Exploring the impact of modular turbine replacement on the effectiveness of power generation plants

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DECLARATION

I, Tsuoise Kerr Mokete, declare that the contents of this dissertation entitled ***"Exploring the impact of modular turbine replacement on plant effectiveness in power generation plants",*** submitted in fulfillment of the requirements for the degree MBA (Master in Business Administration) at the North-west University, represent my own unaided work, except the quotations and citations, which have been duly acknowledged, and that the thesis has not previously been submitted for academic examination towards any qualification.

Signed: ________________

Date: 26 November 2020

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ABSTRACT

It has become imperative for Eskom as the only organisation involved in generating and supplying electricity in South Africa to adopt different strategies to deal with load shedding since post 2008. Some of the business strategies include ensuring that power generating plants are maintained effectively without compromising electricity production. A compromise had to be achieved between maintaining plant, thus ensuring reliability while also ensuring adequate electricity reserves for the economy to grow. Finding balance was difficult in an emerging economy like South Africa where political drivers were more to address the socio-economic factors of the population versus making business decisions for the utility. This has forced the entity to create a balance between improved availability and reliability of units while ensuring maintenance adequacy to the plant. As a result, an option to implement turbine modular replacement seemed feasible as by its nature it should take shorter time to replace a complete module rather than refurbishment during outages, which normally takes longer. Hence the purpose of this study was to investigate the effect of modular turbine replacement on plant effectiveness in power generation plants at Eskom.

A quantitative survey of 171 senior managers, contractors, engineers, supervisors, outage project coordinators and implementers were conducted using a structured self-administered questionnaire. A probability stratified sampling method was used to sample the respondents from two provinces. Exploratory factor analysis was performed to identify the factors contributing to the implementation of turbine modular replacement in the electricity generating plants. Eight factor-solution was extracted using factorability analysis and *senior management interference, lack of skills, management support, implementers skills and competence, replacement engineering skilled staff, skilled project staff, ageing power plant, increase in scope of work and lack of skills by maintenance staff* were identified to be the contributors in the implementation of TMR.

The findings support a positive impact of TMR implementation on high quality of work, costs reduction benefit during outages and cost benefit to Eskom bottom line. Consequently, Eskom is encouraged to continue their efforts in adopting and implementing TMR strategies. In addition, by increasing high quality of work, Eskom can improve their plant effectiveness and

performance. The findings may be used as a guideline for power generation companies in general and Eskom that intend to implement turbine modular replacement.

Keywords: Power generation plant, Turbine modular replacement, plant effectiveness, productivity, outage management, Energy availability factor, construction industry.

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CHAPTER 1

ORIENTATION OF THE STUDY

1.1 INTRODUCTION AND BACKGROUND OF THE STUDY

Power generation plant in the context of this study can be defined as a holistic process of electricity generation whereby energy is converted from one to another up to a point where it is finally converted to electrical energy for distribution. The process of generating electricity is depicted by the diagram below, whereby coal as one form of fuel is supplied via conveyors and into a milling plant which crushes and grinds it into pulverized fuel (PF). The PF is then introduced into the boiler together with some ignition, which is where the combustion happens with the boiler filled with water, then the process of heating up the water starts. The water is heated to extremely high temperatures and pressures thus resulting in steam production, which is used to drive the steam turbines. These steam turbines comprise low pressure (LP) turbines, intermediate pressure (IP) turbines and high pressure (HP) turbines, which then convert energy to mechanical energy, which in turn drives the generator. The generator then converts mechanical energy from the turbine into electrical energy, which is supplied to a generating transformer to either step it down to lower or higher voltages depending on the need to transmit or distribute.

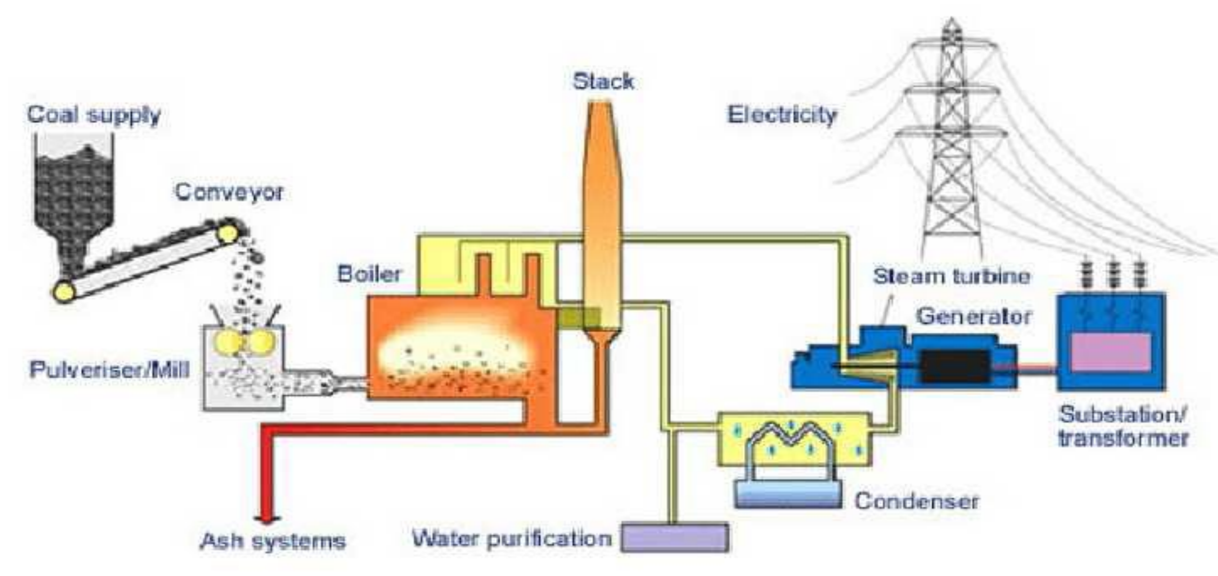

Figure 1.1: Electricity generation from coal

Source: World Coal Institute (2010)

Gas turbines are widely used as prime movers in power generation, or industrial plants, for driving rotating loads, such as electric generators or turbo machines. And assembly of this plant requires relatively long-time intervention of highly specialized staff, as well as the use of cumbersome machinery in putting it together. Modularization of gas turbines having a power rate lower than 40MW is quite common practice. The gas turbine and the load are arranged on a common frame, thus forming a single unit which is tested in the erection and testing yard or site prior to being transported to final destination. The common frame is then transported to a final destination and mounted on a skid. A modular arrangement of this kind is particularly useful since it allows complete assembling and testing of the rotary machines prior to shipping and installation to the final destination.

According to Offshore, gas turbines are removed and replaced in modules, substantially reducing outage durations. In addition to the modular replacement programme for the facility's gas turbines and compressors, GE also will supply spare parts for the duration of the contractual service agreement with the natural gas production facilities. Eric (2016) urged the United States army to take advantage of the technological concept of modularity in designing its equipment. The concept in General Motors Corp.'s family of automotive products which uses modularity to enhance performance, flexibility and efficiency, and elimination of the repair functions through modular replacements have been documented (Ateba, Prinsoo & Gawlik, 2019:121). Turbines are made up of different components, but for the purpose of this study when referring to turbine modular components we shall refer only to components associated with LP turbines, IP turbines, and HP turbines.

The above turbines form a complete modular gas turbine in a power generating plant, which are the components that convert heat energy to mechanical energy for driving the generator.
Plant efficiency and effectiveness in the context of power generating plants refer to the ability of each plant to operate at its optimal limits within the required set standard and legislation while holistically achieving the intended outcome in terms of availability of the entire generating plant for production. For a power generating plan to be effective in the delivery of energy to the power grid, adequate maintenance is required on the components of the power generating unit, which will in turn give the intended output based on design specifications (Mzini & Muhiya, 2014:45; Bah & Azam, 2017:88).

1.2 PROBLEM STATEMENT

Post 2008 load-shedding in South Africa, it became imperative for Eskom as the only organisation involved in the electricity industry to adopt a different business strategy when it comes to ensuring that power generating plants are maintained effectively without compromising their availability to produce electricity. A compromise had to be achieved between maintaining plant to ensure reliability while also maintaining adequate electricity reserves for the economy to grow; finding a balance was difficult in an emerging economy like South Africa where political drivers were more inclined to address the socio-economic factors of the population versus making business decisions for the utility. And Eskom being a state-owned enterprise, meant that the country's interest came first when decisions were made, even if it was for the detriment of the company financially.

This business-related problem forced the entity to think out of the box as to how they could get a balance between improved availability and reliability of units while ensuring maintenance adequacy to the plant. As a result, an option to implement modular turbine replacement seemed feasible as by its nature it should take a shorter time to replace a complete module rather than refurbishment during outages, which normally takes longer. If turbine modular replacement is efficiently executed, it could result in reduced outage durations and costs as the refurbishment of the modules will be done outside the outage duration and only replacement done during the shutdown. With the turbine plant being the driver of most outage philosophies, which was becoming the critical path on most power plant outage, it seemed a no-brainer to implement this modular concept on this plant, as the impact would be significant if successful. What the previous studies have not examined was whether after ten to thirty years of running the turbine plant, the replacement of this module would result in a like-for-like replacement, thus reduction in planned capability loss factor (PCLF). Reduction in the PCLF would positively impact the energy availability factor (EAF), the measure of unit availability to produce and supply electricity to the grid, which meant units available to the grid most of the time. The problem was that it is not known if the perceived outcome of turbine modular replacement would yield the required results in terms of reduction in outage duration and costs, hence the importance of researching the practicality of implementing this turbine modular replacement philosophy across the Eskom fleet. In most power stations where this concept was implemented it is evident that it has not yielded the desired objectives as originally intended. As an organisation it is important to understand the reasons thereof: successful implementation of this concept could have major impact to the organizations due to:

- improved reliability of plant as maintenance strategies will be adhered to.
- improved investor confidence towards Eskom due to no load shedding.
- reduction in overall refurbishment costs as maintenance will be done outside the outage duration; and
- EAF would be significantly improved due to reduced downtime of units when out for refurbishment.

It is even more important now in 2019 with load-shedding again in the horizon, that this study is carried out to identify what needs be done; to ensure successful improvement of the EAF by looking at already implemented strategies in order to improve them versus starting a whole new business case to resolve current electricity constraints within the country. With load-shedding still apparent, even in 2019, this has had a negative impact to the country's economy as a whole as we have not seen significant growth, and low investor confidence does not help the cause in fighting unemployment and improving lives of its citizens. Load-shedding has negatively impacted the employee's morale as they feel directly responsible for the negativity around the company and inability to deliver on its core mandate of ensuring adequate security of supply to all South Africans.

1.3 MOTIVATION FOR THE STUDY

This study hopes to identify the key issues hindering the successful implementation of the turbine modular replacement in reducing outage duration and cost. This may assist management in making decisions on how implementation of this concept should be carried, and ensure that the primary business objectives for implementation are met. The study will also assist project managers within the power generation plant responsible for management of outages in mitigating risks associated with this concept timeously, and in so doing minimize the risk of slip on outages, thus ensuring high availability factor of units in production. It is not unreasonable to believe that the study will contribute to the body of knowledge to better understand the modular replacement concept holistically, especially seeing that electricity availability is key to improving the economy of the country. Addressing this issue could have a positive and significant impact to society as a whole while empowering managers to make the necessary decisions that would impact how outages are carried out in future. Looking at current electricity constraints in South Africa 2019 where we are still experiencing load-shedding, it is important that ageing plants receive the necessary maintenance intervention while averting an economic crisis as a result of this constraint. Innovative solutions should be explored as to how power utilities can maintain the balance of no load-shedding versus plant maintenance. These turbine modular replacement concepts could be the answer to Eskom's dilemma of having to choose whether to maintain plant or avert load-shedding. For any organisation's long term sustainability, there must always be a balance between the two; lack of either one has a negative impact to its operations and reputation.

In addition**,** there are political and socio-economic factors which play a role in the decision making by power utilities as government remains the sponsor and custodian for the power utility. The decisions have made times seem correct, as some power stations were mothballed on the premise that there would be adequate electricity supply. Also, with the New Build projects in the pipeline it seemed a more logical reason to get rid of the older design stations while bringing online the new stations that could meet new laws and with more efficiency build into the design. With the delayed completion of the new build projects, namely, Medupi and Kusile, government together with Eskom have had to invest capital in the older plants in order to counter the deficit as a result of the new builds that were not commercial as intended.

1.4 EXPECTED CONTRIBUTION OF THE STUDY

The identification of the factors contributing to the implementation of the turbine modular replacement to reduce outage durations and costs may assist the management in making informed decisions on how implementation of this concept should be carried out so as to ensure the primary objectives are met. The study may also assist project managers within the power generation plants responsible for outages in mitigating risks associated with this concept implementation timeously, and in so doing minimize the risk of slip on outages, thus ensuring high availability factor of units in production.

1.5 RESEARCH OBJECTIVES

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

1.5.1 General objective

The general objective of this research was to investigate the effect of turbine modular replacement on power plant effectiveness. This was achieved by determining whether turbine modular achieves its perceived return on investment in terms of reduction in outage durations and improved cost benefit due to higher availability factors of units for production purposes.

1.5.2 Specific objectives

The specific objectives of this research were formulated:

- to determine whether there is reduction in outage duration directly linked to the implementation of turbine modular replacement.
- to identify the critical factors within the organisation which impact the turbine modular replacement and how to mitigate or improve their performance.
- to conceptualize and quantify the costs benefit to Eskom when implementing turbine modular replacement during outages.
- to determine whether there is direct correlation between workmanship, skills, and ability to assemble modular turbines within allocated time during outages.
- to assess the skills level of staff involved in the modular turbine replacement and adequacy; and
- to assess management support or involvement towards successful implementation of the turbine modular replacement.

1.6 RESEARCH HYPOTHESES

Based on the aforementioned objectives, the following hypotheses have been proposed:

H1: Turbine modular replacement in power generation plant is likely to fail during outages because of skill inadequacy in Eskom.

H2: Lack of management support in staggering execution of similar modular replacements projects results in failure of turbine modular replacement.

H3: Modularity concept is not fully implementable during outages due to lack of spares and using of old components and this reason cannot be successful.
H4: There is lack of sustainable skills within the organisation to implement multiple turbines modular replacement within the Eskom fleets at the same time, hence the failure to have continuous improvement when assembling turbine modular replacement during outages.
H5: The cost benefit of turbine modular replacement cannot be realised unless the outage durations are reduced as a result of implementation of this concept, as they are interlinked.

1.7 RESEARCH DESIGN AND MEHODOLOGY

According to Polit and Beck (2018:138), all scientific research must be conducted using some relevant methodology. A methodology provides a piece of research with its philosophy, the values and assumptions that drive the rationale for the investigation as well as the standards that will be utilised for the interpretation of information and the drawing of conclusions (Creswell 2014:31).This section covers topics such as the research design, research approach, sampling design, procedures for data gathering, analysis and ethical issues**.**

1.7.1 Research Design and Approach

A research design is defined as a plan or framework for formulating and addressing research objectives and hypotheses (Polit & Beck, 2012:802). It enables a researcher to develop a specific structure to solve a particularly growing research problem, question or opportunity (McDaniel & Gates, 2013:42). This study followed a correlational research design, specifically a single-cross-sectional study because data was collected only once from the sample elements (Burns, Veeck & Bush, 2018:99). A correlational study determined whether or not two or more variables are correlated (Creswell, 2014:32). The single cross-sectional study is quantitative in nature, meaning that it seeks to understand the sample structure and thereafter recommend a final course of action (Malhotra, 2010:108). The cross-sectional strategy was chosen on the basis that it provides inexpensive methods of collecting data over a large sample and it pairs well with quantitative design (Creswll, 2014:32). Quantitative research, using the survey method, was followed in this study.

When using quantitative approach, the following factors are considered: a larger sample size is required to allow the researcher to pull a sufficient conclusion using statistical methods;

relatively shorter time period for data collection; when a researcher intends to take a snapshot of a phenomenon without an in-depth or deeper understanding of the participant's experiences regarding the phenomenon; and it seeks to describe current situations, establish relationships between variables and sometimes explain the causal relationships between the variables (Wiid & Diggines, 2015:70; Chauke & Dhurup, 2017:153). It is therefore appropriate to use a quantitative research approach as it encompasses statistical methods of research in concluding on whether a concept is successful or not.

The study aimed to prove the theory of whether there is a reduction in outage duration when implementing turbine modular replacement on fossil fuel power stations or not. This study was able to quantify in terms of duration data and extrapolate results to a broader population for analysis. The data analysis was gathered from the number of days required when normal refurbishment is explored versus modular replacement. The difference indicated whether the objective of outage duration reduction is achieved or not when implementing turbine modular replacement in power generation plant.

Primary data (empirical research) was collected by the researcher through self-administered structured questionnaires, while secondary data assisted the researcher with an insight into the background of the problem under investigation. In the quantitative research strategy, two methods of research are conducted, namely, a literature review as well as a primary investigation based on empirical data

1.7.2 Literature review

Literature appraisal on relevant variables in this study was conducted with the sole determination of addressing its theoretical intentions. The literature review focused on concepts such as modular turbine replacement, plant performance and power generation plant. To achieve this goal, a review of South African and international literature using secondary data sources such as academic peer reviewed journal articles, Internet, textbooks, business journals, theses and dissertations, published reports on power generation industry and online academic databases were consulted. This was done in order to advance the quality of the overall research. In addition, performance data used in this study was obtained from public domain knowledge such as official company records or annual reports which were accessible from Internet sources.

1.7.3 Sampling process

1.7.3.1 Study population

A sample is a part of population. It is the totality of entities in which we have an interest, which is the collection of individuals, objects or events about which we want to make inferences (Brown, Suter & Churchill, 2018:205). It is therefore a group of individuals or objects that meet specific requirements for inclusion in the overall group from which information is required. The target population can include individuals, groups, organisations, sales, territories and companies (Babin & Zikmund, 2016:337). Informed by the objective of this study, the population was restricted to senior managers in modular replacement, contractors, engineers, supervisors and outage management project coordinators and implementers in Mpumalanga and Free State, both male and female from all racial groups. Mpumalanga and Free State provinces have most coal fired power stations within the republic situated in close proximity to one another, especially in Mpumalanga with only Lethabo Power Station in the Free State. The above-mentioned individuals are involved in outage management of modular replacement projects and would give their insights, opinion and views on the phenomena under investigation. Participants were assessed on their level of awareness when it comes to turbine modular replacement on coal fired power stations and also how they find the level of ease in implementing it on ageing power plants within Eskom fleet.

1.7.3.2 Sample frame

A sampling frame refers to a list of individuals or objects from which a sample is extracted (Clow & James, 2014:227). In other words, it is a list from where a researcher may draw the potential respondents to be included in a study. The sampling frame of this research study was made up of lists of individuals (senior managers in modular replacement, contractors, engineers, supervisors and outage management project coordinators and implementers) in the various plants within the demarcated areas of the study. The selected industry was chosen owing to the accessibility of the sample, cost and time associated with data collection.

1.7.3.3 Sampling method (procedure)

Babbie (2017:273) identified probability and non-probability sampling as the two types of sampling methods available to researchers. In probability sampling, the members of a population have a known and equal chance of being selected. With non-probability sampling, the researcher's subjective opinion determines which sampling elements will be included in a study and which will not (Gupta, 2011:191). Probability sampling methods include simple random, systematic, cluster and stratified sampling techniques (Malhotra, 2015:459). Non-probability methods include judgmental, snowball, quota and convenience sampling (Hair, Black, Babin & Anderson, 2014:85). For this study purpose, stratified probability sampling technique was employed. Stratified sampling is a method of sampling from a population which can be partitioned into subpopulation or stratas (McDaniel & Gates, 2013:284). The participants were divided into homogeneous subgroups before sampling and each strata defined a partition of the population (Malhotra, 2010:459). That is, each strata should be collectively exhaustive and mutually exclusive. Since the sample was drawn from different provinces and different groups of people, the participants were divided into engineers, contractors, supervisors, senior managers, outage management replacement project coordinators and implementers. Although stratified sampling was employed, participants were conveniently sampled based on their availability and knowledge of the subject under examination. Senior managers in modular replacement, contractors, engineers, supervisors and outage management project coordinators and implementers were sent questionnaires through email and others were visited in order to complete the questionnaire in order to quickly facilitate the data collection process.

1.7.3.4 Sample size

A sample size refers to the actual number of population elements chosen for inclusion in a study (McDaniel & Gates, 2013:284). There are various factors to be considered when determining the sample size, such as the nature of the research, completion rates, cost, time, location and type of data analysis (Hair *et al.*, 2014:85). The chosen sample size for this study was pegged at n=200. The sample size determination was based on two approaches. Firstly, the historical evidence approach was used, which focuses on the previous similar studies. Secondly, considering that various multivariate statistical analysis techniques that will be used to analyse the data and test the hypotheses in this study, it is noted that they require a substantial amount of sample units (Hair *et al.,* 2014:85). For example, Pallant (2007:185) recommends a minimum of 150 respondents while Tabachnick and Fidell (2007:613) propose a sample size of at least 200 cases for a multivariate analysis.

1.7.3.5 Data collection method

Once the target population, sampling frame, sampling method and sample size have been determined, data has to be collected (Creswell, 2014:31). Data was collected through a survey using a self-administered questionnaire. Surveys are renowned for reducing response bias, as well as the ability of the respondents to interact with the researcher (Babin & Zikmund, 2016:179). Self-administered questionnaires are characterised by several benefits. These include respondents being able to answer the questionnaires at their own convenience; no need to set up interview appointments; no interviewer is present to inject bias in the way questions are asked; and the low cost-per-completion makes it an economical method for surveying large samples (Bryman & Bell, 2007:242). The researcher made use of an online questionnaire using a Survey Monkey and email of all prospective participants and ask them to complete it using the provided link. This is inexpensive way of getting feedback and can reach those participants which cannot be reached due to either time or financial constraints. The reasons for the study will be explained to the participants to avoid confusion, thus enhancing the response levels from the target population. The questionnaires also addressed the historical data obtained from various power stations where the turbine modular replacement was implemented, which affords the researcher the ability to quantify the impact of this phenomenon against normal refurbishment of components.

1.7.3.6 Measuring instrument

As indicated earlier, a self-administered questionnaire was used to collect the desired data. The questionnaire was divided into five sections. Section A elicited the biographical details of the respondents such as gender, ethnicity, department, position and experience using multiple-choice and dichotomous questions. Section B comprised information on management of turbine modular replacement. Section C comprised information on skills adequacy. Section D comprised information on management support and sustainable skills. Section E comprised information on lack of spares/old components. Section B – E applied a five-point Likert scale ranging from 1= strongly disagree to 5= strongly agree while 3 represent neutral value/undecided. The questions were adjusted accordingly to fit the current context of this study, using feedback collected from a pilot test. The questions were closed-ended (structured) for simplicity of answering.

1.7.4 Statistical analysis

Data analysis was realized using two approaches, namely, secondary dada and primary data. Secondary data in terms historical and financial reports were collected mainly in Gauteng where the Eskom and Rotek head offices are situated as well as access to journals and research documents on the research topic. These documents were given more in-depth analysis of the actual impact that modular replacement had on overall outage execution improvement expectations when the project was initially embarked on. The researcher is an Eskom employee in the Outage Management environment and works with different stakeholders as an implementer of most outages. This makes it easier to access to information because organisations do not trust strangers to disclose such information.

The collected empirical data were captured into Microsoft Excel spreadsheet for cleaning then later transferred to Statistical Package for Social Sciences (SPSS version 26). Several statistical methods were performed such as descriptive, correlation and regression analysis. Initially, the sample composition was analyzed using frequency distribution graphs and tables. Thereafter, an exploratory factor analysis (EFA) was conducted in view of summarising the data set. From the factor scores, the descriptive statistics were computed, comprising measures of central tendency (mean, median and mode), measures of variability (variance and standard deviation) as well as the measures of peakedness (skewness and kurtosis). Thereafter, the strength and direction of relationships between the identified variables were analyzed using Pearson's correlation coefficient statistic. The posited hypotheses were tested using regression analysis.

1.7.5 Reliability and validity assessment

McDaniel and Gates (2013:215) define reliability as "the degree to which measures are free from random error and thus provide consistent data". In other words, reliability refers to the extent to which a measure is unbiased and ensures consistency across time (Sekaran & Bougie, 2013:228). The reliability of this study was thus assessed through computing Cronbach's Alpha coefficients, whereby values between 0.70 and 1.00 are considered adequate evidence of the internal consistency among the scale items.

Validity refers to the extent to which the measurement is accurate. It is an assessment of the exactness of the measurement, relative to what exists (Burns & Bush, 2014:214). In this research, face, content and construct validity were evaluated. First, face validity can be improved by consulting the experts in the modular replacement concept and getting insight into the thinking behind this way of refurbishment to understand what the perceived gains were when they considered modular replacement of turbine components on Eskom fleet. Secondly, content validity was determined through a pilot study with a conveniently selected sample of 10 participants. The pilot study was accompanied by a minimal review of the questionnaire based on limited assessment of the reliability of the scale items. To ensure that construct validity of this work was upheld, convergent, discriminant and nomological validity were appraised. Convergent validity was evaluated by checking the item- total correlations of above 0.30 for each item to be retained in the study (Field, 2013:2047). On the other hand, Malhotra (2010:736) states that the factor loadings should range between 0.50 and 1.00, ideally higher than 0.70. Moreover, the values on the inter-construct correlation matrix were weighed to infer discriminant validity and theoretical uniqueness of each variable.

1.7.6 Ethical consideration

Ethics are moral principles or values, which generally govern the behaviour of a particular group of individuals (McDaniel & Gates, 2013:22). In research, ethics refers to the principles and guidelines that clarify conditions under which the research will be conducted (Oates, Kwiatkowski & Coulthard, 2010:4). This study complied with specific standards of ethical research before, during and after data collection. The informed consent form is included as Annexure A in the document “Ethical requirements for postgraduate studies”. The application form for ethical clearance that is included as Annexure B in the document “Ethical requirements for postgraduate research studies”. The ethical principles and confidentiality of the information due their sensitive nature received prior approval by Eskom senior management prior to sharing with NWU so as to make sure that the contents of this research do not in any way compromise the company’s programmes, especially with the news around SOE’s in South Africa prior to data collection, each respondent was informed about the purpose and legitimacy of the study, including the institution of affiliation and request that they sign an “informed consent form”. Permission was requested in line with the university requirements and sent for the necessary considerations. Participation in the study was also voluntary. During the fieldwork process, the researcher treated all the respondents equally and with respect, while attempting not to be biased or influencing the respondent's opinions in any way. This was done in an effort to uphold the research principle of 'good faith'. Furthermore, the identity of each respondent was protected during and after the fieldwork process. In particular, the respondents were not forced to disclose their names, whereas the research findings would only be used for research purposes and reported on an aggregate basis. Participants were given the opportunity to decline participation. Following submission of the survey, participants were allowed to withdraw their consent at any time. After the data collection process was complete, the researcher reported the findings truthfully and with honesty in the form of a dissertation report.

The researcher signed the plagiarism declaration form, stating that the researcher acknowledged other researchers where necessary. Prior to using any information received from voluntary participants, they were informed of the researcher's intention before it could be published. For publicly known information such as newspapers and internet, the researcher would not request permission prior usage. For any company archives that the researcher intends to use as a reference, permission would be requested from the concerned company.

1.8 CHAPTER CLASSIFICATION

The study consists of five (5) chapters and the narrative on each chapter is to provide clarity and explanation for what should be expected.

Chapter 1: Introduction and background to the study

This chapter delivers an orientation of the study and provides the strategic problem statement with regards to the subject matter. Also, problems encountered in previous studies of a similar topic will be discussed and the resolutions thereof. In addition, study objectives and hypotheses are highlighted as well as the methodology to be followed. Lastly, data analysis, reliability and validity analysis as well as ethical considerations are outlined.

Chapter 2: Modular Turbine Replacement, plant effectiveness and power generation plants

A comprehensive secondary review of the available literature from the body of knowledge related to this study will be discussed to provide readers the theoretical content of what the study is all about, and the background information that could influence the study will be provided.

Chapter 3: Research Methodology

This chapter will elaborate on various instruments used for data gathering and how the results and findings of the sample are interpreted. Research methodology, methods used for sampling and the strategies employed to ensure quality data are discussed. This section will also include tables, figures, and replicas obtained from the research instruments.

Chapter 4: Analysis, interpretation and discussion of empirical findings

A reflection of the findings from both literature reviews as well as an online questionnaire regarding the research will be discussed. This chapter includes the sample results, descriptive statistics of the variable, correlation analysis and provides reports on the factors impacting the effectiveness of turbine modular replacements.

Chapter 5: Conclusion and Recommendations

This chapter provides a conclusion and recommendations on each phase of the study.

1.9 8 CHAPTER SUMMARY

This chapter focused on the background foundation to the study as well as the statement of the problem. It further formulated the research objectives and the hypotheses development. The research design and methods undertaken in data collection were highlighted. The next chapter focuses on the literature review to understand electricity supply and demand in South Africa, turbine modular replacement, power generation, plant performance and plant effectiveness.

CHAPTER 2

TURBINE MODULAR REPLACEMENT, PLANT EFFECTIVENESS AND POWER GENERATION PLANTS

2.1 INTRODUCTION

The preceding chapter provides the introduction and background to the study. It further defines the problem, formulated the research objectives and hypotheses development. In addition, the motivation for the study, the expected contribution, and the methodology that is employed in the study have also been highlighted. The focus of this chapter is to provide an overview of power generation plants in South African. The value of this industry in employment creation and economic prosperity for both developed and developing economies has been known for decades. In an economy desperate for economic growth, with high unemployment figures and various other economic challenges, the power generation sector presents itself as an opportunity for economic growth in South Africa that should be nurtured.

Power generation is one of the most important process industries for engineering professionals. Over the past decades, the power sector has been facing several critical issues; however, the most fundamental challenge is meeting the growing power demand in sustainable and efficient ways. The power generation environment is a very complex sector which is intrinsically linked with the economy as a whole. This industry is also a major source of environmental emissions and organic compounds from electrical furnaces. Broken into sections, this chapter commences by providing an overview of the above-mentioned sector. Secondly, the turbine modular and modular replacement are discussed, as well as plant effectiveness and ways that can be used to improve plant effectiveness. Lastly, the factors influencing power generation plant performance are also discussed.

2.2 OVERVIEW OF ELECTRICITY SECTOR AND POWER GENERATION

This section discusses the electricity sector and power generation plants. Uncovering the supply and distribution of electricity in South Africa will put the study into perspective.

2.2.1 Electricity demand and supply

The electricity sector in South Africa is dominated by the national utility Eskom (South Africa's public electricity provider), which is responsible for most of the generation, transmission and distribution (Ateba, Prinsloo & Gawlik, 2019:1324). South Africa is, however, also home to Africa's biggest Independent Power Producer's (IPP) market, which is envisioned to contribute 30% of South Africa's future generation capacity. Approximately 137 municipal power companies, that are buying 40% of electricity generated by Eskom to supply end-users, hold negligible generation capacity (Khobai, Mugano & Roux, 2017:88). Generation is currently dominated by coal power; however, this dominance is expected to decline due to increased investments in gas, renewables and nuclear power (Department of Energy, 2020). Being an integral part of the South African Power Pool (SAPP), South Africa is both importing and exporting power from and to its neighbouring countries. This is possible because some of the power sources on the continent use seasonal resources to produce hydro-electricity. The electrification rate is comparatively very high for the region, standing between 85% and 90% (Kumo, Chulu & Minsat, 2016:138).

South Africa's peak demand has reached 34,481 megawatts (MW) in 2016/2017 with Eskom transmitting 241,487 GWh to South African customers (Ateba *et al.*, 2019:1325). Eskom's electricity is mostly sold to municipalities, with 42% of them that further distribute electricity to end-users, followed by industrial consumers at 33% and mining at 14% (Mzini & Muhiya, 2014:89; Bah & Azam, 2017:126). When distinguishing electricity consumption by the type of end-user, industrial (41%) and residential users (37%) are responsible for the bulk of electricity consumption, regardless if supplied by municipalities or directly by Eskom. Figure 2.1 below shows different groups (left) and electricity sold distinguished by end-users (right) in which Eskom sells electricity to in the period from 2018 to 2019.

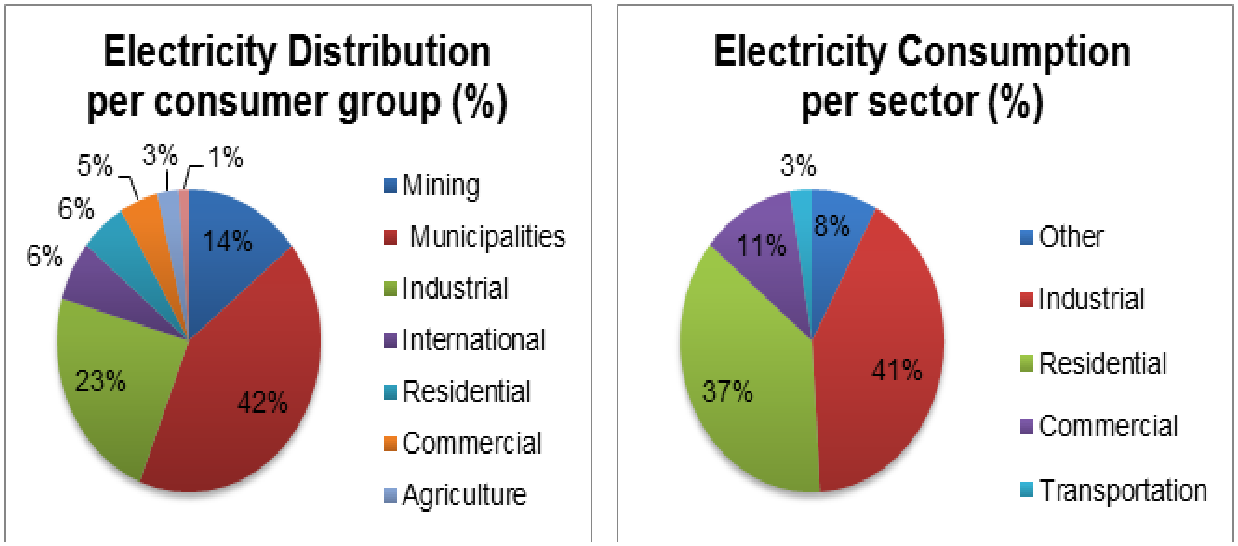

Figure 2.1: Consumption of electricity by different groups of customers

Source: Eskom (2020)

Growth in electricity demand has been low (1%), partially attributed to the economic slowdown faced by the South African economy. This has resulted in electricity demand forecasts being revised downwards, estimating peak demand of 350, 000 GWh by 2030 in the draft Integrated Resource Plan (IRP) 2016, compared to a forecast of 450, 000 GWh by 2030 in the IRP 2010 (Ateba *et al.*, 2019:1325). The South African economy is extremely energy-intensive compared to international standards, with only a handful of countries having higher energy intensities. South African industrial energy efficiency is on average significantly lower than that of other countries (Bah & Azam, 2017:126). In 2015, Eskom introduced load-shedding due to insufficient investment having rendered existing capacity inadequate to meet demand. In addition to now heavily investing in expanding generation capacity, the government is promoting the adoption of solar water heaters (SWH) in households and commercial buildings (Kumo *et al.*, 2016:138). The National Development Plan (NDP) targets an additional 4 million SWH to be installed, resulting in a target of 5 million SWH by 2030. At the same time, Eskom is distributing energy-efficient light bulbs (CFLs) and increasing awareness of energy efficiency measures. The government has also introduced fiscal energy efficiency incentives for businesses and industries with the intention of resolving the load-shedding problem.

2.3 POWER GENERATION PLANTS

A power plant is an industrial facility that generates electricity from primary energy. Most power plants use one or more generators that convert mechanical energy into electrical energy to supply power to the electrical grid for society's electrical needs (Atkins & Escudier, 2013:3). The exception is solar power plants, which use photovoltaic cells (instead of a turbine) to generate electricity. The type of primary energy/fuel flow that provides a power plant its primary energy varies. The most common fuels are coal, natural gas, and uranium (nuclear power). A substantially used primary energy flow for electricity generation is hydroelectricity (water) (Department of Energy, 2017). Other flows that are used to generate electricity include wind, solar, geothermal and tidal (Atkins & Escudier, 2013:3).

2.3.1 Types of power plants

2.3.1.1 Thermal

Thermal power plants use fuel to heat up water from a reservoir, which generates high-pressure steam (Saedi, Thambirajah & Pariatamby, 2014). The highly pressurised steam then travels through pipes to rotate the fan-like blades of a turbine (Mardoyan & Braun, 2015:901). As the turbine begins to spin, it causes giant wire coils inside the generator to turn. This creates relative (continuous) motion between a coil of wire and a magnet, which pushes electrons and starts the flow of electricity (Manzano-Agugliaro, Zapata-Sierra, Juaidi & Montoya, 2017:128). Thermal power plants include the following:

- Fossil fuel power plants burn their fuel in order to create the thermal energy to run their external heat engines (Mardoyan & Braun, 2015:901). A simple cycle gas plant does not use steam like the others: it works similar to a jet engine where natural gas is ignited and burned and the heat creates pressure that turns the turbine. Combined cycle gas plants use both the heat and steam as well (Rasul, 2013:86). Types of fossil fuel plants include coal-fired power plants and natural gas power plants, accounting for the largest producers of electricity around the world (Manzano-Agugliaro *et al.*, 2017:128).

- According to Saedi, Thambirajah and Pariatamby (2014:90), nuclear power plants use fission processes to generate electricity. In these plants, uranium nuclei are split, which creates the thermal energy needed to create steam. It then works just like fossil fuel power plants where the steam spins a turbine, generating electricity. The power plants require the use of nuclear reactors to carry out these fission processes. Some types of reactors include pressurised water reactors, CANDU reactors, RBMK reactors, and boiling water reactors.

- On the other hand, solar thermal power plants use heat from the sun's rays to create the steam that is needed to rotate the turbine (Fischer, Pelka, Puls, Poech, Mertens, Bartschat, Tegtmeier, Broer & Wenske, 2019:220).

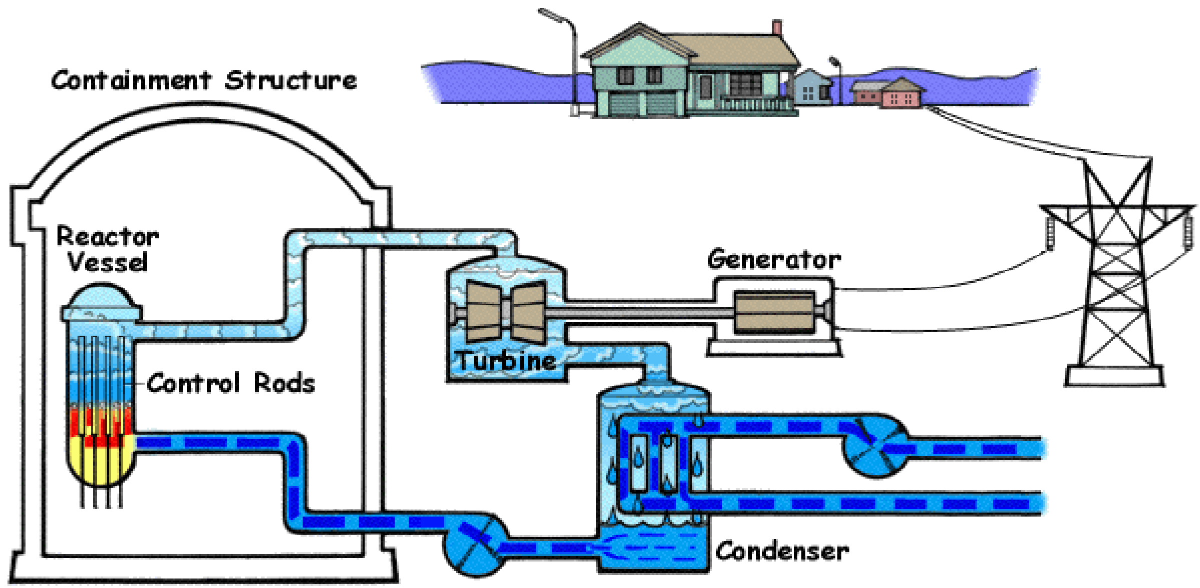

Figure 2.2: A boiling water nuclear plant

Source: Manzano-Agugliaro, Zapata-Sierra, Juaidi and Montoya (2017:128)

Thermal power plants are all limited by the second law of thermodynamics, which means they cannot transform all of their heat energy into electricity. This limits their efficiencies, which can be read about on the Carnot efficiency and entropy pages.

2.3.1.2 Renewable

According to Fischer *et al.* (2019:221), renewable energy power plants get their energy directly from their respective flows in order to generate electricity. These primary energy sources replenish themselves eventually but are limited in the amount of energy that is available at any given time or place. Therefore they are often intermittent and non-dispatchable (Zhou, Blaabjerg, Franke, Tønnes & Lau, 2015:700).

- Hydroelectric facilities use energy from falling water in rivers and reservoirs to spin a generator and create electricity (Zhang, Zhou, Blaabjerg & Yang, 2017:203). This energy source tends to be more reliable (dispatchable) than other renewable resources, especially when the facility runs off of a reservoir.

- Wind turbines get their energy from wind, which upon contact slows down and transfers kinetic energy to the turbine (Zhou, Xue, Li, Xiang & Chen, 2016:700). Air drag causes the turbine to spin, and the maximum efficiency of turbines is given by the Betz limit (Fischer & Wenske, 2018:89).

- Solar panels use photovoltaic cells to create electricity. The incoming photons from the Sun hit atoms inside the panel's semiconductors which causes electrons to flow (Falck, Felgemacher, Rojko, Liserre & Zacharias, 2018:106). Solar energy is intermittent but combined with energy storage technology their power can be much more reliable (Holzke, Brunko, Groke, Kaminski & Orlik, 2018:48).

Figures 2.3, 2.4 and 2.5 present examples of power plants from which many countries generate electricity

Figure 2.3: Coal-fired power plant

Source: Xie, Gao, Zhang, and Zhang (2017)

In most modern coal power stations in South Africa, coal is burned to heat water and convert it into steam (Energy Efficiency Environment, 2020). The steam is directed onto the blades of a turbine to make it rotate. This in turn rotates the magnetic rotor inside the coil to generate electricity (Mahlia, Lim, Aditya, Riayatsyah, Abas & Nasruddin, 2017:38). Once the steam has passed through the turbines, it must be cooled and condensed. The cooling process turns the steam back into water so that it can be pumped back to the boiler for reheating. In the boiler it will be turned into steam again and will restart the cycle. Many of Eskom's coal-fired power stations are built right next to coal mines (Energy Efficiency Environment, 2020). The coal is transported from the mine to the power station on overland conveyor belts. This saves time and money and helps keep the cost of electricity down (Department of Energy, 2020). Coal is also transported to the power stations via rail and by road (Xie, Gao, Zhang & Zhang, 2017:96).

In case of nuclear power as depicted in Figure 2.4, water is heated not by burning coal, but by the heat released in a nuclear reaction (Pettinau, Ferrara & Amorino 2012).

Figure 2.4:Nuclear power plant

Source: Xie *et al.* (2017:96)

The amount of heat can be increased or decreased by controlling the rate at which uranium atoms are split. This can be achieved by means of "control rods" that function similarly to the way an accelerator of a car causes the car to speed up or slow down (Mahlia *et al.,* 2017:38). A “moderator”, composed of highly purified water and boron, circulating in the primary circuit, also assists in controlling reactivity (Rahman, Yusof, Salleh & Leman, 2015:608). The heat from the primary circuit is transferred to a separate secondary circuit where water is turned into steam. The steam produced from heating the water in the second circuit is used to rotate the turbines in the same way as in a coal-fired power station (Pioro & Dufey, 2015:189). The steam is then condensed and returned for re-use (Xie *et al.* 2017:96).

Figure 2.5: Wind power farm

Source: Xie, Gao, Zhang and Zhang (2017:97)

Wind power or wind energy is the use of wind to provide the mechanical power through wind turbines to turn electric generators and traditionally to do other work, like milling or pumping (Xie *et al.*, 2017:97). Wind power is a sustainable and renewable energy source and has a much smaller impact on the environment compared to burning fossil fuels (Zerrahn, 2017:808). Renewable energy is infinite, naturally replenished energy generated from natural resources such as wind, sunrays, water flow, ocean tides and geothermal heat (Rahman *et al*., 2015:608; Zerrahn 2017:808). Different countries get their electricity from different types of power plants. For example, in Canada, most electricity generation comes from hydroelectric power plants, accounting for about 60% of the total electricity generated in Canada. Likewise, South Africa’s electricity comes from different power plants as illustrated by the figures above. In addition, the data visualization below show countries around the world get their electricity using hydroelectric power plant, natural gas power plant and solar plant.

Figure 2.6: Hydroelectric power plant

Figure 2.7: Natural gas power plant


Figure 2.8: Solar panel farm

2.3.2 Eskom electricity generation in South Africa

South Africa's domestic electricity generation capacity is 51,309 megawatts (MW) from all sources, according to the Ministry of Energy (2020). Approximately 91.2% comes from thermal power stations, while 8.8% is generated from renewable energy sources (Department of Energy 2020). Conventional thermal power sources are likely to be the dominant source of electricity generation for the foreseeable future. South Africa's renewable energy Independent Power Producer Procurement Programme (REIPPPP) for utility-scale transactions signed twenty-seven power purchase agreements in June 2018, and plans to add 19, 400 MW of new renewable generation by 2030. As of 2020, electricity generation capacity is dominated by the state-owned utility Eskom with 91% of the country's effective/nominal generation capacity. The remaining generation capacity is held by Independent Power Producers (IPPs) (7.21%) and municipalities (1.77%) that sell power to Eskom (Ateba *et al.*, 2019:1326).

Besides, South Africa as an integral part of the South African Power Pool (SAPP) is trading electricity with Botswana, Lesotho, Mozambique, Namibia, Swaziland, Zambia and Zimbabwe (Department of Energy, 2019). Total imports were 9,703 GWh in 2015/2016 with exports of 13,465 GWh in the same period. Eskom's generation assets are distinguished by coal (85.12%), gas (5.63%), hydro (4.67%), nuclear (4.34%) and wind (0.23%) power plants. Municipal generation assets comprise coal-fired (64.4%) and gas-fired (14.66%) power plants, as well as pumped storage hydropower plants (20.91%). In 2016, IPPs availed 3,392 MW of generation capacity to Eskom as part of South Africa's successful procurement programme for renewable energy to contribute to a decrease in load shedding. IPP-owned renewable energy generation has gained traction with 2,145 MW of available capacity. Solar and wind are responsible for 34.34% and 28.60% of IPP-owned capacity, respectively. Coal (13.56%), gas (17.33%), and others inclusive of cogeneration, landfill gas (5.87%), and hydro (0.29%) are relatively less relevant. Figure 2.9 below shows electricity generation sources by Eskom **(left),** IPP, Municipalities and imports **(right)**.

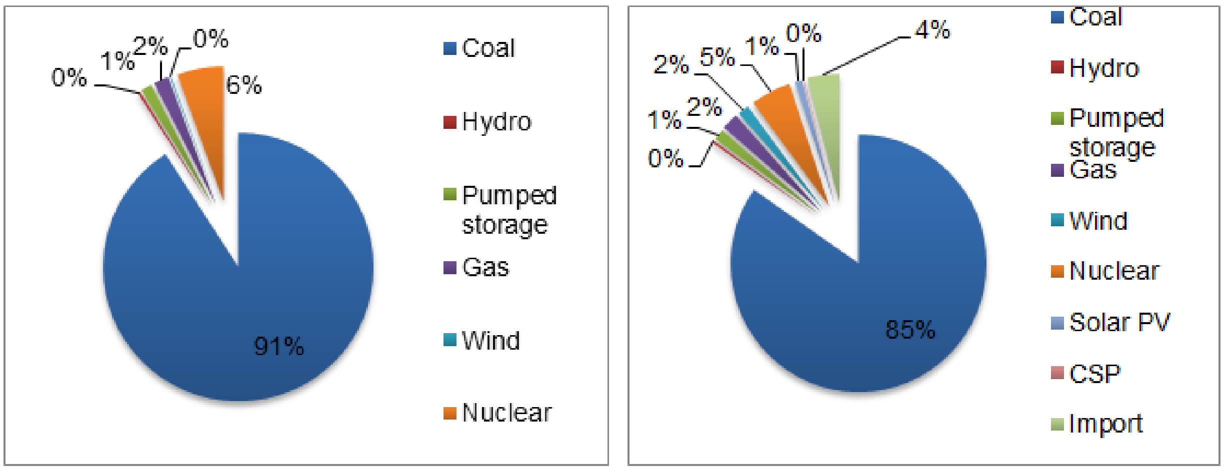

Figure 2.9: Electricity generation source

Source: Eskom Report (2020)

Achieving the new capacity requirement is expected to be driven by investments made by Eskom and IPPs with the target for IPPs to provide 30% of the total capacity in 2030. The Department of Energy, through the REIPPPP, had already contracted 6,376.7 MW of renewable energy-based generation capacity as of July 2016, resulting in an additional 4,032.7 MW to be added to the already operational renewable energy IPPs.

2.3.3 Transportation/transmission of electricity

Electricity transmission is the process of delivering generated electricity, often over long distances, to the distribution grid located in populated areas (Khobai, Mugano & Roux, 2017:89). An important component of this process includes transformers that are used to increase voltage levels to make long-distance transmission feasible. The electrical transmission system power plants, distribution system, and sub-stations form the so-called electrical grid. The grid meets society's electrical needs and is what gets the electrical power from generation to its end-user. Once electricity is generated, transformers "step-up" the electric power to a higher voltage in order to travel long distances with minimal energy loss. It then travels along overhead power cables to its destination, where transformers subsequently "step-down" the electric power to safe voltages for houses and utilities.

2.3.4 Power generation model: technical discussion

The flow sheet for the power generation cycle is presented in Figure 2.10. It shows the steam cycle of a power plant. This cycle is known as the Rankine cycle and includes the reheating and regeneration stages. The boiler in the power plant has a feed water heater, super heater and reheater. The whole turbine is modeled using 7-unit turbine models as shown in the figure. This was done to simultaneously facilitate the use of the inbuilt SysCAD turbine model and steam extraction (Zhou *et al.*, 2016:26). For example, due to two steam extractions from the intermediate pressure stage of the turbine, it is represented by 2-unit models, namely, IP-TRB1 and IP-TRB2.The steam leaves the low-pressure turbine to a condenser, which uses a shell-and-tube type heat exchanger in SysCAD (Fischer & Wenske, 2018:78). The condenser is supplied with cooling water to perform steam condensation. The pressure of the steam at this stage is very low. The bled steam extracted from the turbine is recycled into the condenser.

The makeup water required in the process is added after the condenser. The condensate pump is located after the condenser, and boosts the pressure of the condensate high enough to prevent boiling in the low-pressure feed water heaters (Falck, Felgemacher, Rojko, Liserre & Zacharias, 2018:306). The condensate mixes with the makeup water before entering the condensate pump. There are three low-pressure heaters connected with the extracted steam from different turbine stages as shown in Figure 2.10. The feed water is gradually heated, taking heat from steam with increasing temperature and pressure at each stage. In a low-pressure heater, heat exchange occurs in two stages. At first, the steam condenses to its saturation temperature at steam pressure and then sensible heat exchange take place. All three heaters were developed, based on the same principle. The main purpose of a deaerator is to remove dissolved gases such as oxygen from the feed water. Some heat exchange occurs in the deaerator (Holzke *et al.*, 2018:228). In this model, the deaerator is treated as a heat-exchange device where steam and feed water exchange heat through direct contact. The tank model built-in SysCAD was used to represent the deaerator. The feed water, after heating in the deaerator, is pumped through the feed water pump. The high-pressure feed water is heated through two more high-pressure heaters. The steam for the high-pressure heaters is extracted from the high-pressure turbine exhaust, and from an inter-stage bleed on the intermediate pressure turbine. Each of the high-pressure heaters is developed using two SysCAD heat exchange models as described earlier for the low-pressure heaters.

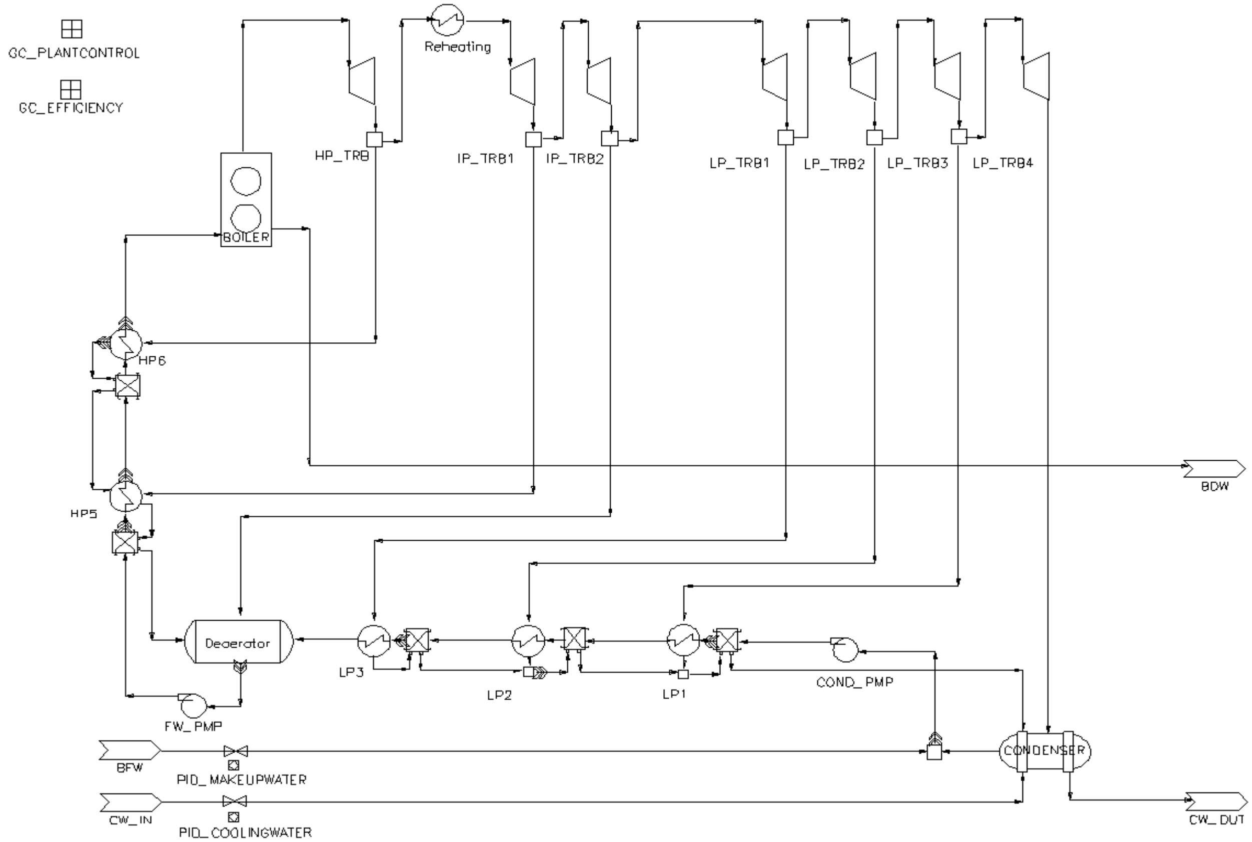

Figure 2.10: Power Plant Model

Source: Mahlia *et al.*, (2017:177)

The operations of all the individual components used in the model flow sheet are described in detail in the subsequent discussion.

2.4 TURBINE MODULAR

The development of the gas turbine in power generation took place in several countries (Soares, 2014:13). Several different schools of thought and contributory designs led up to Frank Whittle's

1941 gas turbine flight. The current gas turbine technology is still widely used across the world. Most of the world's commercial energy needs are met by fossil fuels and are characterised by negative environmental effects (Fischer, Pelka, Bartschat, Tegtmeier, Coronado, Broer & Wenske, 2019:487). To combat global warming and other environmental problems associated with these fossil fuels, many countries, including South Africa, are increasingly adopting renewable energy sources. Such energy sources generally depend on energy flows through the earth's ecosystem from the insolation of the sun and the geothermal energy of the earth (Pelka & Fischer, 2017:66).

Renewable energy resources will be an increasingly important part of power generation in the present century (Marimuthu & Kirubakaran, 2014:144). Besides assisting in the reduction of the emission of greenhouse gases, they add much-needed flexibility to the energy resource mix by decreasing the dependence on fossil fuels. The gas turbine is an internal combustion engine that uses air as the working fluid. The engine extracts chemical energy from fuel and converts it to mechanical energy using the gaseous energy of the working fluid (air) to drive the engine and propeller, which, in turn, propel the aviation (Cast Safety, 2019:6). In Eskom's gas turbine power stations, a fuel/air mixture is ignited to form a hot, high-velocity stream of gas. The gas turns the turbine which is connected to the rotor by means of a shaft. Where available, natural gas can be used as an alternative to liquid fuels such as diesel or kerosene (Gowdar & Gowda, 2016:1).

The traits which make gas turbines preferable to diesel engines are explained by Kayadelen and Üst (2013:34). Gas turbine engines offer a wide range of power in relatively small sizes and are used for a variety of power generation purposes from utility power generation to transportation or military vehicles such as aeroplanes, high-speed jets, helicopters, ships, tanks, locomotives and even in automobile and motorcycle turbochargers (Morisse, Bartschat, Wenske & Mertens, 2016:18). The important characteristic of gas turbines which make them more environmentally friendly than diesel engines and is one of the reasons it has a better power/weight ratio is that combustion in gas turbines is continuous, with average temperatures and pressures lower than the peak levels in diesel engines that foster NOx emissions, with the latter requiring stronger construction (Kayadelen & Üst, 2013:34).

2.4.1 Modular turbine defined

Making electricity and heat environmentally sustainable and reliable anywhere in the world and being capable of doing so in a relatively short time is the basic idea behind the new system power stations from MWM for decentralised power production (Fischer, Pelka, Bartschat, Tegtmeier, Coronado, Broer & Wenske, 2018). According to the present invention, a modular gas turbine engine comprises a generator module and a power turbine module, each module, in turn, comprising rotary members carried by a rotary shaft, each rotary shaft and rotary member assembly being supported from the static portions of its respective module by a plurality of bearings which are so positioned that the bearings in the power turbine module and the downstream bearing within the gas generator module are located in a common bearing chamber, which is defined by portions of both said gas generator module and said power turbine module (Falck *et al.*, 2018:307).

Modular engine technology also allows supplying to complement distributed renewable energy sources in areas that lack transmission infrastructure to support large power stations, providing better matching to changing grid needs (Fischer *et al.*, 2019:487). Expanding power needs in the future can be met with the addition of more engine units and ancillary modules, rather than the construction of a new power plant, provided the raw materials are available. Importantly, using small modular combustion engines to provide flexible load allows larger combined cycle plants to operate at full output, taking advantage of their high efficiencies at full load and reducing electric system costs (Wartsila 2020:1). Gas-fired combined-cycle plants are modular in nature, with many of the components brought to site ready-constructed (Fischer *et al.*, 2019:487). This helps make them cheap to build. In contrast, a large part of a nuclear power station must be constructed at the site. This involves considerable material and labour costs, which costs are part of the reason why nuclear power plants are expensive (there are others). A coal-fired plant, like a nuclear plant, involves significant on-site construction and this again increases the cost (Breeze, 2010:23).

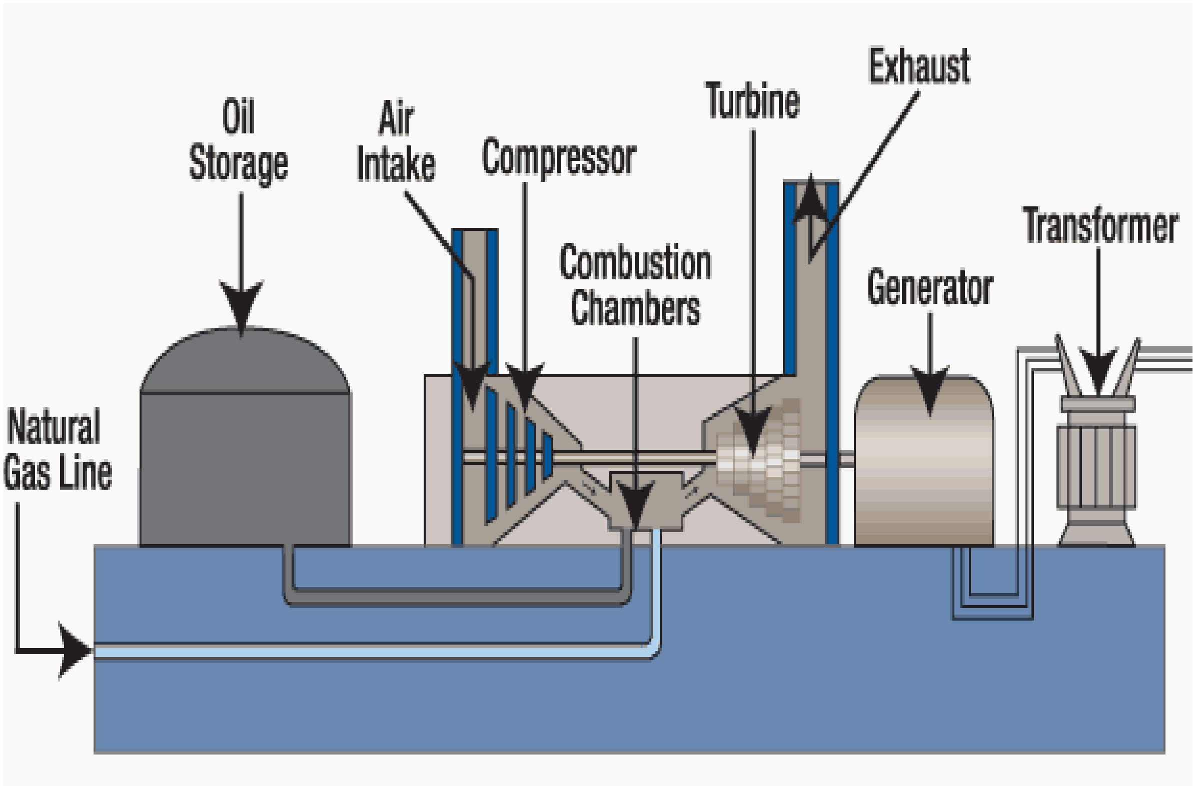

Figure 2.11: Combustion turbine power plants

Source: Tennessee Valley Authority (2014)

Combustion turbines are designed to meet peaks in power demand very quickly. They operate much like a jet engine, drawing in air at the front of the unit, compressing it, mixing it with fuel and ignition (Zhou *et al.*, 2016:90). The combustion occurs immediately, allowing gases to then expand through turbine blades connected to a generator to produce electricity. Combustion turbine power plants are normally run on natural gas as a fuel; however, they may also be run on low-sulphur fuel oil if needed (Fischer & Wenske, 2018:124).

2.4.2 Modular turbine replacement

National Occupation Standards (2019:2) introduced standard procedures that regulate a complete overhaul of an industrial power turbine. According to the standard procedure, the power turbine to be overhauled will have to be isolated, disconnected and removed from its normal operating environment, and the overhauling activities may take place in a maintenance environment or manufacturer's workshop (Fack *et al.*, 2018:101). In carrying out the overhauling operations, companies are required to follow laid-down procedures and use specific dismantling and rebuilding techniques. The overhauling activities involve removing any protective outer casing, removing all ancillary equipment and components and dismantling the power turbine down to the various sub-assembly/modules, such as fan case, front fan, compressor module, combustor module, turbine module and gearbox (National Occupation Standards 2019:2).

According to Holzke, Brunko, Groke, Kaminski and Orlik (2018:165), it will then be expected to rebuild the power turbine, which will involve fitting replacement or overhauled sub-assembly/modules (such as compressor, combustor, and turbine) and the replacement of all damaged, worn and 'end-of-life' components. The overhauling activities will include making all necessary checks and adjustments to ensure that components/modules are correctly replaced, positioned, aligned, adjusted, torque loaded, locked and fastened, and that the correct sealants are used (Fack *et al.,* 2018:101). The responsibilities will require one to comply with organisational policy and procedures for the overhaul of the power turbine, and to report any problems with the overhauling activities or with the tools and equipment used that you cannot personally resolve, or that are outside your permitted authority, to the relevant people (Zhang *et al.,* 2017:65). It should be ensured that all tools, equipment and materials used in the overhauling activities are removed from the work area on completion of the activities and that all necessary job/task documentation is completed accurately and legibly (National Occupation Standards 2019:2).

Replacing an obsolete, ageing or no longer competitive gas turbine unit with a new, more advanced version provides power plant owners with an opportunity to boost the plant's overall performance while leaving most of the existing plant equipment intact (Fadare, Ilori, Soji-Adekunle & Ojo, 2018:221). Gas turbine replacement, therefore, gives an answer to the needs of gas plant operators looking to reach multiple efficiencies, emissions, and capacity targets by investing sensibly in a quick and effective solution that will help them tackle whatever opportunities or challenges of the energy transition (Xie *et al.,* 2017:131).

Gas turbine replacement is the right fit for investors needing to implement an ad-hoc solution to cut energy costs and curb emissions at their facilities with minimum impact on the rest of the existing assets (Mahlia *et al.,* 2017:19). Also, turbine replacements can help overcome the limitations of repairs or other remedial measures carried out on an as-needed basis, by enabling an all-round system improvement and helping keep the remaining existing equipment in good working order (Fadare *et al.,* 2018:221). Turbine replacement measures entail lower investment costs; on top of other advantages, they can facilitate access to finance for your plant improvement programme, offering a higher return on investment compared to other available options (Ansaldo, 2019:2). If maintained and serviced continuously, it surely improves and enhances power generation plant's effectiveness.

2.5 PLANT EFFECTIVENESS

Building and running power plants efficiently and consistently is a difficult and crucially important part of the electricity generation sector and requires more than skills. Power generating plants must be effective to accomplish its desired functions. In the literature, a variety of terminologies have been used to denote plant effectiveness. For instance, Ferdows (1997) used the term "factory role" and operationalizes it through "site competence" and "strategic reason" (Meijboom & Vos, 2004:46). Vereecke *et al.,* (2006) used the term "plant competitiveness" and "the level of capabilities" in the plant to operationalise its operational autonomy. Feldmann *et al.,* (2013) used the terms plant efficient and plant performance interchangeably, and the term "capability" to operationalise plant effectiveness. Plant effectiveness is the capability of a power generation plant to produce the desired result or the ability to produce the desired output, which is power generation (Ansaldo, 2019:2). When the plant is deemed effective, it means it has an intended or expected outcome of producing or generating power (Pioro & Dufey, 2015:15).

Improved efficiency is the requirement for all types of modern gas turbines. Achieving enhanced plant effectiveness for turbines is a major challenge as the surrounding environment is highly aggressive (Saedi *et al.,* 2014:32). This aspect depends not only on the design but also on the selection of appropriate materials for their construction. Between the two, the selection of materials plays a vital role as the materials must perform well for the designed period under severe marine environmental conditions (El-Ahmar, El-Sayed & Hemeida, 2017:1471). Hot corrosion in a marine environment causes the materials to degrade at a significantly faster rate and causes catastrophic failures. It is important to mention that hot corrosion becomes a limiting factor for the life of components in marine gas turbines. Hence, the focus is on the selection of appropriate materials and coatings (Gurrappa, Yashwanth & Gogia, 2011:2).

Based on the observation of Demeter, Szász and Boer (2017:1774), plants can play six different roles. Plants can improve their competences in areas such as production, supply chain management, including purchasing, distribution, and customer relationships, as well as product/process development and, thereby develop themselves toward “higher” roles. Feldmann and Olhager (2013:18) find three basic bundles of competences that plants can develop: production competence, including process improvement, technical maintenance and production, supply chain competence, comprising supplier development, procurement and logistics, and development competence, consisting of product improvement and introduction of new product and process technologies. While these categories largely overlap with the ones proposed by Ferdows (1997), the authors add that they are cumulative: plants with supply chain competencies already have production competence; development competence is built on production and supply chain competence.

Blomqvist *et al.* (2014:278) identify three competence-based clusters. Their set of items related to plant effectiveness is slightly broader than Feldmann and Olhager’s (2013:19), and they arrive at four instead of three competence bundles – development, supply chain, manufacturing and process, but confirm Feldmann and Olhager’s (2013:19) assertion that competences are cumulative. Blomqvist et *al.’s* (2014:278) first cluster has a certain level of manufacturing and process competences, the second is high on these competencies as well as supply chain competences, and the third group is highly competent in all four areas. Very limited studies have paid attention to power generation plants; however, several factors have been identified as the determinants of power generation plant effectiveness/ performance in the literature. These are discussed below in order to understand what power plants need to be fully effective.

2.6 FACTORS INFLUENCING POWER GENERATION PLANT EFFECTIVENESS AND PERFORMANCE

Wind turbine electricity production can depend on the following factors, namely, wind speed, air density and area swept by the rotor blades. Many factors must be considered while designing the wind turbine and solar cell power plant. In the wind turbine, important parameters are wind speed, turbine swept area and air density. Selection of wind turbine should be based on the climate condition of the site (El-Ahmar, El-Sayed & Hemeida, 2017:1471). The power output is directly proportional to the swept area of blades. The capacity of the wind turbine depends on the swept area. The maximum output is obtained at the maximum wind speed. The temperature is directly related to the solar radiation, the critical factor for solar cell efficiency. The optimum solar radiation gives the maximum power output from the solar cell. Good exploitation of wind and solar energy may enhance the renewable energy generation capabilities and participate in generating at good costs (Marimuthu & Kirubakaran, 2014:144). Notwithstanding the aforementioned factors, the following are widely considered as the main set of factors influencing plant effectiveness within the power generation sector with reference to Eskom's (2019) report.

2.6.1 Inadequate capacity and financial limitations

Due to various constraints, most notably inadequate capacity and financial limitations, the mid-life refurbishment and enhancement projects that are required to maintain and improve technical performance as plants age, have generally not been implemented. Inadequate capacity to meet demand, meaning inadequate maintenance space to perform an ideal level of preventative maintenance, particularly mid-life refurbishments that contribute towards plant effectiveness (Eskom 2019). Eskom is operating an ageing generation fleet, notwithstanding the new power stations under construction. More than half of the stations and more than half of the coal-fired stations will be over 37 years old by the start of the fourth multi-year price determination (MYPD4) period.

2.6.2 High plant utilisation

High plant utilisation places higher than expected wear and tear on components and systems at the plants, in particular since 2008, which has contributed to a steady decline in generating plant availability over the past decade (Eskom Report 2019). To validate this point, in the lead up to and during the 2010 World Cup, Eskom had a de facto obligation to meet national electricity demand embodied by the 'Keep the Lights On' (KLO) requirement in Eskom's shareholder compact, and required Eskom to both defer maintenance and run the plant very hard when it was available. This situation was not sustainable and in subsequent years, planned maintenance levels and spend were increased despite the fact that this resulted in load shedding. This was essential but only possible because the shareholder removed the KLO requirement from the shareholder compact from 1 April 2013.

2.6.3 Replacing gas turbine technology with steam turbine technology

Fadare *et al.'s* (2018:222) study revealed from the analysis of the key performance indicators that steam turbine power plants work more effectively compared to gas turbine technology. It can be generalized because the study was conducted in Nigeria where many factors could have contributed towards the outcome. Hence this factor could still be investigated

2.7 IMPROVEMENT OF PLANT EFFECTIVENESS AND PERFORMANCE

As with all complex problems, the solution to improving plant effectiveness is not simple but can be made simpler by focusing on what's most important, as identified by Eskom by the following:

- Costs have to be reduced, but in a manner that ensures that the skills we do have and require are retained and even sourced from outside whilst reviving the morale of all.
- Even with significant cost reductions, the price of electricity must increase to restore generation performance levels.
- An optimum level of maintenance must be executed, even if this means high levels of expensive OCGT usage and/or load shedding.
- The new build units at Medupi and Kusile are not performing as expected, mostly due to design defects that need to be addressed.
- All activities and targets that do not directly contribute to the above points should be parked until Eskom is sustainably stabilized.

2.8 CHAPTER SUMMARY

This chapter has provided an overview of electricity sector in South Africa. By breaking down the electricity sector it discussed Eskom as the national utility supplier and distributor of electricity in the country. It also discussed the sources of electricity generation by Eskom, the municipalities as well as IPPs, including demand and supply of electricity in South Africa. In addition, the turbine modular concept was discussed with the emphasis on modular replacement and power plant effectiveness. The factors contributing to plant effectiveness were identified as well as the ways to improve power plant performance. The next chapter (chapter three) discusses the methodology and designs used for this study.

CHAPTER 3

RESEARCH DESIGN AND METHODOLOGY

3.1 INTRODUCTION

The preceding chapter provided a comprehensive literature review on modular turbine replacement, plant effectiveness and power generation. This chapter aims to provide a detailed outline of the methodologies used to conduct the present research study. The first part of the chapter discusses topics such as research reasoning and paradigms, where the line of thinking, as well as the underpinning philosophy employed in this study, are examined. Thereafter, it examines the research approach, design, strategy as well as the time horizon selected for this research.

The chapter then directs its focus to the literature review followed by the empirical part of the study. In the empirical part of the study, the sampling design is specified in terms of the target population, sampling frame, sample size determination, as well as the approach and techniques employed to select the respondents from Eskom plants in Mpumalanga and Free State. Additionally, it dwells on other important topics such as the data collection instrument and procedures, data analysis as well as ethical considerations. Throughout the discussions in the chapter, motivations are provided for the choices made, which makes it easy for one to understand why available options were not employed.

3.2 RESEARCH REASONING

Leedy and Ormrod (2015:121) view research or scientific reasoning as a process of thinking logically when formulating fair judgment and justifying specific positions to reach the intended goals of a study. Research goals can be achieved by making use of research approaches and methods that belong to either deductive or inductive reasoning (Saunder, Lewis & Thornhill, 2016:76). The deductive approach is a process of developing specific predictions (Creswell, 2014:26). It is theory-driven, explaining causal relationships between variables and is typically applicable to quantitative studies (Polit & Beck 2014:792). On the other hand, the inductive approach is defined as a process of analyzing current evidence and using it to create new theories

(Babin & Zikmund, 2016:330). Hence inductive reasoning is commonly associated with qualitative research.

This study follows a deductive reasoning. Deductive reasoning is used to test the hypothesized relationships in this study by either validating or refuting the proposed relationships between the variables the study intends to test. In other words, this reasoning approach will be used to search for evidence to either accept or to reject the research hypothesis.

3.3 RESEARCH PARADIGMS

Research paradigms serve as frameworks that guide researchers in the identification and clarification of their beliefs with regard to ethics, reality, knowledge and methodology (McDaniel & Gates, 2013:42). Research paradigms help researchers to reflect their primary assumptions concerning the world and the foundation of knowledge (Bryman, 2012:27). In business research, researchers are usually guided by three major research paradigms: positivism, phenomenology, and pragmatism. According to Polit and Beck (2014:794), positivism is based on the assumption that nature is ordered, and that the reality exists independent of human observation. In contrast, phenomenology focuses on experiences, events and occurrences with disregard or minimum regard for the external and physical reality (Dudovskiy, 2018:121). Phenomenology, also known as non-positivism, is a variation of interpretivism, along with other variations such as hermeneutics, symbolic interactionism, and others, and is usually applicable to qualitative studies (Babbie, 2013:35). Last but not least, the pragmatism research paradigm recognises that there are different ways of interpreting the world and undertaking research such that no single point of view can ever give the entire picture and that there may be multiple realities (Creswell, 2014:32; Burns, Veeck & Bush, 2018:99). The pragmatic paradigm is thus associated with mixed method research.

The present study is based on the positivist paradigm. Since this paradigm deals with specific concepts and focuses on the objective and quantifiable evidence obtained, it is highly relevant to this research. Also, the research has specified several hypotheses that are to be tested quantitatively, producing objectively drawn results thereby satisfying the condition of the positivist paradigm.

3.4 RESEARCH APPROACH

Research necessitates choosing an approach that corresponds with the study's problem, purpose, research questions, choice of site and research sample. Brown, Suter and Churchill (2018:205) categorise research into two sets, namely, qualitative and quantitative research. Qualitative research is more useful for exploring new constructs or themes in a phenomenon, while quantitative research is useful for testing objective theories by examining relationships between presumed variables or constructs (Babin & Zikmund, 2016:332). It therefore involves data collection that is typically numerical and analysed using mathematical models (Creswll, 2014:32). Quantitative research is an approach for testing objective theories by examining relationships among variables (Wiid & Diggines, 2011:196). Table 3.1 discusses both characteristics and differences between the two research approaches.

Table 3.1: Qualitative and quantitative research methods

Factors/ Characteristics	Qualitative methods	Quantitative methods
Research objectives	Discovery and identification of new ideas, thoughts, feelings; preliminary insights on and understanding of ideas and objects	Validation of facts, estimates, relationships, predictions
Type of research	Normally exploratory designs	Descriptive and causal designs
Type of questions	Open-ended, semi-structured, unstructured, deep probing	Mostly structured
Type of execution	Relatively short time frames	Usually significantly longer time frames
Representativeness	Small samples, limited to the sampled respondents	Large samples, normally good representation of target populations
Type of analyses	Debriefing, subjective, content, interpretive, semiotic analyses	Statistical, descriptive, causal predictions and relationships
Researcher skills	Interpersonal communications, observations, interpretive skills	Scientific, statistical procedure translation skills; subjective interpretive skills
Generalisability of results	Extremely limited; only preliminary insights and understanding	Usually very good; inferences about facts, estimates of relationships

Source: **Malhotra (2010:108)**

The present study is based on the quantitative approach. This approach was chosen because the current study intends to test relationships between turbine modular replacement, skills, adequacy, lack of management, lack of spares, modular concept, cost benefit and turbine failure, and as a result, five hypotheses will be used for testing these relationships. Moreover, the quantitative approach is selected since it facilitates results that can be generalized to other contexts. In this case, it is expected that the results of the study can be generalized to other contexts of power generation companies throughout South Africa.

3.5 TIME HORIZON

Time horizons are crucial for research designs. Basically, the research employs a cross-sectional or longitudinal design. Polit and Beck (2014:796) state that a cross-sectional design collects data at one point in time or multiple times in a short period and are therefore suitable for describing phenomena at a fixed point. In contrast, longitudinal designs are repeated over an extended period and as such, have a capacity to study change and development. Therefore, longitudinal research is suitable for investigating phenomena that change over time (Kothari 2019:252). This study will follow a correlational research design, specifically a single cross-sectional study because data will be collected only once from the sample elements (Burns, Veeck & Bush, 2018:99). A correlational study determines whether two or more variables are correlated (Creswell, 2014:32). The single cross-sectional study is quantitative in nature, meaning that it seeks to understand the sample structure and thereafter recommend a final course of action (Malhotra 2010:108). The cross-sectional strategy was chosen on the basis that it provides inexpensive methods of collecting data over a large sample and it pairs well with the quantitative. In addition, the research investigates the hypothesized relationships in the present time only without checking the trends of these relationships over a prolonged period.

3.6 RESEARCH DESIGN

A research design is defined as a plan or framework for formulating and addressing research objectives and hypotheses (Polit & Beck, 2012:802). It enables a researcher to develop a specific structure to solve a particularly growing research problem, question, or opportunity (McDaniel & Gates, 2013:42). It also ensures that the research will be relevant to the problem at hand and will use economical procedures (Malhotra 2010:182). Thus, a research design is a preliminary plan for conducting a research. According to Zikmund and Babin (2016:116) and Bloomberg and Volpe (2016:42), there are four most dominant types of designs associated with quantitative research. The first is the descriptive design, which involves the collection of data to test hypotheses or answer questions about the status of the subject inquiry. The second type of design is a correlation study that involves collecting data to determine whether and to what degree a relationship exists between two or more quantifiable variables. The third type of design is causal-comparative research, which attempts to determine the cause or reason for existing differences in behaviour or status of groups of individuals. The fourth design is experimental research, which includes true experiments as well as less rigorous experiments or quasi-experiments (Bloomberg & Volpe, 2016:177).

Saunders *et al.* (2016:68) also identified experiments, surveys, case studies, action research, grounded theory, ethnography, and archival research as strategies employed by researchers in achieving their goals. Each design is linked to a specific research approach. The present study will follow descriptive and correlational designs since the relationships proposed in the hypotheses will be tested (Wiid & Diggines, 2011:196). Additionally, the research will adopt a survey strategy to achieve the objectives and to enhance accuracy and validity. A survey strategy will also facilitate the collection of data from many respondents since a questionnaire will be used. This will further facilitate the generalisation of the research results to other contexts of steel manufacturing companies in South Africa.

The design of this study involves a review of the literature and an empirical study.

3.7 LITERATURE REVIEW

The first part of the research involves a comprehensive review of literature. A literature review is a collection and analysis of secondary data to understand how it relates to the present research, addressing research objectives, supporting the research question/s and providing a background to the study (Brown *et al.,* 2018:205). It covers issues such as overview of electricity sector and power generation in South Africa, focusing on supply and demand. In addition, research constructs under consideration in this study, namely, modular turbine replacement, plant effectiveness and the factors affecting plant effectiveness and performance. Relevant literature was sourced from both hard copy, and online peer-reviewed journals, books, peer-reviewed books, business magazines, relevant acts and other government documents. Databases such as Emerald, Science Direct, Sabinet, EBSCOhost and JStor, amongst others were used as portals for accessing some of the literature, while some were accessed directly from other credible Internet sources.

3.8 EMPIRICAL RESEARCH

Empirical research pertains to the actual collection of primary data. Empirical research in the present study comprised sampling design process, the data collection approach, and data analysis approach.

3.8.1 Sampling Design

Once a particular research design is selected, the data collection needs to be determined. Pragmatic marketing research appreciates the notion that a sample rather than a census is a more feasible approach for data collection (Babin & Zikmund, 2016:171). The development of a sampling plan is a particularly critical aspect of survey methodology as it provides a foundation for a sound measurement (McDaniel & Gates, 2013:284). Specific steps, as recommended by Gupta (2011:88) as well as Clow and James (2014:227), were followed in developing the sampling procedure for the empirical study.

3.8.1.1 Defining the target population (who and where?)

It is suggested by Wiid and Diggines (2011:184) that at the inception of the sampling procedure, the researcher needs to clearly define the target population by responding to the question, "who do we want to investigate?" When defining the target population, elements such as the geographical boundaries, time and units are included (Sekaran & Bougie, 2013:228). Babin and Zikmund (2016:337) describe the target population as the total number of elements of a specific population which is relevant to the research project and influenced by the objectives of the study. Informed by the objectives, the target population of this study comprised senior managers in modular replacement, contractors, engineers, supervisors and outage management project coordinators and implementers. Confining the study to Mpumalanga and Free State province is justified by the fact that they have the most coal fired power stations within the republic situated in close proximity to one another, especially in Mpumalanga, with only Lethabo power station in the Free State. The individuals mentioned above are involved in outage management of modular replacement projects and would give their insights, opinion and views on the phenomena under investigation. Participants will be assessed on their level of awareness when it comes to turbine modular replacement on coal fired power stations and also how they find the level of ease in implementing it on ageing power plants within the Eskom fleet.

3.8.1.2 Identifying the sample frame

After the target population is defined, the researcher assembled a list of all eligible sampling units referred to as the sampling frame. Bryman and Bell (2007:182) define sample frame as "a listing of all units in the population from which the sample is selected and each unit of analysis is included only once." It consists of a set of directions for identifying the target population, including the different types of sample sources and the basis on which respondents are selected (Creswell, 2014:31). Common examples of sample frames include, but are not limited to, customer lists and maps as well as physical sampling frames such as shopping malls and centres, amongst others (Berndt & Petzer, 2011:173). For the study's purpose, lists of senior managers in modular replacement, contractors, engineers, supervisors and outage management project coordinators and implementers in each of the visited plant were provided. The lists were obtainable from the HR databases of Eskom.

3.8.1.3 Determining the sample size

Determining the appropriate sample size is an important consideration in academic research (Hair, Black, Babin & Anderson, 2014:85). Hence a number of factors are commonly considered when deciding on a sample size. These include the available funds to cover the cost, time constraints, the heterogeneity of the population and the type of analysis the study seeks to undertake (Malhotra, 2010:459). These factors were considered when determining the sample size of this study. Firstly, an historical evidence approach was used, which uses previous similar studies.

Secondly, various multivariate statistical analysis techniques are used to analyze the data and test the hypotheses in this study. The main techniques include exploratory confirmatory factor analysis and regression analysis. These analyses require a substantial amount of sample units. For example, Pallant (2007:185) recommends a minimum of 150 respondents while Tabachnick and Fidell (2007:613) propose a sample size of at least 200 cases for a multivariate analysis.

Hair, Black, Babin and Anderson (2014:120) suggest that the sample size should be determined by the number of constructs, number of measured items, as well as multivariate normality.

Hair *et al.* (2014:30) suggest that for a study with five or fewer constructs, the minimum sample size required is 150 or more. In line with the recommendations shown above, this study initially targeted a minimum of 200 respondents. The final sample size of 171 was used in the survey. The methods and approaches used to collect data are explored in the following subsection.

3.8.1.4 Sample procedure and technique

As argued by Strong (2015:46), sampling procedures and techniques should be chosen in a manner that ensures that the respondents in the level of analysis will be generalizable to the intended population. There are two distinctive categories of sampling that can be applied in research, namely, probability and non-probability sampling methods (Zikmund, Babin, Carrand & Griffin, 2009:128; Malhotra, 2010:215). A probability sampling procedure is one in which every member of the population has an equal chance of being selected (Grove, Burns & Gray 2013:362). Its major advantage is that it commonly results in the selection of a sample that is highly representative of the population (Polit & Beck, 2018:166). In contrast, non-probability sampling involves the subjective selection of a sample, especially when the full list of the population is not available (Gerrish & Lathlean, 2015:587). For this study's purpose, a stratified probability sampling technique was employed. Stratified sampling is a method of sampling from a population which can be partitioned into subpopulation or stratas (McDaniel & Gates, 2013:284). The participants were divided into homogeneous subgroups before sampling and each strata was defined a partition of the population (Malhotra, 2010:459). That is, each strata was collectively exhaustive and mutually exclusive. Since the sample was drawn from different provinces and different groups of people, the participants were divided into engineers, contractors, supervisors, senior managers, outage management replacement project coordinators and implementers. Although stratified sampling was employed, participants were conveniently sampled based on their availability and knowledge of the subject under examination. The identified plants were visited to complete the questionnaire. In addition, email and Survey Monkey were also used as platforms of reaching the target population to quickly facilitate the data collection process.

3.9 DATA COLLECTION INSTRUMENT

In the present study, data was collected through a survey using structured questionnaire. A survey was carried out providing easy, quick, inexpensive, efficient and accurate information about the population (Babin & Zikmund, 2016:179). The use of a self-administered questionnaire was employed because of its cost effectiveness and is easy to administer. According to Malhotra (2010:230), a questionnaire is a list of carefully structured questions which have been chosen after considerable testing to elicit reliable responses from a particular group of people. The questionnaire method is used for collecting primary data by asking a sample of respondents to answer a list of carefully structured questions chosen after considerable testing, to elicit reliable responses (Berndt & Petzer, 2011:173). The decision to make use of a questionnaire is influenced by the characteristics of the respondents from which the study intends to collect data; the importance of reaching each targeted respondent; the importance of respondents' answers not being contaminated or distorted; the size of sample and the nature, and the types of the questions (Saunders *et al.,* 2016). In this study, a questionnaire was deemed suitable since a large, predetermined sample size of n=200 was required to satisfy the sample-size requirements for quantitative research.

In this study, questionnaire items were closed-ended, which denotes that the participants were restricted to indicating their answers to the structured questions provided in the survey questionnaire. Gupta (2011:177) emphasises the importance of the process of designing a questionnaire since questions must be logically ordered and should not be arranged haphazardly. This is because the initial questions can affect a respondent's willingness to answer a questionnaire. If the early questions are confusing, time-consuming, or threatening the respond may refuse to participate (O'Sullivan *et al.*, 2017:86). In view of this, the questionnaire was designed systematically, taking care to ensure that respondents will be able to understand the questions and provide the information elicited easily. The questionnaire was self-administered, which suggests that respondents were expected to complete it themselves and without additional assistance. This enabled respondents to be free and objective as they answered the questions without duress. This study used a structured questionnaire consisting of a series of questions that respondents answered. The research questionnaire was partitioned into four sections comprising closed-ended questions.

Section A

This section comprised three questions that elicited information on the demographic profile of the respondents. The questions elicited information on the department where the participants are working, position held and years of experience on the job. This section applied multiple choice questions.

Section B

Section B elicited information on the management of turbine modular replacement with ten (10) items. These questions were adapted from validated scales used in previous studies.

Section C

Section C of the questionnaire elicited responses to skills adequacy with nine (9) items.

Section D

Section D of the questionnaire comprised five questions to elicit responses on outage duration.

Section E

Section E of the questionnaire comprised six questions to elicit responses on funding.

Response options used in sections B to E of the questionnaire were presented in the form of a five-point Likert-type scale format ranging from 1= strongly disagree to 5= strongly agree was employed. The median ‘3’ position on the scale was labelled as ‘neutral’ since it was considered more appropriate to allow respondents the freedom to state their actual views regarding any item, without being arbitrarily forced to take either the negative or positive position. A Likert-type scale is a psychometric and bipolar scale that measures both negative and responses in questionnaires (Grove, Burns & Gray, 2013:362). This type of scale was used in this study due to its compatibility with questionnaires as well as its ability to measure the opinions and attitude of people objectively (Malhotra, 2010:256). Respondents were further requested to prove their own comments on the research constructs or the entire questionnaire. This provided the respondents with an opportunity to add more in-depth insights to the survey.

3.10 DATA COLLECTION PROCEDURES

There are various methods of distributing a questionnaire, such as emails, postal, telephone, drop and collect, group administered and online surveys, each of them having its own pros and cons. In this study, questionnaires were distributed to the participants using three methods. The first one was the drop and collect method, which involved the face to face distribution and collection of hard copies of the questionnaires to and from the respondents. The questionnaires were personally delivered by the researcher to the respective workstations of the respondents. The second method involved email surveys owing to the pandemic (Covid-19), which forced some people to work from home. Email addresses for such respondents were collected from their respective departments and used as a reference point for contacting them. The third was a Survey Monkey method, which allows a link to be sent to the respective participants.

Respondents were given two weeks to complete the task, and the date of collection was communicated either by email or during the drop off period. Respondents were not offered any incentives for participating in the study since the covering letter outlined the ethical considerations.

Data collection activities took place within the Mpumalanga and Free State provinces between September and October 2020. A total number of 200 questionnaires were distributed by the researcher. They were then screened after data collection. However, due to a number of reasons, some questionnaires were not returned, while some were incomplete. After systematically screening all questionnaires, and getting rid of incomplete ones, a total of 171were found usable, representing an 85.5 percent response rate.

3.11 PROCEDURES FOR DATA ANALYSIS

Data analysis is the process of defining, grouping and interpreting the data collected into suitable formats that facilitate addressing the research objectives (Clow & James, 2014:227). After the data has been collected, they are subjected to the process of data preparation to ensure that they are ready for the actual analysis. After data preparation procedures have been completed, the data will be analysed using descriptive statistics (including tests for normality of data), exploratory factor analysis and regression analysis. Descriptive statistics, exploratory factor analysis and regression analysis will be analyzed using the Statistical Packages for the Social Sciences (SPSS version 26.0).

3.11.1 Data Preparation

After data has been collected, it is normal practice to prepare it for analysis before being subjected to analysis. The initial stage of data preparation involves converting the data from numerous survey questionnaires that have been gathered into a format that can be readily and accurately analyzed to meet current research needs (Brown & Moore, 2012:3). Data preparation is an important prerequisite during data analysis because it ensures that only accurate data are entered into the analysis system and that corrective action is taken to address any existing anomalies in the data before the actual analysis is performed (Malhotra, 2010:266). There are four phases of data preparation, which the researcher of this study employed, namely, data capturing, data editing, coding and cleaning. These phases were employed to ensure that the data collected were complete and ready for analyzing (Polit & Beck, 2017:739). The discussion of these four phases follows in the next sections.

3.11.1.1 Data capturing

Malhotra (2010:459) defines data capturing as a method of transferring coded information from the questionnaires or coding sheet directly into the computer by keypunching. In this study, the researcher performed data capturing by using the Microsoft Excel programme.

3.11.1.2 Data editing

Data editing is a quality control process in which the collected survey data in questionnaires are assessed to detect any existing anomalies (Gerrish & Lathlean, 2015:587). Typical anomalies of data that may exist in questionnaires include omissions, inconsistencies, incompleteness, illegibility and any other identifiable errors (Burns & Bush, 2014:214). In this study, each collected questionnaire was evaluated to ensure that it has been filled out completely and befittingly. Where variances that exist had been detected, corrective action was taken by comparing the respondent’s data with that of similar respondents and then making suitable adjustments where necessary, as suggested by Malhotra (2010:260).

3.11.1.3 Data coding

Data coding is a technical procedure of assigning numeric codes to responses of a question (McDaniel & Gates, 2014:108). In this study, the collected questionnaires were assigned values/ numbers and entered into an Excel (spreadsheet) document. For instance, 171 questionnaires were collected; each questionnaire was allocated a specific and unique number ranging between 1 and 171. Additionally, all responses to questions were allocated a specific code. For instance, two responses, namely, 'male' and 'female' were expected for the categorical variable 'gender', Male was allocated a code '1' while female was coded '2', This ensured that only the codes 1 and 2 were entered in the Excel document to facilitate data analysis. The process of allocating codes was applied to all questions in the questionnaire and their respective codes.

3.11.1.4 Data cleaning

After the data has been coded and transformed into the excel format, it must be assessed again to detect any irregularities. Data cleaning is the most imperative part of data preparation process (McDaniel & Gates, 2014:400). Data cleaning involved error checking and treatment of missing responses, substitution of neutral value, substituting imputed response, and a case-wise and pair-wise deletion (Malhotra, 2010:461). It is an important step in that it ensures that the final data set to be used is sufficiently consistent and accurate to facilitate its objective statistical analysis. A common example of such irregularities is missing entries that may have been a result of human error during the entering of data in the Excel document. Another inconsistency might be the entering of wrong digits, such as, for example, entering a '6' on a five-point Likert-type scale. To check for and correct such errors, the columns and rows of the excel spreadsheet where the collected data has been entered was analyzed several times. Should any errors be identified, corrections were made by referring to the actual numbered questionnaire and then re-entering the missing/wrong data using the correct code. This process was repeated until no missing and wrong entries could be found on the data set.

3.11.2 Descriptive Statistics

Descriptive statistics are the most elementary statistical forms of data analysis. As its name indicates, descriptive statistics describes the basic characteristics of a variable including central tendency, distribution and variability (Zikmund & Babin, 2010:77). Descriptive statistics involve summarising and organizing the data to ensure that they may be easily understood. They simply describe the distributions/patterns shown by the data. The results of the descriptive statistics apply to the sample under consideration and cannot be inferred to the entire population from which the sample is drawn (unless the study is a census). In this study descriptive statistics include tabulations (frequency tables), mean, standard deviation, cross-tabulations. Frequency tables including frequencies and percentages will be used to help describe the socio-demographic characteristics of the sample. Means and standard deviations respectively provided information on the average and how spread out are the continuous variables.

3.11.2.1 Frequencies

The most fundamental of descriptive techniques is the construction of frequency distributions. Frequency distribution by definition is a mathematical distribution with the aim of obtaining a count of a number of respondents associated with different values of one variable and to express these counts in percentage terms (Malhotra & Peterson, 2006:429). Frequencies are a form of descriptive statistics that show the number of times a particular value occurs in each category of measurement (Carlson & Winquist, 2014:201). In this study, statistical frequencies will first be applied in the analysis of the demographic profile of respondents. Secondly, the frequencies will be applied in determining the perceptions of respondents towards each research construct. For example, the frequencies will reveal how many respondents agreed or disagreed with each of the items in a construct. The frequencies will be presented in a frequency table that will show the variable, its categories/response options, the actual number/score occurring (n) and the percentage (%) of that score against the total sample. Some of the frequencies will also be shown using specially designed graphs (for example, histograms) and charts (for example, bar and pie charts).

3.11.2.2 Mean Scores

An arithmetic mean ($\bar{x}$) is a measure of central tendency that calculates the average value in a given distribution (McDaniel & Gates, 2013:284). It is a summation of the scores of a given characteristic divided by the number of these scores (Zikmund & Babin, 2013:91). In this study, the mean will first be applied to establish the most important score amongst a set of items in a specific construct. For example, for a construct under consideration in this study, the item with the highest mean is the most important. Secondly, the mean will be applied to establish the most dominant construct when compared with the others under consideration in the study. Thus, the construct that scores the highest mean is taken as the most dominant and important when compared to the others.

3.11.2.3 Standard deviation

A standard deviation (SD) is a statistic that is used to measure the extent of dispersion or variance between each score and the data around the mean (Malhotra, 2010:281; Polit & Beck, 2018:166). A low SD implies that the data is closer to the mean whereas a higher SD suggests that measures are widely dispersed (spread out) from the mean over a wider range of values (Polit & Beck, 2018:166). In this study, the SD will be applied further to confirm whether data are normally distributed. Normal distribution is assumed when the values of the data are dispersed evenly around one representative value (Babin & Zikmund, 2016:82). Hence the analysis of SD concurrently values will be useful in further ascertaining the distribution of the data.

3.11.3 Exploratory Factor Analysis

Exploratory factor analysis (EFA) is a statistical procedure utilised for exploring the degree to which the observed variables specified in the research model represent the latent variables (or constructs) (Henseler, Dijkstra, Sarstedt, Ringle, Diamantopoulos, Straub, Ketchen, Hair, Hult & Calantone, 2015:205). It is also employed to explore the basic factor structure of a set of observed variables without imposing a predetermined structure on the outcome (Brown & Moore, 2012:3). This study has several latent variables under consideration and the proposed factor structure of these variables is as presented through the items under each item in the questionnaire, and these items are the observed variables. However, it is necessary to establish whether the collected data are consistent with the factor structure proposed in the research model, and this is achieved by applying EFA. For instance, skills adequacy is one factor. However, after applying EFA, it could be that the actual factor structure in this study using the collected data may reveal more than one factor for this variable. It is thus necessary to conduct EFA before further analyses, in order to determine the factor structure of the data collected for this study.

In determining the factor structure of the variables in this study, it is considered necessary first to check whether the data collected are factorable, as proposed by Field (2013). To check for the factorability of the data, Bartlett’s Test of Sphericity and a Kaiser Meyer Olkin (KMO) test of

Sampling Adequacy will be performed. Bartlet's test establishes whether the correlation matrix is an identity matrix. If the variables are unrelated, they would be deemed unsuitable for EFA. A significant p value less than 0.05 indicates that the variables in the correlation matrix are related, and hence factor analysis is useful for this data. The KMO tests whether the sample is large enough, indicated by a value greater than 0.5 (Field, 2013).

3.11.4 Reliability analysis

Reliability is the extent to which a test or measure can produce the same results if it is repeated under identical conditions (Feinberg, Kinnear & Taylor, 2013:128). It is the degree to which the measurement instrument is free from measurement error (McDaniel & Gates, 2013:215). Hence through reliability, biases and errors are minimized, and consistent results are achieved. According to Malhotra (2010:731), there are various methods employed to test for reliability, which include the split-half reliability coefficient, composite reliability test, the Cronbach alpha test and item-to-total correlations. In this study, reliability will be tested using the Cronbach alpha test and inter-item correlations.

3.11.4.1 Cronbach alpha

The Cronbach alpha coefficient is an indicator of internal consistency reliability or simply how well the items in a measurement scale measure the same concept (Sekaran & Bougie, 2013:228). In other words, it is the correlation of each item in a measurement scale with the sum of all the other items. A high Cronbach alpha represents a great extent of applicability across the items in the scale (Malhotra, 2010:734). In applying the Cronbach alpha coefficient, the current study will employ the guidelines presented in Table 3.2 put forward by Cronbach (1951).

Table 3.2: Rules of Thumb for the Cronbach Alpha

Cronbach Alpha Value	**Internal Consistency**
$\alpha \geq 0.9$	Excellent
$0.8 < \alpha \leq 0.9$	Good
$0.7 < \alpha \leq 0.8$	Acceptable
$0.6 < \alpha \leq 0.7$	Questionable

Cronbach Alpha Value	Internal Consistency
$0.5 < \alpha \leq 0.6$	Poor
$\alpha < 0.5$	Unacceptable

Source: Cronbach (1951)

The present study will use the rule of thumb, as indicated in the above. The table reveals that the minimum acceptable alpha value is 0.7. It is expected, therefore, that the alpha values for all measurement scales to be used in the study will be above the 0.7 threshold.

3.11.4.2 Item-total correlations

According to Field (2013:189), item-total correlations are a psychometric measure used to judge the reliability and consistency of measurement scales. The measure is applied to test whether any item in a scale is consistent with the behavior of the other items on the same scale (Burns & Bush, 2014:214). Any inconsistent items are garbage items that must be discarded. Normally, the discarding of such inconsistent items leads to the improvement of reliability in a process called scale purification. To meet the cut-off level of reliability, the study will adopt Nunnally's (1978:88) recommendation that the item-total correlation of each item should be above 0.3.

3.11.5 Validity assessment

The validity of a measure points to the degree to which a specific measure of an instrument is meaningful and facilitates the drawing of inferences from the target population (Hair *et al.*, 2017:142). It is also the degree to which the instrument measures the construct it purports to measure (Burns & Bush, 2014:216). Validity can be enhanced through suitable instrumentation, meticulous sampling and the appropriate handling of statistical data (Feinberg *et al.*, 2013:128). Although there are various types of validities, this study will test for three major forms, namely, face, content and construct validities.

3.11.5.1 Face validity

Face validity is a measure of whether a research project appears to be a good project and how representative it is 'at face value' (Schreiber *et al.*, 2010:324). It thus assesses what the questionnaire superficially appears to measure. In this study, face validity was established through a review of the questionnaire by one faculty member, who is a promoter of the study.

After reviewing the questionnaire, feedback was provided that was used to improve the questionnaire by implementing some changes regarding its structure, wording and technical aspects.

3.11.5.2 Content validity

Content validity refers to the degree to which the items on a test are fairly representative of the entire domain the test seeks to measure (Maree, 2007:217). To ascertain content validity, a pilot study was conducted after implementing the suggestions from the expert review of the questionnaire. A pilot study involving a convenient sample of 10 respondents, who are in turbine modular replacement environment was conducted. The sample size for the pilot study is determined using the suggestion by some scholars (Dhurup, 2004:249; Henseler & Sarstedt 2013; Hair *et al.* 2017), that the sample size for a pilot study should be at least 10 per cent of the project sample size. Since this study had a predetermined sample size of n=200 respondents, 20 cases are deemed adequate for the pilot sample size. Again, the questionnaire was modified using the feedback obtained from the pilot sample.

3.11.5.3 Construct Validity

Construct validity has traditionally been defined as the experimental demonstration that a test is measuring the construct it claims to be measuring (Malhotra, 2010:736). It may also be defined as the extent to which a test measures what it claims to measure (Polit & Beck, 2018:206). This study will test for the two variants of construct validity, which are convergent and discriminant validity.

3.11.5.3.1 Convergent validity

Convergent validity refers to the extent to which two indicators of a construct that should be related are in fact, related (Sekaran & Bougie, 2013:228). In this study, convergent validity will be tested through two techniques. The first technique is to use the item (factor) loadings. Convergent validity will be considered acceptable if each item loading is at least 0.5 (Hair *et al.*, 2014). The other technique is to calculate the Average Variance Extracted (AVE) values for each measurement scale. The AVE is the proportion of accurately explained variance within measured indicators by their latent factor relative to the total variance with error variance inclusive in the total (Fornel& Larcker 1981:108). A minimum cut off value of 0.4 will be applied to establish convergent validity.

3.11.5.3.2 Discriminant validity

Zikmund (2000:223) emphasises that discriminant validity involves demonstrating a lack of correlation between differing variables. Discriminant validity measures the extent to which a measure does not correlate with other constructs from which it is supposed to differ. Hence it pertains to the degree to which constructs that are supposed to be unrelated are in fact distinct from each other. In this study, discriminant validity will be ascertained using the Fornell and Larcker criterion, which involves checking whether the average variance extracted (AVE) value is larger than the highest shared variance (SV), where the latter is the highest correlation between each construct and others (Hair *et al*., 2014). Discriminant validity will be considered acceptable if the AVE is higher than the SV for each construct.

3.12 . ETHICAL CONSIDERATIONS

In general, ethics are the moral principles of right or wrong that govern how people should behave at different contexts. In the context of research, ethics refer to standards of behaviour that govern or guide your conduct towards the rights of people who become subjects of the research process or those affected by it (Saunders *et al*., 2016:239). These are acceptable norms of conduct that distinguish between right and wrong, and acceptable or unacceptable behaviour (Parveen & Showkat, 2017:2). Ethics are central to the research process. Researchers need to take care of various ethical issues at different levels of this process. The reality is there are ethical concerns at every step of the research process (Parveen & Showkat, 2017:3). Every research study should therefore be conducted morally and soundly, and sensitive findings must be reported in such a way that does not harm the relationship between the parties involved (Akaranga & Makau, 2016:102). In this study, four ethical research principles were considered, namely, informed consent, protection from harm, confidentiality, research integrity, beneficence as well as permission to conduct the study. As suggested by Hammersley and Traianou (2012:56), these four are the main ethical concerns relevant to a quantitative study such as the present research.

3.12.1 Informed Consent

According to Saunders *et al.* (2016:244), informed consent is provision of sufficient information and assurance to individuals participating in the research on the implications of the research process and outcomes. This is done to enable potential participants to come up with fully informed decisions free of any pressure and coercion. Fouka and Mantzorou (2011:3) highlight that informed consent involves the provision of enough information to the targeted respondents which enables them to make decisions to participate in the study or to turn down the request to participate. In this study, respondents were made aware of the aims of the study and how it was to be conducted. This enabled the selected respondents to realise the extent of the consent, enabling them to participate voluntarily and on informed decisions (Dongre & Sankaran, 2016:2). In this case, respondents were provided with necessary information on the study. In addition, a covering letter explaining the aims of the study was attached to the questionnaire together with a consent form to show voluntary participation in the research. Furthermore, respondents were made aware of the right to withdraw from the study at any given time with no adverse consequences.

3.12.2 Ensuring confidentiality

Identities of individuals and organisations participating in the research should remain anonymous and given deserving strict confidentiality (Sunders *et al*., 2016:244). In this study respondents were requested to avoid writing names on the questionnaires, to ensure confidentiality and anonymity. This was to ensure that the study valued their right to privacy.

3.12.3 Protection from harm/or victimization

Harm or victimization comes in the several forms which may result in emotional, psychological or sociological distress if information given is not properly handled. This depends largely on the amount and nature of information given out by respondents (Fouka & Mantzorou, 2011:5). In this regard, Pillay (2014:78) highlights that in any research, it is important to protect respondents from any form of harm or victimization. To ensure that this was observed in this study, all respondents were fully informed and assured that the research was for academic purposes only. Furthermore, all completed questionnaires were always kept in a safe lockable place.

3.12.4 Ensuring permission is obtained

An ethics committee at an institution of higher learning is responsible for all aspects of ethical review and approval (Saunders *et al*., 2016:242). During this study, ethical clearance was obtained from the Ethics Committee of the North-West University. The survey questionnaire was examined and then approved by the research committee before it was distributed to respondents.

Permission to collect data was sought from the relevant authorities at the demarcated power generation plants before the data are collected.

3.12.5 Research integrity

According to Burns and Bush (2010:93), research integrity has to do with conducting research that is consistent with accepted standards. Researchers can be tempted to falsify data, alter findings or withhold important information. The integrity of the present study was ensured by the involvement of academics in the process of analyzing the data. Not only did the academic supervisors monitor the whole process, but also independent statisticians were involved throughout the research process.

3.12.6 Beneficence

This principle requires the researcher to maximize the benefits that the research will afford to the participants in the research study (Chauke, 2014:80; Chauke, 2018:199). During the fieldwork, the researcher prioritized the fact that the research was not for researcher's direct financial benefit. Respondents were advised that the data would be used only for academic purposes, and that the aggregated report would be available for their access at the North-West University upon request. Conversations were intended to build mutual trust. Participants were reminded constantly by the researcher to ensure they did not divert into confrontations

3.13 CONCLUSION

This chapter aimed to discuss comprehensively the research methodology employed in this study. It first examined the researched reasoning and paradigms selected. It emerged that the study is based on deductive reasoning and the positivist paradigm. It also outlined the research approach, time horizon, design and strategy. The discourse indicated that the study is based on a quantitative approach, used a descriptive design, and was based on a correlational cross-sectional method, using a survey strategy. The chapter further discussed the literature review and sampling design. On the latter, it was shown that the sample would be composed of several senior managers, contractors, implementers, and other role players within the modular turbine replacement in Mpumalanga and Free State provinces of South Africa. A sample size of n=171 respondents has been predetermined and the samples selected using a probability based stratified technique. The chapter further revealed that the measurement instrument was a survey questionnaire that was distributed using emails and the drop and collect method. Statistical analysis to be used was detailed. The study also tested for reliability and various types of validities. Various ethical considerations were also followed as the study seeks to maintain the standards of professionalism.

The next chapter discusses the data analysis, interpretation, and discussion of the empirical findings of the study.

CHAPTER 4

ANALYSIS, INTERPRETATION AND DISCUSSION OF EMPIRICAL FINDINGS

4.1 INTRODUCTION

The previous chapter provides an outline on the research methodology which highlighted the research design and methods utilized for this study. This chapter reports on the analysis, discussion, and interpretation of the empirical findings. It commences with preliminary data analysis focusing on coding and tabulation and presents the demographic composition of the sample. Thereafter, it provides data normality assessments as well as the exploratory factor analysis. Factor analysis is later discussed with the emphasis on the eight-factor solution established for the study, followed by discussing the reliability and validity analysis of the main survey. The descriptive statistics and the correlation analysis is discussed. The recap of research hypotheses for this study is highlighted and tested, using regression mode.

To perform the data analysis, SPSS (Versions 26.0) for Windows was used, as indicated in Chapter three. The data analysis was conducted in two stages. The next section will discuss the data analysis procedures involved in the pilot phase.

4.2 PRELIMINARY DATA ANALYSIS

Before analyzing a data set, it is recommended that a preliminary data analysis be conducted on the data set, which is done by using coding and tabulation.

4.2.1 Coding

In the questionnaire for this study, the questions are classified into five sections, namely, Section A, demographical data, Section B, management of turbine modular replacement, Section C, skills adequacy, Section D, outage duration, and Section E, focuses on the funding. The same questionnaire was administered to all the participants in the sample. Table 4.1 presents the variable codes and assigned values.

Table 4.1: Coding information

Section A: Demographical data			
Question	**Code**	**Construct measured**	**Value assigned to responses**
Question 1	A1	Department	Outages (1), Rotek (2), Engineering (3), Contractor (4), Maintenance (5)
Question 2	A2	Position held	Supervisory (1), Junior management (2), Middle management (3),Senior management (4), Executive (5)
Question 3	A3	Years of experience within Eskom	1-5 (1), 6-10 (2), 11-15 (3), 16 – 20 (4), 20 - 25 (5)
Section B: Management of Turbine Modular Replacement			
Item 1	B1	Modularity perceived benefits in refurbishment of components	Strongly Disagree (1), Disagree (2) , Neither agree or disagree (3), agree (4), Strongly Agree (5)
Item 2	B2	Benefits to implementing modular replacement turbine	Strongly Disagree (1), Disagree (2) , Neither agree or disagree (3), agree (4), Strongly Agree (5)
Item 3	B3	Implementation of turbine outages results in high quality work	Strongly Disagree (1), Disagree (2) , Neither agree or disagree (3), agree (4), Strongly Agree (5)
Item 4	B4	Success and failure of turbine rests on management support	Strongly Disagree (1), Disagree (2) , Neither agree or disagree (3), agree (4), Strongly Agree (5)
Item 5	B5	TMR can be successful if managed by single team from offsite	Strongly Disagree (1), Disagree (2) , Neither agree or disagree (3), agree (4), Strongly Agree (5)
Item 6	B6	Staggering of outages in TMR improve skills of implementers	Strongly Disagree (1), Disagree (2) , Neither agree or disagree (3), agree (4), Strongly Agree (5)
Item 7	B7	Failure to stagger TMR outages causes failure during outages	Strongly Disagree (1), Disagree (2) , Neither agree or disagree (3), agree (4), Strongly Agree (5)
Item 8	B8	Inadequacy in project management results in TMR failure	Strongly Disagree (1), Disagree (2) , Neither agree or disagree (3), agree (4), Strongly Agree (5)
Item 9	B9	Senior authority interference impacts the success of TMR negatively	Strongly Disagree (1), Disagree (2) , Neither agree or disagree (3), agree (4), Strongly Agree (5)

Item 10	B10	TMR improves readiness to execute turbine SOW	Strongly Disagree (1), Disagree (2) , Neither agree or disagree (3), agree (4), Strongly Agree (5)
Section C: Skills Adequacy			
Item 1	C1	Refurbishment staff are trained adequately to assemble the modules	Strongly Disagree (1), Disagree (2) , Neither agree or disagree (3), agree (4), Strongly Agree (5)
Item 2	C2	Replacement staff have skills to do final assembly of turbine modules	Strongly Disagree (1), Disagree (2) , Neither agree or disagree (3), agree (4), Strongly Agree (5)
Item 3	C3	Skilled engineers give assurance for workmanship of modules preassembly	Strongly Disagree (1), Disagree (2) , Neither agree or disagree (3), agree (4), Strongly Agree (5)
Item 4	C4	Skilled project staff give assurance for workmanship of modules preassembly	Strongly Disagree (1), Disagree (2) , Neither agree or disagree (3), agree (4), Strongly Agree (5)
Item 5	C5	Lack of resources (skilled personnel & spares) leads to project failure	Strongly Disagree (1), Disagree (2) , Neither agree or disagree (3), agree (4), Strongly Agree (5)
Item 6	C6	Adequate technical skills ensure successful implementation of TMR	Strongly Disagree (1), Disagree (2) , Neither agree or disagree (3), agree (4), Strongly Agree (5)
Item 7	C7	Lack of skills during refurbishment causes failure during outages	Strongly Disagree (1), Disagree (2) , Neither agree or disagree (3), agree (4), Strongly Agree (5)
Item 8	C8	TMR success or failure depends on skills and competence of staff	Strongly Disagree (1), Disagree (2) , Neither agree or disagree (3), agree (4), Strongly Agree (5)
Item 9	C9	Lack of skills by maintenance staff cause failure or success of TMR	Strongly Disagree (1), Disagree (2) , Neither agree or disagree (3), agree (4), Strongly Agree (5)
Section D: Outage Duration			
Item 1	D1	Reduction of outages is realised through modular turbine	Strongly Disagree (1), Disagree (2) , Neither agree or disagree (3), agree (4), Strongly Agree (5)
Item 2	D2	There is increase in scope of work & duration due to TMR	Strongly Disagree (1), Disagree (2) , Neither agree or disagree (3), agree (4), Strongly Agree (5)
Item 3	D3	Turbine components refurbishment takes longer than MR during outages	Strongly Disagree (1), Disagree (2) , Neither agree or disagree (3), agree (4), Strongly Agree (5)
Item 4	D4	TMR duration is linked to the skills	Strongly Disagree (1), Disagree (2) , Neither agree

		level of the staff putting it together	or disagree (3), agree (4), Strongly Agree (5)
Item 5	D5	TM does not reduce outages duration in ageing power generating plant	Strongly Disagree (1), Disagree (2) , Neither agree or disagree (3), agree (4), Strongly Agree (5)
Section E: Funding			
Item 1	E1	Capital investment made towards TM is effectively utilised	Strongly Disagree (1), Disagree (2) , Neither agree or disagree (3), agree (4), Strongly Agree (5)
Item 2	E2	There is enough funding to support TMR	Strongly Disagree (1), Disagree (2) , Neither agree or disagree (3), agree (4), Strongly Agree (5)
Item 3	E3	There are cost benefits in the implementation of TMR	Strongly Disagree (1), Disagree (2) , Neither agree or disagree (3), agree (4), Strongly Agree (5)
Item 4	E4	Implementation of modular replacement results in cost reduction	Strongly Disagree (1), Disagree (2) , Neither agree or disagree (3), agree (4), Strongly Agree (5)
Item 5	E5	Cost benefits to Eskom bottom line due to TMR implementation	Strongly Disagree (1), Disagree (2) , Neither agree or disagree (3), agree (4), Strongly Agree (5)
Item 6	E6	Turbine outages costs are reduced by modular replacement implementation	Strongly Disagree (1), Disagree (2) , Neither agree or disagree (3), agree (4), Strongly Agree (5)

The questionnaire for this study comprised five sections with codes provided on Table 4.1. Section A provides demographical information of the participants. Section B displays the management of turbine modular replacement. Section C measured skills adequacy. Section D measured outage duration within the power generation plant. The last section, which is Section E, comprised measuring items for funding.

4.2.2 Data cleaning

As discussed in chapter three, data editing is more of a quality control process in which the collected survey data in questionnaires are assessed to detect any existing anomalies. During this step, questionnaires completed by individuals falling outside the defined target population were discarded. In addition, scaled responses within questionnaires with missing values of less than 10 per cent as suggested by Malhotra (2010:425) were estimated, based on the mode. The Excel spreadsheet comprised 171 respondents and transferred on to SPSS to check for any errors and missing values in the data sets.

4.2.3 Tabulation

Tabulation of data is the next step after data cleaning and coding. Tabulation involves calculating the number of responses in each of the predetermined categories to ensure that the data is easily readable and understandable (McDaniel & Gates, 2014:118). Table 4.2 presents the frequency table based on the collected data of modular turbine modular replacement within the power generation plants. The table below presents the frequencies derived from the total sample for Section B to E of the questionnaire.

Table 4.2: Frequency table of responses

Scale item	Strongly disagree (1)	Disagree (2)	Neither agree nor disagree (3)	Agree (4)	Strongly agree (5)
Section B: management of turbine modular replacement					
B1	1	1	50	27	92
B2	4	7	5	46	109
B3	15	10	10	46	90
B4	4	7	91	20	49
B5	6	4	10	39	112
B6	1	3	31	102	34
B7	17	7	43	32	72
B8	18	6	10	88	49
B9	15	24	18	75	39
B10	13	13	20	23	102
Section C: Skills adequacy					
C1	14	14	28	17	98
C2	12	16	14	72	57
C3	12	17	83	41	18
C4	4	16	20	107	24

Scale item	Strongly disagree (1)	Disagree (2)	Neither agree nor disagree (3)	Agree (4)	Strongly agree (5)
C5	1	10	19	86	55
C6	22	12	13	36	88
C7	21	13	5	46	86
C8	0	4	9	43	115
C9	23	23	12	96	17
Section D: Outage duration					
D1	11	14	23	101	22
D2	10	15	7	103	36
D3	18	17	28	75	33
D4	0	4	34	90	43
D5	8	14	20	23	106
Section E: Funding					
E1	6	10	37	91	27
E2	0	5	10	113	43
E3	6	15	43	99	8
E4	19	28	29	29	66
E5	3	20	42	88	18
E6	22	22	28	65	34

Frequency tabulation was anchored on a 5-point Likert scale as shown in Table 4.2, measuring different variables. The next section provides an overview of the demographic information (Section A) of the respondents.

4.3 DEMOGRAPHIC INFORMATION OF THE SAMPLE

This section presents the composition of the sample's department, position held and years of experience working for the company.

4.3.1 The department

Figure 4.1 provides an overview of the department composition of the respondents. Of the 171 questionnaire analyzed, 25 percent (n=43) of the respondents were from the Outage department, followed by Rotek with 24 percent (n=40). Engineering (n=33), Contractors (n=31) and Maintenance (n=24) with 19, 18 and 14 per cent respectively. These results suggest a balanced representation of the sample in terms of the company's diversity in departmental portfolios.

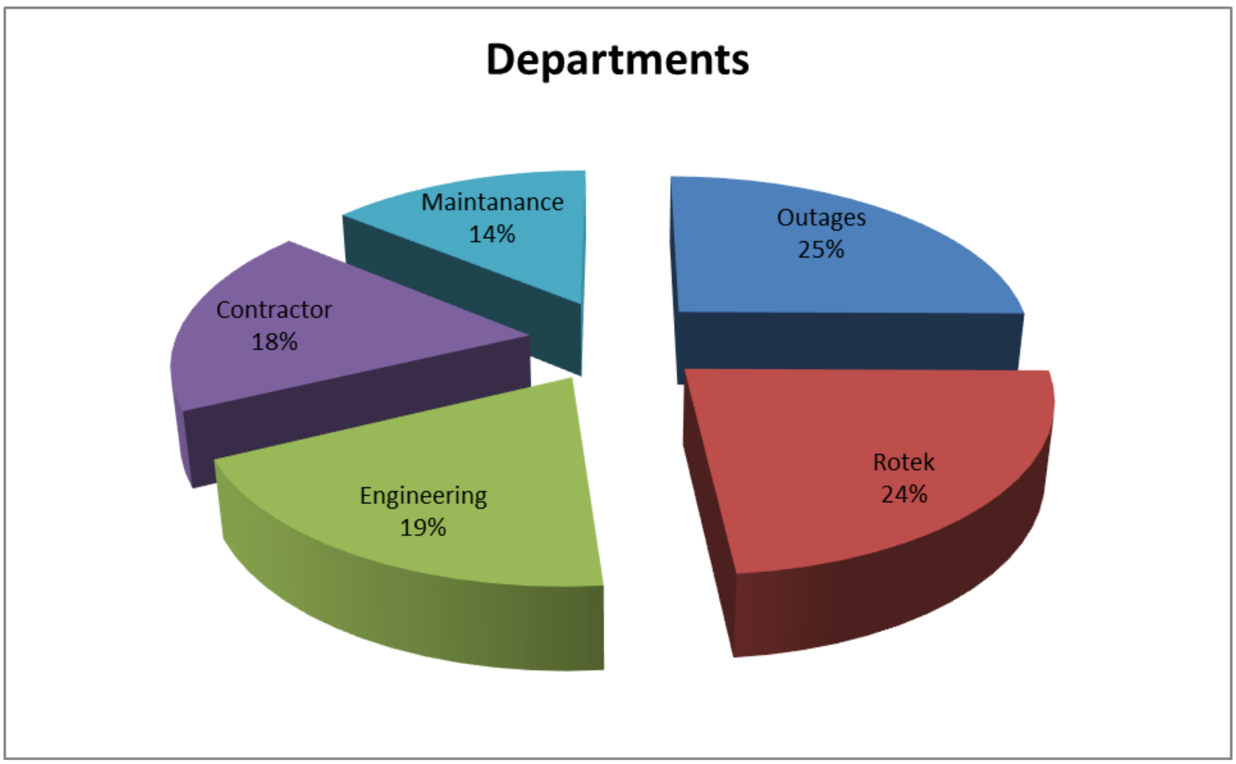

Figure 4.1: Department composition of the sample

4.3.2 Position held

In terms of the position held, five categories were identified as depicted in Figure 4.2 below. The figure illustrates that 41 per cent of the respondents were in a supervisory capacity, 31 per cent from middle management, 20 per cent were junior managers, while 7 per cent from senior management and only 1 per cent from executive.

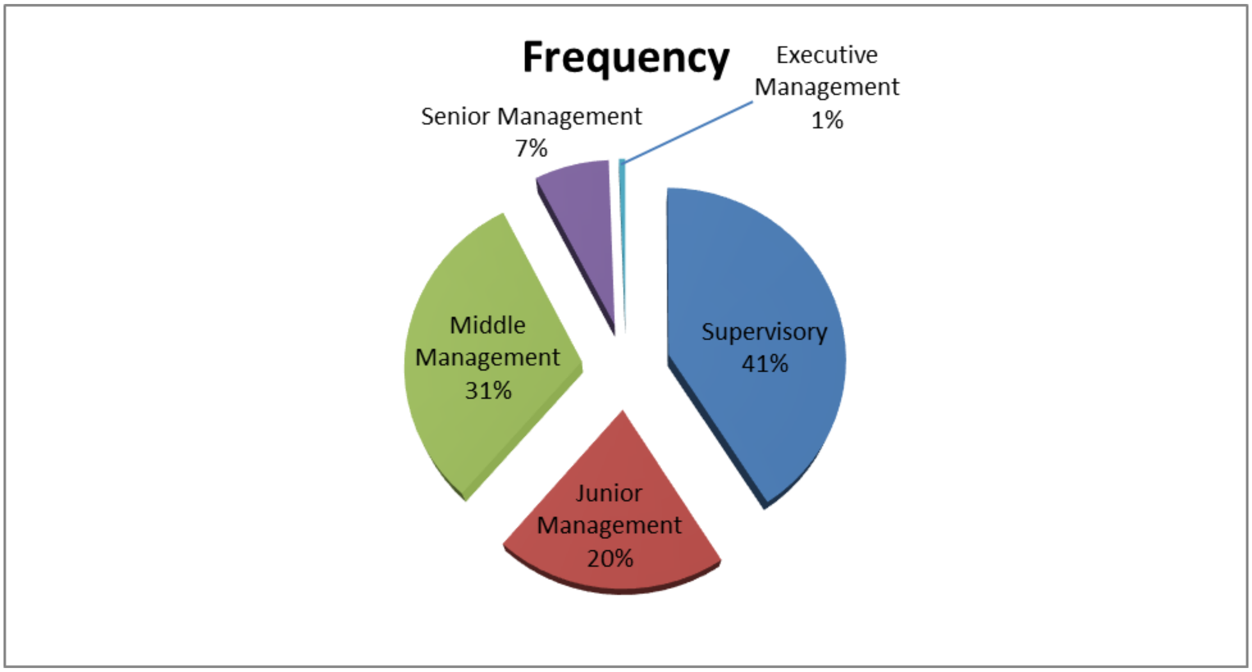

Figure 4.2: Position held

4.3.3 Years of experience within the company

In terms of years of experience, Figure 4.3 below shows the sample composition regarding the number of years within the company and/or position. Figure 4.3 illustrates that the majority of the respondents, which is 33.9 percent (n=58) had between 6 and 10 years of experience, followed by 28 per cent (n=47) with between 1 and 15 years of experience and 31 per cent with between 16 and 20 years of experience working for the company. Eighteen (18) per cent of the respondents had only between 1 and 5 years of working experience, while 17 per cent had over 20 years. The findings suggest that most of the sampled respondents have enough experience working with turbine modular replacement in the power generation plant, thus experienced enough to provide the much-needed information regarding the matter under investigation.

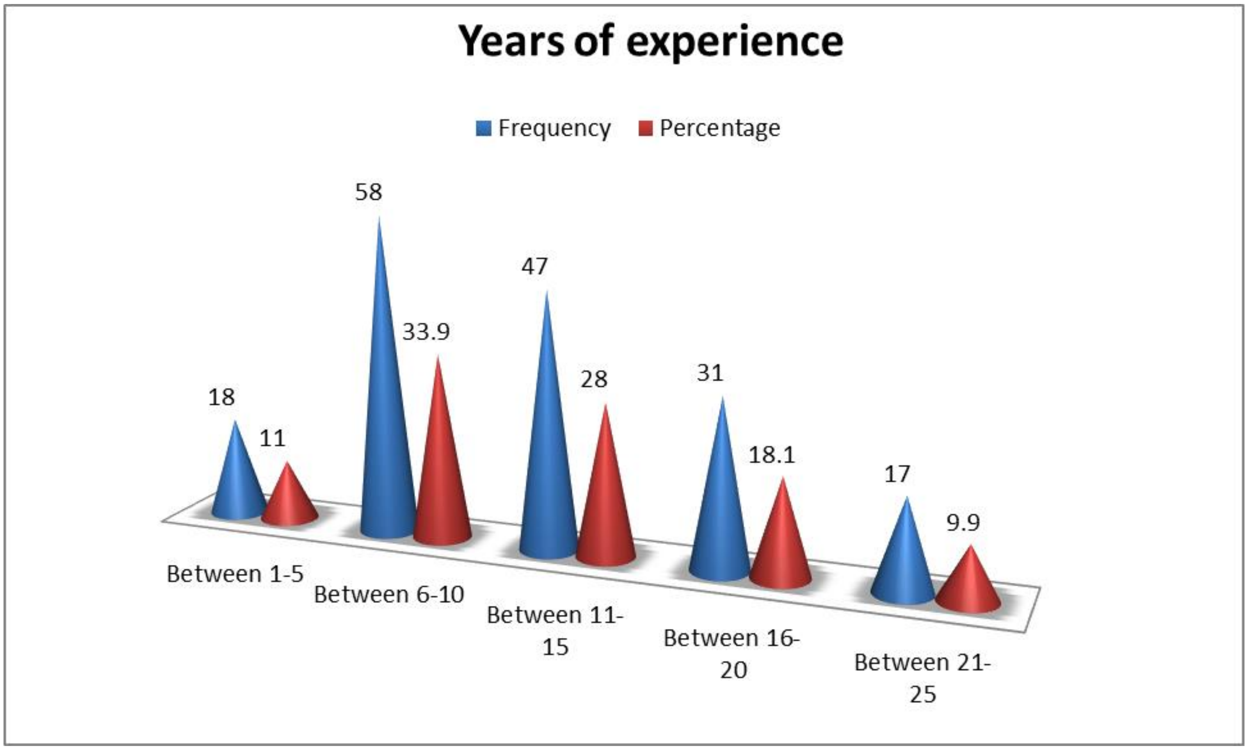

Figure 4.3: Years of experience in the company

To continue with data analysis, assessment normality of the collected data was necessary.

4.4 DATA NORMALITY

In measuring normality, Field (2013:172) points out that for an average sample size such as the one in this study, the central limit theorem stipulates that the assumption of normality has little effect on the analysis of data. Although the central theorem provides a studied theoretical background for the issue of normality in this study, mean, standard deviation, the skewness and kurtosis of each item are presented in Table 4.3 below. With regard to countering non-normality of data, it was noted that the computed mean values in this work ranged between 3.21 and 4.57 while the standard deviation values were spread narrowly around the population variance (ranging between 0.641and 1.423). In addition, the computed skewness and kurtosis statistics were within the recommended range of ±2 for a normal distribution, as suggested by Field (2013).

Table 4.3: Assessment of normality

Variables	N	Mean	Std. Deviation	Skewness	Kurtosis
B1	171	4.22	.930	-.667	-.809
B2	170	4.46	.917	-2.111	4.413
B3	171	4.09	1.269	-1.390	.778
B4	171	3.60	1.020	.089	-.641
B5	171	4.44	.965	-2.108	4.284
B6	171	3.96	.710	-.647	1.442
B7	171	3.79	1.303	-.814	-.360
B8	171	3.84	1.190	-1.343	1.008
B9	171	3.58	1.231	-.758	-.465
B10	171	4.10	1.305	-1.232	.204
C1	171	3.96	1.382	-.981	-.431
C2	171	3.85	1.187	-1.081	.299
C3	171	3.21	1.001	-.221	.122
C4	171	3.77	.890	-1.143	1.344
C5	171	4.08	.847	-.968	.978
C6	171	3.91	1.426	-1.075	-.290
C7	171	3.95	1.397	-1.187	-.021
C8	171	4.57	.702	-1.759	2.933
C9	171	3.36	1.230	-.825	-.584
D1	171	3.64	1.022	-1.164	.938
D2	171	3.82	1.050	-1.327	1.304
D3	171	3.51	1.214	-.772	-.319
D4	171	4.01	.740	-.362	-.171
D5	171	4.20	1.206	-1.326	.547

Variables	N	Mean	Std. Deviation	Skewness	Kurtosis
E1	171	3.72	.922	-.961	1.150
E2	171	4.13	.641	-.804	2.154
E3	171	3.51	.857	-1.097	1.094
E4	171	3.56	1.423	-.467	-1.173
E5	171	3.57	.894	-.648	.154
E6	171	3.39	1.294	-.566	-.796

The value for skewness and kurtosis between -2 and +2 is considered acceptable to prove normal univariate distribution (Field, 2013). Table 4.3 indicates that overall, the items of the scales have satisfactory skewness and kurtosis values. It can therefore be said confidently that the assumption of normality is met. Hashim (2012) suggests that the data is non-normal if about 80% of the data presented skewness and kurtosis above the recommended threshold of -3 to +3.

4.5 EXPLORATORY FACTOR ANALYSIS

Prior to conducting the exploratory factor analysis, sample size requirements as well as common methods bias were checked. In general, it is recommended that in order to have a good factor analysis, a minimum of 300 cases should be maintained whereas Hair *et al.* (2014:89) recommend a minimum of five observations for each variable (5:1 cases) under study, which was evident in this study. Initially, a Harman one-factor score test was conducted by running the preliminary EFA on the sample data, whereas the unrotated factor solution was examined to determine the number of factors that are necessary to account for the variance in the variables. The single factor that emerged yielded one general factor accounting for approximately 25.643 percent of the covariance among the measures leading to the conclusion that common method variance is not a problem.

An EFA was then performed using principal axis factoring by applying an orthogonal method of rotation termed, Varimax, which helped to evaluate the construct validity. A maximum iteration value of eight for convergence was used to search for the optimal factor solution. The suitability of data for factorability was ascertained after examining the large Kaiser-Meyer Olkin test statistic (KMO = 0.761) as well as the Bartlett spherical test, which showed a significant result with a large chi-square value ($\chi2$=8 2655.918; p<0.000).

Table 4.4: KMO and Bartlett's test

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.761
Bartlett's Test of Sphericity	Approx. Chi-Square	2655.918
	Df	435
	Sig.	.000

4.5.1 Factor rotation

Factors were rotated to enhance the interpretability of variables that load onto factors, as observed by Malhotra, Nunan and Birks (2017:283). The Varimax method has proved highly successful as an analytic approach in obtaining an orthogonal rotation of factors and is the most frequently used and reported option (Zikmund, Babin, Carr & Griffin, 2013:347). Factor rotation allows for factor clarification, showing the relationship of items to factors by maximizing the loadings on one factor and minimizing loadings on all the others. The principal components method of extraction with Varimax orthogonal factor rotation procedure was used.

Table 4.5: Rotated factors

Variables	Factors							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
E3	0.796							
E5	0.793							
B2	0.757							
B10	0.688							
E4	0.626							
B3	0.549							
E6	0.501							

Variables	Factors							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
D3		0.762						
C7		0.672						
B9		0.642						
B4			0.828					
C5			0.732					
B1			0.500					
B6				0.723				
B5				0.709				
C8				0.605				
C2					0.675			
C3					0.653			
D1					0.507			
E6					0.499			
C4						0.777		
D5						0.500		
B7						0.473		
D2							0.758	
C9								0.647
Cronbach's Alpha	**0.829**	**0.688**	**0.624**	**0.704**	**0.732**	**0.694**	**0.612**	**0.528**
Scale means	**3.8134**	**3.6823**	**3.9649**	**4.3275**	**3.5234**	**3.9181**	**3.9181**	**3.9649**
Standard deviation	**.85235**	**.97539**	**.69362**	**.59461**	**.80314**	**.86836**	**.74204**	**.74627**

*Rotation Method: Varimax with Kaiser Normalisation *Loadings of 0.45 and more were considered significant because of the average sample size. * Items B8, C1, C6, D4, E1 and E2 reflected low factor loading and were omitted.

Factor loadings of 0.45 and more were considered significant with factor loading matrix showing the loadings above 0.5 except for items E6 and B7. This exceeded the criterion of Hair *et al*. (2014:239), which states that - factor loadings greater than ± 0.300 are considered to meet the minimum levels, loadings of ± 0.400 are considered important, and loadings of ± 0.500 and greater are considered more important.

4.6 FACTOR ANALYSIS

Prior to factor analysis, the factorability of the data for all the scales was established. The correlation matrix testing the linear association among variables was examined. Initial examination of the correlation matrix revealed that a substantial number (97.83%) of correlations were larger than 0.300, indicating good factorability. Since a majority of the correlations were more than 0.300 in value, it could be inferred that the correlation matrix is not an identity matrix bearing zero correlations (Pallant, 2013).

4.6.1 Eigenvalues and percentage of variance

An eigenvalue is the total variance explained by each factor. The general rule of thumb of extracting factors with eigenvalues greater than 1.0 is considered appropriate (Malhotra, 2010:367). In keeping with the eigenvalue criterion, only factors with eigenvalues greater than 1.0 were retained, as illustrated in Table 4.6. According to Malhotra *et al.* (2017), it is assumed that in factor analysis, the variables do not account for 100% of the variance. Although the loading patterns of the factors extracted do not differ substantially, their respective amounts of explained variance do. Table 4.6 reports on the percentages of variance, and the cumulative percentage of variance explained of 69.96% of the total variance which, according to Malhotra (2010:367), is satisfactory.

Furthermore, Hair *et al. (*2014:91) posit that an important point to consider in deciding how many factors to retain is to examine the percentage of variation in the data set that is explained by each factor. Based on this recommendation, the eight factors would be retained. This was in line with previous studies undertaken, considering the factors expounded in sections in chapter two (literature review). In line with the literature study, the eight factors were meaningfully named and interpreted in terms of the various studies investigated the factors affecting plant effectiveness in different sectors.

Table 4.6 presents the eigenvalues of the extracted factors and the total (%) variance explained by the eight-factor solution.

Table 4.6: Eigenvalues and variance explained – TMR factors affecting plant effectiveness

Value	**Eigenvalues (Nine factors)**			
	Eigenvalue	**% Total Variance**	**Cumulative Eigenvalue**	**Cumulative %**
1	8.029	26.764	8.029	26.764
2	2.839	9.464	10.868	36.228
3	1.794	5.981	12.662	42.209
4	1.637	5.457	14.299	47.666
5	1.544	5.145	15.843	52.811
6	1.505	5.017	17.348	57.828
7	1.327	4.422	18.675	62.250
8	1.228	4.092	19.903	66.342
9	1.087	3.623	20.99	69.965
Extraction Method: Principal Component Analysis				

In this main factor analysis procedure, no restriction was placed on the number of factors to be extracted. Instead, the Eigen values ‘greater than one criterion’ as well as the threshold of a cumulative percentage of variance in excess of 60 percent (Malhotra *et al.*, 2017) were applied. In this regard, only eight unique components based on Kaiser’s eigenvalue rule (eigenvalues ranged between 1.087and 8.029) as well as the scree plot point of tailing off. The eight factors accounted for 69.965 per cent of total variation across all variables, whereas the first factor to be extracted after Varimax rotation yielded a 26.764 percentage of variance, demonstrating that no single factor in the model was domineering. Most of the items loaded as expected with their factors, except for item B8 (“Inadequacy in project management results in modular replacement failure”), C1 (“Refurbishment staff are trained adequately in assembling the modules”), C6 (“There are adequate technical skills within Eskom to ensure successful implementation of

TMR") and D4 ("TMR duration is linked to the skill level of the staff putting it together"), E1 ("Capital investment made towards TM is effectively utilized"), which were deleted since they yielded weak and insignificant loadings on any of the extracted factors (below 0.45; p >0.01). The eight factors were labeled: (1) turbine modular replacement benefits and cost benefits; (2) senior management intervention and lack of skills; (3) management support and lack of resources; (4) offsite single team and implementers skills/competencies; (5) replacement engineering staff; (6) skilled project management staff and ageing power plant; (7) increase in scope of work and duration; and (8) lack of skills by maintenance staff.

4.6.2 The Scree plot

In addition, the scree plot reflected in Figure 4.4 shows a flattening of the scree after four factors, depicting the four factors deemed suitable for the study.

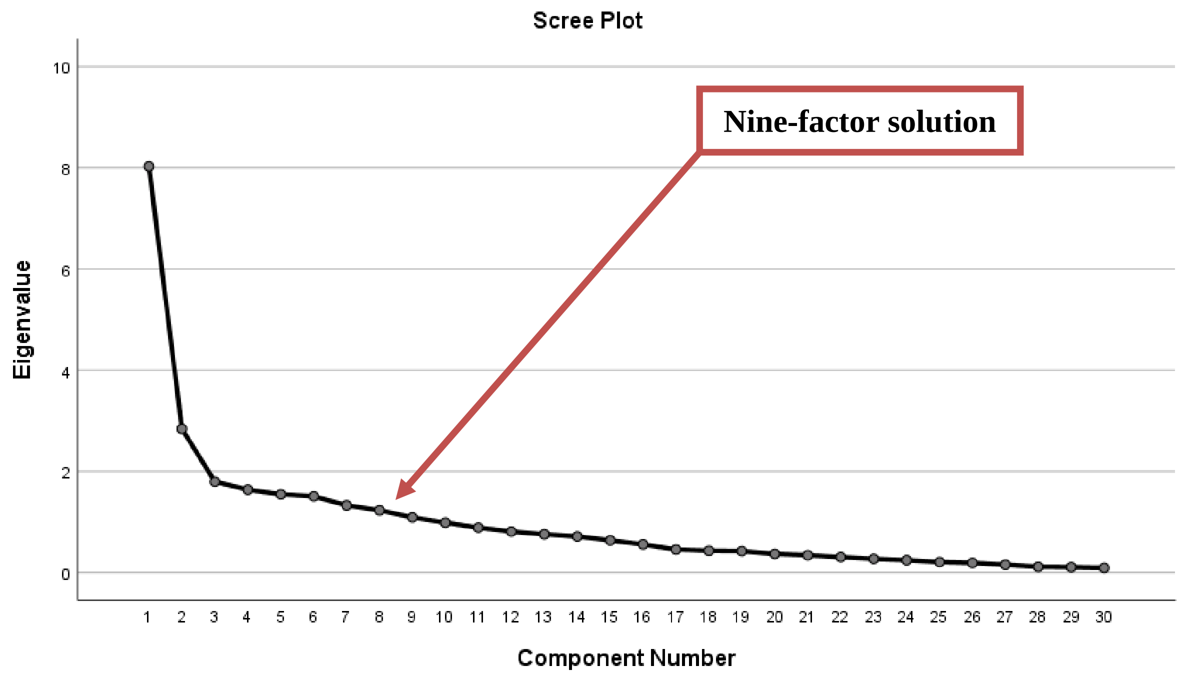

Figure 4.4: Scree plot

A scree test involves examining the graph of the eigenvalues to note the natural bend or break point in the data where the curve flattens out. The number of data points above the - break is usually the number of factors to retain (Dubihlela, 2012).

4.6.3 Interpretation of the market orientation factors

Factor one, *Turbine modular replacement and costs benefits*, comprised 7 variables and accounted for 26.76% of the variance, with eigenvalue of 8.029. The items that loaded onto the factor relate mainly to the benefits emanating from turbine modular replacement implementation such as high quality work, improve readiness (Breeze, 2019:18), cost reduction during outages and company's cost bottom line, as espoused by Pettinau, Ferrara and Amorino (2012:33). The factor incorporates all the aforementioned benefits associated with the implementation of turbine modular replacement.

Factor two, labelled *senior management interference and lack of skills*, comprised 3 variables that accounted for 9.46% of the variance, with eigenvalue of 2.839. The factor incorporates a set of beliefs that interference by senior management during planning and execution impacts negatively on the success of modular replacement. In addition, the factor adds lack of skills by maintenance staff during refurbishment as the reason for failure during outages as well as the duration in which turbine components refurbishment take, compared to modular replacement during outages. To achieve smooth and grand execution, it is advised that senior management need not to interfere with the planning and implementation.

Factor three, *Management support and skilled personnel*, comprises 3 variables accounting for 5.98% of the variance, with eigenvalue of 1.794. This factor places emphasis on the management support and skilled personnel as the key drivers of success or failure of turbine replacement. Lack of resources such as skilled personal may hamper the implementation of the turbine modular replacement since modularity as a concept has perceived benefits in the refurbishment of components.

Factor four, labelled *offsite single team, implementers skills and competence,* comprised 3 variables accounting for 5.457% of the variance with eigenvalue of 1.637. This factor involves allowing a single team from offsite refurbishment to execute on site and having implementers with skills and competence for turbine modular concept to be successful. Reder, Gonzalez and Melero (2016) suggest that staggering of outages involved in modular replacement can improve skills of implementers due to rotation around different sites, especially if done by internal staff.

Factor five, named *replacement engineering skilled staff,* comprised 4 variables loading into this factor, accounting for 5.14% of the variance with eigenvalue 1.544. This factor places emphasis on equipping replacement staff with necessary required skills to do final assembly of turbine modules, skilled engineering staff to give assurance for workmanship of modules preassembly. Furthermore, the reduction of outage duration can be realised when applying modular concept on turbine and turbine outage costs can be reduced by the implementation of modular replacement (Pettinau *et al.,* 2012).

Factor six, *skilled project management staff and ageing power plant,* comprised 3 variables accounting for 5.017% of the variance, with eigenvalue of 1.505, relates failure to stagger turbine modular replacement outages as the reason for failure during outages. Good skilled project management staff is required to give assurance for workmanship of modules preassembly. It is assumed that turbine modular replacement does not reduce outage durations when applied to ageing power generation plants. In line with El-Ahmar, El-Sayed and Hemeida (2017:1471), this possibly means that continuous emphasis on skills development amongst the involved departments may result in greater overall successful implementation of the concept, thus achieving greater power generation results at the plants.

Factor seven was named *increase in scope of work and duration*, accounting for 4.42% of variance with eigenvalue of 1.327. This factor had only one variable loading into the factor with a factor loading of 0.758. It relates to a situation where turbine modular replacement increases the scope of work and duration (Marimuthu & Kirubakaran, 2014:144). It is so because turbine modular replacement duration is linked to the skill level of the staff putting it together.

Lastly, factor eight named *lack of skills by maintenance staff,* comprised one (1) variable loading into this factor accounting for 4.09% of the variance with eigenvalue of 1.228. It relates to lack of adequate skills by maintenance staff on site that causes failure or success of turbine modular replacement in a power generating plant. An optimum level of maintenance must be executed, even if this means high levels of expensive OCGT usage (Fadare *et al.*, 2018:12).

4.7 RELIABILITY AND VALIDITY ANALYSIS ASSESSMENTS

Table 1 provides a summary of the statistics that were computed in lieu of evaluating the reliability and validity of this research.

Table 4.7: Summary of reliability and validity test results

Measures	Factor label	Cronbach's Alpha coefficient	Factor loadings	Communalities	Corrected item-to total correlations
B2, B3, B10, E3, E4, E5,& E6	Turbine modular replacement costs benefits	0.829	0.733 to 0.806	0.581 to 0.862	0.415 to 0.605
B9, C7 and D3	Senior management interference and lack of skills	0.688	0.652 to 0.824	0.684 to 0.817	0.487 to 0.555
B1, B4 and C5	Management support and skilled personnel	0.634	0.699 to 0.894	0.443 to 0.767	0.462 to 0.503
B5, B6 and C8	offsite single team, implementers skills and competence	0.704	0.615 to 0.740	0.646 to 0.686	0.501 to 0.578
C2, C3, D1 and E6	Replacement engineering skilled staff	0.732	0.604 to 0.767	0.530 to 0.809	0.458 to 0.509
B7, C4 and D5	Skilled project management staff and ageing power plant	0.691	0.531 to 0.749	0.687 to 0.835	0.406 to 0.538
D2	Increase in scope of work and duration	0.612	0.714 to 0.865	0.623	0.444 to 0.600
C9	Lack of skills by maintenance staff	0.628	0.797 to 0.855	0.803	0.416 to 0.569
Recommended threshold suggested by Malhotra *et al.*		**Above 0.70**	**Above 0.50**	**Between 0.20 and 0.50**	**Above 0.30**

Measures	Factor label	Cronbach's Alpha coefficient	Factor loadings	Communalities	Corrected item-to total correlations
(2018)					
Minimum score= 1; Maximum score = 5; N=171					

Cronbach's alpha test results ranged between 0.612 and 0.829, which is above the 0.70 benchmark for acceptable *internal-consistency reliability* (Field, 2013), save for several factors were slightly below 0.70; they were retained in this research based on Babin and Zikmund's (2016) lenient benchmark that Cronbach's alpha coefficients between 0.60 and 0.70 infer "fair reliability". *Face and content validity* of the instrument were assessed by the faculty research and ethics committee of the university during the ethics application. In addition, a supervisor participated by evaluating the linguistic errors, survey timing and questionnaire format. As an indicator of both *construct* and *convergent validity*, the significant loadings (0.531 to 0.894), strong communalities (0.432 to 0.755) and item-to-total correlations (0.406 to 0.605) inferred a large variance (above 40 percent) is captured by each of the measures applied in the survey.

4.8 DESCRIPTIVE STATISTICS

The mean score for factor four labelled offsite single team (3 items) had the highest mean score of 4.3275, followed by factor eight (1 item) and three (3 items) with the mean rating of 3.9649 respectively. In essence, all the recoded mean scores ranged from 3.5234 to 4.3275. This suggests that these factors are the antecedents of plant effectiveness in the power generation environment. The mean score ratings of the eight-factor solution are presented in Table 4.8 below.

Table 4.8: Descriptive statistics – factors influencing plant effectiveness

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
FACTOR1	170	1.43	4.71	3.8134	.85235	-.609	.186	-.919	.370
FACTOR2	171	1.00	5.00	3.6823	.97539	-.819	.186	-.419	.369
FACTOR3	171	1.67	5.00	3.9649	.69362	-.029	.186	-.593	.369

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
FACTOR4	171	2.00	5.00	4.3275	.59461	1.496	.186	1.949	.369
FACTOR5	171	1.25	4.75	3.5234	.80314	-.649	.186	-.222	.369
FACTOR6	171	1.67	5.00	3.9181	.86836	-.929	.186	-.146	.369
FACTOR7	171	1.50	5.00	3.7281	.74204	-.668	.186	.268	.369
FACTOR8	171	2.00	5.00	3.9649	.74672	-.769	.186	-.795	.369
Valid N (listwise)	170								

The standard deviation is often closely attached to the mean because it is a measure designed to resolve the average distance of interpretations from the measurement of the arithmetic mean interpretation. The greater standard deviation in all the factors computed occurred on factor 2 (senior management interference) scale (.97539), followed by factor 6 (turbine modular replacement staggering failure scale with .86836, while the lowest had a standard deviation value of .59461 (factor 4 - offsite single team). The standard deviation ranged from 59461 to 97539. The findings suggest that there was more agreement amongst respondents concerning most of these factors.

4.9 CORRELATION ANALYSIS

Hair *et al*. (2010:710) indicate that constructing a matrix of construct correlations is useful in assessing the nomological validity of a proposed measurement model. In order to assess nomological validity, the Pearson Product-Moment correlation coefficients between each pair of constructs were examined. The correlation matrix is reported on in Table 4.9.

Table 4.9: Correlation matrix

	1	2	3	4	5	6	7	8
TMR costs benefits	1							
Senior Mgnt	0,468**	1						

Management support	-0,018	-0,186	1					
Offsite single team	0,397**	0,063	0,166	1				
Replacement staff	0,643**	0,250**	0,121	0,265**	1			
Skilled Project Mgnt	0,658**	0,281**	-0,056	0,413	0,478**	1		
Scope of work	0,171	-0,009	0,037	0,171	0,213**	0,197	1	
Lack of skills	0,513**	0,458**	0,075	-0,247	0,386**	0,499**	0,187*	1
**Correlation is significant at the 0.01 level (2-tailed) * Correlation is significant at the 0.05 level (2-tailed)								

The eight-factor solution were further analysed to check the correlations amongst the factors. Turbine modular replacement and cost benefits correlate significantly with senior management support, offsite single team, replacement engineering staff, skilled project management staff, scope of work and lack of skills but not with management support. Furthermore, there was no significant relationship between senior management intervention and management support as well as with skilled project management staff. In addition, lack of skills from maintenance staff has no relationship with offsite single team.

It was important to recap the hypotheses and test the relationships amongst the identified factors affecting plant effectiveness.

4.10 HYPOTHESES TESTING

Hypotheses testing was undertaken whereby the significance level was set at the conventional a=0.05 level. In accordance with the hypotheses posited in chapter one, the following hypotheses were recapped:

H1: Turbine modular replacement in power generation plant is likely to fail during outages because of skill inadequacy in Eskom.
H2: Lack of management support in staggering execution of similar modular replacements projects results in failure of turbine modular replacement.

H3: Modularity concept is not fully implementable during outages due to lack of spares and using of old components and this reason cannot be successful.
H4: There is lack of sustainable skills within the organisation to implement multiple turbines modular replacement within the Eskom fleets at the same time, hence the failure to have continuous improvement when assembling turbine modular replacement during outages.
H5: The cost benefit of turbine modular replacement cannot be realized unless the outage durations are reduced as a result of implementation of this concept, as they are interlinked.

The following section discusses the structural equation modelling and path analysis undertaken to test these hypotheses in this study.

4.11 REGRESSION ANALYSIS

Table 4.10 reports the regression analysis between skills inadequacy and turbine modular replacement failure. The predictor that was held constant was skills inadequacy (independent variable), and the dependent variable that was entered into the prediction model was turbine modular replacement failure. On the examination of this relationship, the adjusted R^2= 0.535, indicating that skills inadequacy explained 53.5 percent of variance on turbine modular replacement. The beta coefficient of skills inadequacy (β=0.733) suggests that there is a strong positive relationship between skills inadequacy and turbine modular replacement failure in the power generating plant. Thus, lack of skills is linked with turbine modular replacement failure in the power generation plant.

Table 4.10: Regression on skills inadequacy and turbine modular replacement failure

Construct	Adjusted R^2	Beta (β)	t-value	*p*-level
Dependent: Turbine modular replacement failure **Independent variable**: Skills inadequacy	0.535	0.733	13.974	0.000*
R = 0.733 R^2 = 0. 538 B = 0.754 F = 195.262 p<0.000				

Table 4.11 below reports the regression analysis between lack of management support and turbine modular replacement failure. The predictor and independent variable held constant was lack of management support, and the dependent variable was turbine modular replacement failure. The rating (the adjusted) of the relationship between these variables was R^2=0.003, indicating that lack of management support explained 00.5 percent of variance on turbine modular replacement.

The beta coefficient of β=-0.056 suggests that there is no relationship between lack of management support and turbine modular replacement failure. Thus, the absence of management in the staggering execution of similar modular replacements projects does not contribute towards failure of turbine modular replacement.

Table 4.11: Regression on lack of management support and turbine modular replacement failure

Construct	Adjusted R^2	Beta (β)	t-value	*p*-level
Dependent: Turbine modular replacement failure **Independent variable**: Lack of management support	0.003	-.056	10.840	0. 469*
R = 0.056 R^2 = -.003 B = 0. .277 F = .528 p<0. 469				

Table 4.12 below reports the regression analysis between lack of spares/using old components and successful implementation of turbine modularity during outages. The predictor and independent variable held constant was lack of spare/use of old components, and the dependent variable was successful implantation of modularity concept. The rating (adjusted) of the relationship between satisfaction and repurchase intentions was R^2=0.360, indicating that lack of spares/old components explained 36.0 percent of variance on successful implementation of modularity concept.

The beta coefficient of β=0.603 suggests that there is a strong positive relationship between lack of spares and the successful implementation of modularity concept. The independent variable was lack of spares/old components, whereas the dependent variable was successful implementation of modularity concept. Thus, lack of spares and use of old components are likely to hamper the successful implementation of modularity concept in the power generation plant.

Table 4.12: Regression on lack of spares/old components and successful implementation of modularity concept

Construct	Adjusted R^2	Beta (β)	t-value	p-level
Dependent variable: successful modularity concept implementation **Independent variable**: lack of spares/using old components	0.360	0. 603	9.798	0.000*
R = 0. 603 R^2 = 0.364 B =0. 770 F = 95.997 p<0.000				

Table 4.13 below reports the regression analysis on the relationship between lack of sustainable skills within the organisation and implementing multiple turbines modular replacement within the Eskom fleets at the same time. The independent variable and the predictor held constant was lack of sustainable skills, and the dependent variable was implementing multiple turbines modular replacement. On the examination of the relationship between these two constructs, the score (adjusted) was R^2=0.587. The beta coefficient of β=0.768, suggests that there is a strong positive relationship between lack of sustainable skills and implementing multiple turbines modular replacement. Therefore, the results indicate that lack of sustainable skills within the company to implement multiple turbines modular replacement and at the same time results in failure to have continuous improvement when assembling turbine modular replacement during outages.

Table 4.13 Regression on lack of sustainable skills and implementing multiple turbines modular replacement

Construct	Adjusted R^2	Beta (β)	t	p-level
Dependent variable: Lack of sustainable skills **Independent variable:** Implementing	0.587	0.768	15.546	0.000*

Construct	Adjusted R^2	Beta (β)	t	p-level
multiple turbines modular replacement				
R = 0.768 R^2 = 0.590 B = 1.082 F = 241.676 p<0.000				

Table 4.14 below reports the regression analysis on the relationship between reduced outage durations and cost benefit of turbine modular replacement. The independent variable and the predictor held constant was reduced outage durations, and the dependent variable was cost benefit of turbine modular replacement. On the examination of the relationship between these two constructs, the score (adjusted) was R^2=0.473, which suggests that reduced outage duration explains 47,3 percent of cost benefit associated with turbine modular replacement.

The beta coefficient of reduced outage durations (β=0.690) suggests that there is a strong positive relationship between reduced outage durations and cost benefit of turbine modular replacement. Therefore, the results indicate thatthe cost benefit of turbine modular replacement can be realised, provided the outage durations are reduced as a result of implementation of this concept, as they are interlinked.

Table 4.14: Regression on reduced outage duration and implementing multiple turbines modular replacement

Construct	Adjusted R^2	Beta (β)	t	p-level
Dependent variable: Lack of sustainable skills **Independent variable:** Implementing multiple turbines modular replacement	0.473	0.690	12.385	0.000*
R = 0.690 R^2 = 0.476 B = 485 F = 153.377 p<0.000				

4.12 CONCLUSION

The purpose of the present study is to explore the impact of turbine modular replacement on plant effectiveness in power generation plants. There is a limited literature and research studies on the turbine modular replacement and plant effectiveness, especially in a power generation setting. The study used exploratory factor analysis to explore the factors of turbine modular replacement and test the relationships using regression model. Eight-factor solution was established and factors were named and interpreted based on the literature. The findings of this study attempt to add to the body of knowledge on these relationships that exist and established new relationships that can further be tested using difference multivariate statistics in the power generation environment.

According to the findings of the empirical study reported in this chapter, the preliminary data analysis was presented focusing on data coding, cleaning and tabulation of responses. Secondly, the findings of the study were presented, interpreted and discussed in the form of tables, graphs and charts. One of the core purposes of this study was to explore factors of turbine modular replacement implementation and test the hypotheses posited. To this end, correlation and regression analyses were undertaken to further validate the theoretical background of the relationship that exists among these factors. A positive linear association of these constructs was established and validated.

Reliability of the scales was computed and established using the Cronbach alpha values. Satisfactory reliability values (above the benchmark value of 0.70) were obtained in relevant sections of the measuring instrument. Various validity measures, including face, construct and convergent, were also undertaken.

The next chapter addresses the attainment of the research objectives of the study. The main conclusions and recommendations of the research are presented in chapter five. Limitations of the study are highlighted. Finally, the value and implications of this study for further research are highlighted.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 INTRODUCTION

The primary objective of this research was to explore the impact of turbine modular replacement on plant effectiveness in power generation plant. The preceding chapter provided the analysis, discussions and interpretations of the empirical findings. The stages for data collection and analysis were identified and described. The information was analyzed and summarized using cross-tabulations, figures, factor analysis, correlations and regression analysis.

This concluding chapter commences by providing an overview of the study. Thereafter, the key findings and conclusions are presented, followed by recommendations for power generation companies/institutions in general and Eskom in particular. The chapter continues by highlighting the theoretical and practical contributions of the study. Limitations of the study and suggestions for future research areas are discussed before presenting final concluding remarks. Arising out of theory and the empirical study, the benefits, limitations, and implications for future research are presented.

5.2 OVERVIEW OF THE STUDY

To achieve the study objective, a review of the literature pertaining to power generation in South Africa, supply and demand, distribution channels, turbine modular replacement, and factors influencing plant effectiveness and performance was conducted. To provide the applicable recommendations based on this study, it is essential to include the insights gained over the previous five chapters.

Chapter one provided a background to the research study and identified the research problem. The problem statement highlighted the importance of power generation to the South African households, businesses and economic development as a whole. In addition, this chapter highlighted the source of power generation. Both political and social forces are some of the most likely factors playing a crucial role in the decision making by power utilities as government remains the sponsor and custodian for the power utility. The primary, theoretical and empirical objectives were presented in sections 1.4. The hypotheses were also set out in chapter one under section 1.5. The chapter concluded with a description of a research design and methodology that the empirical part of this study followed, as well as the ethical considerations of the study.

Chapter two provided a comprehensive literature review guided by the theoretical objectives of the study. It commenced by providing an overview of the electricity sector and power generation in South Africa (see section 2.2). Electricity demand and supply and the consumption of electricity by different groups of customers guided the literature on the overview of electricity sector.

In terms of power generation, the literature identified discussed the type of primary fuel, or primary energy flow that provides a power plant its primary energy. The most common fuels are coal, natural gas, and uranium (nuclear power). In addition, types of power plants were also deliberated upon, including thermal and renewable. The literature appraisal on electricity generation and transmission in South Africa was presented as well as the model of power generation. Furthermore, turbine modular was defined and discussed as well as the turbine modular replacement. The chapter also discussed the factors influencing plant effectiveness in power generation plants. Lastly, it recommended ways in which plant effectiveness and performance can be enhanced through reducing costs, optimum level of maintenance and building new units.

Chapter three comprises a description of the research methodology followed in the study. The study followed a deductive reasoning since it tested the hypothesized relationships by either validating or refuting the proposed relationships between the variables it intended to test. The study is situated within the positivism paradigm. Positivism deals with specific concepts and focuses on the objective and quantifiable evidence obtained; hence it was relevant for this study. Moreover, descriptive research design was followed, especially single cross-sectional. The sampling procedure followed focused on target population, which the study defined as senior managers in modular replacement, contractors, engineers, supervisors and outage management project coordinators and implementers from Mpumalanga and Free State provinces of South Africa.

The sampling frame for this study consisted of the lists of employees working at the power generation plants from the demarcated areas of study using a stratified sampling method. Although participants were selected using strata, they were conveniently sampled based on their availability. A self-administered questionnaire that included existing scales was used to gather the required data. The various techniques used to interpret and report on the collected data for the statistical analysis in chapter five. This included the factor analysis technique, correlation analysis technique and regression modelling.

Chapter four provides data analysis, presentation, interpretation and discussion of the empirical findings. This chapter provided the descriptive statistics to examine the composition of the sample. The chapter further provided factor analysis which resulted in eight-factor solution and the factors were renamed and discussed thereof. In addition, reliability and validity analysis, correlations and regression analysis were presented and discussed.

Chapter five reports on the findings of the empirical portion of the study. The results presented in this chapter are in accordance to the empirical objectives formulated for the study.

5.3 MAIN FINDINGS OF THE STUDY

This section discusses the main findings of this study in accordance with the empirical objectives formulated in chapter one:

The empirical objectives formulated in the beginning of the study are recapped in this section. Thus, chapter four presents the empirical results of the data analysis and interpretation, namely:

- **to identify the critical factors within the organisation which impact the turbine modular replacement and how to mitigate or improve effectiveness thereof.**

This objective was achieved in chapter four under section 4.5 and 4.6, where exploratory factor analysis was performed. The results demonstrated that eight factor solutions exist with correlated variables that measure plant effectiveness. Section 4.6.3 provides a description of the eight extracted factors:

- **to determine whether there is reduction in outage duration directly linked to the implementation of turbine modular replacement.**

This objective was achieved in section 4.11 of chapter four through regression analysis. Table 4.14 shows a strong correlation between reduction in outage duration and the implementation of turbine modular replacement:

- **to conceptualize and quantify the costs benefit to Eskom when implementing turbine modular replacement during outages.**

This objective was achieved in section 4.6.3, where factor analysis was performed and factor 1 labelled turbine modular replacement benefits accounted for 26.76% of variance with eigenvalue of 8.029. The factor places emphasis on high quality work, cost reduction on Eskom bottom line and reduced outage duration as the benefits of implementing turbine modular replacement, therefore:

- **to determine whether there is direct correlation between workmanship, skills and ability to assemble modular turbines within allocated time during outages.**

In chapter four under section 4.11 (regression analysis), it was established that the ability to assemble modular turbines within the stipulated time period is linked with the level of skills and workmanship that the implementer possesses. Section 4.9, which focused on correlations, showed that turbine modular assembling rests upon skills and workmanship with 0,513 correlation matrix. Therefore, suggesting a strong relationship between the two variables:

- **to assess the skills level of staff involved in the modular turbine replacement and adequacy thereof.**

This objective was achieved through factor analysis (see section 4.6.3), where factor six and eight relates to skills and competencies of the project and maintenance staff as the key attributes in implementing turbine modular replacement in power generation setting. Also, descriptive statistics (mean scores) showed the importance of these two factors with the mean score of 3.9181 and 3.9649 respectively:

- **to assess management support or involvement towards successful implementation of the turbine modular replacement.**

This objective was achieved in chapter four under section 4.11 (see Table 4.11), where the regression analysis results showed that lack of management support does not impact the implementation of turbine modular replacement. The findings suggest that turbine modular replacement implementation can be successful without management involvement**.**

5.4 MANAGERIAL IMPLICATIONS AND RECOMMENDATIONS

The research findings offered several important managerial implications. Firstly, the present study clearly supports a positive impact of turbine modular replacement implementation on high quality of work, costs reduction benefit during outages and cost benefit to Eskom bottom line. Consequently, Eskom is encouraged to continue their efforts in adopting and implementing turbine modular replacement strategies. Secondly, by increasing high quality of work, the company can improve their plant effectiveness and performance. The findings can be used as a guideline for power generation companies in general and Eskom that intend to accept implement turbine modular replacement.

The implications of this study are both academic and practical. The implications on the academic front are that firstly, a contribution is made to the existing literature on turbine modular replacement implementation, high quality work and cost reduction benefits, particularly in the context of a sole supplier and transmitter of electricity such as Eskom in the country. Secondly, a pioneering attempt is made to avoid using senior management in the implementation of turbine modular replacement to be successful.

The study further validated the negative impact of lack of skills by maintenance, project and implementers on the implementation of turbine modular replacement. Power generating institutions can try to find ways in which staff members from the plants can be developed (skilled) to be able to assemble turbine modules within the stipulated time and during outages. The study also found a positive influence of reduced outages duration and implementing multiple turbines modular replacement. It is therefore recommended that Eskom continue to improve their plant effectiveness by reducing outages' duration.

The study, through exploratory factor analysis, identified eight factors contributing towards turbine modular replacement implementation as well as plant effectiveness and performance. The factors are: 1) turbine modular replacement benefits; (2) senior management intervention and lack of skills; (3) management support and lack of resources; (4) offsite single team and implementers skills/competencies; (5) replacement engineering staff; (6) skilled project management staff and ageing power plant; (7) increase in scope of work and duration; and (8) lack of skills by maintenance staff. It is therefore expected that the company must devote their resources and attention to these factors to have a successful implementation of turbine modular replacement.

Based on these research findings, limitations and implications are discussed and future research directions are suggested.

5.5 LIMITATIONS AND IMPLICATIONS FOR FUTURE RESEARCH

In assessing the findings of this study, it should be noted that it is by no means without limitations, which offer avenues for future research. These limitations and associated areas for future research are discussed below.

The first limitation was the fact that the study was confined to Mpumalanga and Free State provinces where there are many power generation plants. Whether the findings of this study might apply to less pressured power plants in other provinces or geographical areas needs further study. Doing so would help increase the external validity of findings. Another limitation is related to the research methodology employed. A survey using self-administrated questionnaires was employed in this study. While the use of self-reporting may rightly gauge the turbine modular replacement implementation and its impact on plant effectiveness, the report may need implicit studies or experimental methods.

A valuable research direction may be to conduct a longitudinal study of the five hypothesised relational influences, of which the eight factors are the centre, to validate the current research findings. Replication of this kind of study in other regions of South Africa and sub-Saharan Africa may also be useful in substantiating the findings observed in this investigation.

The third limitation relates to the fact that the study was cross-sectional in nature. This means that findings reported relate to only a particular point in time. To some extent, applying a cross-sectional design implies that the study has focused on reported implementation of turbine modular replacement instead of emphasising observed changes in the power generating plans over time. Future research can apply a longitudinal survey and/or observation research focusing on uncovering factors affecting plant effectiveness over a long period of time. For example, researchers can track the frequency of turbine modular replacement and the duration of ageing plants in which some factors are considered irrelevant.

Furthermore, the study performed factor analysis to explore the factors without a proposed research model incorporating the factors in order to determine the extent to which they influence plant effectiveness using structural equation modelling. Future research could incorporate these factors into a model that will be used to predict power generation plant effectiveness and performance.

5.6 CONCLUDING REMARKS

The purpose of this study was to explore the impact of turbine modular replacement on plant effectiveness in power generation plants. Using a survey that involved 171 senior managers in modular replacement, contractors, engineers, supervisors and outage management project coordinators and implementers in Mpumalanga and Free State provinces of South Africa, the study proposed and tested five hypotheses. It also used exploratory factor analysis to identify eight-factor solutions which may impact turbine modular implementation and plant effectiveness. It made theoretical contributions by testing the hypotheses and identifying factors, which improves the understanding of power generation plants in South Africa. Practical contributions are also made by exposing areas where policy makers could improve their efforts in supporting the implementation of turbine modular replacement and plant effectiveness to realize the objectives of the business.

Despite the substantial importance of the turbine modules concept and its implementation in the power generation plants, extensive research has not been undertaken in developing countries such as South Africa. The necessity to explore different factors of turbine modular replacement implementation, which in turn may impact plant effectiveness is very crucial. The study opens avenues for future research to expand the findings obtained and deal with the few limitations associated with it. While the factors driving turbine modular implementation and power generating plant effectiveness can be useful in improving duration of outages, corresponding efforts should be made to increase the skills of the implementers to improve business performance.

REFERENCES

Ansaldo, N.S. 2019. *Why choose a gas turbine replacement? Gas Turbine Replacement.*

Babbie, E. 2017. *Tee basics of social research.* 7th ed. Wadsworth Cengage Learning.

Babin, B.J. & Zikmund, W.G. 2016. *Essentials of marketing research*. 6th ed. USA: Cengage Learning.

Blomqvist, M., Turkulainen, V., Eloranta, E. & Laiho, A. 2014. *Factory roles: a Scandinavian perspective*. Aalborg, Denmark: Aalborg University Press.

Brown, T.J., Suter, T.A. & Churchill, G.A. 2018. *Basic marketing research: customer insights and managerial action*. 9th ed. USA: Cengage Learning.

Bryman, A. & Bell, E. 2007. *Business research methods*.2nd ed. Oxford: Oxford University Press.

Burns, A.C. & Bush, R.F. 2014. *Marketing research*. 7th International Ed. USA: Pearson.

Burns, A.C., Veeck, A. & Bush, R.F. 2018. *Marketing research*. 8th ed. England: Pearson Education.

Cast safety. 2020. Fundamentals of gas turbine engines, 1-13.

Chauke, X.D. 2014. *Online shopping satisfaction, loyalty and repurchase intentions of generation X consumers in southern Gauteng*. Vanderbijlpark: Vaal University of Technology. (MTech Dissertation).

Clow, K.E. & James, K.E. 2014. *Essentials of marketing research: putting research into practice.* New York. USA: Sage.

Creswell, J.W. 2014. *Research design: qualitative, quantitative & mixed methods approach.* 4th ed. Thousand Oaks, CA: Sage.

Department of Energy. (South Africa). 2019. *Power generation technology data for integrated resource plan of South Africa*. : Electric Power Research Institute (EPRI), 1-278.

Dhurup, M. 2003. Customer perceptions of service quality: Scale development, measurement and validation. Potchefstroom: Potchefstroom University for Christian Higher Education. (Unpublished PhD Thesis).

El-ahmar, M.H., El-Sayed, A.H.M. & Hemeida, A.M. 2017. Evaluation of factors affecting wind turbine output power. In: 2017 Nineteenth International Middle East Power Systems Conference (MEPCON), 1471-1476.

Eskom Report. 2019. Eskom reveals factors contributing to generation plant performance. Available at https://www.esi-africa.com/industry-sectors/generation/eskom-reveals-factors-contributing-to-generation-plant-performance/ Accessed 21/06/2020

Fadare, O.A., Ilori, O.O., Soji-Adekunle, A.R. & Ojo, O.O. 2018. Factors influencing the performance of gas and steam turbines for electricity generation in Nigeria. *International Journal of Multidisciplinary Sciences and Engineering*, 9(9):11-14.

Falck, J., Felgemacher, C., Rojko, A., Liserre, M. & Zacharias, P. 2018. Reliability of power electronic systems: an industry perspective. *IEEE Industrial Electronic Management*, 12:24–35.

Feldmann, A., Olhager, J., Fleet, D. & Shi, Y. 2013. Linking networks and plant roles: the impact of changing a plant role. *International Journal of Production Research*, 51(19):5696-5710.

Field, A. 2013. *Discovering statistics using IBM SPSS statistics.* USA: Sage.

Fischer, K. & Wenske, J. 2015. Towards reliable power converters for wind turbines: Field-data based identification of weak points and cost drivers. In: Proceedings of the Proceedings of EWEA Conference, Paris, France, 7–20 November 2015, pp 1-17.

Fischer, K., Pelka, K., Bartschat, A., Tegtmeier, B., Coronado, D., Broer, C. & Wenske, J. 2018. Reliability of power converters in wind Turbines: Exploratory Analysis of Failure and Operating Data from a Worldwide Turbine Fleet. *IEEE Trans. Power Electron.* 2018, 1.

Fischer, K., Pelka, K., Puls, S., Poech, M.H., Mertens, A., Bartschat, A., Tegtmeier, B., Broer, C. & Wenske, J. 2019. Exploring the Causes of Power-Converter Failure in Wind Turbines based on Comprehensive Field-Data and Damage Analysis. *Energies,* 12(593):1-27.

Guptas, S.L. 2011. *Marketing research.* New Delhi: Excel Books.

Hair, J.F., Black, W.C., Babin, B.J. & Anderson, R.E. 2014. *Multivariate data analysis*. New International ed. Harlow: Pearson.

Holzke, W., Brunko, A., Groke, H., Kaminski, N. & Orlik, B.A. 2018. Condition Monitoring System for Power Semiconductors in Wind Energy Plants. In Proceedings of the PCIM Europe 2018; International Exhibition and Conference for Power Electronics, Intelligent Motion, Renewable Energy and Energy Management, Nuremberg, Germany, 5–7 June 2018, pp. 1–7.

Kayadelen, H.K.& Üst, Y. 2013. Marine gas turbine. 7th International Advanced Technologies Symposium, 34-38.

Mahlia, T.M.I., Lim, J.Y., Aditya, L., Riayatsyah, T.M I., Abas, A.E. & Nasruddin, P.G. 2017. Methodology for implementing power plant efficiency standards for power generation: potential emission reduction. *Clean Technologies and Environmental Policy*, 1-19.

Malhotra, N.K. 2010. *Marketing research: An applied orientation*. 6th ed. USA: Pearson Education.

Malhotra, N.K. 2015. *Marketing research: 1st orientation.1sted*. USA: Pearson Education.

Manzano-Agugliaro, F., Taher, M., Zapata-Sierra, A., Juaidi, A. & Montoya, F.G. 2017. An overview of research and energy evolution for small hydropower in Europe. Renew Sustain *Energy Review,* 75:476–489.

Mardoyan, A. & Braun, P. 2015. Analysis of Czech subsidies for solid biofuels. *International Journal of Green Energy,* 12:405–408.

Marimuthu, C. & Kirubakaran, V. 2014. A critical review of factors affecting wind turbine and solar cell system power production. *International Journal of Advanced Engineering Research Studies,* 143:143-147.

McDaniel, C., Lamb, C.W. & Hair, J.F. Jr. 2013. *Introduction to marketing*. 12th ed. Boston: South Western Cengage Learning.

National Occupation Standards. 2019. Overhauling industrial power turbines by module replacement. *Mechanical Manufacturing Engineering Suite,* 3:1-9.

Pettinau, A., Ferrara, F. & Amorino, C. 2012. Techno-economic comparison between different technologies for a CCS power generation plant integrated with a sub-bituminous coal mine in Italy. *Applied Energy, 99*(2012):32–39.

Polit, D.F. & Beck, C.T. 2012. Nursing Research: Generating and assessing evidence for nursing practice. 9th ed. Philadelphia: Lippincokk Williams & Wilkins.

Rahman, K.A., Yusof, M.Z.M., Salleh, M.N.M. & Leman, A.M. 2015. Implementation of energy efficiency standards and labelling for household electrical appliances: a comparison among Asian countries. *Applied Energy*, 4(12):601-614.

Saedi, A.M., Thambirajah, J.J. & Pariatamby, A. 2014. A HIRARC model for safety and risk evaluation at a hydroelectric power generation plant. *Safety Science,* 70(2014):308–315.

Saunders, M., Lewis, P. & Thornhill, A. 2012. *Research methods for business students*. Harlow UK: Pearson Education.

Sekaran, U. & Bougie, R. 2013. *Research Methods for Business. A skill- building approach*. 6th ed. UK: Wiley.

SPSS. 2019. *Statistical package for social sciences (SPSS) for windows, 26.0*. Chicago, IL: SPSS.

Wiid, J. & Diggines, C. 2011. *Marketing research*. Cape Town: Juta.

Wiid, J. & Diggines, C. 2015. *Marketing research.* Cape town. Juta.

Xie, B.C., Gao, J., Zhang, S. & Zhang, Z.X. 2017. What factors affect the competiveness of power generation sector in China? An analysis based on game cross-efficiency. CCEP Working Paper 1702, Crawford School of Public Policy, the Australian National University, pp. 1-45.

Zerrahn, A. 2017. Wind power and externalities. *Ecological Economics,* 141:245–260.

Zhang, G., Zhou, D., Blaabjerg, F. & Yang, J. 2017. Mission profile resolution effects on lifetime estimation of doubly-fed induction generator power converter. In: Proceedings of the 2017 IEEE Southern Power Electronics Conference (SPEC), Puerto Varas, Chile, 4–7 December 2017, pp. 1–6.

Zhou, Q., Xue, S., Li, J., Xiang, C. & Chen, S. 2016. Evaluation of wind power converter reliability considering multi-time scale and mission profiles. In Proceedings of the 2016 IEEE International Conference on High Voltage Engineering and Application (ICHVE), Chengdu, China, 19–22 September 2016, pp. 1–4.

ANNEXURE A - COVERING LETTER AND CONSENT FORM

Dear Participant

I, Tsuoise Kerr Mokete am a student at North-West University currently conducting a research project based on ***"The effect of modular turbine replacement on plant effectiveness in power generation plants at Eskom"*** in order to complete my MCom degree (***Master of Business Administration***). We shall be talking about modular turbine replacement and power generation plants. There are no wrong or right answers; I would just like to hear your views. Your view will be extremely helpful to me. If you have experience regarding the modular turbine replacement, please read the following questions carefully and tick the options that you consider correct and appropriate.

I therefore request you to complete the enclosed questionnaire yourself and confidentially. I declare to you that the survey data are only for academic research and won't be used for any money-making purpose. This interview will take roughly 5-10 minutes. By agreeing to participate in this study gives the researcher your **consent**. Your participation is voluntary and as such, you are free to withdraw from the study should you feel uncomfortable at any stage. Your responses will be treated in the strictest confidentiality and your personal information will always remain anonymous. Please note that there are no wrong or right answers. Nevertheless, the information gathered from this survey will be aggregated for research purposes only in the form of an academic dissertation of which the reported results will be made available to you upon request.

If you understand and willing to participate in this study, sign this cover letter as a consent form:

………………………
Participant

Thank you for your time and effort in completing the questionnaire enclosed.

Yours faithfully

ANNEXURE B - SURVEY QUESTIONNAIRE

INVESTIGATING THE EFFECT OF MODULAR TURBINE REPLACEMENT ON PLANT EFFECTIVENESS IN POWER GENERATION PLANTS

Thank you for participating in this important research endeavor. We are interested in finding out your views and perceptions regarding modular turbine replacement in power generation plants and plant effectiveness. There are various sections to this questionnaire. Please complete all sections of the questionnaire and answer the questions honestly.

SECTION A: DEMOGRAPHIC INFORMATION

Please answer the following questions by selecting the appropriate box. Mark with 'X' to show your selection.

A1	**Department**	Outages	Rotek	Engineering	Contractor	Maintenance
	Other (specify)					

A2	**Position Held**	Supervisory	Junior Management	Middle Management	Senior Management	Executive Management

A3	**Years of experience within Eskom**	1 - 5 years	7 - 10 years	12 - 1 5years	22 - 25 years	18 - 20 years

SECTION B: MANAGEMENT OF TURBINE MODULAR REPLACEMENT

The following section pertain management of turbine modular replacement. Please indicate in your opinion, the extent to which you agree with the following statements anchored along 1 (Strongly disagree), 2 (Disagree), 3 (Neither agree nor disagree), 4 (Agree) and 5 (Strongly agree). Mark only one number with a 'X' for each statement.

B1	Modularity as a concept has perceived benefits in the refurbishment of components	Strongly disagree	1	2	3	4	5	Strongly agree
B2	There are benefits to implementing modular turbine replacement	Strongly disagree	1	2	3	4	5	Strongly agree
B3	Implementation of turbine modular on outages results in high quality work	Strongly	1	2	3	4	5	Strongly agree

		disagree						
B4	Success or failure of turbine modular replacement rests on management support	Strongly disagree	1	2	3	4	5	Strongly agree
B5	Turbine modular concept can be successful if managed by single team from offsite refurbishment to execution on site	Strongly disagree	1	2	3	4	5	Strongly agree
B6	Staggering of outages involved in modular replacement can improve skills of implementers due to rotation around different sites	Strongly disagree	1	2	3	4	5	Strongly agree
B7	Failure to Stagger turbine modular replacement outages is the reason for failure during outages	Strongly disagree	1	2	3	4	5	Strongly agree
B8	Inadequacy in project management results in modular replacements failure	Strongly disagree	1	2	3	4	5	Strongly agree
B9	Interference by senior management during planning and execution impacts negatively on the success of modular replacement	Strongly disagree	1	2	3	4	5	Strongly agree
B10	Turbine modular replacement improves readiness to execute turbine SOW	Strongly disagree	1	2	3	4	5	Strongly agree

SECTION C: SKILLS ADEQUACY

The following statements pertains skills adequacy. Please indicate in your opinion, the extent to which you agree with the following statements anchored along 1 (Strongly disagree), 2 (Disagree), 3 (Neither agree nor disagree), 4 (Agree) and 5 (Strongly agree). Mark only one number with a 'X' for each statement.

C1	Refurbishment staff are trained adequately in putting together the modules	Strongly disagree	1	2	3	4	5	Strongly agree
C2	Replacement staff have the required skills to do final assembly of turbine modules	Strongly disagree	1	2	3	4	5	Strongly agree
C3	There is skilled engineering staff to give assurance for workmanship of modules pre assembly	Strongly disagree	1	2	3	4	5	Strongly agree
C4	There is skilled project management staff to give assurance for workmanship of modules pre	Strongly disagree	1	2	3	4	5	Strongly agree

	assembly							
C5	Lack of resources such as skilled personnel, inadequate spares that leads to project failure	Strongly disagree	1	2	3	4	5	Strongly agree
C6	There are adequate technical skills within Eskom to ensure successful implementation of this concept during outages	Strongly disagree	1	2	3	4	5	Strongly agree
C7	Lack of skills by maintenance staff during refurbishment is the reason for failure during outages	Strongly disagree	1	2	3	4	5	Strongly agree
C8	Turbine modular replacement success or failure depends entirely on skills and competence of implementers	Strongly disagree	1	2	3	4	5	Strongly agree
C9	Lack of adequate skills by maintenance staff on site is the reason for failure or success of this concept	Strongly disagree	1	2	3	4	5	Strongly agree

SECTION D: OUTAGE DURATION

The following statements pertain outage duration. Please indicate in your opinion, the extent to which you agree with the following statements anchored along 1 (Strongly disagree), 2 (Disagree), 3 (Neither agree nor disagree), 4 (Agree) and 5 (Strongly agree). Mark only one number with a 'X' for each statement.

D1	Reduction of outage durations is realized when applying modular concept on turbine	Strongly disagree	1	2	3	4	5	Strongly agree
D2	There is increase in scope of and duration as a result of turbine modular replacement	Strongly disagree	1	2	3	4	5	Strongly agree
D3	Turbine components refurbishment takes longer than modular replacements during outages	Strongly disagree	1	2	3	4	5	Strongly agree
D4	Turbine modular replacement duration is directly linked to the skill level of the staff putting it together	Strongly disagree	1	2	3	4	5	Strongly agree
D5	Turbine modular concept cannot release reduced outage durations when applied to ageing power generating plants	Strongly disagree	1	2	3	4	5	Strongly agree

SECTION E: FUNDING

The following statements pertain funding. Please indicate in your opinion, the extent to which you agree with the following statements anchored along 1 (Strongly disagree), 2 (Disagree), 3 (Neither agree nor disagree), 4 (Agree) and 5 (Strongly agree). Mark only one number with a 'X' for each statement.

E1	Capital investment made towards turbine modules is effectively utilized	Strongly disagree	1	2	3	4	5	Strongly agree
E2	There is enough funding provided to support turbine modular replacement	Strongly disagree	1	2	3	4	5	Strongly agree
E3	There a cost benefit to Eskom in implementation of the turbine modular concept	Strongly disagree	1	2	3	4	5	Strongly agree
E4	Implementation of turbine modular replacement results in cost reduction during outages	Strongly disagree	1	2	3	4	5	Strongly agree
E5	Implementation of turbine modular replacement results in cost benefit to Eskom bottom line	Strongly disagree	1	2	3	4	5	Strongly agree
E6	Turbine outage costs are reduced by implementation of modular replacement	Strongly disagree	1	2	3	4	5	Strongly agree

THANK YOU FOR YOUR TIME!!

ANNEXURE C - LANGUAGE-EDITOR’S LETTER

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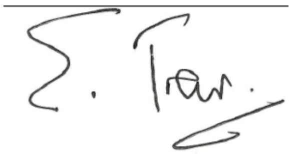
23 November 2020.

LANGUAGE EDITING

This is to certify that I language-edited the dissertation, “Exploring the impact of modular turbine replacement on plant effectiveness in power generating plants” by Tsuoise Mokete, for the MBA degree at North-West University.



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