification Programs.
Question 10.5	The outage scope considers Engineering Programs and lessons learnt.

4.6.6 Scope management

Question 11.1	A scope management process in place.
Question 11.2	Scope management process is adhered too.
Question 11.3	Reactive/Emergent work uses a new work orders.
Question 11.4	Repairs/follow-up work performed uses new work order.
Question 11.5	Emergent and additional work receives a separate follow-up work order.
Question 11.6	A new work order created for rework with the duration and cost quantified.

4.6.7 Outage progress

Question 12.1	Outage progress updated in real time updates per shift.
Question 12.2	Scheduling tools accurately capture start and finish information.
Question 12.3	The outage execution schedule provides actual progress feedback and controls work.
Question 12.4	Enterprise Resource Planning (ERP) systems (captures actual progress performance data i.e. cost and hours worked).
Question 13.1	Provide weekly verbal feedback on Outage progress.
Question 13.2	Provide daily verbal feedback on Outage progress.
Question 13.3	Provide verbal progress feedback on Outage progress at the end of each shift.

4.6.8 Single outage plan

Question 14.1	Single outage plan is formal, universally understood and published to all stakeholders.
Question 14.2	Single outage plan developed in a scheduling tool.
Question 14.3	Single outage plan includes the input and oversight from all affected disciplines.
Question 14.4	The critical path of the outage defined and lower priority jobs arranged around it.
Question 14.5	Level of detail on the plan supports an hour-to-hour breakdown.

4.6.9 Outage work order usage

Question 15.1	Each activity executed in the outage has an outage work orders.
Question 15.2	The outage work orders are task specific.
Question 15.3	Routine outage work has task specific work orders.
Question 15.4	All proactive and reactive jobs have individual work orders.

4.6.10 Work order closeout

Question 16.1	Work orders remains in an open status for a long periods after work is completed.
Question 16.2	Work orders history captures all part codes identified.
Question 16.3	Work orders history captures all problems and reason codes identified.
Question 16.4	Written feedback provided on less than 15% of work orders.
Question 16.5	Written feedback provided on less than 50% of work orders.
Question 16.6	Written feedback provided on more than 50% of work orders.
Question 16.7	More than 90% of all work orders have written feedback provided on the same shift.

4.6.11 Work order – coordination delays

Question 17.1	Coordination are known delays are recorded.
Question 17.2	All coordination delays greater than 60 minutes recorded.
Question 17.3	All coordination delays over 30 minutes recorded.

4.6.12 Outage lessons learnt

Question 18.1	Outage team records lessons learnt.
Question 18.2	Outage team discusses and accurately document lessons learnt.
Question 18.3	Outage team cycles lessons learnt into future outage planning.
Question 18.4	Outage team captures lessons learnt in an information management system and shares throughout the organisation.

4.6.13 % Planned vs % Unplanned

Question 19	0% Planned Work and 100% Unplanned Work
	30% Planned Work and 70% Unplanned Work
	50% Planned Work and 50% Unplanned Work
	70% Planned Work and 30% Unplanned Work
	90% Planned Work and 10% Unplanned Work

4.6.14 Outage schedule adherence

Question 20.1	Outage schedule adherence is known and measured.
Question 20.2	Outage schedule adherence is greater than 30%.
Question 20.3	Outage schedule adherence is than 50% schedule.
Question 20.4	Outage schedule adherence is than 70% schedule.
Question 20.5	Outage schedule adherence is than 80% schedule.

4.6.15 Risk analysis

Question 21.1	Risk analysis performed.
Question 21.2	Risk analyses are objective.
Question 21.3	Risk analysis identifies specific factors for critical jobs defined.
Question 21.4	Risk mitigation measures drills down to specific recovery or avoidance actions to be taken.
Question 21.5	Organisation executes risk avoidance and recovery actions.
Question 21.6	Personal responsibilities assigned to both recovery and avoidance activities identified.

4.6.16 Risk mitigation

Question 22.1	Some jobs are identified to be “watched more closely”.
Question 22.2	Level of detail drills down to specific recovery or avoidance actions to be taken.
Question 22.3	Organisation executes avoidance and recovery actions.
Question 22.4	Both recovery and avoidance activities identified and personnel responsibilities assigned for most critical jobs.

4.7 CONCLUSION

The chapter describes the research design and methodology used in the research study. The chapter reviewed:

- Major research approaches.
- Research design and methodology.
- The research assumptions and constraints.
- Research questions.

The research study adopts a descriptive research design and a quantitative research approach, employing a structured data collection technique using statements in the form of a survey. The survey questionnaire is chosen to determine the respondents’ perception of the maturity level of the outage process.

It is assumed that respondents have been trained and understand the outage process. The respondents should be experienced in power station maintenance engineering operations or project management. The survey outcome should confirm or refute these assumptions.

Smith’s (2013: **Online**) Maintenance Planning and Scheduling Maturity Matrix forms the basis for the survey statements. The survey is divided into sixteen subsections and incorporates a 5-option Likert scale.

The following chapter focuses on data collection, analysis and interpretation.

CHAPTER 5: DATA COLLECTION, ANALYSIS AND INTERPRETATION OF RESULTS

5.1 INTRODUCTION

Leedy and Ormrod (2014:282) assert that data is worthless unless we examine and understand the data in order to disclose the truth that lies beneath the data. The data is meaningless without analysis and interpretation. The chapter describes the data collection, analysis and provides an interpretation of the results thus answering the research question. The chapter:

- Describes the process used to collect data.
- Describes the analysis of the data.
- Presents data validation and reliability.
- Provides an interpretation of the results.

The chapter begins with an explanation the process for data collection.

5.2 DATA COLLECTION

According to Creswell (2009: 166), the data collection steps set boundaries for the study. The data collection sections:

- Describes the data collection process used for the research project.
- Describes the unit of analysis for the data collected.
- Identify research variables.

5.2.1 Data collection process

Punch (2003: 40), contends that the means used for data collect can greatly influence the quality of the data. Punch (2003:41), returned that a realistic data collection strategy and appropriate period should be chosen.

According to Creswell (2009: 166), data collection includes the stages of gathering information using unstructured or semi-structured interviews and observations, documentation, and graphic material, and established procedure for documenting information. Table 5.1 sums up a number of data collection methods.

Table 5.1: Data Collection Methods (**Source:** Own Source adopted from Coldwell & Herbst, 2004)

Data Collection Methods Source	
Observation	Surveys
Interviews	Checklists
Documents	Focus Groups
Questionnaires	Case Studies

According to Weathington, Cunningham and Pittenger (2012: 125), they highlight three subsections that describe (i) how to identify and obtain the sample for the study, (ii) provide the measures, material and equipment used to collect the data and (ii) the research procedure used during the research.

Weathington, Cunningham and Pittenger (2012: 125) data collection method states:

- The research environment focuses on outage process at Eskom. The Outage Management Department is responsible for planning and executing outage. The employees of the Outage Management Department were invited to participate in the research study by completing a survey questionnaire done so on a voluntary basis.
- The material used to develop the structured survey questionnaire was based on the Maintenance Planning and Scheduling Maturity Matrix by Smith (2013: **Online**). The equipment used to develop the survey was the Kwiksurveys online survey tool. The staff in the Outage Management Department received an emailed with a URL to access and completes the survey. Responses are captured in the survey tool and did not record the respondent's email address, maintaining their anonymity.

- A URL to access the research survey questionnaire was included in an email to all the employees of the Outage Management Department. The email requested the employees to participate in the research study and completing the survey questionnaire by clicking the link included in the email. The employees had one month to respond to the survey questionnaire. A weekly following up email was sent to all employees as a reminder of the survey questionnaire. The feedback email provided feedback on the areas that completed the survey. After one month the survey questionnaire was closed in Kwiksurveys online tool and the data downloaded into a Microsoft Excel spreadsheet for analysis. The author sent an email to all employees thanking them for their participation.

The Kwiksurveys online survey tool presented the data in two formats. The first format was a 20 page Quick Report in a PDF format. The report presents the survey questions, the number of respondents per question, standard deviation (the tool uses a population standard deviation) and weighted average. The Quick Report provides a selection of graphs to present the data. A second data source was a Microsoft Excel Spreadsheet that provides the same information set out in the Quick Report, but the data format allows for further data analysis. SPSS Statistical tool was used to complete additional descriptive statistics.

The data collected during the survey requires a unit of analysis and the following section considers the unit of analysis identifies applicable variables and determine a suitable the sample type.

5.2.2 Data collection – unit of analysis

Malhotra and Grover (1998: **Online**), emphasise the importance the defining unit of analysis at the start stating that all information should be at a consistent unit of analysis, whether industry, project function, working group or individual.

The respondent being an individual should clearly state the unit of analysis it represents and the measuring instrument should constantly reflect the unit of analysis (Malhotra & Grover: 1998: **Online**).

Malhotra and Grover (1998: **Online**) highlight an important point to consider when the individual answers a question with an organisation as the unit of analysis; points out that possible bias depending on the organisational hierarchy.

The example presented by Malhotra and Grover (1998: **Online**) point to a research question direction to functional worker focused on organisation level change Malhotra and Grover (1998: **Online**) citing Huber and Power (1985), conclude that the most knowledgeable person of the focus area should be selected. Malhotra and Grover (1998: **Online**) asks the following questions:

- Is the unit of analysis unmistakably clear for the research study?
- Does the measurement instrument constantly consider the unit of analysis?
- Are the selected respondents suitable for the research question?

Table 5.2 provides the questions and answers used to assist in determining the unit of analysis of the research project.

Table 5.2: Unit of Analysis Questions and Answers (**Source:** Own Source adopted from Malhotra & Grover, 1998: **Online**)

Unit of Analysis Questions and Answers		
1.	What is the unit of analysis for the research study/	The unit of analysis is the individual's response to the survey questionnaire.
2.	Does the measurement instrument consistently reflect the unit of analysis?	The survey questionnaire is completed by an individual and seeks to determine the individual's perception.
3.	Are the respondents appropriate for the research questions	The respondents are within the Outage Management Department and it is assumed that there are knowledgeable about outage process.
4.	How was the respondents selected	The survey questionnaire was sent to all the employees in the Outage Management Department and their participation was voluntarily.

With the unit of analysis determined the following section reviews the data collection variable.

5.2.3 Data collection – variable

This section explains and identifies various types of variables. Creswell (2009:59), citing Creswell (2007), explains that variables refers to the attributes or characteristics for one person or a group that can be determined or perceived and that differs amongst the people or group being studied. Creswell (2009: 59) found that variables frequently assessed in research studies include age, gender, behaviors attitudes or behaviors such as leadership, political power, social control and racism.

Creswell (2009: 59) explains that variables have two characteristics: one is a time-based order and the other is their observation and measurement. Creswell (2009: 59) returns that temporal order or time-based variables mean that one variable precedes the other in time; the one variable brings about the other variable. Creswell (2009: 60), found two types of variables namely, independent and dependent variables.

5.2.3.1 Independent variable

Weathington, Cunningham and Pittenger (2012: 45), refer to an independent variable as the variable responsible that causes or accounts for the change observed in the dependent variable. Creswell (2009: 60) defines an independent variable as the variables that cause, impact, or affects the outcome of a study, also known as treatments, manipulated, predecessors or predictor variables.

Weathington, Cunningham and Pittenger (2012: 45) point out that different types of independent variables namely manipulated and subject variables. Weathington, Cunningham and Pittenger (2012: 45) find that manipulated variables enable the research to manipulate or control the intensity of the independent variable. Subject variable is a condition or characteristic and cannot be controlled or changed by the researcher.

Weathington, Cunningham and Pittenger (2012: 45) highlight an important point; every time people take part in a research study, they bring exclusive features to the study.

5.2.3.2 Dependent variable

According to Weathington, Cunningham and Pittenger (2012: 45), dependent variable is the focal point of the study; the condition that the research wants to explain. Weathington, Cunningham and Pittenger (2012: 45) mention other terms used to describe dependent variables and these terms include response variable or outcome variable. Creswell (2009: 60) defines dependent variable as variables that are dependent on the independent variables; the results impact the independent variables and are also known as criterion, outcome or effect variables.

Final Weathington, Cunningham and Pittenger (2012: 45) maintain that while researchers cannot change the characteristic of the people involved in the research project, uses these features as focus variables to forecast results.

The variables identified within the ambit of the research study are included in the demographic section of the survey questionnaire. The variables are:

- The number of years the respondents is in Eskom's service.
- Respondents task grade.
- The respondents power station.
- The departments the respondent worked in prior to joining the Outage Management Department.

5.2.4 Data collection – sample type

According to Weathington, Cunningham and Pittenger (2012: 170), a population is defined as the individuals the researcher wants to describe. The employees in the Outage Management Department made up the target population.

Weathington, Cunningham and Pittenger (2012: 170) mention that a researcher will draw a sample from the subset of the population.

Weathington, Cunningham and Pittenger (2012: 170) further describe a sample population as an accessible group of people who work in the in the same area and have share the same characteristics of the target population. The employees in the Outage Management Department work in the same area and are assumed to have the same training and relevant experience of the outage process.

The sample for the research study was drawn using the sample frame concept. According to Weathington, Cunningham and Pittenger (2012: 170), a sample frame is a group of people in a target populace that can be contacted for a particular research purpose. The employees in the Outage Management Department are reachable for the research purpose. The employees that chose to respond to the survey make up the research sample. The employees were informed that their participation were voluntary and was encouraged take part in the survey questionnaire. When the data collection is completed, the following step is the data analysis.

5.3 DATA ANALYSIS

Creswell (2009: 171) return that the data analysis process makes sense out of text and images. Creswell (2009: 171) point out that the process includes arranging the data, performing various analyses, getting a better grasp of the data and represents the data, and drawing conclusions.

Leedy and Ormrod (2014: 286), mention the electronic spreadsheets an important tool when processing large amounts of data. Leedy and Ormrod (2014: 286) found that the use of spreadsheets to sort and recode, create formulas and graphs as well as explore by trial and error.

Denscombe (2007: 288) explains a logical order for analysing qualitative data:

- Prepare the data.
- Become familiar with and interpreting the data.
- Verify the data.
- Present the data.

The outcomes of data analysis are the development of graphs and tables (Leedy & Ormrod, 2014: 15). These presentations of tables and graphs are part of the final research report.

5.3.1 Data preparation

The data collection tools used to conduct the research is the KwikSurveys online free survey tool. KwikSurveys produces a report that includes descriptive statistical analysis shown in Appendix B. The quick report states each research question along with the number of responses, standard deviation and number of respondents. The standard deviation in the quick report assumes the respondents represent the population. The sample standard deviation needs to be recalculated and can be captured in the excel spreadsheet. The data collected was exported into a spreadsheet, which enabled further analysis.

5.3.2 Data intepretation

In an endeavor to become acquainted with the data, the author reviewed the data in the two formats. The quick report in the PDF format provided a quick overview of the data and provides basic descriptive statistics. The one format exported into a spreadsheet enables further analysis within the spreadsheet program while the second format can be imported into a statistical program.

Crosby (1979: 31) identified the initial step necessary when using his Quality Management Maturity Grid was to ask managers indicate which stage they think their processes were at for each of the measurement categories, then to score it. The employees of the Outage Management Department are asked to rank each element of the outage process based on their perception. This research study makes use of data collected from the survey question then applies descriptive statistics to describe the current perception of the maturity level of the outage process.

5.3.3 Data presention

The Kwiksurveys online tool provides various methods of presenting the data. The online survey tool presents data in a number of graphs, as well as the export formats allow for expansion of the basic graphs available from Kwiksurveys. The Microsoft Excel format was selected as method to present the survey data.

The Microsoft Excel report presents the questionnaire in a table with the Likert scale, the standard deviation, responses and the weighted average. At the bottom of each set of questions, an average weighted average is calculated. The Outage Management Maturity Framework instrument is applied in this research study to determine the as is state of and gain a deeper understanding of the outage process (De Bruin, Freeze, Kaulkarni & Rosemann, 2005: **Online**).

5.4 DATA VALIDITY AND RELIABILITY

According to Leedy and Ormrod (2014: 91), the reliability and validity of a measurement instrument influences the degree to which a researcher can understand the phenomenon under investigation, gain statistical significance in the data, and have an effect on the extent to which researchers draw meaningful conclusions from the data.

The section provides a brief overview of the following:

- Validity of the data; and
- reliability of the data.

5.4.1 Data validity

Jackson (2008: 71) and Bell (2005: 117), found that validity confirms that the measuring instrument measures what it says it measures. Greener and Martelli (2015: **Online**), return that validity speaks to the correctness of measurements and observations. Green and Martelli (2015: **Online**), point out the importance of research having face, construct and internal validity.

Greener and Martelli (2015: **Online**) briefly explain the terms as:

- **Face Validity:** Non-researcher or a layperson can broadly identify the research method as valid and makes sense.
- **Construct Validity:** are a more complicated idea and means that the method must essentially measure what you assume it measures.
- **Internal Validity:** Refers to the cause and effect, does Factor A have an impact on Factor B.

According Weathington, Cunningham and Pittenger (2012: 102), internal validity is the degree to which it is assumed that any variations in the independent variable cause variation in the dependent variable. Weathington, Cunningham and Pittenger (2012: 102), describes external validity as the extent to which the outcomes can be generalised and conclusion is reached using the sample to the population.

The Outage Management Maturity Framework is adopted from Smith's (2013: **Online**) Maintenance Planning and Scheduling Maturity Matrix and Rosemann and de Bruin's (**s.a.**: **Online**) Business Process Maturity Model.

The face validity by Greener and Martelli (2015: **Online**) is satisfied when considering Smith's (2013: **Online**) Maintenance Planning and Scheduling maturity matrix in Appendix C, the outage planning forms part of the matrix. Smith (2013: **Online**) states that the Maintenance Planning and Scheduling maturity Matrix is used to assess the present status of maintenance planning and scheduling within an organisation. The outage scope forms part of this maturity matrix. The Outage Management Maturity Framework intends to measure the maturity of the outage processes. The results of the survey research measures the maturity level of the outage process.

The review of data reliability follows in the next section.

5.4.2 Data reliability

According to Bell (2005: 117), reliability is the degree to which a procedure or test produces a related result in the same circumstances when repeated. Jackson (2008: 67) states that reliability is the consistency or stability of a measuring instrument. Greener and Martelli (2015: **Online**), describe reliability as being consistent and repeatable. Greener and Martelli (2015: **Online**), find that *just because something is repeatable does not mean it is also valid*. Greener and Martelli (2015: **Online**), highlight participant errors and bias along with observer error and bias as factors which can affect reliability and validity of data collections in research.

The reliability checks are usually introduced during the development of questions and its wording (Bell, 2005: 117). According to Creswell (2009: 143), the researcher should complete a *reliability check for the internal consistency of the scale* and refers to the Cronbach's Alpha statistic.

5.4.3 Cronbach's Alpha

According to Tavakol and Dennick (2011: **Online**) and Goforth (2015: **Online**), the Cronbach's Alpha measures of the internal consistency of a scale or test and is expressed in a number between zero and one. Tavakol and Dennick (2011: **Online**), the internal consistency described the degree to which all elements in a test measure similar construct.

Gliem and Gliem (2003: **Online**) found the nearer the alpha is to one the better the internal consistency. , Gliem and Gliem (2003: **Online**) cites George and Mallery (2003), offers the next rule of thumb:

- Excellent is greater than 0.9.
- Good is greater than 0.8.
- Acceptable is greater than 0.7.
- Questionable is greater than 0.6.
- Poor is greater than 0.5.

SPSS Data Analysis tool was used to complete the Cronbach's Alpha reliability test based on the selected variables seen in Table 5.3. The Cronbach's Alpha was completed on the survey questions that used the Likert-type scale with the results shown in Table 5.4.

Table 5.4 shows results of the Cronbach's Alpha test with a 95,3% reliability.

Table 5.3: Variables used for the Reliability Check for Internal Consistency of the Scale (**Source:** Own Source)

RELIABILITY for VARIABLES=	
Question 6 – Outage organisation	Q6.1 Q6.2 Q6.3 Q6.4 Q6.5 Q6.6 Q6.7 Q6.8 Q6.9
Question 7 – Outage process	Q7.1 Q7.2 Q7.3 Q7.4 Q7.5
Question 8 – Outage planning	Q8.1 Q8.2
Question10 – Outage scope development	Q10.1 Q10.2 Q10.3 Q10.4 Q10.5
Question 11 – Scope management	Q11.1 Q11.2 Q11.3 Q11.4 Q11.5 Q11.6
Question 12 – Outage progress	Q12.2 Q12.3 Q12.4
Question 14 – Single outage plan	Q14.1 Q14.2 Q14.3 Q14.4 Q14.5
Question15 – Outage work order usage	Q15.1 Q15.2 Q15.3 Q15.4
Question16 – work order closeout	Q16.1 Q16.2 Q16.3 Q16.4 Q16.5 Q16.6 Q16.7
Question 17 – Work order – coordination delays	Q17.1 Q17.2 Q17.3
Question18 – Outage lessons learnt	Q18.1 Q18.2 Q18.3 Q18.4
Question 20 – Outage schedule adherence	Q20.1 Q20.2 Q20.3 Q20.4 Q20.5
Question 21 – Risk analysis	Q21.1 Q21.2 Q21.3 Q21.4 Q21.5 Q21.6
Question 22 – Risk mitigation	Q22.1 Q22.2 Q22.3 Q22.4
/SCALE('ALL VARIABLES') ALL	
/MODEL=ALPHA.	

According to Gliem and Gliem (2003: **Online**) citing the rule of thumb from George and Mallery (2003), the Cronbach's Alpha Excellent as the scope shown in Table 5.4 is above 0.9.

Table 5.4: Cronbach's Alpha Reliability Statistic (**Source:** Own Source)

Reliability Statistics	
Cronbach's Alpha	N of Items
.953	68

5.5 THE RESEARCH STUDY DATA ANALYSIS

Farooq (2015: **Online**) explains that data is collected to analyse the behavior, opinions, attitude, desired, habits, values and beliefs of a certain population being studied. University of Reading (2001: **Online**), mentioned a number of methods of analysing surveys and includes One-Way Tables and Cross-Tabulation.

According to University of Reading (2001: **Online**), considers the One-Way Tables as the straightforward analysis. Roberts (2016: **Online**), found that the One-Way table is data from graphs put into a table format. University of Reading (2001: **Online**) found that One-Way Tables provide for most of the basic information needs as it tabulates results question by question and is useful to determine the frequency of responses to questions. Roberts (2016: **Online**), observed that One-Way tables works with one category variable.

The University of Reading (2001: **Online**) explains that at its most basic level, cross-tabulation breaks down the sample into two-way table presentation the response categories of one question as headings of a row those of another question as column headings.

Weathington, Cunningham and Pittenger, (2012:47) describes descriptive statistics as a number of some sort that helps to arrange, summarise and explain data. The research study used the descriptive statistics to describe the current situation of the outage process.

The survey questionnaire started with gathering data on:

- The demographic of the Outage Management Organisation,
- then continues to focus on the Outage Planning,
- Outage Control; and
- Outage Improvement phase.

These outage phases make up the twelve elements of the Outage Management Maturity Framework. The outage process maturity is determined using a staged representation. Ulster University (**s.a.**, **Online**) shared the view on staged representation and found that *in order for an organisation to be at a particular level of maturity it must have satisfied the goals of all the process areas associated with that level of maturity and all of the goals of the processes associated with any lesser levels of maturity*. The maturity level of the element in the Outage Management Maturity Framework is determined by the weighted average of the lowest scoring sub-element within that element.

5.5.1 Demographic information

The survey focused on the entire Outage Management Department. The population stands at 160 staff. The survey gathered information on the staff demographic.

The Demographic information included:

- The respondents number of years in the service of Eskom.
- The respondents task grade.
- The respondents and the power stations they represent.
- The departments the respondents work in prior to joining the Outage Management Department.

5.5.1.1 Respondents years of service with Eskom

The objective of this section is to review the work experience of the staff employed in the Outage Management Department.

A notable aspect in Table 5.5 show 33.7% of the respondents with 0-5 years' service with Eskom and 60% of the respondents have less than eleven years' service within Eskom.

Table 5.5 indicates that 30.2% of the respondents have more than fifteen-year service. The other 25.6% of the respondents have between five to ten years' service with Eskom.

Table 5.5: Respondents number of years in Eskom service (**Source:** Own Source)

How many years do you have in Eskom service?					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0-5 years	29	33.7	33.7	33.7
	5-10 years	22	25.6	25.6	59.3
	11-15 years	9	10.5	10.5	69.8
	Greater than 15 years	26	30.2	30.2	100.0
	Total	86	100.0	100.0	

The data suggests that the Outage Management Department shows an even spread in the years of service of the employees in the department. The following section reviews the respondents' job grades.

5.5.1.2 Respondents task grade

Table 5.6 presents the respondent for each task grade. The number of respondents is 86 of a possible 160 respondents to the demographic section of the survey questionnaire. Table 5.6 also indicates that 57% of the responses were from the bargaining unit employees.

Table 5.6: Respondent's Task Grade (**Source:** Own Source)

What is your TASK grade level?					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Bargaining Unit	49	57.0	57.0	57.0
	Management	22	25.6	25.6	82.6
	Middle Management	9	10.5	10.5	93.0
	Executive Management	6	7.0	7.0	100.0
	Total	86	100.0	100.0	

Respondents from management made up 25.6%, with 10% respondent from middle management and seven percent from executive management.

This indicates that the employees in the Outage Management Department showed interest in completing the survey. The next section reviews the responses from the various power stations.

5.5.1.3 Respondents from various Power Stations

Table 5.7 shows the responses from the various power stations representing the Outage Management Department. Responses include respondents that are from various power stations.

Notice that the largest number of respondents in this category is from Support Department - 14, accounting for 27.9% of the respondents. The second highest number of respondents was from Power Station 7 with 20.9% followed by Power Stations 1, 6 and 12 with 8.1%. Table 5.7 shows that 27.9% of the respondents were not placed at a power station.

Table 5.7: Respondents per Power Station (**Source:** Own Source)

Which Power Station do you fall under?				
	Frequency	Percent	Valid Percent	Cumulative Percent
Power Station - 1	7	8.1	8.1	8.1
Power Station - 2	3	3.5	3.5	11.6
Power Station - 3	1	1.2	1.2	12.8
Power Station - 4	1	1.2	1.2	14.0
Power Station - 5	1	1.2	1.2	15.1
Power Station - 6	7	8.1	8.1	23.3
Power Station - 7	18	20.9	20.9	44.2
Power Station - 8	6	7.0	7.0	51.2
Power Station - 9	1	1.2	1.2	52.3
Power Station - 10	2	2.3	2.3	54.7
Power Station - 11	6	7.0	7.0	61.6
Power Station - 12	7	8.1	8.1	69.8
Power Station - 13	2	2.3	2.3	72.1
Support Department- 14	24	27.9	27.9	100.0
Total	86	100.0	100.0	

The cross tabulation in Table 5.8 shows the spread of the years of service for each group of respondents.

The data in Table 5.8 indicates that 29 respondents to this survey question indicate that the most experienced employees are from Support - 14.

Table 5.8: Cross-Tabulation comparing the years in Eskom Service per Power Station (**Source:** Own Source)

Crosstabulation – Power Station and Eskom Service					
	0-5 years	5-10 years	11-15 years	Greater than 15 years	Total Number of Respondents
Power Station- 1	1	2	3	1	7
Power Station - 2	1	2			3
Power Station - 3	1				1
Power Station - 4		1			1
Power Station - 5				1	1
Power Station - 6	5		1	1	7
Power Station - 7	1	8	2	7	18
Power Station - 8	5	1			6
Power Station - 9		1			1
Power Station - 10	1	1			2
Power Station - 11	5	0	1		6
Power Station - 12	3	4			7
Power Station - 13	1			1	2
Support Department -14	5	2	2	15	24
Total	29	22	9	26	86

The Support Department - 14 have 15 employees with more than 15 years of service more than double of the closes power station. Power Station 7 has seven employees with more than 15 year service and eight employees with between 5-10 years of service. The notable observation is that the most experience respondents to the survey do not work at a power station.

The following section reviews the work experience of the respondents prior to joining the outages.

5.5.1.4 Respondents prior work experience before the Outage Management Department

In Figure 5.1, the graph shows the previous work experience of the respondents prior to joining the Outage Management Department.

A research assumption assumes that the participants have experience in power station maintenance, engineering, operating or project management processes and practices.

Considering Figure 5.1, provides an answer to the assumption that participants have experience in power station maintenance, engineering, operating or project management.

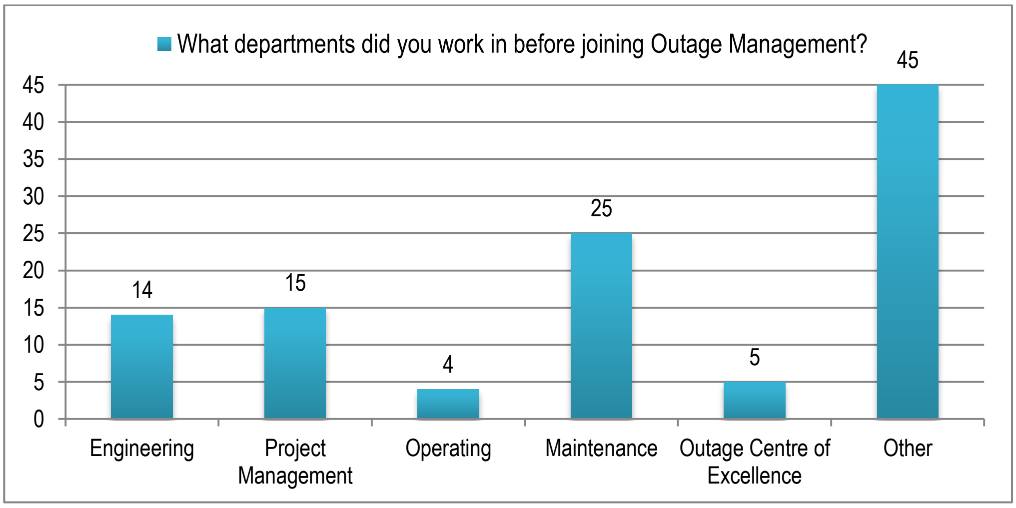
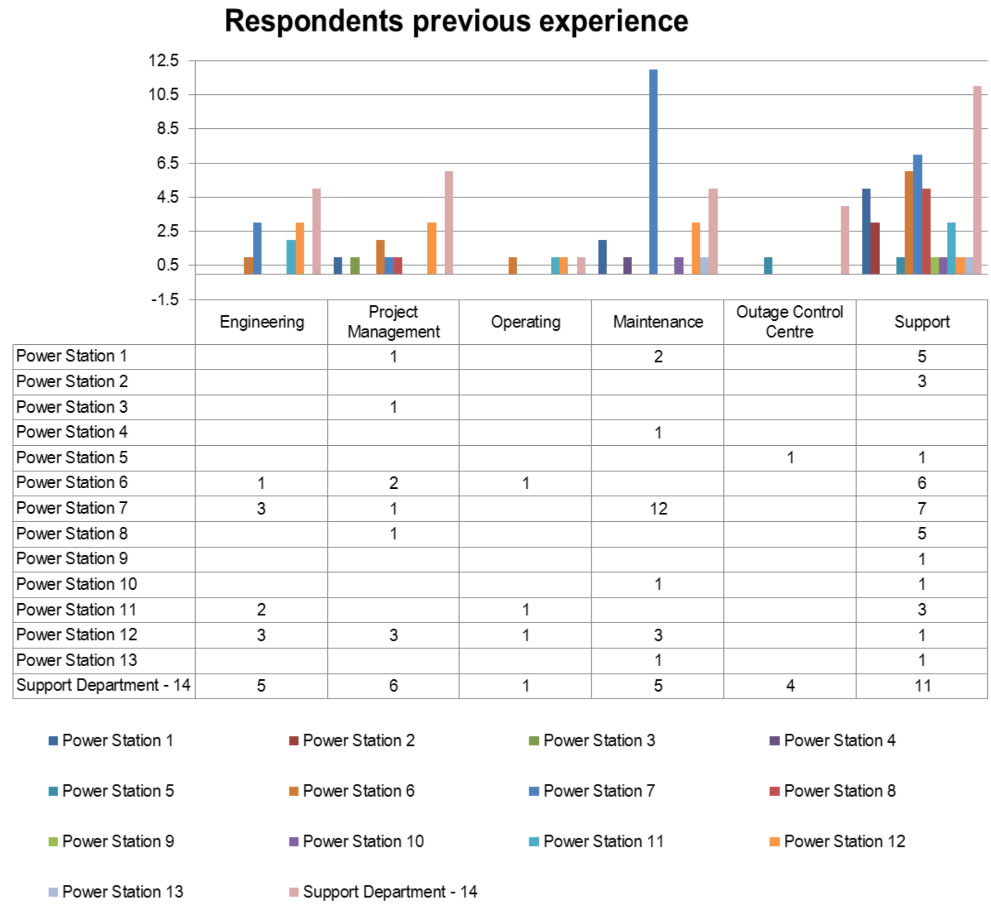


Figure 5.1: Work Experience prior to joining the Outage Department (**Source:** Own Sources)

Figure 5.1 reveals that 45 respondents do not have experience in the engineering, maintenance, project management, operating, outage management or maintenance environment prior to joining the Outage Management Department. The findings in Figure 5.1 disprove the research assumption that the participants have experience in power station maintenance, engineering, operating or project management where incorrect.

Figure 5.2 uses cross tabulation to present the respondents previous work experience and their current power station.



	Engineering	Project Management	Operating	Maintenance	Outage Control Centre	Support
Power Station 1		1		2		5
Power Station 2						3
Power Station 3		1				
Power Station 4				1		
Power Station 5					1	1
Power Station 6	1	2	1			6
Power Station 7	3	1		12		7
Power Station 8		1				5
Power Station 9						1
Power Station 10				1		1
Power Station 11	2		1			3
Power Station 12	3	3	1	3		1
Power Station 13				1		1
Support Department - 14	5	6	1	5	4	11

Figure 5.2: Summary indicating the department the respondents worked in prior to Joining the Outage Management Department (**Source:** Own Source)

The data presented in Figure 5.2 shows that the respondents to the survey do not have the assumed experience required to work in the Outage Management Department. The Outage Management Department should consider previous experience of the potential employees before introducing new employees to the Outage Management Department. The following section focuses on Outage Processes and starts with the Outage Planning process.

5.5.2 Outage planning

The data analysis continues with a review of the Outage Planning portion of the survey. The elements that form part of Outage Planning include:

- Outage Organisation.
- The Outage Process.
- Outage Planning.
- Outage Planning Start.
- Outage Scope Development.
- Single Outage Plan.

The elements of Outage Planning are analysed using the results of the survey starting with the Outage Organisation element.

5.5.2.1 Outage organisation

This section reviews the respondents' perception of the outage organisation. An Outage Organisation with a high level of maturity will satisfy the requirements of Level 5, the Best Practice criteria of the Outage Management Maturity Framework. The Outage Organisation section of the survey showed 64 respondents.

Table 5.9 shows a portion of the Kwiksurveys Report.

Table 5.9: Summary of the respondents to the Outage Organisation Section of the Survey (**Source:** Own Source)

Outage Organisation	Responses	Weighted Ave	Standard Deviation
Formal outage organisation defined.	64	4.06	15.45
Individuals make decisions regarding outages considering the big picture.	64	3.23	11.01
The outage management leadership is recognised.	64	3.44	11.82
The Outage leadership roles are defined with responsibilities for communication and decision-making.	64	3.78	17.15
Outage leaders are faced with making a small number of decisions.	64	2.52	10.03
The responsibilities for areas like materials management, maintenance, engineering, operating, project management, safety and the contractor interface are defined.	64	3.66	16.63
Fully integrated outage organisation with specific roles and responsibilities are defined.	64	3.52	12.91
Outage teams and stakeholders work in a cooperative manner and adhere to processes.	64	2.89	8.84
Communication and decision making is largely seamless.	64	2.80	7.63
Total Average		3.32	12.39

The data in Table 5.9 shows a total weighted average of 3.32 for the Outage Organisation. The Average Standard Deviation is 12.39.

The high standard deviation is an indication that the understanding of the perceived maturity of this section spread over a wide range.

Figure 5.3 presents the responses to the Outage Organisation with the Likert scale of each statement with most of the statements in the Agree selection though one sub-element showed a Disagree selection.

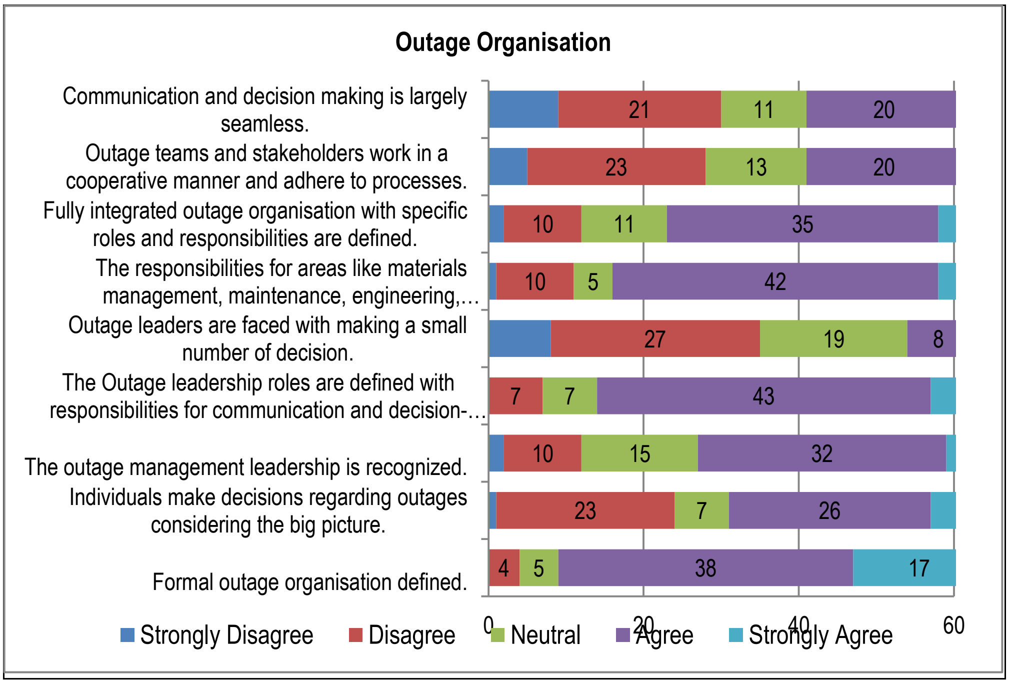


Figure 5.3: Outage Organisation (**Source:** Own Source)

Table 5.9 shows three sub-elements of the Outage Organisation that has a weighted average less 3. The Outage Organisation element is ranked at a Level 2 maturity, Experimenting.

5.5.2.2 Outage process

This section reviews the respondents' perception of the outage process. An Outage Organisation with a high maturity level in the outage process element will satisfy the requirements of Level 5, the Best Practice criteria of the Outage Management Maturity Framework. The Outage Process section of the survey showed 63 respondents. Table 5.10 shows a portion of the Kwiksurveys Report.

The data in Table 5.10 shows a total weighted average for 3.61 for the Outage Process. The Average Standard Deviation is 12.45. The high standard deviation is an indication that the understanding of the perceived maturity of this section spread over a wide range.

Table 5.10: Summary of the respondents to the Outage Process Section of the Survey (**Source:** Own Source)

The Outage Process	Responses	Weighted Average	Standard Deviation
A formal process for outage planning is in place.	63	4.17	14.52
The outage process identifies and adhere cut-off dates.	63	3.75	11.33
The outage process only covers critical elements of outage planning process– Prepare and execute.	63	2.92	11.15
Outage Readiness Review process is established, with review due dates established and adhered too.	63	3.68	12.42
The outage management team depends on readiness reviews and lessons learned integrated into future outages.	63	3.51	12.84
Total Average		3.61	12.45

Figure 5.4 presents the responses to the Outage Process with the Likert scale of each statement with most of the sub-elements in the Agree selection though one sub-element in Disagree selection.

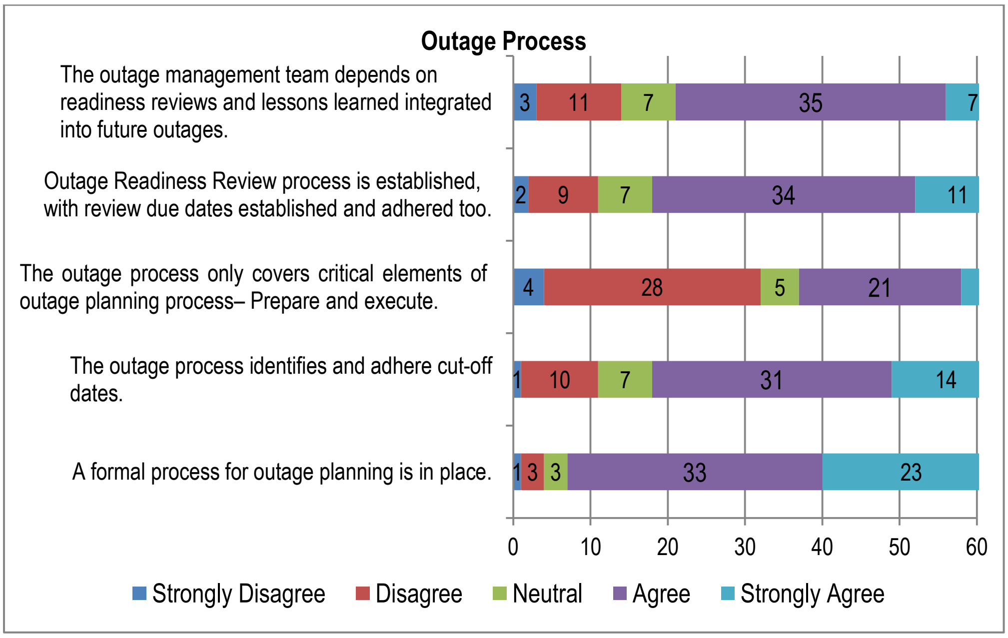


Figure 5.4: Outage Process (**Source:** Own Source)

Table 5.10 shows one sub-element of the Outage Process has a weighted average less 3. The Outage Process element is ranked at Level 2 maturity, Experimenting.

5.5.2.3 Outage planning and outage planning start

This section reviews the respondents' perception of outage planning. The Outage Organisation with a high level of maturity in outage planning will satisfy the requirements of Level 5, the Best Practice criteria of the Outage Management Maturity Framework. The Outage Planning section of the survey showed 62 respondents.

The data in Table 5.11 shows a total weighted average of 3.56 for Outage Planning. The Average Standard Deviation is 12.97 showing that the understanding of the perceived maturity of this section spread over a wide range.

Table 5.11: Summary of the respondents to the Outage Planning Section of the Survey (**Source:** Own Source)

Outage Planning	**Responses**	**Weighted Ave**	**Standard Deviation**
Outage Management Plan (OMP) developed and used to add the outages planning.	62	3.61	15.60
The Outage Management Plan clearly established roles and responsibilities for all stakeholders and the OMP is adhered too.	62	3.50	10.99
Total Average		3.56	12.97

Figure 5.5 presents the responses to the Outage Process with the Likert scale of each statement with most of the sub-elements in the Agree selection.

The Outage Planning Starts form part of the Outage Planning section, and with a high level of maturity will satisfy the requirements of Level 5, the Best Practice criteria of the Outage Management Maturity Framework.

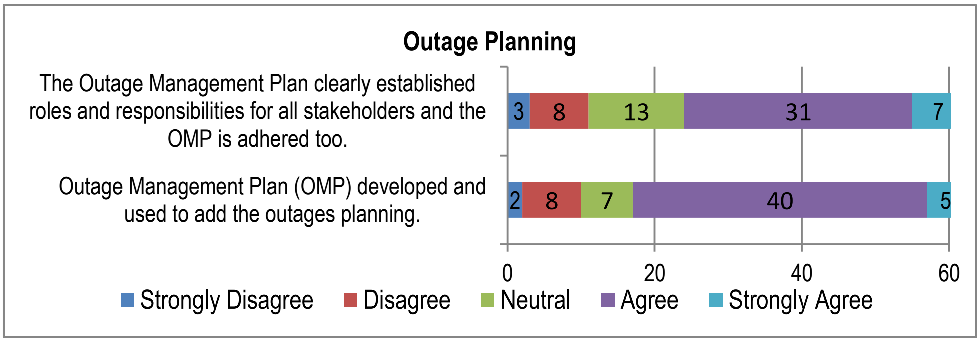


Figure 5.5: Outage Planning (**Source:** Own Source)

The data in Table 5.12 shows the Outage Planning Start section of the survey showed 62 respondents. The total weighted average of 4.37 for the Outage Planning. The Average Standard Deviation is 17.73 showing that the understanding of the perceived maturity of this section is spread over a wide range.

Table 5.12: Summary of the respondents to the Outage Planning Start (Outage Starts) Section of the Survey (**Source:** Own Source)

Outage Planning starts 3 months prior to the start of the outage.	Outage Planning starts 3 to 6 months prior to the start of the outage.	Outage Planning starts 12 months prior to the start of the outage.	Outage Planning starts 18 months prior to the start of the outage.	Outage Planning starts 24 months prior to the start of the outage.	Responses	Weighted Ave	Standard Deviation
2	5	5	6	44	62	4.37	17.73

The data in Table 5.11 and Table 5.12, shows the Outage Planning and Outage Planning Start have a combined weighted average of greater than 3. The Outage Planning and Outage Planning Start elements is ranked at Level 3, Enlightened.

5.5.2.4 Outage scope development

This section reviews the respondents' perception of outage scope development. The Outage organisation with a high outage scope development maturity level will satisfy the requirements of Level 5, the Best Practice criteria of the Outage Management Maturity Framework. The Outage Scope Development section of the survey showed 62 respondents.

The data in Table 5.13 shows a total weighted average of 3.56 for the Outage Scope Development. The Average Standard Deviation is 12.97 showing that the understanding of the perceived maturity of this section spread over a wide range.

Table 5.13: Summary of the respondents to the Outage Scope Development Section of the Survey (**Source:** Own Source)

Outage scope is developed based on:	Responses	Weighted Ave	Standard Deviation
The outage scope considers previous outage scope.	62	3.40	12.46
The outage scope considers Preventative Maintenance Programs.	62	3.44	10.04
The outage scope considers Corrective Maintenance, and Inspection Reports.	62	3.65	10.78
The outage scope considers the Modification Programs.	62	3.79	15.27
The outage scope considers Engineering Programs and lessons learnt.	62	3.55	11.39
Total Average		3.56	11.99

Figure 5.6 presents the responses to the Outage Scope Development with the Likert scale of each statement with most of the sub-elements in the Agree selection.

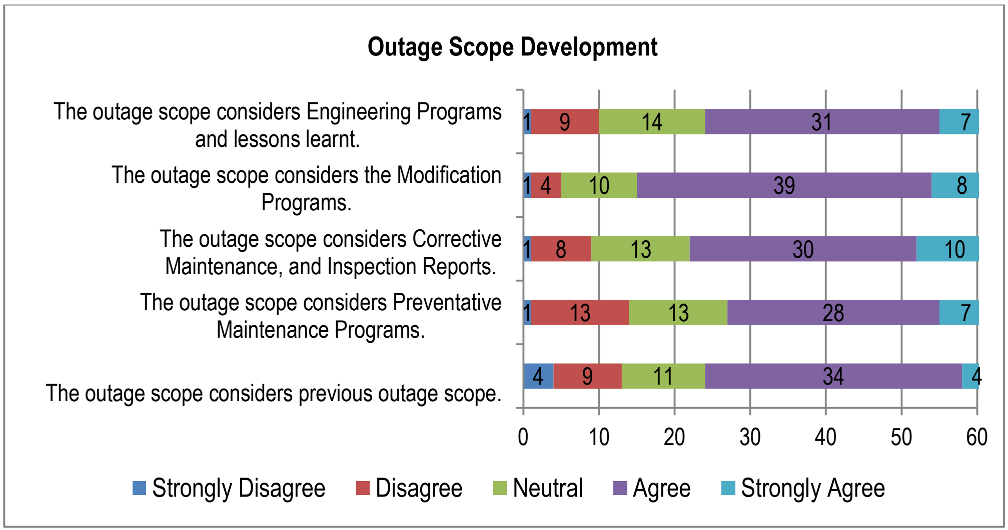


Figure 5.6: Outage Scope Development (**Source:** Own Source)

The data presented in Table 5.13 indicates that the Outage Scope Development has a sub-element weighted average of greater than 3. The Outage Scope Development element is ranked at Level 3, Enlightened.

5.5.2.5 Single outage plan

This section reviews the respondents' perception of the single outage plan. The Outage Organisation with a high level of maturity for the single outage plan will satisfy the requirements of Level 5, the Best

Practice criteria of the Outage Management Maturity Framework. The Single Outage Plan section of the survey showed 57 respondents.

The data in Table 5.14 shows a total weighted average of 3.83 for the Outage Scope Development. The Average Standard Deviation is 12.84 showing that the understanding of the perceived maturity of this section spread over a wide range.

Table 5.14: Summary of the respondents to the Single Outage Plan Section of the Survey (**Source:** Own Source)

Single Outage Plan	Responses	Weighted Ave	Standard Deviation
Single outage plan is formal, universally understood and published to all stakeholders.	57	3.84	13.15
Single outage plan developed in a scheduling tool.	57	4.07	16.64
Single outage plan includes the input and oversight from all affected disciplines.	57	3.74	11.63
The critical path of the outage defined and lower priority jobs arranged around it.	57	4.05	13.50
Level of detail on the plan supports an hour-to-hour breakdown.	57	3.46	9.26
Total Average		3.83	12.84

Figure 5.7 presents the responses to the Single Outage Plan with the Likert scale of each statement with most of the sub-elements in the Agree selection.

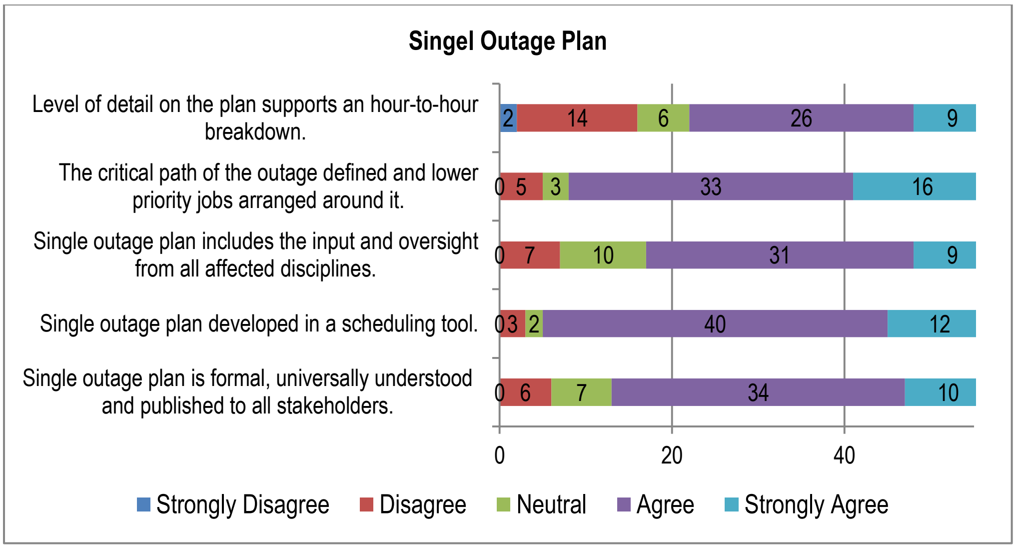


Figure 5.7: Single Outage Plan (**Source:** Own Source**)**

Table 5.14, Single Outage Plan has a weighted average of greater than 3. The Single Outage Plan element is ranked at Level 3, Enlightened.

The Outage Planning Phase consists of five elements. The Outage Planning and Planning Start, the Scope Development and Single Outage Plan are all ranked at level 3, Enlightened. However, the Outage Organisation and Outage Process elements are ranked at Level 2, Experimenting.

The Outage Planning Phase is ranked at level 2, Experimenting. The followed section covers the data analysis for the Outage Control Phase.

5.5.3 Outage control

The data analysis continues with a review of the Outage Control Phase of the survey and includes:

- Scope management.
- Outage progress.
- Outage progress feedback.
- Outage work order usage.
- Work order closeout.
- Percentage planned versus unplanned work.
- Outage schedule adherence.

The elements of outage control are analysed using the results of the survey starting with the Scope Management.

5.5.3.1 Scope management

This section reviews the respondents' perception of scope management. The Outage Organisation with a high maturity level for scope management will satisfy the requirements of Level 5, the Best Practice criteria of the Outage Management Maturity Framework. The Scope Management section of the survey showed 64 respondents.

The data in Table 5.15 shows a total weighted average of 3.36 for the Scope Management. The Average Standard Deviation is 10.85 showing that the understanding of the perceived maturity of this section spread over a wide range.

Table 5.15: Summary of the respondents to the Scope Development Section of the Survey (**Source:** Own Source)

Scope Management	Responses	Weighted Ave	Standard Deviation
A scope management process in place.	59	3.95	12.95
Scope management process is adhered too.	59	3.02	8.76
Reactive/Emergent work uses a new work orders.	59	3.47	11.82
Repairs/follow-up work performed uses new work order.	59	3.25	12.11
Emergent and additional work receives a separate follow-up work order.	59	3.42	11.03
A new work order created for rework with the duration and cost quantified.	59	3.05	8.41
Total Average		3.36	10.85

Figure 5.8 presents the responses to the Scope Management with the Likert scale of each statement with most of the sub-elements in the Agree selection.

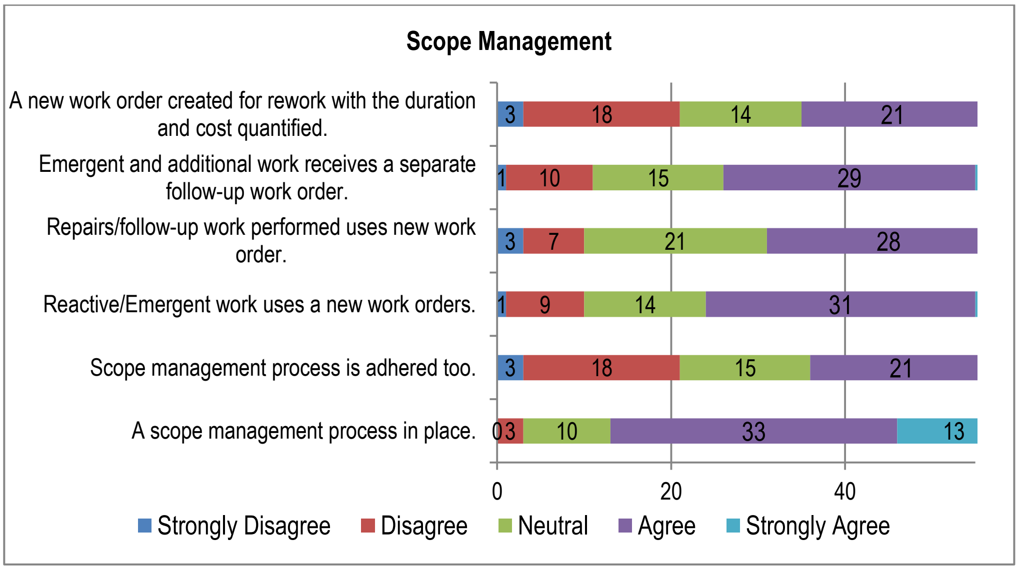


Figure 5.8: Scope Management (**Source:** Own Source)

Table 5.15, Scope Management has a weighted average of greater than 3 for all sub-elements. The Scope Management element is ranked at Level 3, Enlightened.

5.5.3.2 Outage progress

This section reviews the respondents' perception of outage progress. The Outage Organisation with a high level of maturity in outage progress will satisfy the requirements of Level 5, the Best Practice criteria of the Outage Management Maturity Framework.

The Outage Progress section of the survey showed 59 respondents.

The data in Table 5.16 shows the total weighted average of 3.28 for the Outage Progress is 3.28. The Average Standard Deviation is 10.85 showing that the understanding of the perceived maturity of this section spread over a wide range.

Table 5.16: Summary of the respondents to the Outage Progress Section of the Survey (**Source:** Own Source)

Outage Progress	**Responses**	**Weighted Ave**	**Standard Deviation**
Outage progress updated in real time updates per shift.	59	3.37	10.03
Scheduling tools accurately capture start and finish information.	59	3.44	10.83
The outage execution schedule provides actual progress feedback and controls work.	59	3.41	10.52
Enterprise Resource Planning (ERP) systems (captures actual progress performance data i.e. cost and hours worked).	59	2.88	8.70
Total Average		3.28	10.02

Figure 5.9 presents the responses to the Outage Progress with the Likert scale of each statement with most of the sub-elements in the Agree selection with one sub-element with a Neutral selection.

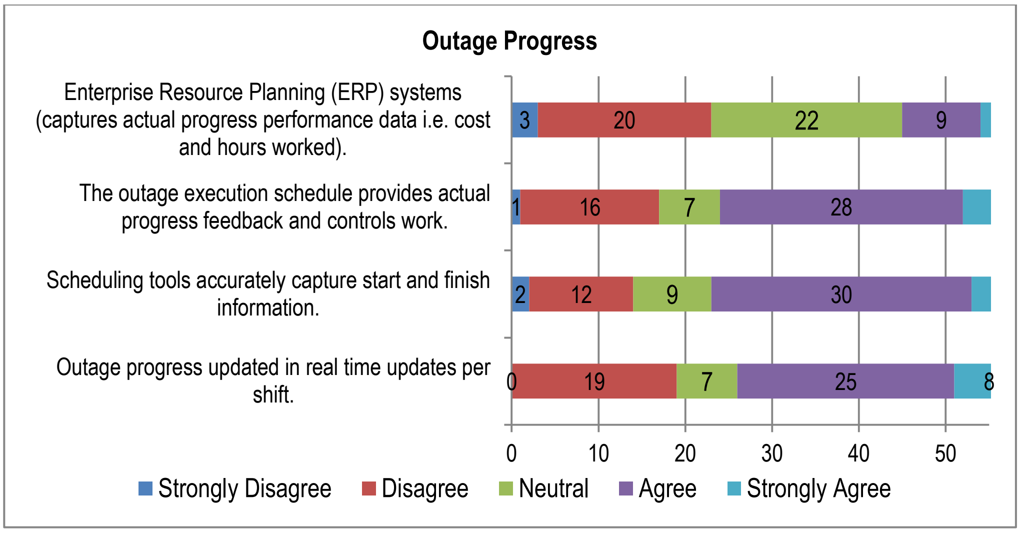


Figure 5.9: Outage Progress (**Source:** Own Source)

One sub-element in Table 5.16 of the Outage Progress has a weighted average less than 3. The Outage Progress element is ranked at a Level 2 maturity, Experimenting.

5.5.3.3 Outage work order usage

This section reviews the respondents' perception of outage work order usage. The Outage Organisation with a high outage work order usage maturity level will satisfy the requirements of Level 5, the Best Practice criteria of the Outage Management Maturity Framework. The Outage Work Order Usage section of the survey showed 51 respondents.

The data in Table 5.17 shows a total weighted average of 3.32 for the Outage Work Order Usage. The Average Standard Deviation is 8.04 showing that the understanding of the perceived maturity of this section is spread over a wide range and is only two standard deviations from six standard deviations.

Table 5.17: Summary of the respondents to the Outage Work Order Usage Section of the Survey (**Source:** Own Source)

Outage Work Order Usage	Responses	Weighted Ave	Standard Deviation
Each activity executed in the outage has an outage work orders.	51	3.33	7.50
The outage work orders are task specific.	51	3.33	9.04
Routine outage work has task specific work orders.	51	3.53	9.71
All proactive and reactive jobs have individual work orders.	51	3.10	5.93
Total Average		3.32	8.04

Figure 5.10 presents the responses to the Outage Work Order Usage with the Likert scale of each statement with most of the sub-elements in the Agree selection.

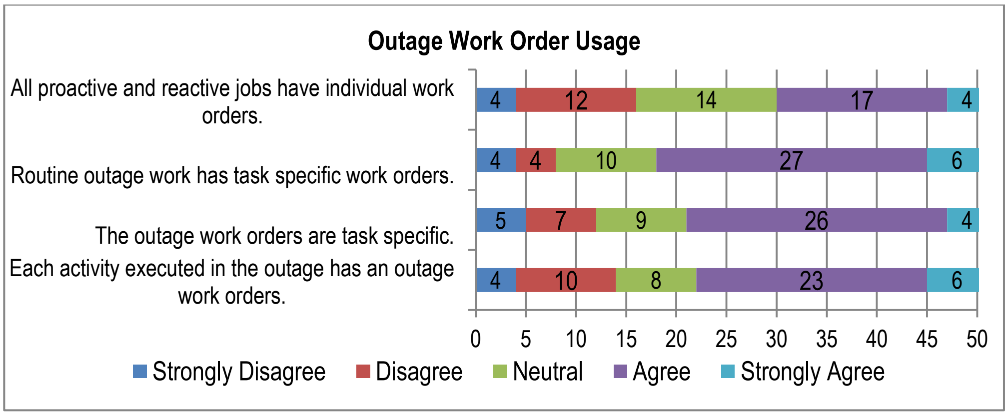


Figure 5.10: Outage Order Usage (**Source:** Own Source)

Table 5.17, Outage Work Order Usage, all sub-elements have a weighted average of greater than 3. The Outage Work Order Usage element is ranked at Level 3, Enlightened.

5.5.3.4 Work order closeout

This section reviews the respondents' perception of work order closeout. The Outage Organisation with a high work order closeout maturity level will satisfy the requirements of Level 5, the Best Practice criteria of the Outage Management Maturity Framework. The Work Order Closeout section of the survey showed 51 respondents.

The data in Table 5.18 shows the total weighted average of 2.97 for the Work Order Closeout. The Average Standard Deviation is 7.67 showing that the understanding of the perceived maturity of this section is spread over a range with less than 2 standard deviations from a normal distribution.

Table 5.18: Summary of the respondents to the Work Order Closeout Section of the Survey (**Source:** Own Source)

Work Order Closeout	Responses	Weighted Ave	Standard Deviation
Work orders remains in an open status for a long periods after work is completed.	51	3.18	5.85
Work orders history captures all part codes identified.	51	3.16	7.89
Work orders history captures all problems and reason codes identified.	51	3.12	7.76
Written feedback provided on less than 15% of work orders.	51	2.84	8.29
Written feedback provided on less than 50% of work orders.	51	2.75	8.29
Written feedback provided on more than 50% of work orders.	51	2.88	8.26
More than 90% of all work orders have written feedback provided on the same shift.	51	2.90	7.33
Total Average		2.97	7.67

Figure 5.11 presents the responses to the Work Order Closeout with the Likert scale of each statement with most of the sub-elements in the Neutral selection with two sub-elements with an Agreed selection.

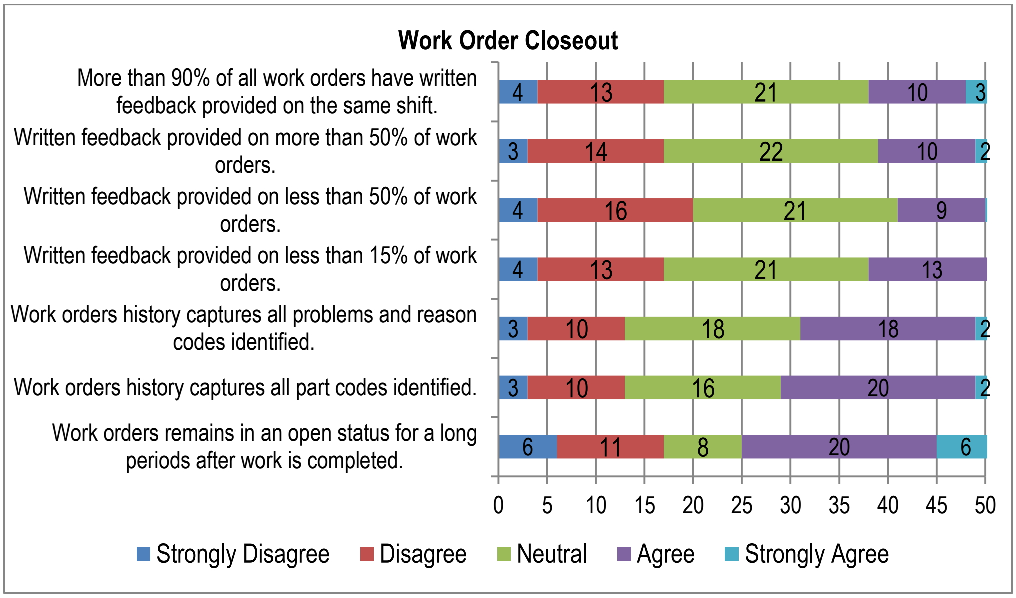


Figure 5.11: Outage Order Usage (**Source:** Own Source)

The Work Order Usage element Table 5.18 has four elements with a weighted average less 3. The Work Order Usage element is ranked at a Level 2 maturity, Experimenting.

5.5.3.5 Percentage planned versus unplanned work

This section reviews the respondents' perception of percentage planned versus unplanned work. The Outage Organisation with a high percentage planned versus unplanned work maturity level will satisfy the requirements of Level 5, the Best Practice criteria of the Outage Management Maturity Framework.

The Percentage Planned versus Unplanned Work section of the survey showed 50 respondents.

Table 5.19: Summary of the respondents to the Percentage Planned versus Unplanned Work Section of the Survey (**Source:** Own Source)

0% Planned and 100% Unplanned Work	30% Planned and 40% Unplanned Work	50% Planned and 50% Unplanned Work	70% Planned and 30% Unplanned Work	0% Planned and 10% Unplanned Work	Responses	Weighted Ave
0	2	7	40	1	50	3.80

The total weighted average for the Percentage Planned versus Unplanned Work is 3.80 ranking it at level 3, Enlightened.

5.5.3.6 Outage schedule adherence

This section reviews the respondents' perception of outage schedule adherence. The Outage Organisation with a high outage schedule adherence maturity level will satisfy the requirements of Level 5, the Best Practice criteria of the Outage Management Maturity Framework. The Outage Schedule Adherence section of the survey showed 49 respondents.

The data in Table 5.20 shows the total weighted average of 3.23 for the Outage Schedule Adherence. The Average Standard Deviation is 7.56 showing that the understanding of the perceived maturity of this section is spread over a range with less than 2 standard deviations from a normal distribution.

Table 5.20: Summary of the respondents to the Outage Schedule Adherence Section of the Survey (**Source:** Own Source)

Outage Schedule Adherence	Responses	Weighted Ave	Standard Deviation
Outage schedule adherence is known and measured.	49	3.61	9.83
Outage schedule adherence is greater than 30%	49	3.47	7.40
Outage schedule adherence is greater than 50%	49	3.12	7.19
Outage schedule adherence is greater than 70%	49	3.06	6.53
Outage schedule adherence is greater than 80%	49	2.90	6.83
Total Average		3.23	7.56

Figure 5.12 presents the responses to the Outage Schedule Adherence with the Likert scale of each statement with three of the sub-elements in the Agreed selection with two sub-elements in the Disagreed selection.

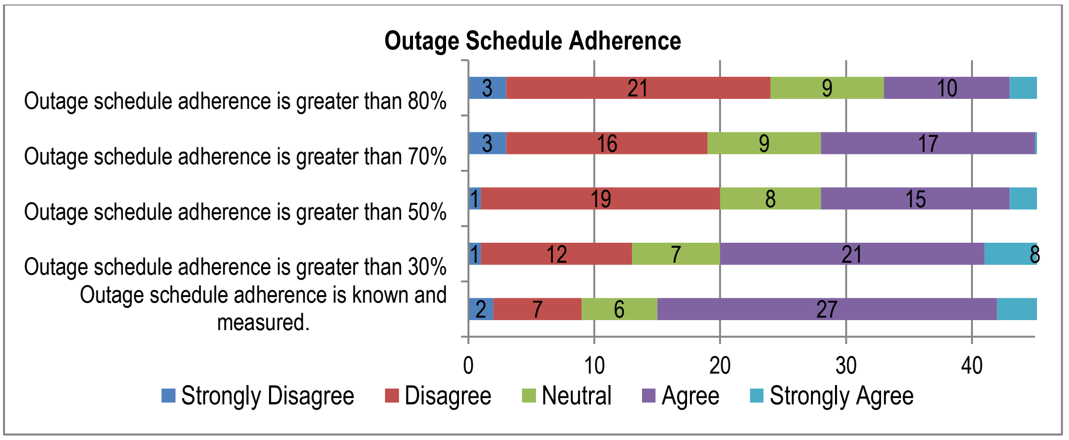


Figure 5.12: Outage Schedule Adherence (**Source:** Own Source)

The Outage Schedule Adherence element Table 5.20 has one sub-element with a weighted average less 3. The Outage Schedule Adherence element is ranked at a Level 2 maturity, Experimenting.

The Outage Control Phase consists of six elements. The Scope Management, Outage Work Order Usage and Percentage Planned versus Unplanned Work are all ranked at level 3, Enlightened. However, the Outage Progress, Work Order Closeout and Outage Schedule Adherence are ranked at Level 2, Experimenting. Therefore, the Outage Control Phase is ranked at level 2, Experimenting.

5.5.4 Outage improvement

The data analysis continues with a review of the Outage Improvement Phase of the survey and includes:

- Work order: coordination delays.
- Lessons learnt.
- Risk assessmen.t
- Risk mitigation.

The elements of Outage Improvement will be analysed using the results of the survey starting with the Work Order Coordination Delays.

5.5.4.1 Work order coordination delays

This section reviews the respondents' perception of work order coordination delays. The Outage Organisation with a high work order coordination delay maturity level will satisfy the requirements of Level 5, the Best Practice criteria of the Outage Management Maturity Framework. The Work Order Coordination Delays section of the survey showed 51 respondents.

The data in Table 5.21 shows a total weighted average of 3.08 for the Work Order Coordination Delays. The Average Standard Deviation is 7.92 showing that the understanding of the perceived maturity of this section is spread over a range with less than 2 standard deviations from a normal distribution.

Table 5.21: Summary of the respondents to the Work Order Coordination Delays Section of the Survey (**Source:** Own Source)

Work Order - Coordination Delays	Responses	Weighted Ave	Standard Deviation
Coordination delays are known and recorded.	51	3.18	5.72
All coordination delays greater than 60 minutes are recorded.	51	2.90	7.12
All coordination delays greater than 30 minutes are recorded.	51	2.57	7.36
Total Average		3.08	7.92

Figure 5.13 presents the responses to the Work Order Coordination Delays with the Likert scale of each statement. The responses are balanced between Agree and Disagree for two of the three sub-elements.

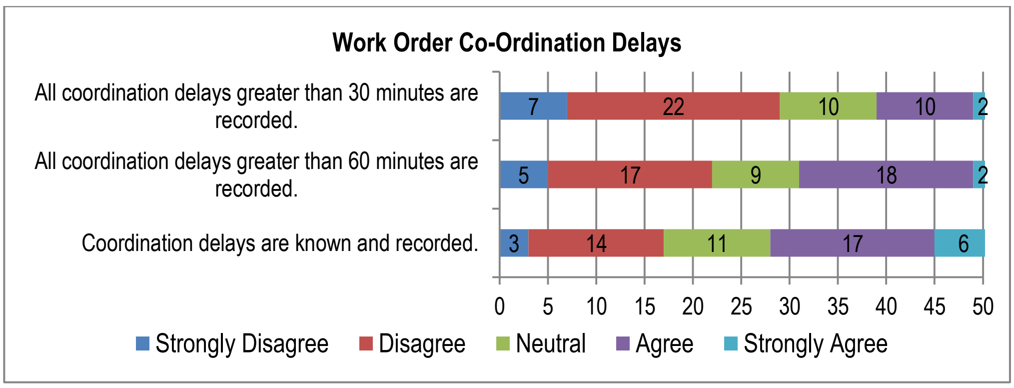


Figure 5.13: Work Order Coordination Delays (**Source:** Own Source)

The Work Order Coordination Delays sub-element shown in Table 5.21 has two sub-elements with a weighted average less than 3. The Work Order Coordination Delays element is ranked at a Level 2 maturity, Experimenting.

5.5.4.2 Lessons learnt

This section reviews the respondents' perceptions of lessons learnt. The Outage Organisation with a high lessons learnt maturity level will satisfy the requirements of Level 5, the Best Practice criteria of the Outage Management Maturity Framework. The Lessons Learnt section of the survey showed 51 respondents.

The data in Table 5.22 shows a total weighted average of 3.70 for the Lessons Learnt. The Average Standard Deviation is 10.31 showing that the understanding of the perceived maturity of this section spread over a wide range.

Table 5.22: Summary of the respondents to the Lessons Learnt Section of the Survey (**Source:** Own Source)

Lessons Learnt:	**Responses**	**Weighted Ave**	**Standard Deviation**
Outage team records lessons learnt.	50	4.16	13.86
Outage team discusses and accurately document lessons learnt.	50	3.76	12.08
Outage team cycles lessons learnt into future outage planning.	50	3.50	8.60
Outage team captures lessons learnt in an information management system and shares throughout the organisation.	50	3.38	6.71
Total Average		3.70	10.31

Figure 5.14 presents the responses to the Lessons Learnt with the Likert scale of each statement with all of the sub-elements the Agree selection.

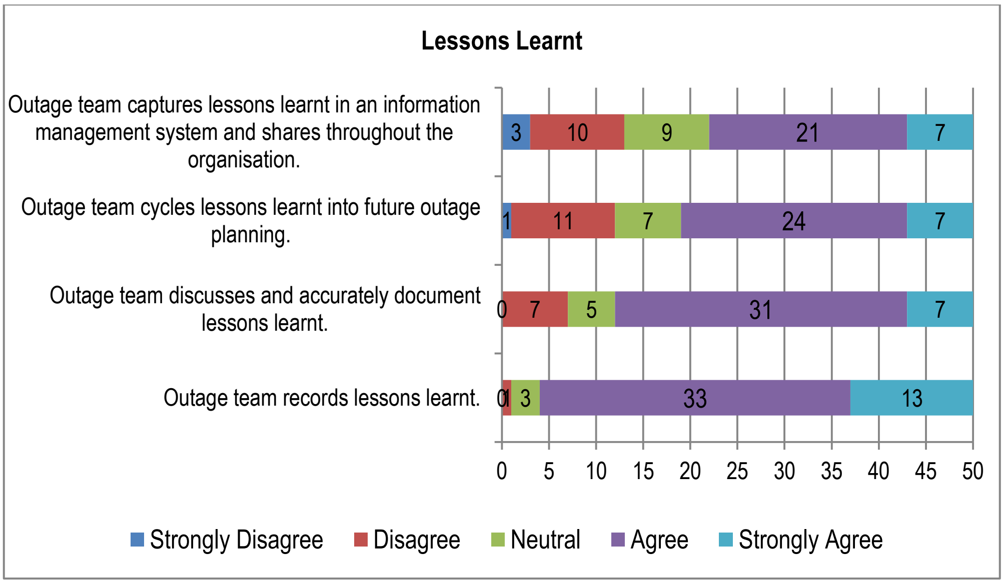


Figure 5.14: Lessons Learnt (**Source:** Own Source)

The Lessons Learnt sub-elements shown in Table 5.22, all have a weighted average of greater than 3. The Lessons Learnt element is ranked at Level 3, Enlightened.

5.5.4.3 Risk assessment

This section reviews the respondents' perception of risk assessment. The Outage Organisation with a high risk assessment maturity level will satisfy the requirements of Level 5, the Best Practice criteria of the Outage Management Maturity Framework. The Risk Assessment section of the survey showed 48 respondents.

The data in Table 5.23 shows a total weighted average of 3.62 for the Risk Assessment. The Average Standard Deviation is 10.31 showing that the understanding of the perceived maturity of this section spread over a wide range.

Table 5.23: Summary of the respondents to the Risk Assessment Section of the Survey (**Source:** Own Source)

Risk Assessments:	**Responses**	**Weighted Ave**	**Standard Deviation**
Risk analysis performed.	48	3.83	12.24
Risk analyses are objective.	48	3.69	9.24
Risk analysis identifies specific factors for critical jobs defined.	48	3.79	12.76
Risk mitigation measures drills down to specific recovery or avoidance actions to be taken.	48	3.50	9.50
Organisation executes risk avoidance and recovery actions.	48	3.38	8.59
Personal responsibilities assigned to both recovery and avoidance activities identified.	48	3.54	9.56
Total Average		3.62	10.31

The Risk Assessment sub-elements shown in Table 5.23, have all sub-elements with a weighted average of greater than 3 and therefore the Risk Assessment element is ranked at Level 3, Enlightened.

5.5.4.4 Risk mitigation

This section reviews the respondents' perception of the risk mitigation. The Outage Organisation with a high risk mitigation maturity level will satisfy the requirements of Level 5, the Best Practice criteria of the Outage Management Maturity Framework. The Risk Mitigation section of the survey showed 48 respondents.

The data in Table 5.24 shows a total weighted average of 3.69 for the Risk Mitigation.

The Average Standard Deviation is 11.47 showing that the understanding of the perceived maturity of this section spread over a wide range.

Table 5.24: Summary of the respondents to the Risk Mitigation Section of the Survey (**Source:** Own Source)

Risk Mitigation	Responses	Weighted Ave	Standard Deviation
Some jobs are identified to be "watched more closely".	48	4.04	14.54
Level of detail drills down to specific recovery or avoidance actions to be taken.	48	3.52	9.29
Organisation executes avoidance and recovery actions.	48	3.56	10.69
Both recovery and avoidance activities identified and personnel responsibilities assigned for most critical jobs.	48	3.63	11.37
Total Average		3.69	11.47

Figure 5.15 presents the responses to the Lessons Learnt with the Likert scale of each statement with all of the sub-elements in the Agree selection.

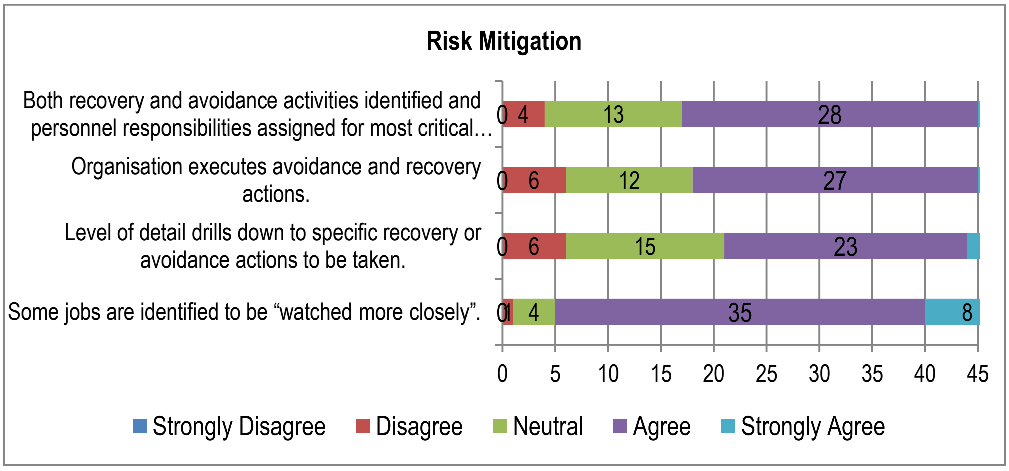


Figure 5.15: Risk Mitigation (**Source:** Own Source)

The Risk Mitigation sub-elements shown in Table 5.24,have a weighted average of greater than 3 and therefore the Risk Assessment element is ranked at Level 3, Enlightened.

The Outage Improvement Phase consists of four elements. The Lessons Learnt, Risk Assessment and Mitigation elements are all ranked at level 3, Enlightened. However, the Work Order Coordination Delays is ranked at Level 2, Experimenting.

Therefore, the Outage Improvement Phase is ranked at level 2, Experimenting. The following section summarises the Outage Planning, Control and Improvement phases.

5.5.5 Summary of the data analysis

The sections summarised the data analysis and provides the maturity level for the Outage Planning, Outage Control and Outage Improvement phases.

5.5.5.1 Outage planning phase

The Outage Planning phase had of five elements. Three elements where ranked at level 3, Enlightened but the Outage Organisation and Outage Process elements where ranked at Level 2, Experimenting. The Outage Planning Phases final ranking is level 2, Experimenting.

5.5.5.2 Outage control phase

The Outage Control Phase had six elements. Three elements where ranked at level 3, Enlightened but the Outage Progress, Work Order Closeout and Outage Schedule Adherence where ranked at Level 2, Experimenting. The Outage Control Phases final ranking is level 2, Experimenting.

5.5.5.3 Outage improvement phase

The Outage Improvement Phase had of four elements. Three elements where ranked at level 3, Enlightened but the Work Order Coordination Delays is ranked at Level 2, Experimenting. The Outage Improvement Phases final ranking is level 2, Experimenting.

The following section interprets the research data and draws a conclusion.

5.6 INTERPRETATION OF THE RESEARCH DATA

The research question inquired if the Outage Management Department is able to identify improvement opportunities if the maturity level of the outage process is established.

By determining the outage process maturity level the Outage Management Department established the “as is” state of the outage process. The instrument to determine the process maturity level developed for this research study is the Outage Management Maturity Framework. This instrument established that the outage process maturity is ranked at Level 2, Experimenting.

The data analysed in section 5.5 was used as is inputs to determine the maturity level of the Outage Process. The interpretation considers the maturity of each element.

5.6.1 Outage management maturity

Figure 5.16 showed the maturity levels for the twelve outage process elements in the Outage Management Maturity Framework. The Outage Planning, Outage Scope Development, Scope Management, Single Outage Plan, Work Order Usage and Risk Analysis are rated at a level 3, maturity level.

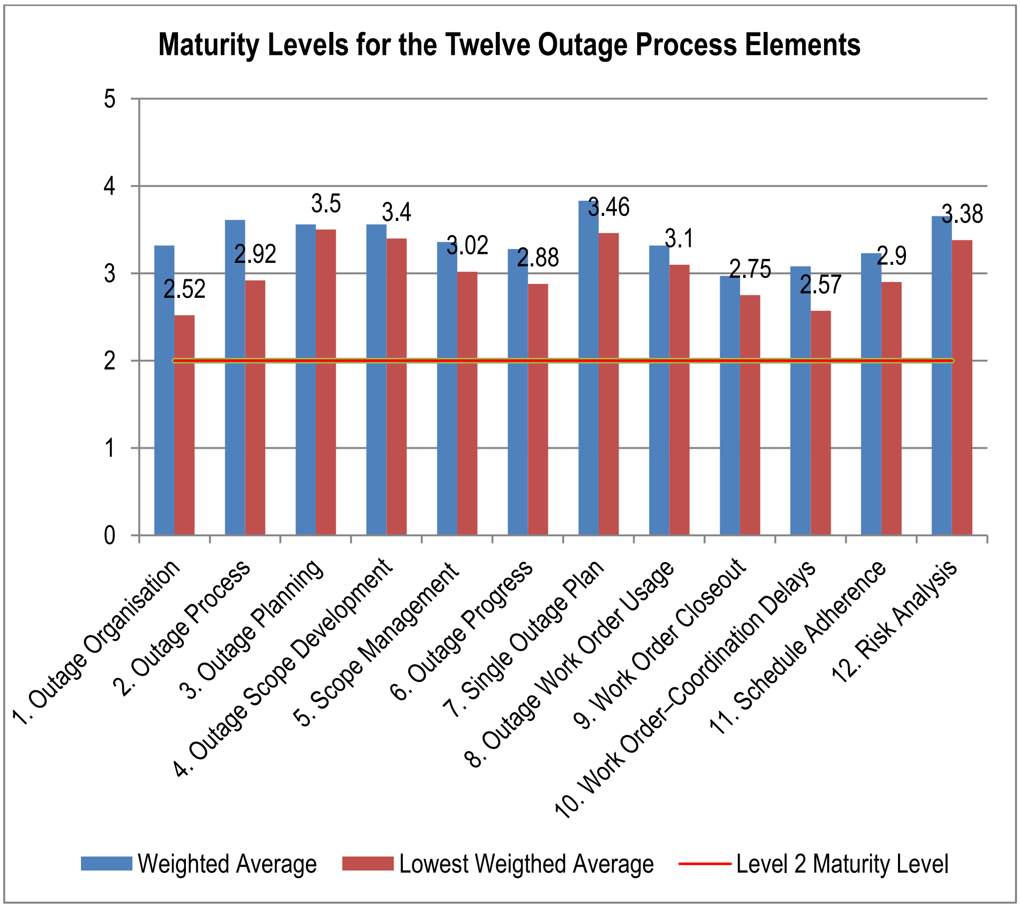


Figure 5.16: Outage Management Maturity Level July 2016 (**Source:** Own Source)

The Outage Organisation, Outage Process, Outage Progress, Work Order Closeout, Work Order Coordination Delays and Schedule Adherence are rated under level 3 maturities. Therefore, the Outage Process Maturity is at Level 2, Experimenting.

5.6.2 Overview of the Level 2 maturity

The section briefly explains the characteristics of the elements at a level 2 maturity (see Appendix A):

- **Outage Organisation Level 2**: Outage leader implied by job title, but authority and centralisation of communication and leadership not recognised. Still have a high degree of individual decision making with no coordination to the big picture.
- **Outage Process Level 2**: An outage process established and cut-off dates established, but cut-off dates are not enforced. No formal Outage readiness review process but informal reviews are completed on an adhoc basis. Outage performance is poor and organisation struggles to recover outages.
- **Outage Progress Level 2:** Verbal feedback on Outage progress updates provided daily.
- **Work Order Closeout Level 2:** Work orders are closed with some part codes identified. Verbal feedback provided at best, but poor performance.
- **Work Order Coordination Delays Level 2:** Know coordination delays but do not record the delays.
- **Schedule Adherence Level 2**: Greater than 30% schedule adherence.

5.7 CONCLUSION

The chapter expanded on the following:

- Data collection methods.
- Data analysis.
- Data validity and reliability.
- Complete the data analysis of the research study.
- Interpret the research data and determine the outage process maturity level.

The research established the overall outage process maturity level of Eskom's outage process as well as identified the low ranking sub-elements as possible improvement opportunities. The Outage Management Maturity Framework was further used to determine the individual maturity level at power station level. Appendix D provides the maturity level of individual power stations with the lowest ranking element(s) clearly identifiable. The data in Appendix D provides the opportunity for bench marking best practice across the power stations.

The conclusion and recommendations are discussed in the last chapter.

CHAPTER 6: CONCLUSION AND RECOMMENDATION

6.1 INTRODUCTION

A process maturity model is a set of well-defined structured levels that illustrate how well the practice, behavior and processes of an organisation can consistently and sustainably produce the predetermined result (Boutros & Purdie, 2014: **Online**). The Outage Management Department contributes to reliable electricity supply when they can consistently and sustainably complete outages on time and in budget. The research outcome provided an approach that supports the mandate of the Outage Management Department.

This chapter presents the research conclusion and offers recommendations based on the research findings.

6.2 THE RESEARCH THUS FAR

The research established the perceived maturity level of Eskom's outage process. Improving the outage process has a direct impact in Eskom's ability to provide reliable electricity supplier to power the South African economy. The Outage Management Maturity Framework provides a structured improvement approach that if implemented, resulting in process improvement of the outage process. Eskom should consider applying the process maturity approach to the online maintenance process and identify potential areas where this approach could add value.

The research thus far consisted of:

- **Chapter 1:** This chapter highlights the research problem statement, the research questions and the research objectives.
- **Chapter 2:** This chapter describes the research environment highlighting the background to the research.
- **Chapter 3:** This chapter reviews literature related to the research objectives. The content of this chapter includes:

  - Process maturity.
  - Outage process.
  - Outage planning.
  - Outage control.
  - Outage improvement.
  - Measurement instrument to determine outage maturity.
- **Chapter 4:** This chapter explains how the research design and methodology is selected.
- **Chapter 5:** This chapter analyses and interprets the research data.
- **Chapter 6:** This is the final chapter of the research study and provides the final analogies and recommendations to mitigate the research problem.

6.3 REFLECTION ON THE RESEARCH QUESTION

The section reflects on the research question.

6.3.1 Research question: How would process maturity enable improvement?

The literature review described the process maturity model and found it useful as a descriptive approach to determine the current state of a process, prescriptive approach provides a roadmap for improvement and a comparative approach allows benchmarking (De Bruin, Freeze, Kaulkarni & Rosemann, 2005: **Online**). The literature review found that the Crosby's Quality Management Maturity Grid is used as an assessment and improvement tool (Maier, Moultrie & Clarkson ,2012: **Online**).

Consider the research finding that ranked the outage process maturity at Level 2, Experimenting, and the Outage Management Department at Eskom is now able to describe its outage process. The Outage Management Maturity Framework also provides a structured path to improve the outage process across 12 elements as it identified six elements ranked at Level 2 and six elements ranked at Level 3, Enlightened. To move to Level 3 Eskom should focus the improvement efforts on the six Level 2 elements.

6.3.2 Research question: What are the critical elements in an outage process?

Electric Power Research Institute (EPRI) (2006: **Online**), found that an outage process consists of three phases and starts long before the outage start date, and includes both budget and resource planning. The literature explored the outage process and found that the three outage phases are outage planning and preparation, outage execution and post outage reviews (IAEA, 2002: **Online**).

Eskom's outage process consist of the same three phase and includes the outage preparation and planning phase, the outage execution phase and the post outage review phase.

12 critical elements that make up the Outage Management Maturity Framework and that is important to the outage process was adapted from Smith's Maintenance Planning and Scheduling Maturity Matrix, supported by the literature from international publications namely:

- Outage Organisation
- Outage Process
- Outage Planning
- Outage Scope Development
- Scope Management
- Outage Progress
- Single Outage Plan
- Outage Work Order Usage
- Work Order Closeout
- Work Order Coordination Delays
- Schedule Adherence
- Risk Analysis

6.3.3 Research question: What is included in outage planning, contol and improvement?

According to Spring (2010: **Online**) some outage types may require outage planning to start up to 24 months prior to the execution date. Bashir (2011: **Online**), recommend that outage preparation work should start 12 months before the outage starts. The IAEA (2006: **Online**), found that an important element of outage planning is identifying and monitoring pre-outage indicators.

The outage planning phase included the elements listed below and the research findings ranked these elements at:

- The outage organisation - Level 2 maturity.
- The outage process - Level 2 maturity.
- Outage planning and outage planning start - Level 3.
- Outage scope development - Level 3.
- Single outage plan - Level 2.

McMahon (2015: **Online**) contests that effective execution of outages is challenging and requires years of experience and the proper resources ensure that the outage work stay within budget and on schedule. The IAEA (2006: **Online**) emphasises the importance of tight controls of the work and good communication between the team member when an outage starts. Bashir (2011: **Online**) points out that the level 1 and 2 outage execution schedule should be developed one month prior the start of the outage. Use outage execution indicators to assess the outage progress and monitor the schedule adherence while this technique enables effective outage management and decision-making (IAEA, 2006: **Online**). Bashir (2011: **Online**) point out that measuring outage progress should include daily outage coordination meetings, daily planning meetings, daily progress meetings and weekly progress meetings.

The outage control phase included the elements listed below and the research findings ranked these elements at:

- Scope management - Level 3
- Outage progress - Level 2.
- Outage work order usage – Level 3.
- Outage work closeout - Level 2.
- Percentage planned versus unplanned work – Level 3.
- Outage schedule adherence – Level 2.

IAEA (2006: **Online**), mentions that a post-outage evaluation be used on the entire outage process with the aim to identify and consider possible risks in future outages. Bashir (2011: **Online**) puts emphasis on outage follow-up experience feedback reports from the work organisations and the contractors, critique meetings that captured problems encountered and lessons learnt. McMahon (2015: **Online**) found the benefits from a post outage review on completion of the outage when the contractor and the outage team reviews the performance indicators and identify good practices and areas for improvement.

The outage improvement phase included the elements listed below and the research findings ranked these elements at:

- Work order coordination delays – Level 2.
- Lessons learnt – Level 3.
- Risk assessment – Level 3.
- Risk mitigation – Level 3.

6.3.4 Research question: What measurement instrument is able to determine the outage process maturity level?

Smith (2013: **Online**) developed the Maintenance Planning and Scheduling Maturity Matrix, a grid type maturity model when applied to determine the Planning and Scheduling maturity. The Outage Management Maturity Framework draws on the work of Smith's (2013: **Online**) Maintenance Planning and Scheduling Maturity Matrix and the

Business Process Management Maturity Rosemann and de Bruin (**s.a.**, **Online**).

The Outage Management Maturity Framework was then used as the measurement instrument to determine the outage process maturity level. Outage Management Maturity Framework ranked Eskom's outage process at Level 2, Experimenting.

6.3.5 Research question: What is the current maturity level of the outage process at Eskom?

The aim of the research was to establish the maturity level of Eskom's outage process as Eskom had no indictor to measure the process maturity level. The outcome of the research established Eskom's outage process was ranked at Level 2, Experimenting with 6 elements ranked at Level 2 and six elements ranked at Level 3. The research findings quantified the process maturity level in addition to identified 6 improvement areas to move its process maturity level to Level 3, Enlightened.

6.4 THE RESEARCH QUESTIONS REVISITED

The research question for this research study read: Will the Outage Management Department be able to identify improvement opportunities if the maturity level of the outage process is established?

Eskom implemented an outage process in 2012 and by 2016 had no measure of the process performance. Eskom collected data during post outage reviews and was trending outage readiness but had no indicator the processes' maturity.

The research set out to establish maturity level of Eskom's outage process and found that Rosemann and de Bruin's Business Process Maturity Model as a suitable model to establish the maturity level of a process. The content of Rosemann and de Bruin's Business Process Maturity Model did not address the outage process honing the research to identify literature on the outage process. The literature review considered the views from international bodies, articles and found that Smith's Maintenance Planning and Scheduling Maturity Matrix provided the contents to outage process. The Outage Management Maturity Framework drew on the work of Rosemann and de Bruin's Business Process Maturity Model and Smith's Maintenance Planning and Scheduling Maturity Matrix. This Framework not only established the maturity level of Eskom's outage process and ranked it at Level 2, Experimenting but identified improvement opportunities to Eskom's outage process.

6.5 THE KEY RESEARCH OBJECTIVES REVISITED

The research objective read as follows:

- **Primary Research Objective:** The primary research objective is to establish the maturity level of Eskom's outage process using a process maturity model.

The research objective to establish the maturity level of the outage process of Eskom's outage process was achieved using a Outage Management Maturity Framework. Establishing the initial maturity level enables the Outage Management Maturity Framework to identify an improvement plan focusing on by identifying the low ranking elements.

- **Secondary Research Objectives:**
  - To consider how process maturity enables improvement
  - To identify critical elements in an outage process
  - To determine what is included in outage planning, control and improvement
  - To identify a measurement instrument to determine the maturity level of Eskom's outage process
  - To establish the current maturity level of the outage process at Eskom.

6.6 THE RESEARCH DESIGN AND METHODOLOGY REVISITED

The research set out to establish the maturity level of Eskom's outage process and describe the current state of the outage process. Therefore the research adopted the descriptive research design. The survey research method was selected as the focused on Eskom's Outage Management Department and its staff and collected data by requested the staff to respond to a survey questionnaire to obtain the staff's perceptions on the twelve elements of the Outage Management Maturity Framework.

6.7 CONCLUSION AND RECOMMENDATIONS

The following conclusions are drawn and recommendations made for consideration by the Outage Management Department:

- **Conclusion 1:** The Outage Management Maturity Framework has proven effective in determining the outage process maturity level of Eskom's outage process which was ranked it at Level 2, Experimenting.
- **Recommendation 1:** Eskom should focus its improvement plan on the six Level 2 elements to improve the outage process maturity level to Level 3.
- **Conclusion 2:** The outage process ranked at Level 2 of five possible levels. Eskom's outage process is in an experimental stage. Six elements are at Level 2 are:
  - **Outage Organisation Level 2**: Outage leader inferred by job title, but authority and centralisation of communication and leadership not recognised. Still have a high degree of individual decision making with no coordination to the big picture.
  - **Outage Process Level 2**: An outage process established and cut-off dates established, but cut-off dates are not enforced. No formal Outage readiness review process but informal reviews are completed on an adhoc basis. Outage

performance is poor and organisation struggles to recover outages.

- **Outage Progress Level 2:** Verbal feedback on Outage progress updates provided daily.
- **Work Order Closeout Level 2:** Work orders are closed with some part codes identified. Verbal feedback provided at best, but poor performance.
- **Work Order Coordination Delays Level 2:** Know coordination delays but do not record the delays.
- **Schedule Adherence Level 2**: Greater than 30% schedule adherence.

- **Recommendation 2:** It is recommended that Eskom consider developing an improvement plan for the six Level 2 elements referred to in Conclusion 1 and address the gaps to move the six elements to Level 3, Enlightened.
- **Conclusion 3:** The outage process has six elements ranked at Level 3, Enlightened.
- **Recommendation 3:** Develop an improvement plan for the six Level 3 elements to address the gaps to move these six elements to Level 4, Good practice.
- **Conclusion 4:** The Outage Management Maturity Framework enables benchmarking among power stations (see Appendix D)
- **Recommendation 4:** Identify best performing power stations (see Appendix D) in each element and establish benchmark opportunities.
- **Conclusion 5:** The use of Outage Management Maturity Framework as a process maturity indicator increases the ability of the Outage Management Department to comprehend the outage process maturity level.
- **Recommendation 5:** Outage Management should use the Outage Management Maturity Framework as an indicator to understand the outage process maturity level at least twice yearly.

The Outage Management Department plays an integral part in Eskom's mandate to provide a sustainable electricity supply. The effectiveness of the outage process depends on the effective planning, execution and closeout of outages.

The research demonstrated that the use of the Outage Management Maturity Framework assisted Eskom in establishing the maturity level of the outage process and as well as identifying opportunities to improve outage process from Level 2, Experimenting to Level 3, Enlightened. The Outage Management Maturity Framework is an appropriate instrument to assist with the continues improvement of the outage process and can further aid in developing an improvement plan to improve Eskom's outage process to Level 4, Good Practice, or even to Level 5, Best Practice.

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APPENDIX A: OUTAGE MANAGEMENT MATURITY FRAMEWORK EXCLUDING THE SMITH'S PLANNING AND SCHEDULING MATURITY MATRIX ELEMENTS

Element	Level 1 Not Engaged	Level 2 Experimenting	Level 3 Enlightened	Level 4 Good Practice	Level 5 Best Practice
Outage Organisation	No formal outage organisation defined. Decisions regarding outages are made by individuals, independent of the big picture.	Outage leader implied by job title, but authority and centralization of communication and leadership not recognized. Still a high degree of individual decision making with no coordination to the big picture	Outage leadership role defined with responsibilities for communication and decision making. Organisation not further defined. Leader is tied to a high number of decision making, resulting in slow progress and independent decision making with no coordination to the big picture	Formal Outage organisation with responsibilitie s defined for areas such as materials management, safety, mobile equipment, contractor interface and overhaul outage leadership. Team still challenged with communicatio n gaps, delaying decisions and progress	Fully integrated outage organisation with specific roles and responsibilities defined. Clear evidence that this team works in a cooperative manner and adhere to processes. Communicatio n and decision making is largely seamless
Single Outage Plan	Outage plan not formal or published. Groups work off informal lists. Multiple plans for the outage exist (maintenanc e, Engineering, Operating).	Single Outage plan developed, but the quality of the plan is severely lacking. Plan consists largely simple work lists developed with spotty job plans. Knowledge of plan resides largely with maintenance leaders.	Single Outage plan developed cooperatively with inputs and oversight from all affected disciplines. No critical path identified. All jobs are consider equal; no consistent view on priority.	Level III + Critical path job for the outage identified and lower priority jobs arranged around. Higher degree of understanding across the organisation.	Level of detail on the plan to support an hour-by-hour breakdown. Plan is communicated clearly across the organisation and universally understood. Scheduling conflicts between tasks is extremely rare.

Risk Analysis	No Risk analysis performed	Rudimentary risk analysis performed. Some jobs are identified to be “watched more closely”.	Formal risk analysis performed but largely subjective. Level of detail do not drill down to specific recovery or avoidance actions to be taken. Largely a prioritization exercise based on risk, little or no action taken from analysis results.	Level III + Specific factors for critical jobs defined. Organisation still struggles with execution of avoidance and recovery actions. Emergencies occur and focus is on quick recovery.	Level IV + Both recovery and avoidance activities identified and personnel responsibilities assigned for most critical jobs. Emergencies still occur, but they are rare and organisation is well prepared for them.
Outage Process	No formal process for outage planning; resources allocated as ‘just-in-time’ immediately prior to outage. Greatly diminished outage performance.	An Outage process and cut-off dates have been stablished, but cut-off dates are not enforced. Outage performance is poor; organisation struggles to recover from outages.	Formal Outage process established and routinely adhered to, covering only critical elements of the outage planning process – Identification, Prepare and Execute. Process only includes those directly impacted.	Level III + Check Readiness and Review processes incorporated. Process includes total organisation involvement.	Level IV + Heavy reliance on the review element with lessons learnt integrated into future outages. Measureable and quantifiable improvements to outage performance over time.
Work Request	Work Request are not used, work reporting is extremely informal (verbal).	Work is requested informally in most cases. A formal system for reporting work exists, but is overlooked and people prefer to use face-to-face requests.	All requested work is reported via some formal system, but only certain individuals have access to the system. Delays in requesting work occurs. Limited feedback to the requestor.	Individuals reports all requests work within the same shift as the problem is noted, but multiple systems for reporting work may still exist. Some consolation issues prevail.	Every individual is able to use a single reporting system for reporting work with detailed information and reports work when problem is noted. Feedback to requestor is ensured.
Work order Prioritization	Not Applicable to Outages				

Work Order Usage	Work orders are rarely or never used.	Individual work orders are rarely issued. Blanket work orders are commonplace.	Individual work orders are used for proactive work. Reactive work is covered under blanket work orders.	All proactive and reactive jobs have individual work orders. Repairs/follow-up work performed under parent work order or PM work order.	All proactive and reactive jobs have individual work orders. Scope creep and additional work receive a separate follow-up work order.
Work Order Status	Not applicable to Outages				
Work Order Closeout	When the work is complete, work orders are often left in an open status for a long period of time, with little or no feedback provided	Work orders are closed with some part codes identified. No coordination delays recorded. Verbal feedback at best, but poor performance.	Work orders are closed with part, some problems, and some reason codes identified. All coordination delays greater than 60 minutes recorded. Written feedback provided on less than 50% of work orders	Work orders are closed with part, and problem identified as well as some reason codes. All coordination delays over 30 minutes recorded. Written feedback on more than 50% of work	Work orders closed with part and problem identified. Required follow-up work is noted and new work order created. All work orders have some form of written feedback provided on the same shift.
Backlog Management & Measurement	Not Applicable to Outages				
Work Order History	Failure data is not tracked.	Failure codes exist, but usage spotty. Some artisans record them diligently, most do not.	Failure codes are entered for most work orders, but little or no data analysis done. Poor knowledge of failure codes.	Level III + Organisation does proper analyses and understands codes, struggles with corrective action follow-up.	Level IV + The Organisation gains benefit from the solutions executed as a result of the Failure Reporting and Corrective Action System.
% Planned Vs Unplanned	0% Planned 100% Unplanned	30% Planned 70% Unplanned	50% Planned 50% Unplanned	70% Planned 30% Unplanned	90% Planned 10% Unplanned

Ready Backlog	Not Applicable to Outages				
Wrench/Tool Time	Less than 25%	25-35%	35-45%	45-55%	Greater than 55%
% Estimated vs Actual Hours	Unknown or not measured	50% Accuracy	60% Accuracy	70% Accuracy	80% Accuracy
% Available Labor Scheduled	Unknown or not measured	30%	50%	75%	100%
Schedule Compliance	Unknown or not measured	Greater than 30%	Greater than 50%	Greater than 70%	Greater than 80%

APPENDIX B: SURVEY RESULTS

1	Do you work in the Outage Management Organisation?	Yes	NO
		84	2

Q2	How many years do you have in Eskom service?	0-5 years	5-10 years	11-15 years	Greater than15 years
		29	22	9	26

Q3	What is your TASK grade level?	Bargaining Unit	Management	Middle Management	Executive Management
		49	22	9	6

Q4	Which Power Station do you fall under?	Arnot	Kendal	Hendrina	Matla	Tutuka	Majuba	Matimba	Peaking	Koeberg	Grootvlei	Komati	Camden	Lethabo	Duvha	Kriel	Other Support Department
		0	7	3	1	1	1	0	7	18	6	1	2	6	7	2	24

Q5	What departments did you work in before joining Outage Management?	Q5.1 Engineering	Q5.2 Project Management	Q5.3 Operating	Q5.4 Maintenance	Q5.5 Outage Centre of Excellence	Q5.6 Other
		14	15	4	25	5	45

Q6	Outage organisation.	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Q6.1	Formal outage organisation defined.	0	4	5	38	17
Q6.2	Individuals make decisions regarding outages considering the big picture.	1	23	7	26	7
Q6.3	The outage management leadership is recognized.	2	10	15	32	5
Q6.4	The Outage leadership roles are defined with responsibilities for communication and decision-making.	0	7	7	43	7
Q6.5	Outage leaders are faced with making a small number of decision.	8	27	19	8	2
Q6.6	The responsibilities for areas like materials management, maintenance, engineering, operating, project management, safety and the contractor interface are defined.	1	10	5	42	6
Q6.7	Fully integrated outage organisation with specific roles and responsibilities are defined.	2	10	11	35	6
Q6.8	Outage teams and stakeholders work in a cooperative manner and adhere to processes.	5	23	13	20	3
Q6.9	Communication and decision making is largely seamless.	9	21	11	20	3

Q7	The Outage Process:	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Q7.1	A formal process for outage planning is in place.	1	3	3	33	23
Q7.2	The outage process identifies and adhere cut-off dates.	1	10	7	31	14
Q7.3	The outage process only covers critical elements of outage planning process– Prepare and execute.	4	28	5	21	5
Q7.4	Outage Readiness Review process is established, with review due dates established and adhered too.	2	9	7	34	11
Q7.5	The outage management team depends on readiness reviews and lessons learned integrated into future outages.	3	11	7	35	7

Q8	Outage Planning	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Q8.1	Outage Management Plan (OMP) developed and used to add the outages planning.	2	8	7	40	5
Q8.2	The Outage Management Plan clearly established roles and responsibilities for all stakeholders and the OMP is adhered too.	3	8	13	31	7

Q9	Outage Planning Start	Outage Planning starts 3 months prior to the start of the outage.	Outage Planning starts 3 to 6 months prior to the start of the outage.	Outage Planning starts 12 months prior to the start of the outage.	Outage Planning starts 18 months prior to the start of the outage.	Outage Planning starts 24 months prior to the start of the outage.
		2	5	5	6	44

Q10	Outage scope is developed based on:	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Q10.1	The outage scope considers previous outage scope.	4	9	11	34	4
Q10.2	The outage scope considers Preventative Maintenance Programs.	1	13	13	28	7
Q10.3	The outage scope considers Corrective Maintenance, and Inspection Reports.	1	8	13	30	10
Q10.4	The outage scope considers the Modification Programs.	1	4	10	39	8
Q10.5	The outage scope considers Engineering Programs and lessons learnt.	1	9	14	31	7

Q11	Scope Management	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Q11.1	A scope management process in place.	0	3	10	33	13
Q11.2	Scope management process is adhered too.	3	18	15	21	2
Q11.3	Reactive/Emergent work uses a new work orders.	1	9	14	31	4
Q11.4	Repairs/follow-up work performed uses new work order.	3	7	21	28	0
Q11.5	Emergent and additional work receives a separate follow-up work order.	1	10	15	29	4
Q11.6	A new work order created for rework with the duration and cost quantified.	3	18	14	21	3

Q12	Outage Progress	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Q12.1	Outage progress updated in real time updates per shift.	0	19	7	25	8
Q12.2	Scheduling tools accurately capture start and finish information.	2	12	9	30	6
Q12.3	The outage execution schedule provides actual progress feedback and controls work.	1	16	7	28	7
Q12.4	Enterprise Resource Planning (ERP) systems (captures actual progress performance data i.e. cost and hours worked).	3	20	22	9	5

Q13	Outage Progress Feedback	Provide weekly verbal feedback on Outage progress.	Provide daily verbal feedback on Outage progress.	Provide verbal progress feedback on Outage progress at the end of each shift.
		7	42	26

Q14	Single Outage Plan	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Q14.1	Single outage plan is formal, universally understood and published to all stakeholders.	0	6	7	34	10
Q14.2	Single outage plan developed in a scheduling tool.	0	3	2	40	12
Q14.3	Single outage plan includes the input and oversight from all affected disciplines.	0	7	10	31	9
Q14.4	The critical path of the outage defined and lower priority jobs arranged around it.	0	5	3	33	16
Q14.5	Level of detail on the plan supports an hour-to-hour breakdown.	2	14	6	26	9

Q15	Outage Work Order Usage	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Q15.1	Each activity executed in the outage has an	4	10	8	23	6

	outage work orders.					
Q15.2	The outage work orders are task specific.	5	7	9	26	4
Q15.3	Routine outage work has task specific work orders.	4	4	10	27	6
Q15.4	All proactive and reactive jobs have individual work orders.	4	12	14	17	4

Q16	Work Order Closeout	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Q16.1	Work orders remains in an open status for a long periods after work is completed.	6	11	8	20	6
Q16.2	Work orders history captures all part codes identified.	3	10	16	20	2
Q16.3	Work orders history captures all problems and reason codes identified.	3	10	18	18	2
Q16.4	Written feedback provided on less than 15% of work orders.	4	13	21	13	0
Q16.5	Written feedback provided on less than 50% of work orders.	4	16	21	9	1
Q16.6	Written feedback provided on more than 50% of work orders.	3	14	22	10	2
Q16.7	More than 90% of all work orders have written feedback provided on the same shift.	4	13	21	10	3

Q17	Work Order - Coordination Delays	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Q17.1	Coordination delays are known and recorded.	3	14	11	17	6

Q17.2	**All coordination delays greater than 60 minutes are recorded.**	5	17	9	18	2
Q17.3	**All coordination delays greater than 30 minutes are recorded.**	7	22	10	10	2

Q18	**Lessons Learnt:**	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
Q18.1	**Outage team records lessons learnt.**	0	1	3	33	13
Q18.2	**Outage team discusses and accurately document lessons learnt.**	0	7	5	31	7
Q18.3	**Outage team cycles lessons learnt into future outage planning.**	1	11	7	24	7
Q18.4	**Outage team captures lessons learnt in an information management system and shares throughout the organisation.**	3	10	9	21	7

Q19	**What is the % planned vs % unplanned work?**	**0% Planned and 100% Unplanned**	**30% Planned and 70% Unplanned**	**50% Planned and 50% Unplanned**	**70% Planned and 30% Unplanned**	**(0% Planned and 10% Unplanned**
		0	2	7	40	1

Q20	Outage Schedule Adherence	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Q20.1	Outage schedule adherence is known and measured.	2	7	6	27	7
Q20.2	Outage schedule adherence is greater than 30%	1	12	7	21	8
Q20.3	Outage schedule adherence is greater than 50%	1	19	8	15	6
Q20.4	Outage schedule adherence is greater than 70%	3	16	9	17	4
Q20.5	Outage schedule adherence is greater than 80%	3	21	9	10	6

Q21	Risk Assessments:	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Q21.1	Risk analysis performed.	1	5	3	31	8
Q21.2	Risk analyses are objective.	0	8	7	25	8
Q21.3	Risk analysis identifies specific factors for critical jobs defined.	0	6	4	32	6
Q21.4	Risk mitigation measures drills down to specific recovery or avoidance actions to be taken.	0	9	10	25	4
Q21.5	Organisation executes risk avoidance and recovery actions.	0	9	15	21	3
Q21.6	Personal responsibilities assigned to both recovery and avoidance activities identified.	0	5	16	23	4

Q22	Risk Mitigation	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Q22.1	Some jobs are identified to be “watched more closely”.	0	1	4	35	8
Q22.2	Level of detail drills down to specific recovery or avoidance actions to be taken.	0	6	15	23	4
Q22.3	Organisation executes avoidance and recovery actions.	0	6	12	27	3
Q22.4	Both recovery and avoidance activities identified and personnel responsibilities assigned for most critical jobs.	0	4	13	28	3

APPENDIX C: SMITH'S MAINTENANCE PLANNING AND SCHEDULING MATURITY MATRIX

Elements		Your Score (1-5 Maturity)	LEVEL 1 NOT ENGAGED	LEVEL 2 EXPERIMENTING	LEVEL 3 ENLIGHTENED	LEVEL 4 GOOD PRACTICE	LEVEL 5 BEST PRACTICE
PLANNING	Planning Education		No formal training provided.	Planners have attended a formal planner training course or workshop.	Planners have been formally trained. Affected individuals have been provided awareness training but nothing related to specific expectations.	Processes are well defined, with maintenance and operations leaders given specific training on expectations with additional on-the-job coaching.	All affected individuals have received specific training to expectations. Training is ongoing for new hires. All personnel modeling expected behaviors.
	Planner Role and Responsibilities		No planner role identified.	Role and responsibilities not clearly defined. Planner is involved with reactive work and parts chasing. No dedicated planner.	Planners develop and assemble limited job packages. Dedicated planner as a full-time resource. Unclear expectations.	Expectations of full-time planners well defined. Still an excessive amount of time spent on non-core activities.	Planners strictly focused on future work. Zero involvement with reactive work. Roles and responsibilities are clearly adhered to.
	Standard Work Procedures		No effective work procedures or accurate time estimates developed by planner.	High level work procedures developed for large jobs and outages. Heavily dependent on OEM manuals. Standard set of expectations for job plan content not established.	Standardized format for job plans established; expectations on quality and content are subjective. No clear expectations for which jobs should have a detailed plan developed.	Formal expectations developed for job plan format and content that is generally followed. Job plans are developed for work on critical assets. Moving towards quantitative vs. subjective inspection criteria.	Level IV + Evidence of continuous improvement system in place. Craftspersons involved in review and approval process.
	Labor Estimation		Job plans have no estimated labor hours assigned.	Jobs are grossly overestimated (1/2 shift or full shift) and not taken seriously in scheduling process. No formal estimating techniques are used.	Job estimates are generally more accurate; basic estimating process applied. Estimates are usually accepted as being accurate but are often overridden.	Jobs are broken down into steps and tasks with a time estimate rolled up into a total. Accepted as accurate and utilized in building the weekly schedule.	Level IV + Job plan includes estimates for coordination and other outside resources. Estimates adjusted based on history/craft feedback.
	Job Site Visits		Job site visits are rare or non-existent while "planning" work.	Planner visits job sites for "high profile" jobs only while planning work.	Planner visits large or complex job sites during planning only when no pre-existing job plan exists.	Planner reviews some job plans with maintenance supervisors and technicians at the job site to ensure completeness.	Job site visits and significant interaction with those who will perform the work is a standard practice.

	Identification of Safety Requirements		No identification of Safety/Tag out/Permit requirements by the planner.	Planner includes high-level references to site safety policies on work order.	Planner makes reference to generic safety procedures or requirements on the work order based on the equipment type/environment.	Planner prepares detailed list of safety hazards and references permits required based on job task breakdown and site visit.	Level IV + Methods to address these hazards are provided. Permits are pre-populated as much as possible and included in the work packet.
	Bill of Materials (BOM) Management		Equipment-specific BOMs do not existent.	Some BOMs developed, but only for a small portion of equipment. Most are incomplete or inaccurate; almost never formally reviewed or corrected/updated.	Level II + Some BOMs are linked to drawings, item number, and lead time for delivery.	Level III + Formal plan in place to address shortcomings on BOMs. Focus on equipment level. Plan is clearly being executed with results of efforts evident.	BOMs developed to the component level with minor exceptions. Continuous improvement and corrections a standard process. BOMs are standard part of CAPEX process.
	Determination of Required Materials		No predetermination of needed materials. Materials acquisition is entirely up to technicians “on the fly” while executing job.	Technicians identify their own materials and the planner places the order. List is quite often inaccurate. Job delays from missing material are common.	Planners work with maintenance supervisors and technicians along with past job history to develop list. Storeroom runs during job execution still common.	BOMs and job history utilized, but gaps exist. Planner expends a significant amount of time researching materials. Job delays from missing materials only occasionally occur.	BOMs and past job history leveraged extensively. Delays in job execution due to missing materials are a very rare occurrence.
	Materials Kitting		No kitting process in place. Materials acquired “on the fly” by technicians and supervisors.	Materials lay down areas exist in storeroom; informal process, much confusion and inaccuracy.	Materials kitting and staging occurs for most outage jobs and only ad hoc for weekly/daily work. Technicians drive the process.	Materials kitting and staging occurs for all outage jobs and most weekly/daily work. Storeroom personnel receive pick-lists and assemble the kits.	Kitting is standard practice with few errors. Kits are kept in a secure area, verified for accuracy against the work order and easily identified.
	Work Order Closeout		Work orders are not returned to the planner for closeout.	Work orders are returned to planner for closeout, but contain very little if any useful feedback (“Fixed, Done, Complete”).	Work orders are returned to planner with hours (actual almost always matches estimate) and no indication of missing materials. Planner occasionally makes updates.	Level III + Improvement suggestions, materials consumed, and actual hours spent. History allows management reporting on MTBF and Planned vs. Actual hours.	Level IV + Component codes and failure codes. Failure information can be discerned from work order history to drive reliability improvements.
SCHEDULING	Scheduling Meeting Participation		Scheduling meetings not held. Organization completely reactive.	Scheduling meeting only occurs for outages attended only by maintenance personnel. Production does not attend.	Scheduling meeting occurs with a standard agenda, date, time, and required attendees. Production attends meetings on occasion, but not actively engaged when present. Schedule not taken seriously.	Level III + Attendees are on time and actively engaged in the scheduling meeting. Moderate level of confidence exists in the developed schedule. Maintenance driven.	Scheduling meeting occurs like clockwork and is efficient - standard time, place, agenda. Operations drives meetings. Formal approval process (Maintenance and Operations). Senior Management sponsorship.

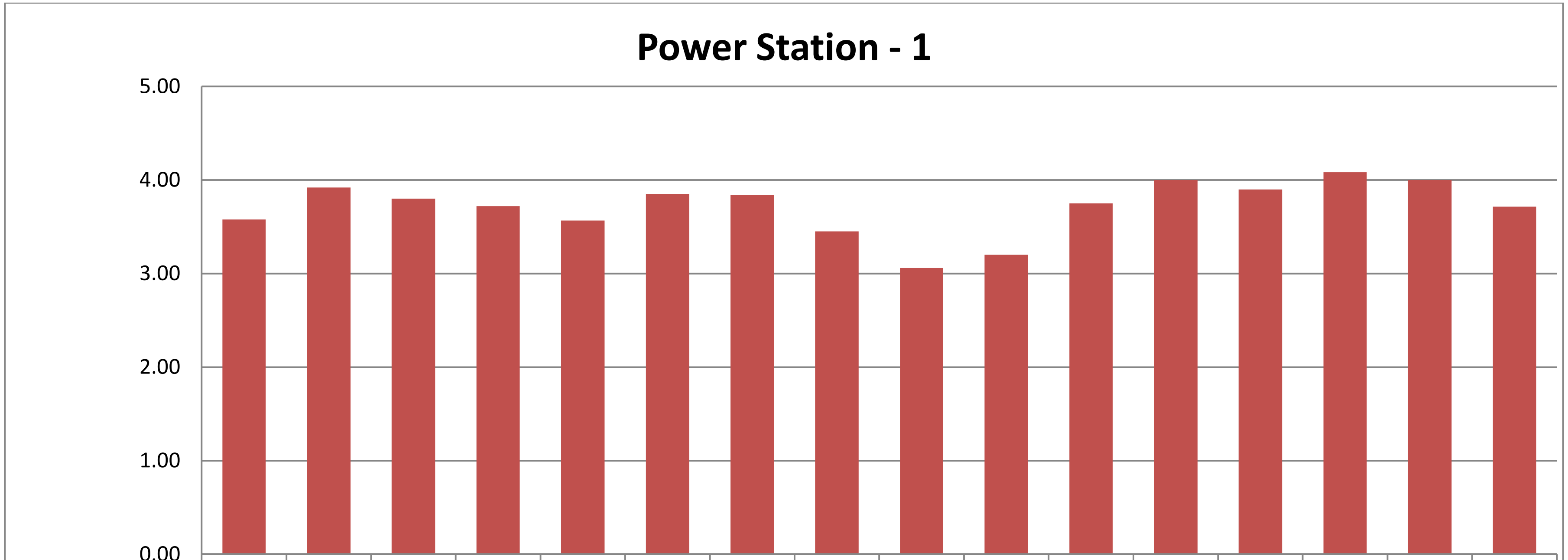
	Operations/Maintenance Use of Backlog for Scheduling		Backlog is not considered when developing a schedule. Daily reactive coordination occurs vs. weekly scheduling.	Backlog largely inaccurate and not taken seriously. Next week's schedule originates from both the backlog and on-the-spot production requests. Many very old (>90 days) jobs on the backlog; backlog is large.	Schedule is developed using a combination of backlog and last minute emergency lists. Team understands the importance of scheduling from the backlog, but still struggles with execution.	Backlog is generally considered accurate and most jobs are only scheduled from backlog, not necessarily strictly from the ready backlog (total backlog as well).	Ready backlog is the primary driver for building the schedule. Backlog size and age appropriate.
	Schedule Communication		Largely verbal agreements and informal lists. Shared only between small subset of workforce.	Schedule is published on a network drive or emailed. Rarely viewed/passive communication/small subset of organization aware of existence.	Schedule is passively posted and displayed in maintenance shops/areas only. Frequency of updates sporadic and rarely paid attention to.	Schedule is published and displayed in all areas. Schedule is regularly posted at set date/time/place; awareness of schedule content/importance varies.	Level IV + Schedule is regularly and actively reviewed with personnel at set date/time/place; published at least one week in advance. Minimal coordination delays.
	Resource Utilization		Personnel react entirely to radio/trouble calls from production/maintenance supervisors. Resource availability not known.	Available resources not taken into consideration during scheduling. Personnel select their jobs from an assignment box; no names listed. Resource utilization low.	Scheduling based on availability of resources; significant portion of schedule empty to accommodate "emergencies". Resources not scheduled to 100% availability.	Labor Hours formally scheduled to 100%. Front line supervisors react to schedule breakers, but no formal process exists. Resource utilization is moderate. Jobs assigned to personnel the day prior to work.	Level IV + Formal process in place for "schedule breakers". Resource utilization is very high. Personnel assigned to jobs the week before. Schedule breakers analyzed for improvement.
	Measuring Schedule Compliance		Not measured. No accountabilities set.	Number of work orders completed is tracked. Numbers are suspect to manipulation; methods of measurement are sporadic and variable. No system of accountability.	Only tracking work order completion rate. Formal standard in place but not consistently followed. Measurement published regularly; results not used to drive improvement.	Compliance measured by dividing the total number of labor hours completed by the total number of labor hours scheduled. Measurements formalized and trended, but not always followed.	Level IV + Method formalized and consistently followed. Organization regularly tracks and seeks out improvement opportunities.
OUTAGE PLANNING	Outage Organization		No formal outage organization defined. Decisions regarding the outage are made by individuals, independent of the big picture.	Outage leader implied by job title, but authority and centralization of communication and leadership not recognized. Still a high degree of individual decision making with no coordination to the big picture.	Outage leadership role defined with responsibility for communication and decision making. Organization not further defined. Leader tied to high number of decisions, resulting in slow progress and independent decision making with no coordination to the big picture.	Formal outage organization with responsibilities defined for areas such as materials management, safety, mobile equipment, contractor interface, and overall outage leadership. Team still challenged with communication gaps, delaying	Fully integrated outage organization with specific roles and responsibilities defined. Clear evidence that this team works in a cooperative manner and adheres to the process. Communication and decision making is largely seamless.

					decisions and progress.	
Single Outage Plan		Outage plan not formal or published. Groups work off of informal lists. Multiple plans for the outage exist (maintenance, engineering, operations, etc.).	Single outage plan developed, but the quality of the plan is severely lacking. Plan consists largely of simple work lists developed with spotty job plans. Knowledge of plan resides largely with maintenance leaders.	Single outage plan developed cooperatively with input and oversight from all affected disciplines. No critical path identified. All jobs are considered equal; no consistent view on priorities.	Level III + Critical path job for the outage identified and lower priority jobs arranged around it. Higher degree of understanding across the organization.	Level of detail on the plan to support an hour-by-hour breakdown. Plan is communicated clearly across the organization and universally understood. Scheduling conflicts between tasks is extremely rare.
Risk Analysis Performed		No risk analysis performed.	Rudimentary risk analysis performed. Some jobs are identified to be "watched more closely".	Formal risk analysis performed, but largely subjective. Level of detail does not drill down to specific recovery or avoidance actions to be taken. Largely a prioritization exercise based on risk; little or no action taken from analysis results.	Level III + Specific factors for critical jobs defined. Organization still struggles with execution of avoidance and recovery actions. Emergencies occur and focus is on quick recovery.	Level IV + Both recovery and avoidance activities identified and personnel responsibilities assigned for most critical jobs. Emergencies still occur, but they are rare and organization is well prepared for them.
Outage Process		No formal process for outage planning; resources allocated as "just-in-time" immediately prior to outage. Greatly diminished outage performance.	An outage process and cut-off dates have been established, but cut-off dates are not enforced. Outage performance is poor; organization struggles to recover from outages.	Formal outage process established and routinely adhered to, covering only critical elements of the outage planning process - Identification, Prepare, and Execute. Process only includes those directly impacted.	Level III + Check Readiness and Review processes incorporated. Process includes total organization involvement.	Level IV + Heavy reliance on the review element with lessons learned integrated into future outages. Measurable and quantifiable improvements to outage performance over time.

WORK CONTROL	Work Requests		Work Requests are not used; work reporting is extremely informal (verbal).	Work is requested informally in most cases. A formal system for reporting work exists, but it is overlooked and people prefer to use the phone or make face-to-face requests.	All requested work is reported via some formal system, but only certain individuals have access to these systems. Delays in requesting work occur. Limited feedback to the requestor.	Individuals report all requested work within the same shift as the problem is noted, but multiple systems for reporting work may still exist. Some consolidation issues prevail.	Every individual is able to use a single system for reporting work with detailed information and reports work when problem is noted. Feedback to requestor is ensured.
	Work Order Prioritization		Production areas receive attention based on loudest complaints. Priorities are constantly shifting.	Work Orders are managed by the planner or maintenance supervisor based on production input. No consistent method applied.	Formal system documented, but not consistently applied. Maintenance leader determines priorities.	Work Orders prioritized by either asset criticality, defect severity, or Work Order type. Formal system documented and followed most of the time.	Work Orders prioritized by asset criticality, defect severity, and Work Order type simultaneously. Formal documented system consistently applied.
	Work Order Usage		Work Orders rarely or never used.	Individual Work Orders are rarely issued. Blanket Work Orders are commonplace.	Individual Work Orders are used for proactive work. Reactive work is covered under blanket Work Orders.	All proactive and reactive jobs have individual Work Orders. Repairs/follow-up work performed under parent Work Order or PM Work Order.	All proactive and reactive jobs have individual Work Orders. Scope creep and additional work receive a separate follow-up Work Order.
	Work Order Status		Work Order Status not in use; all Work Orders entered as the same status.	Excessive number of statuses used. No one pays attention to Work Order Status and statuses are not generally understood.	Work flow processes documented, but only understood and used by a core group. The organization as a whole does not react properly to the Work Order Status. No controls over adding statuses to the system.	Level III + Controls over adding Work Order statuses to the system exist. Organization as a whole understands the statuses, but utilization of the status codes is not consistent.	Level IV + Work flow is bound by Work Order Status; evidence of consistent compliance is present. Process mapped and consistently followed.
	Work Order Closeout		When the work is complete, Work Orders are often left in an open status for a long period of time, with little or no feedback provided.	Work Orders are closed with some part codes identified. No coordination delays recorded. Verbal feedback at best, but spotty performance.	Work Orders are closed with part, some problem, and some reason codes identified. All coordination delays greater than 60 minutes recorded. Written feedback provided on less than 50% of Work Orders.	Work Orders are closed with part and problem identified as well as some reason codes. All coordination delays over 30 minutes recorded. Written feedback on more than 50% of Work Orders.	Work Orders are closed with part, problem, and reason codes identified. Required follow-up work is noted. All Work Orders have some form of written feedback provided on same shift.

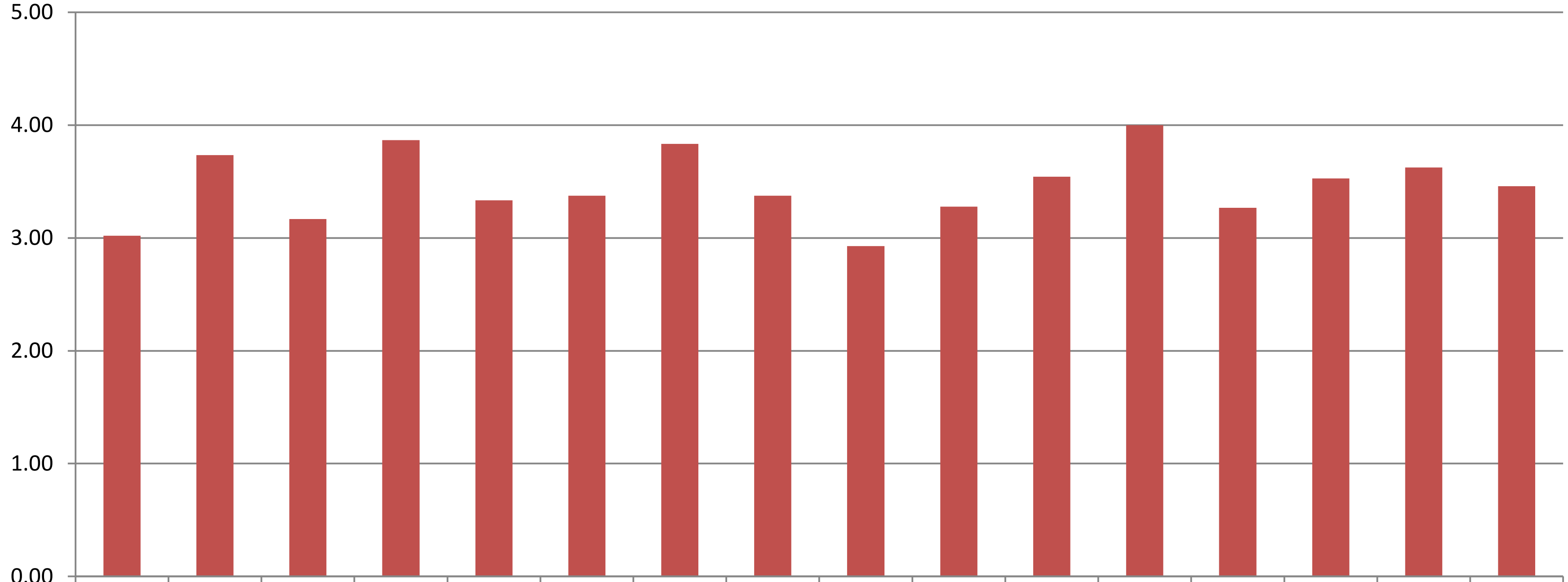
	Backlog Management and Measurement		Backlog is not measured or understood.	Backlog is understood and actual performance is known by a few select people. Backlog calculations largely inaccurate. No reaction to current performance.	Work Orders have estimated hours assigned and backlog is known in total number of hours. Organization struggles to do anything with this information, but it is generally accurate.	Work Order backlog is calculated in “crew weeks”. “Ready to Schedule” backlog is easily identified. Appropriate reaction to backlog calculations by leaders in the organization.	Level IV + Management closely monitors backlog trends to determine proper staffing and contract labor needs. Constantly seeking ways to expand "Ready" backlog.
	Work Order History: Failure Reporting and Corrective Action System (FRACAS)		Failure data is not tracked.	Failure codes exist, but usage is spotty. Some craftspersons record them diligently, most do not.	Failure codes are entered for most Work Orders, but little or no data analysis is done. Poor knowledge of failure codes.	Level III + Organization does proper analyses and understands codes; struggles with corrective action follow up.	Level IV + The organization gains great benefit from the solutions executed as a result of the FRACAS process.
METRICS / SCORECARDS	% Planned vs. Unplanned		0% Planned 100% Unplanned	30% Planned 70% Unplanned	50% Planned 50% Unplanned	70% Planned 30% Unplanned	90% Planned 10% Unplanned
	Ready Backlog		Unknown or not measured.	Less than 1 week Ready Backlog.	1 week Ready Backlog.	2 weeks Ready Backlog.	4 weeks Ready Backlog.
	Wrench Time		Less than 25%.	25 - 35%	35 - 45%	45 - 55%	Greater than 55%.
	% Estimated vs. Actual Hours		Unknown or not measured.	50% accuracy.	60% accuracy.	70% accuracy.	80% accuracy.
	% Available Labor Scheduled		Unknown or not measured.	30%	50%	75%	100%
	Schedule Compliance		Unknown or not measured.	Greater than 30%.	Greater than 50%.	Greater than 70%.	Greater than 80%.

APPENDIX D – INDIVIDUAL POWER STATION MATURITY LEVELS

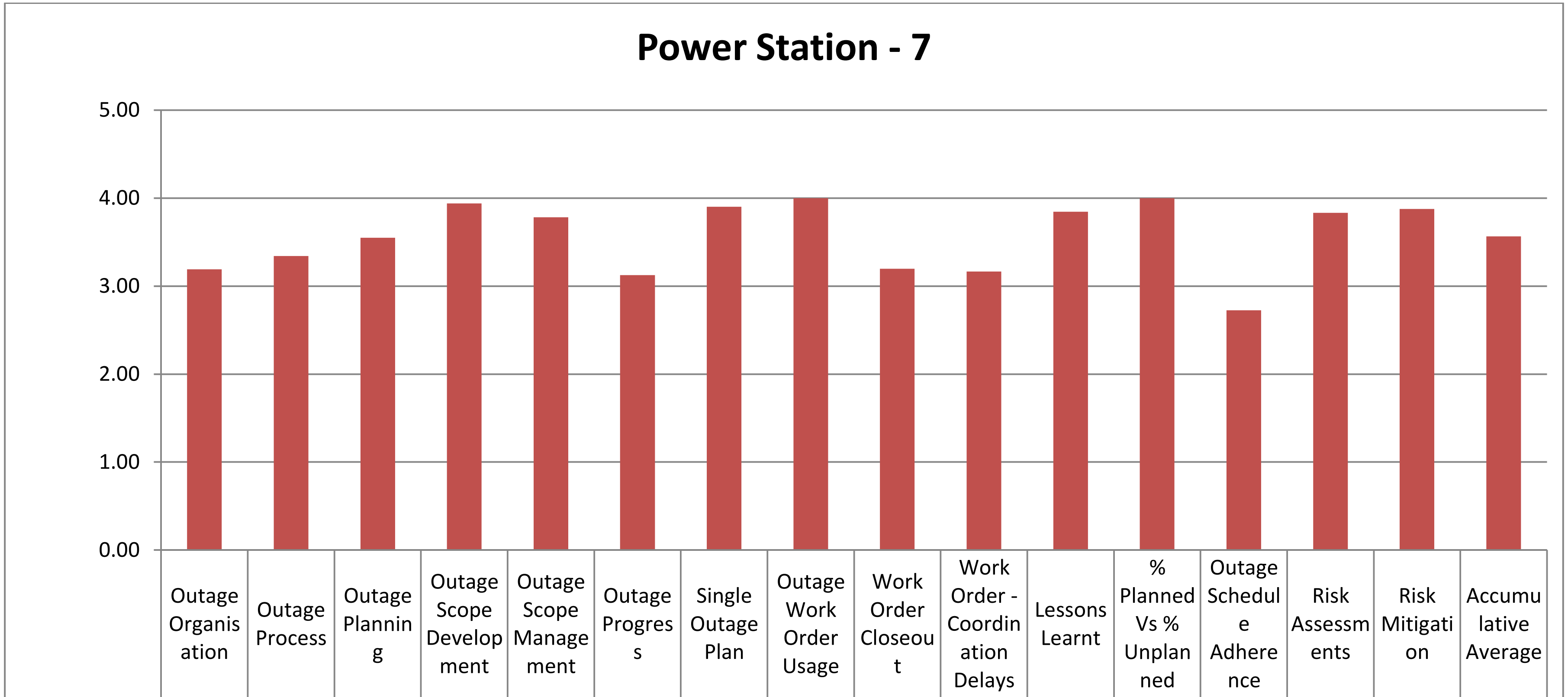


	Outage Organisation	Outage Process	Outage Planning	Outage Scope Development	Outage Scope Management	Outage Progress	Single Outage Plan	Outage Work Order Usage	Work Order Closeout	Work Order - Coordination Delays	Lessons Learnt	% Planned Vs % Unplanned	Outage Schedule Adherence	Risk Assessments	Risk Mitigation	Accumulative Average
Average	3.58	3.92	3.80	3.72	3.57	3.85	3.84	3.45	3.06	3.20	3.75	4.00	3.90	4.08	4.00	3.71

Power Station - 6

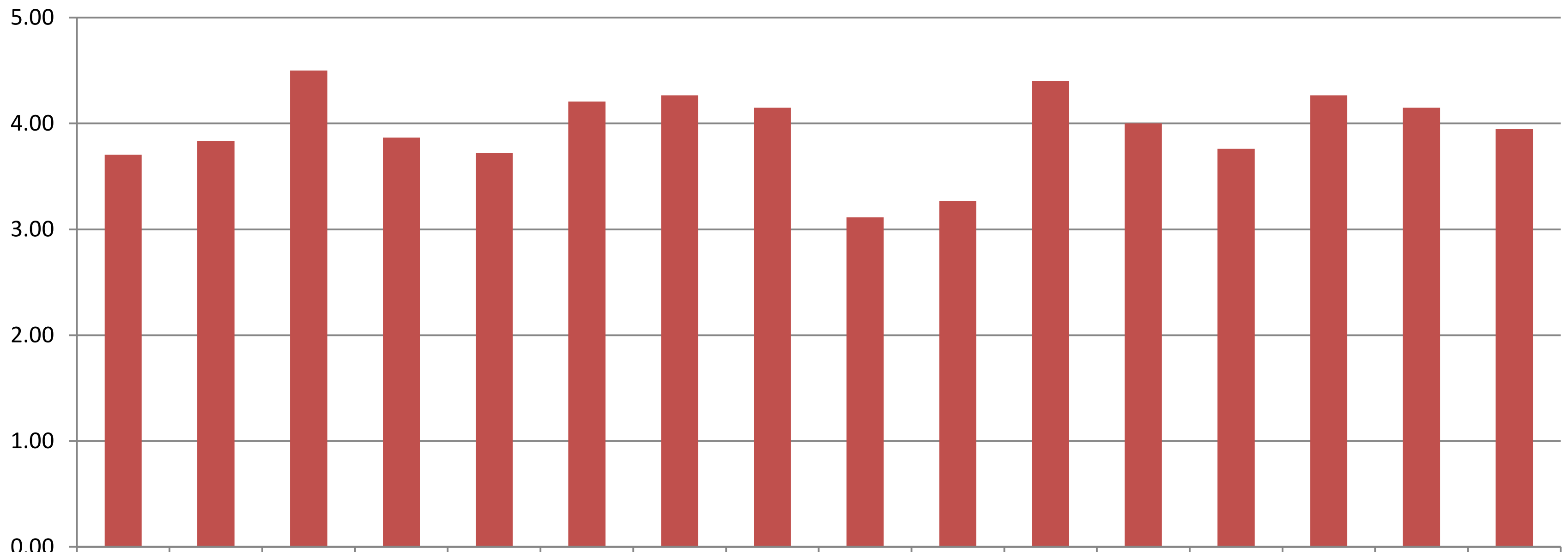


	Outage Organisation	Outage Process	Outage Planning	Outage Scope Development	Outage Scope Management	Outage Progress	Single Outage Plan	Outage Work Order Usage	Work Order Closeout	Work Order - Coordination Delays	Lessons Learnt	% Planned Vs % Unplanned	Outage Schedule Adherence	Risk Assessments	Risk Mitigation	Accumulative Average
Average	3.02	3.73	3.17	3.87	3.33	3.38	3.83	3.38	2.93	3.28	3.54	4.00	3.27	3.53	3.63	3.46

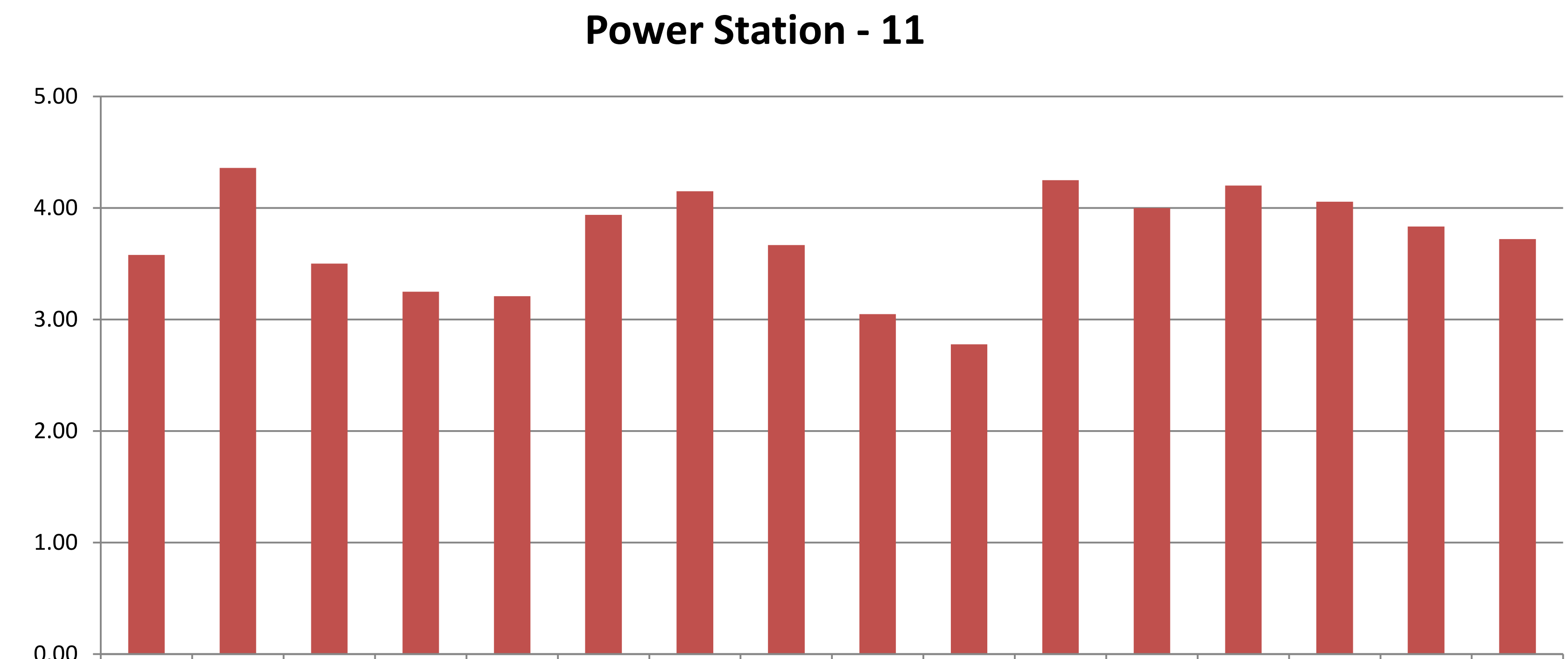


	Outage Organisation	Outage Process	Outage Planning	Outage Scope Development	Outage Scope Management	Outage Progress	Single Outage Plan	Outage Work Order Usage	Work Order Closeout	Work Order - Coordination Delays	Lessons Learnt	% Planned Vs % Unplanned	Outage Schedule Adherence	Risk Assessments	Risk Mitigation	Accumulative Average
Average	3.19	3.34	3.55	3.94	3.78	3.13	3.90	4.00	3.20	3.17	3.84	4.00	2.73	3.83	3.88	3.56

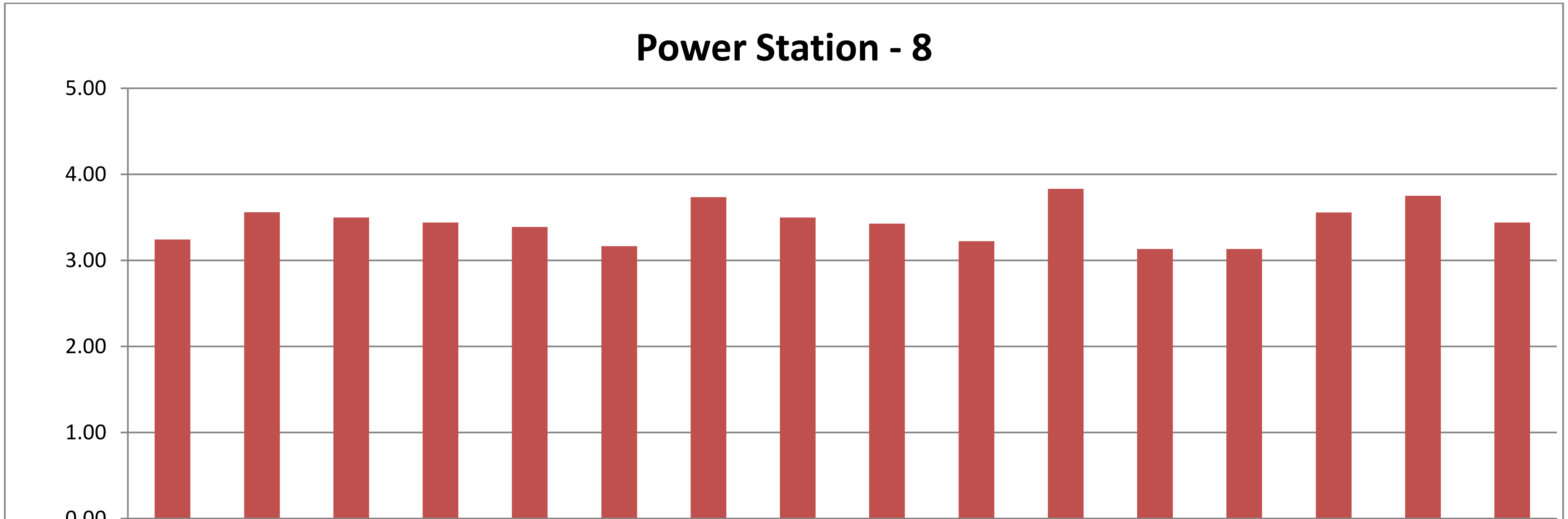
Power Station - 12



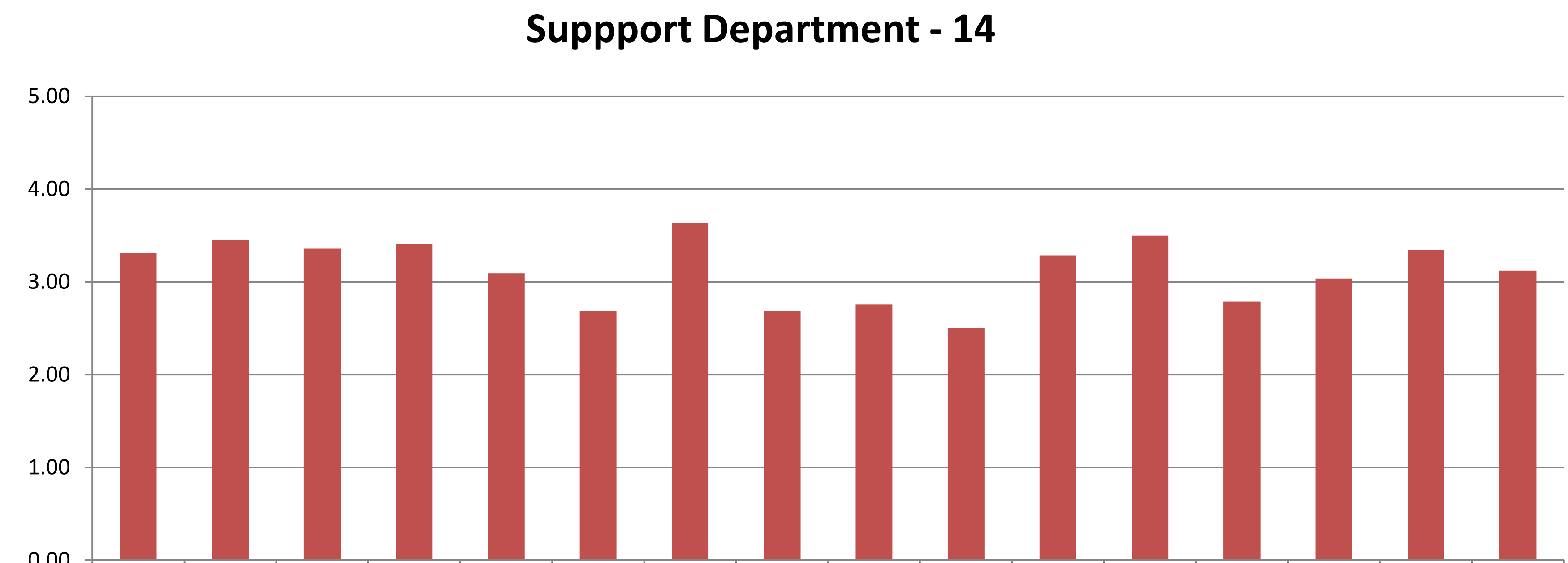
	Outage Organisation	Outage Process	Outage Planning	Outage Scope Development	Outage Scope Management	Outage Progress	Single Outage Plan	Outage Work Order Usage	Work Order Closeout	Work Order - Coordination Delays	Lessons Learnt	% Planned Vs % Unplanned	Outage Schedule Adherence	Risk Assessments	Risk Mitigation	Accumulative Average
Average	3.70	3.83	4.50	3.87	3.72	4.21	4.27	4.15	3.11	3.27	4.40	4.00	3.76	4.27	4.15	3.95



	Outage Organisation	Outage Process	Outage Planning	Outage Scope Development	Outage Scope Management	Outage Progress	Single Outage Plan	Outage Work Order Usage	Work Order Closeout	Work Order - Coordination Delays	Lessons Learnt	% Planned Vs % Unplanned	Outage Schedule Adherence	Risk Assessments	Risk Mitigation	Accumulative Average
Average	3.58	4.36	3.50	3.25	3.21	3.94	4.15	3.67	3.05	2.78	4.25	4.00	4.20	4.06	3.83	3.72



	Outage Organisation	Outage Process	Outage Planning	Outage Scope Development	Outage Scope Management	Outage Progress	Single Outage Plan	Outage Work Order Usage	Work Order Closeout	Work Order - Coordination Delays	Lessons Learnt	% Planned Vs % Unplanned	Outage Schedule Adherence	Risk Assessments	Risk Mitigation	Accumulative Average
Average	3.24	3.56	3.50	3.44	3.39	3.17	3.73	3.50	3.43	3.22	3.83	3.13	3.13	3.56	3.75	3.44



	Outage Organisation	Outage Process	Outage Planning	Outage Scope Development	Outage Scope Management	Outage Progress	Single Outage Plan	Outage Work Order Usage	Work Order Closeout	Work Order - Coordination Delays	Lessons Learnt	% Planned Vs % Unplanned	Outage Schedule Adherence	Risk Assessments	Risk Mitigation	Accumulative Average
Average	3.31	3.46	3.36	3.41	3.09	2.69	3.64	2.69	2.76	2.50	3.28	3.5	2.79	3.04	3.34	3.12