A skills measurement model for the South African Energy Sector: applying the Analytic Hierarchy Process to the SA electric power industry

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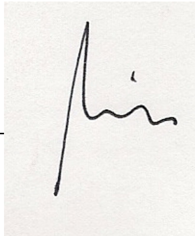
Declaration

I declare that this research is my own unaided work. It is being submitted as due requirement to the University of Witwatersrand, Johannesburg, in partial fulfilment for the degree of Master of Science in Engineering (Industrial) (50/50).



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This the 14th day of July 2019

Abstract

The need to understand the skills value inherent in a project in the South African electrical power sector lies at the core of addressing various skills related challenges in this sector that can hamper effective implementation of projects. In this study a model was developed based on the Analytic Hierarchy Process (AHP) by Thomas Saaty whereby three different power generating projects were compared to one another as to their skills values at the feasibility stage.

A hierarchy was developed that contains all the elements that form part of this problem and the criteria and sub-criteria that form part of this hierarchy were identified. Four industry specialists were approached to apply this model in a real-world example by comparing three different power generating projects with one another as to their skills values - with the goal to identify the project that had the highest skills value. The three alternatives to be compared were coal-fired power, nuclear power and wind power. This process was conducted by completing individual guided survey questionnaires with each participant where the questions in the questionnaires were designed in such a manner that they represented the pairwise comparisons that form a part of the hierarchy to compare sub-criteria with each other in relation to criteria on a higher level of the hierarchy.

Tests to determine consensus of participants were conducted along the way, with the Consistency Ratios for each matrix. The three options were compared to the sub-criteria along with each sub-criteria's priorities and the overall ranking thus derived. A sensitivity analysis was carried out to determine the validity and accuracy of the final result and all were found acceptable. The final ranking had coal-fired power at first position followed by nuclear and solar.

Acknowledgements

My sincerest gratitude goes out to my supervisor, Ms Bernadette Sunjka, for her patience, guidance and well-intended nudging where necessary. The haul was long and she was in it for its entirety.

My dearest Andrea, whose rise above any adversity is a source of constant inspiration, was and remains my main source of motivation, both in my academic as well as my personal life. Any victories I might have achieved along this long, winding and bumpy road pale in significance when compared to the daily challenges overcome by her. Ich liebe Dich.

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Nomenclature

AHP	Analytic Hierarchy Process
CI	Consistency Index
CR	Consistency Ratio
CRQ	Critical Research Question
ELECTRE	ELimination Et Choix Traduisant la REalité
IMF	International Monetary Fund
MAV	Multi-Attribute Value Theory
MADM	Multi-Attribute Decision Making
MCDM	Multi-criteria decision-making method
MEW	Multiplicative Exponential Weighting
NEP	National Energy Program
PPP	Public-Private Partnerships
REIPPP	Renewable Energy Independent Power Producers Procurement Programme
SAW	Simple Additive Weighting
TFN	Triangular Fuzzy Numbers
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution

CHAPTER 1
Introduction

1.1. Research Background and Context

Apart from rapid human population growth and the associated need for additional infrastructure development, South Africa is in need of additional energy sources to stimulate economic growth (Forsyth, 2016: 1). In 2015, then-minister of Energy, Tina Joemat-Petterson, emphasized that the 5.5 percent economic growth as envisaged by the National Development Plan would only be achievable with adequate energy supply (Forsyth, 2016: 1).

At the 2008 Electricity Distribution Maintenance Summit, engineering skills were identified as the key driver of adequate and secure energy supply (McKechnie & Bridgens, 2008: 1). Large infrastructure projects place a strain on the skills available in the infrastructure development sector, including the electricity supply sector. SASOL had indicated that they were already experiencing delays on some projects due to lack of engineering skills available and forecast that projects would take up to 11 percent longer to complete (McKechnie & Bridgens, 2008: 1). There has been a long hiatus in the electricity distribution sector with restructuring and strategic planning failures causing an exit of many skills out of the industry, creating shortfalls in skills development and proper mentoring of younger professionals. This demand for skills only seems to be intensifying (Lomey & McNamara, 2007: 5). Mohd-Yusuf et al (2015) refer to the challenge engineering schools are facing in producing graduates that are relevant and have the skills required to meet current demand. Kane and Tomer (2016) estimate that globally 11% of the workforce is employed in infrastructure-related activities. Mihelcic et al (2016) argue that environmental engineering disciplines have a significant role to play in developing energy projects, while Chassidim et al (2016) argue that students are not sufficiently prepared for the changing demands in sectors that have an agile nature.

Ettmayer and Lloyd (2017) have pointed to the fact that the growing South African economy has placed increased pressure on the electricity network with a clear government-driven strategy being required. Professor Anton Eberhard of the University of Cape Town’s Power Futures Lab lists the problems of recent energy supply failures as being energy policy uncertainty, poor co-ordination between various stakeholders, incorrect planning assumptions and inadequate maintenance (Lomey & McNamara, 2007: 12). Above all, he sees the failure of these to be resting on the “inadequate investment in human and physical capital” (Lomey & McNamara, 2007: 12). Human skills form the backbone of many discussions and policies, involving the necessity of skills development, prevalent skills shortages or the gradual disappearance of critical skills, at various levels of the South African landscape. Skills lie at the core of implementing any infrastructure project the government has planned in its National Development Plan (NDP) and could become the critical factor to determining its success, with Sambumbu and Okanga (2016) arguing that the successful implementation of the NDP is a necessary catalyst for an effectively functioning economy. The

NDP could also be used as a vehicle for promoting training and skills development, according to Dlungwana and Wall (2014).

1.2. Problem Statement

Gregory (2017) highlights the current problems the South African energy sector has in delivering a reliable supply of energy, pointing to technical skills deficiencies in this sector as one of the main problems. Pollett et al (2015) describe the current energy supply challenges as being the result of many years of underinvestment in power infrastructure and skills development. Although there is an increased interest for the science, technology and innovation (STI) capabilities in South Africa (Hart et al, 2019), to a large extent the tertiary education sector does not yet meet the demand for those associated skills amongst graduates. Lomey and McNamara (2007) researched the sector focusing on the "generation, transmission, and distribution of electrical energy in South Africa" (Lomey & McNamara, 2007: 3). Their study identified severe skills shortages in both the non-renewable and renewable sectors with regards to professional and technical electrical engineers. Studies indicate that the numbers of engineers produced every year needs to increase from 1400 to 2400 (Lomey & McNamara, 2007: 6). Forsyth points out that one of the main factors preventing renewable energy projects from being implemented is the lack of skills and training available (Forsyth, 2016: 3). This lack of skills might mean that these projects are terminated in the feasibility stage of the project because the skills either are not available locally or need to be sourced internationally at an unaffordable rate. Feasibility studies naturally focus primarily on economic factors, but the level of skills is seldom taken into account – resulting in financially feasible projects often taking much longer to complete or being terminated completely (Hall & Sandelands, 2009).

There needs to be a measure when adjudicating projects' feasibility that takes into account the level and complexity of skills necessary to complete the project, that is, what level is available in South Africa and which skills can be developed through the project. Government institutions need to accept accountability for how they are implementing official policy, also with regards to their targets of skills development. A model can help with getting feedback on targets and possible interventions. It can also be a deciding factor when two projects of similar nature and financial return must be evaluated for which one to go ahead.

Thus, this research seeks to develop a model based on the Analytic Hierarchy Process (AHP), developed by Thomas Saaty (1994), to measure skills in the energy sector in pairwise comparisons and consequently being used to evaluate three projects with regards to their inherent skill values.

1.3. Research Question

How can a model be developed to measure the skills value at the feasibility stage of projects in the energy sector?

1.4. Research Objectives

The goal of this research project is to develop a model to estimate the required skills at the feasibility stage of projects in the energy sector.

The objectives of this research are:

A. To determine a list of skill categories inherent in a typical energy construction project to determine the criteria that form part of the model;
B. To develop a model based on the Analytic Hierarchy Process with which to measure skills in the energy sector; and
C. To apply this tool in a real-world example by comparing three energy options with each other.

1.5. Summary of research method

The objectives were achieved by identifying a panel of industry experts with whom a guided survey questionnaire process was carried out. A combination of convenience sampling and snowball sampling was employed to compile the group of specialists, with the focus being on trying to get a diverse group in terms of technical background, demographics and experience. The guided questionnaire process was interactive with feedback to test consistency of answers and consensus amongst respondents built into the process.

The data collected in the guided survey questionnaire process underwent a thematic analysis to identify patterns amongst the responses of participants, both to look for consistencies, as well as finding matrices that were not consistent. Reliability of research was ensured by only one person administering all questions and interviews so that there was no misinterpretation from a third party. The measure to test consistency is inherently built into the AHP process by means of the calculation of the Consistency Ratio, which also aids in ensuring the reliability of the data. Additionally, a Sensitivity Analysis was carried out to verify this.

Ethics Clearance for this research report was applied for through the School Ethics Committee and approval was granted with the ethics clearance number MIAEC 119/18.

1.6. Limitations

In the literature review, it will become clear that the focus will only be on professional engineering skills, since little accurate information exists for artisanal skills, a sector that also is too varied to reduce effectively for this type of study.

Statistics do exist on the lack of artisanal skills in the electrical distribution sector, where Reddy published figures relating to the changes of the employed labour force between 2010 and 2014 (Reddy, 2016: 63), as well as changes in the educational levels of occupational groups (Reddy, 2016: 66). These statistics are still difficult to quantify and remain less accurate. McKechnie and Bridgens (2008) describe the collapse of the traditional artisan training structures, where numbers of registered artisans have dropped from 30 000 in 1975 to an estimated 3000 in 2006, with most of the artisans left approaching retirement age, being in their mid-fifties (McKechnie & Bridgens, 2008: 3), but the varied nature of training facilities and initiatives to promote skill growth in this sector is too vast and varied to include in this study. Lomey and McNamara (2007: 9) discuss the various stakeholders that are tasked with ensuring skills development in the electrical sector, and this list points to a dynamic and fluctuating sector, where accurate statistics are difficult to source and verify. This is corroborated by Watermeyer and Pillay (2012), who look at the shortage of skills in the maintenance of infrastructure.

Various surveys and statistics about Engineering Councils and training institutions in the engineering sector are available, like the National Engineering Skills Survey by ECSA (2013) and the ECSA Annual Report (2017, 2018). Parallel to this, a study was conducted by Amrop Landelahni (2012) on the development of skills in the infrastructure development sector. Again, the emphasis in these reports and studies is more on professional skills.

The focus of this study will thus be on professional skills only, because of the nature and consistency of the information available as stated above. Along with this, the industry specialists used in the interviews and questionnaires can offer more insight in the professional skill category.

The list of skills that form part of the criteria will not be exhaustive, as the requirements and skills fluctuate during a project with no finite list possible. Also, the different natures of various projects necessitate that these can differ from project to project. The list of skills analysed will be a broad spectrum of the cross-section through the project (as far as possible) to be evaluated at the feasibility stage of a project. The nature of this model must be robust enough that skills may be added as they become apparent or necessary, or taken away when they are deemed superfluous to the needs of the project.

1.7. Outline of chapters

The following chapter will outline the available literature on the topics of this study, starting off with a look at the energy sector at a global level, followed by the African and the South African context, including renewable energy in particular. Other topics to be discussed will be multi-criteria decision-making methods and the AHP process.

Chapter 3 will explain the research methods used in this study. This includes the research design, sampling, instrumentation, data collection and analysis. This also contains the methodology on how the AHP hierarchy specific to this study was developed, along with its overall goal, criteria and sub-criteria. It also contains the process through which the questionnaire was developed that accompanied the decision hierarchy (representing the pairwise comparison process).

Chapter 4 contains the data analysis and results, and elucidates each matrix that was developed for the related pairwise comparison, looking at the consistency and reliability of the data and the process to determine these. It also explains how the various local and global priorities were derived and what the final weightings of the three alternatives were.

Chapter 5 discusses what these findings represent, looking at the results and the implications thereof. Furthermore, the chapter examines whether the objectives of the study have been satisfactorily achieved, and the research questions have been answered. The final chapter, chapter 6, summarises the findings and draws necessary conclusions, as well as highlighting directions for future studies.

CHAPTER 2
Literature Review

This literature review explores the information available regarding skills in the energy sector, beginning with the international context, before zooming in on the African context and South African context, specifically. The focus is on the availability of skills, along with current and future trends. Different projects and project types are investigated for their response to required skills and how the availability of skills influences the implementation of these.

Renewable energy as an alternative energy source is also investigated with the purpose of determining whether this energy source is a viable alternative to form part of the further analysis. This is done in the South African context, looking at different renewable energy options and their respective standing in South Africa, as well as current trends in renewable energy options. The South African legislation governing renewable energy, as well as government initiatives in this sector are also discussed.

A brief background and theory of the feasibility stage in general is investigated, along with an in-depth study of the Analytic Hierarchy Process (AHP), looking at its background and theoretical framework, applications of the AHP and criticism levelled against it. The AHP is also compared with other multi-criteria decision making methods.

2.1. Skills

2.1.1. Skills Background – International Context

Skills shortages in general, and specifically in the energy and electricity sector, are not just a South African phenomenon. Hidayatullah et al (2011) studied smart grid technologies and other future trends in electricity distribution (focusing on Europe and the USA) and found skills lacking in these sectors even in developed countries. The advantages that many technological advances have in energy provision are often offset by the difficulty they have in implementation due to lack of critical skills (Hidayatullah et al, 2011: 216). Painuly (2001) investigated barriers preventing more widespread implementation of renewable energy. Amongst many factors, one of the key challenges identified remains that of the skills shortage within the industry as a whole. Some of the reasons for the dearth of skills in this sector are a lack of experts available to train new graduates, too few training facilities, and inadequate efforts as a whole (Painuly, 2001: 83). Mihelcic et al (2017) argue that the worldwide provision of infrastructure support has historically been focused on the provision of water, sanitation, and hygiene (WASH) services, while energy sector skills might have been neglected somewhat.

A study looking at the skills and labour requirements of the UK offshore wind industry found that there is a growing demand for skills in this sector. These projections show that an additional workforce of around 760 000 individuals will be necessary by 2024 in the energy and infrastructure sectors in general, and that

26 000 people will be needed in the offshore wind sector specifically to satisfy this demand (Aura, 2017: 52). These skills are generally difficult to find due to competition in other sectors within the industry where some of these skills can also be employed, as well as competition from other sectors outside.

In addition to this, the current situation in the UK reflects an engineering graduate shortfall of an estimated 20 000 engineers (Aura, 2017: 55). There is a general lack of engineering graduates in all fields of engineering, with analysis of the school system pointing to a severe shortage in STEM skills. Students with these skills could go on to pursue further studies in engineering and related technical disciplines, but this is frequently not the case (Aura, 2017: 76).

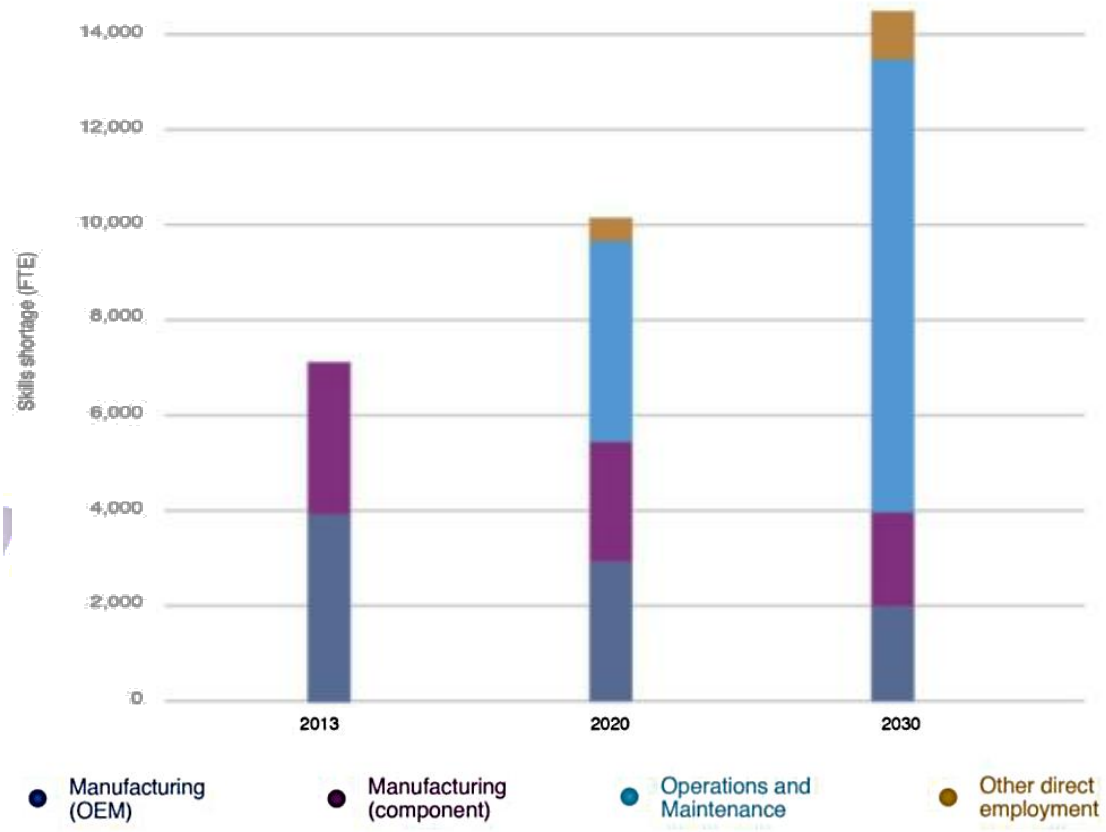


Figure 1: Predicted extent of European Skills Shortages (2013 to 2030) (Energy & Utility Skills Limited, 2018: 60)

Energy and Utility Skills Limited (2018: 55-59) offer a breakdown of the lost UK skills required to implement an offshore wind power plant, including *inter alia*:

- Development and project management (consent approvals, surveys, studies)
   - Graphic design

- Legal
- Port studies
- Geotechnical and geophysical
- Wildlife survey
- EIA specialist

- Turbine design and manufacture
  - Mechanical engineering
  - Welding, boilermaker, electrician
  - Need both R&D skills in the design, as well as artisan skills in manufacture

- Balance of plant (foundations, structure, turbine power, cabling)
  - Architecture
  - Civil engineering
  - Structural engineering
  - Electrical engineering
  - Product design engineering

- Installation and Commissioning
  - Electrical engineering
  - Mechanical engineering
  - Civil engineering
  - Structural engineering
  - Architecture
  - Project management
  - Commissioning engineering
  - Environmental management
  - Installation support

- Operations, maintenance and service
  - Turbine maintenance
  - Offshore substation maintenance
  - Turbine foundation maintenance
  - Inspection and maintenance of safety-critical devices
  - Supervisory control and data acquisition monitoring

- Cross-cutting
  - Marine co-ordinator and ship agents

- Warehouse manager and operative
- Vessel operations and maintenance
- Site manager and engineer
- Vessel master
- Vessel mate and deckhand

This list, along with the International Labour Office Research Brief information, will also be employed to determine a list of skill categories inherent in a typical energy construction project to determine the criteria that form part of the model.

Kahrl et al (2011) studied the Chinese electricity system, where reforms happen very slowly due to the inflexibility of the system. Next to a number of factors causing this inflexibility, the lack of appropriate skills plays a significant role in keeping the system inflexible for change. The authors see the skills and experience transfer from other OECD partners as a possible solution (Kahrl et al, 2011: 4033).

A study by the International Labour Office still sees the renewable energy sector in its early stages of development with key challenges in skills shortages globally. The Green Jobs Report of 2008 estimated that by 2030 up to 12 million people could be employed in the biofuels sector, 2.1 million in wind energy and 6.3 million in solar PV (International Labour Office Research Brief, 2011: 3). Skills shortages still occur in the renewable energy sector, with developing countries the most severely affected (International Labour Office Research Brief: 6), while mostly engineers and skilled technical staff are sought globally.

Some proposed solutions to the skills shortage (International Labour Office Research Brief, 2011: 11) include the following suggestions:

- Skills provision must be co-ordinated with energy policy and investment to ensure that the necessary skills are aligned with projected projects and strategic goals;
- Renewable energy skills development must be planned for developing countries as a priority to ensure new and sustainable development opportunities without permanent mentorship from outside stakeholders;
- Emphasis must be placed on portable skills, skills that can be applied in varying geographical locations as well as varying sectors. Skills must constantly be adaptable to ensure that the person skilled can adapt as the needs change;
- Stronger projections and strategic knowledge must be generated to anticipate skills shortages before they become apparent;
- As renewable energy becomes more prominent and drives out some traditional fossil fuel-based plants, so traditional workers must be upskilled to work in the new field. This will ensure a smooth transition

between different electricity fields, as well as work on existing skills that can become useful in new fields; and

- An increase in suitable and qualified trainers must be encouraged at all levels of professionalization.

Subsequently, a list of skills and professions per sector was compiled, as per Table 1. This list also mentions the level of skill for each of the possible positions, from H= highly skilled to M= medium skilled to L= low skilled. Table 2 highlights specific occupations in each sector that are difficult to fill. These lists helped in deciding the skills value of various projects and developing the criteria and sub-criteria that should form part of the model.

Table 1: Occupations in selected renewable energy sub-sectors by value chain (International Labour Office Research Brief, 2011: 4)

Value chain elements	Occupations	
Equipment Manufacture and Distribution (Wind energy)	• R&D Engineers (computer, electrical, environmental, mechanical, wind power design) (H) • Software Engineers (H,M) • Modellers (prototype testing) (H,M) • Industrial Mechanics (M) • Manufacturing Engineers (H) • Manufacturing Technicians (M) • Manufacturing Operators (L) • Manufacturing Quality Assurance Experts (H,M)	• Certifiers • Logistics Professionals (H,M) • Logistics Operators (L) • Equipment Transporters (L) • Procurement Professionals (H,M) • Marketing Specialists (H,M) • Sales Personnel (H,M)
Project Development (Solar energy)	• Project Designers (Engineers) (H) • Architects (H) (small projects) • Atmospheric Scientists and Meteorologists (H) • Resource Assessment Specialists and Site Evaluators (H) • Environmental Consultant (H) • Lawyers (H) • Debt Financier Representatives (H) • Developers/Facilitators (H,M)	• Land Development Advisor (H) • Land Use Negotiator (H) • Lobbyist (H) • Mediator (H) • Environmental and Social NGO Representatives (H,M) • Public Relations Officer (H) • Procurement Professionals (H,M) • Resource Assessment Specialists (H)

Construction and Installation (Hydropower)	• Engineers (civil, mechanical, electrical) (H) • Project Managers (H) • Skilled Construction Workers (Heavy Machinery Operators, Welders, Pipe-fitters etc.), (M) • Construction Labourers (L)	• Business Developers (H) • Commissioning Engineer (Electrical) (H) • Transportation Workers (L)
Operation and Maintenance (Geothermal energy)	• Plant managers (H) • Measurement and Control Engineers (H) • Welders (M) • Pipe Fitters (M) • Plumbers (M)	• Machinists (M) • Electricians (M) • Construction Equipment Operator (M) • HVAC technicians (M)
Biomass production (Bioenergy)	• Agricultural Scientists (H) • Biomass Production Managers (H,M) • Plant Breeders & Foresters (H,M)	• Agricultural / Forestry Workers (L) • Transportation workers (L)
Cross-cutting/ Enabling Activities (all sub-sectors)	• Policy Makers and Government Office Workers (H,M) • Trade Association and Professional Society Staff (H, M,L) • Educators & Trainers (H) • Management (H,M,L) • Administration (H,M,L) • Publishers and Science Writers (H,M)	• Insurer Representatives (H,M) • IT Professionals (H,M) • Human Resources Professionals (H) • Other Financial Professionals (Accountants, Auditors and Financers) (H) • Health and Safety consultants (H,M) • Sales and Marketing Specialists (H,M) • Clients (H,M,L)

* H: Highly-skilled (professional/managerial); M: Medium skilled (technical/skilled crafts/supervisory); L: low skilled.

Table 2: Difficult occupations to fill per sub-sector (International Labour Office Research Brief, 2011: 6)

Sub-sector	Occupations
Wind energy	Project developers; service technicians; data analysts; electrical, computer, mechanical and construction engineers
Solar energy	PV and solar thermal system installers and maintainers; building inspectors
Hydropower	Electrical and operations and maintenance engineers; technicians; tradespersons; sustainability specialists
Geothermal	Trainers; geothermal engineers
Bioenergy	R&D and design engineers; service technician; trainers

Yoeurp (2017: 8) suggests a couple of steps that can be followed by private employers to deal with skills shortages within their organisations and the industry as a whole:

- Service providers should partner with the academic sector to ensure that valuable practical experience is passed onto the learning institutions
- Provide constant training programs within the organisation. This ensures own staff is retained, as well as contributing to the overall body of knowledge and skills development within the sector.

2.1.2. Skills Background (energy and electricity sector) – African Context

Within the African energy and electricity sector, Ozoemena (2017) argues that some progress has been made towards dealing with the energy shortfalls, but Ogano and Pretorius (2017) highlight frequent power outages still occurring in sub-Saharan Africa, pointing to a shortage of qualified engineers. Aliyu et al (2018) state the position that many sustainable energy projects in Africa are often hampered by the lack of skills and technology present to implement them. This view is supported by Gabriel (2016), who sees the lack of skilled labour amongst 6 of the key challenges in the implementation of energy projects in Africa.

Looking at the electricity sector reform in developing countries, Jamasb (2006) points out that these countries generally have less technical and financially strong electricity sectors. Skill shortages present a significant challenge to developing countries where these skills are often imported to implement energy projects (Jamasb, 2006: 15), leading to little skills transfer happening. Lack of qualified human resources, regulatory experience and skills can create a shortfall of resources in relation to international investors (Jamasb, 2006: 23). Gabriel et al (2016) explain that renewable energy entrepreneurs are available in many developing countries in Africa, yet the political will and lack of skills can be limiting factors in their endeavours. This viewpoint is shared by Engelken et al (2016) who argue that the lack of quantitative data makes it difficult for business models to be developed. Karekezi (2000) identifies skills shortages as part of the challenge to distribute electricity in Africa. Local training programs that focus on technical, social-cultural and economic skills are required to satisfy the capacity and demand for local analytical expertise in sourcing and developing new electricity sources (Karekezi, 2002: 1066). Another reason offered for the lack of infrastructure delivery in the African continent is the complexity these projects often pose, a complexity not easily managed by developing economies (Awuzie & McDermott, 2013).

The solution identified by many developing countries is to include a level of private sector participation in order to bridge certain gaps that inherently exist (Jamasb, 2018). The results of this private ownership have led to more cost efficiency, lower prices and reduced system losses. Additionally, privatisation of existing assets has the advantage of offering governments a way in which to increase revenue (Jamasb, 2006: 15).

In Nigeria, there has been some understanding in how to use public-private partnerships (PPP) effectively in skills transfer. The skills shortages in the country hamper infrastructure development and, according to Babatunde et al (2012: 212), PPP partnerships should not only be about private sector capital being used to finance capital projects, but they should also be used to promote skills transfer to local resources to ensure these projects are also maintained over time.

Cameroon has also asked whether privatisation of the electricity sector is the answer to infrastructure development. Similar concerns to that of many African countries exist where the lack of funding and skills hampers this. Economic challenges to government-owned companies in Cameroon have led to the

International Monetary Fund (IMF) aiding the government to set up a program of privatisation of these resources (Pineau, 2002: 999).

PPP partnerships do, however, have their drawbacks, and consequently Pineau (2002) argues that the approach should always be one of partnered privatisation, where government also has a say in which way decision-making and ownership go. Privatisation's goals are financial gain, which goes against many governmental policies of knowledge and skills transfer. When this transfer of skills and culture occurs, the result will be of more lasting significance than projects purely delivered by private ownership (Pineau, 2002: 1010). Current IMF-World Bank reform already addresses education and skills transfer, but this is only with respect to regulatory agencies and not with regards to tertiary and professional skills. Polemis (2016) also cautions against too much optimism of privatisation of the energy sector until more long-term studies have been conducted and the performance activity is improved. Whether these proposed reforms will stem the regular occurrence of corruption and thereby stifle possible development must still be determined (Imam et al, 2019).

Table 3 below depicts the goals of the electricity sector according to Turvey and Anderson (cited by Pineau, 2002: 1007). Once again, the national goal should be the autonomy of knowledge and skills. These goals will probably not be in line with privatized electricity supply, seeing that many of these are not conducive to increased financial growth.

Table 3: Specific roles of the electricity sector (Turvey & Anderson in Pineau, 2002: 1007)

Specific roles of the electricity sector

Goals			
Social	Industrial	Environmental	National
Efficient social services (security, education, health care)	Improved mechanization	Reduction of pollution (substitution of electricity to coal, wood and oil)	Energy autonomy
Accessible information (radio, television, internet)	Local and extended transformation capabilities	Lower land degradation risks (lower wood consumption)	Knowledge and skill autonomy
Fulfilled household needs (light, heat, refrigeration)	Efficient communication		
Extended public lightening	Efficient training		
Water pumping	Agricultural productivity		
Prevention of rural–urban migration			

Similar challenges to PPP relations are experienced in the electricity sector in Uganda, where the low level of skills in the public sector challenges implementation of new projects. Along with that, this can strain the relationships between the PPP partners and the country's governance, having the result that no further skills transfer can take place (Akampurira et al, 2009: 4). This being said, Manyuchi (2017) refers to some instances of successful skills transfer from the South African energy sector to the Ugandan.

The Government of Mozambique has also recently embarked on a process to reform its electricity sector along with the support of the World Bank. This reform aims at both increase the efficiency of the electrical distribution, as well as look at expanding the network into rural areas that to date have not been reached (Nhete, 2007: 190). Again, privatisation is seen as the impetus to drive some reform, with parts of the Mozambican electricity network already in private control. Nhete (2007) argues that outright privatisation of the Mozambican electricity sector is not an option due to its relative size and level of subsidies required to roll this out. His suggestion is that ownership should remain in government hands, whereas operation and expansion should fall within the private sector's mandate (Nhete, 2007: 202). Skills transfer from the private sector to local professionals still remains an open point for discussion. Figure 2 (below) gives an indication on the level of electrification in some African countries, indicating the vast shortcomings in this regard.

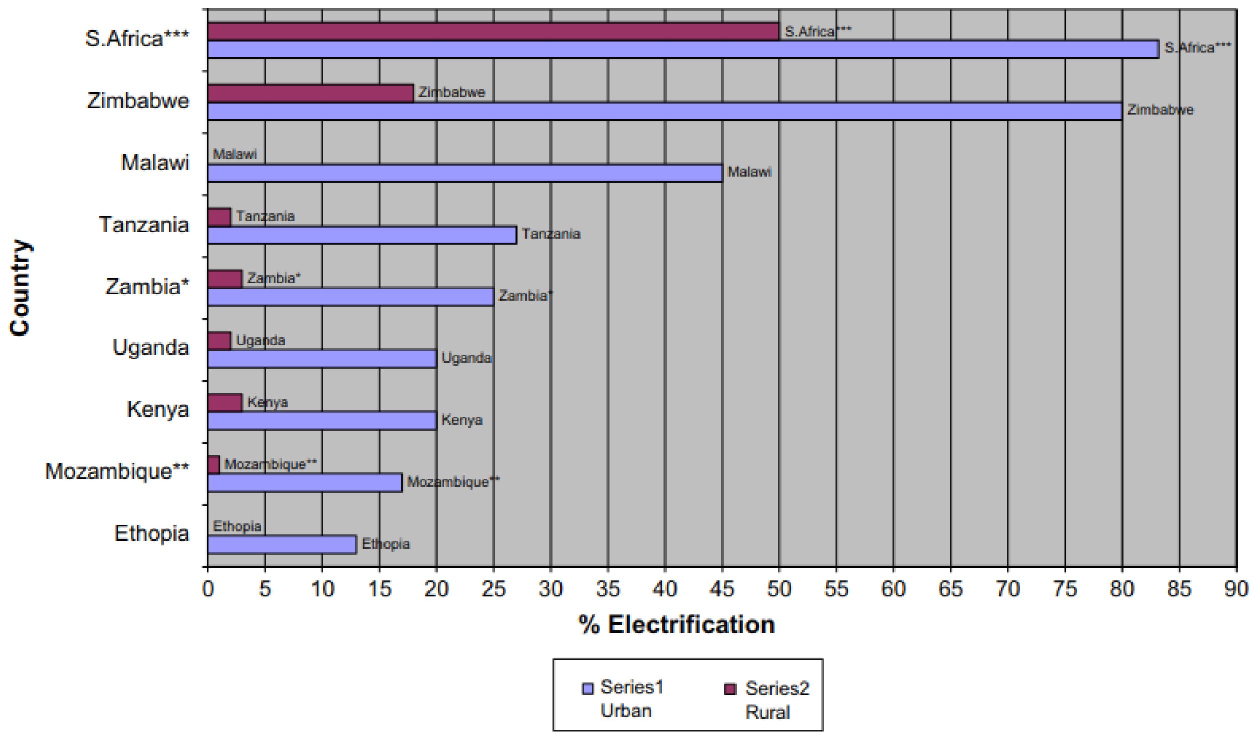


Figure 2: Urban and rural electrification in selected African countries (Nhete, 2007: 193)

Some success stories of skills transfer in the African electricity sector have been identified by Chaureya et al (2004). Their study looked at the electricity access for geographically disadvantaged rural communities. They found that certain technologies are easier to implement in these rural areas and have found some successes in promoting photovoltaic electricity projects. Next to the easier-to-install technology, it was also found that the local youth has easily acquired the skills to understand this technology and have used entrepreneurial skill to advance this technology in a low-technology format, independent from national energy suppliers. It was found that all the skills to install and maintain the PV systems was available locally, with only the manufacturing having to be insourced (Chaureya et al, 2004: 1699). Mahumuza et al (2018) see renewable energy technology as a suitable means of reaching communities in rural areas. Gabriel and Kirkwood (2016) have also conducted a wide ranging study in determining whether entrepreneurship can aid the uptake of renewable energies into the African energy sector and have identified successes along the various levels of business models present.

2.1.3. Skills Background – South African Context

The South African energy market grew by significantly in the last decade, with a current nominal capacity of 44 175MW. Projections are that by 2025 and additional 40 000 MW will be required (Msimange & Sebitosi, 2014). Gregory (2017) points to the current problems the South African energy sector experiences in delivering a reliable supply of energy, pointing to technical skills deficiencies in this sector as one of the main problems. Pollett et al (2015) describe the current energy supply challenges as being the result of many years of underinvestment in power infrastructure and skills development. It is a widely publicised opinion that there is a large shortfall of skills in the energy sector in South Africa, amongst all levels of professionalisation. McKechnie and Bridgens (2008) examine skills availability and development in the South African Electricity distribution sector and report that large infrastructure projects are putting a vast strain on skills availability. They identify the problems this sector is facing as being the historical education legacy South Africa has, the global demand for skills causing an exodus out of the local sector, the deficiencies in the South African basic education sector making it difficult for many learners to advance to tertiary education, the collapse of traditional training of artisans and the insufficient work done by Sector Education and Training Authorities [SETAs] (McKechnie and Bridgens, 2008: 1).

A study by Lomey and McNamara (2007) highlights the dissonance the energy sector still experiences where some stakeholders fail to accept that there are tangible skills shortages. There seems to be a large discord between the various stakeholders, with the Commissioner for Employment Equity referring to the skill shortage as "artificial" (Lomey & McNamara, 2007: 5), whereas most independent analysts and industry specialists refer to a definite and identifiable shortage. For the most part, government has accepted that this shortfall exists and has launched various plans and initiatives like the Skills Development Act, Accelerated and Shared Growth Initiative for South Africa and the Joint Initiative on Priority Skills Acquisition (Lomey & McNamara, 2007: 5). Awuzie and McDermott (2013) point to the fact that government buy-in and support is necessary when implementing complex energy project. In general there thus exists a need to understand the skills shortfalls and to determine methods in which these can be supported in their growth.

Compared to global numbers, South Africa produces far less engineers per population, between 10 and 20 times less than Western Europe, North America, India and China. The trend has shown a slight increase from 2004 onwards, yet it is still recommended that the amount of graduate engineers increase from 1300 per annum to 2400 (McKechnie & Bridgens, 2008: 2). This can also be ascertained from Watermeyer and Pillay (2012), who look at the shortage of skills in the maintenance of infrastructure. In 2006, the National Energy Regulator (NERSA) released an audit report of 11 energy distribution utilities, including two Eskom distribution regions, some larger municipalities, as well as smaller municipalities. The findings were that the level of skills available decreases remarkably as the size of distributor decreases, with smaller municipalities showing clear signs of skills shortages. Kessides et al (2007: 47) point out the lack of skills in the South African at local municipal level has also inhibited the implementation of reforms. Eskom did show some positive trends at the technologist and technician levels, but at the engineering and artisan levels there were significant shortcomings (McKechnie & Bridgens, 2008: 5). Pollett et al (2015) describe the current energy supply challenges as being the result of many years of underinvestment in power infrastructure and skills development. Although there is an increased interest for the science, technology and innovation (STI) capabilities in South Africa (Hart et al, 2019), to a large extent the tertiary education sector does not yet meet the demand for those associated skills amongst graduates.

During a Committee meeting for the Parliamentary Monitoring Group held on 10 September 2012, it was reported that various Energy sector training authorities and companies had made advances in skills transfer, yet at managerial level, shortcomings still remain. The Energy and Water Sector Education and Training Authority (EWSETA) had been placed under administration in September 2010 and only during 2012 had shown some signs of improving. A number of learners had been placed at institutions and projects, but the methods and capacity of skills transfer remain critical. Eskom reported an increase in internal learners and that the majority of engineers and technicians were of a young age. This poses the problem of adequate mentoring and transfer of skills by experienced engineers onto junior staff. Johan van den Berg of the South African Renewable Energy Council (SAREC) pointed to the fact that many high skilled jobs needed to be created, but these skills still lack largely at municipal level (Nijikelana, 2012: 3).

In a research report in 2016 funded by the Department of Higher Education and Training, Reddy et al 2016: 72) take a look at the supply and demand of skills in South Africa in general. Their findings show that employment in the Electricity Gas and Water supply sector increased by nearly 30% between 2010 and 2014, with 83% of this increase being in the electricity supply and distribution sectors. That being said, there still remains a lack of technical knowledge and skills amongst the employees in this sector (Reddy, 2016: 62). The growth in management and professional skills has been very little. Engineering science professionals still remain on the list for occupations with high demands (Reddy, 2016: 70).

Looking at the energy sector in general, and the renewable energy sector in more detail, Forsyth (2016) discusses the impediments implementing renewable energy projects in South Africa, focusing mainly on skills availability. He points out that skills transfer in the renewable energy market is lacking on a global level, but in Africa, and particularly South Africa, this shortage is even more detrimental due to the availability of so many natural resources. A study looking at the barriers SME’s experience in the electricity sector, found that next to access to capital and information, the lack of both internal and external skills within the organisation does not help in securing projects in the electricity sector (Triani & Cagno, 2012: 503).

Training and skills transfer does not take place regularly, particularly at management level, which becomes a problem at the latter levels of South Africa's Renewable Energy Independent Power Producers Procurement Program (RE IPPPP) process, where local sub-contractors need to act as sole contractors and not under the auspices of the large multi-nationals. (Forsyth, 2016: 33). Very few degrees or diplomas are currently offered at South African tertiary institutions, with more emphasis on short courses, something that does not aid the transfer of skills. The REIPPP was launched in South Africa in 2011, a program whereby some sort of privatisation was to take place in the South African electricity supply sector. There has been a mistrust of renewable electricity within many sectors of government for a long time, which has hampered this programme. Nevertheless certain advances have already been made, not least because of the establishment of a regulatory framework, as well as keen interest from international renewable energy developers. As of 2016, the REIPPP program has already allocated 3725 MW to five bidders, with many more programs currently underway (Baker et al, 2015: 28)

The result of this program brings with it, amongst others, significant skills development. This is largely still a theoretical goal, whereas in practise, this skills transfer has not taken place to a significant extent. South Africa still lags behind in renewable technology manufacturing and the wind and solar PV industries are more knowledge than labour intense. This often calls for more semi- to highly skilled workers being required, something South Africa does not yet possess, and as such are often imported (Baker et al, 2015: 31).

Table 4: Electricity generation in South Africa (Baker et al, 2015: 7)

Electricity generation				
Coal	%	91.8	0	0
Natural gas	%	0.2	5.7	6.1
Nuclear	%	5.5	0	0
Hydro	%	2.1	1.6	1.7
Wind on-shore	%	0	15.8	16.6
Solar PV	%	0	13.0	13.0
Solar thermal	%	0	62.5	61.2
Biomass	%	0	1.3	1.4

Table 4 indicates South Africa's reliance on coal generating electricity sources, which means that most skills development occurs in this sector, but through the REIPPP, along with an understanding of the finite fossil fuel sources, this scenario may change. The political understanding of decarbonisation and de-nuclearization remain points that must be monitored, along with the political will to do so.

As a possible way forward, a study in 2015 on the changing electrical supply landscape looked at two possible scenarios in the labour force in South Africa and modelled these (Table 5). The first scenario looked at reducing unemployment by increasing growth in high technology and low carbon sectors, while the second scenario looked at the impact when a higher skilled labour force is injected into the economy, thus changing the make-up of this labour force (Baker et al, 2015: 4).

Table 5: Key metrics for the Economic Structure and High Skills scenarios in 2010 and 2050 (Baker et al: 6)

Indicator	*Units*	*2010*	*Economic Structure 2050 Scenario 1*	*High Skills 2050 Scenario 2*
Population	Millions	51.5	62.3	62.3
GDP per capita	Real US$ 2005/person	4 825	12 973	12 294
Unemployment	%	24	12	18
Population in low income bracket	%	50	18	17
Persons per Vehicle	Person/vehicle	10.2	5.6	5.7
Final Energy Consumption	EJ	2.48	4.75	4.58
Annual GHG Emissions	Mt CO_2-eq	398	241	242
Per capita total GHG emissions	Tons CO_2-eq/cap	7.7	3.9	3.9
Energy Intensity of GDP	TJ/Million US$ 2005	10.0	5.9	6.0
Levelised cost of electricity	US$/kWh	0.056	0.110	0.106

The results of this projection indicate the vast impact both these scenarios will have on efficiency, unemployment, emissions and energy intensity. There are increases in energy cost and consumption, but these increases can be directly attributed to inflation and population growth. What must also be mentioned is that scenario 1, whereby focusing on the growth of the high technology electricity sectors, cannot support the growth projected without the adequate supply of skills to implement this growth. The natural conclusion is thus that the kind of growth, both financially and socially, whereby the emissions are also reduced will only be possible with adequate skills to support this growth. What must also be borne in mind is that this model does not take into account any of the inhibiting factors that prevent these scenarios from taking place (Baker et al, 2015: 7).

2.2. Renewable Energy

The traditional energy sector has already been discussed and will form part of this study. When considering the different alternatives that form part of the hierarchy that will be developed, the renewable energy sector can naturally form part of this study. The following section investigates whether there is enough value in including this sector as a viable alternative to coal and nuclear power generation.

Renewable energy remains a topic that is strongly debated in South Africa. Olatayo et al (2018) point out that the South African electricity network is currently powered 90% by coal, with nuclear contributing to

5% and the other 5% contributed by mixed sources (Olatayo et al, 2018: 1). However, the instability of coal supply and environmental challenges have necessitated a review of this supply contribution. Krupa and Burch (2011) contend that focusing on inequity and hierarchical struggles is always a good lens to determine its status in South Africa. Although the traditional energy sector has produced enough environmental damage and marginalization that an alternative should become interesting, there still remains little political will and enough corruption to dampen the progress of this alternative slightly. Pegels (2010) has identified the primary barrier to the implementation of renewable energy technologies in South Africa as being the economics of this technology. Cost and risk structures must be borne by the independent power suppliers and thus have slowed down the process of its implementation. The South African Government has introduced some support measures, but many of these have not been successful (Pegels, 2010: 4945). Yet even though these pitfalls exist, there is a steady stream of positive growth forecast in this sector, not least due to changing political climate and the need for private partnerships in delivering electricity (Krupa & Burch, 2011: 6260). Additionally, there exist tensions within the sector between the needs of the government for social and economic advancement and commercial success on the side of the private sector (Baker & Sovacool, 2017).

Electricity demand has not decreased by the required 10% to stabilise the South African power grid. Since 2008 when Eskom instituted load shedding in order to curb peak demand, there has been a steady increase in electricity demand, as a result of economic, urban and infrastructural development (Sebitosi, 2008: 1591). The solution that Eskom initially touted was the focus on energy efficiency, issuing compact fluorescent bulbs and offering rebates for the installation of solar geysers. Most of these measures offered little respite to the network pressures. Additional power stations have been planned and are in varying stages of completion, but the overall electricity grid is still under great strain. In general it can be observed that numerous government legislation exists on energy conservation, yet it is in the practical implementation that most of this has fallen flat. Sebitosi's observation is that the private sector has taken the lead in energy conservation and will do so for the foreseeable future (Sebitosi, 2008: 1595)

The REIIIP has been discussed relative to skills development and transfer. This portion of the report will focus on how it affected the national electricity grid and cost, and offer a projection on future expectations. The REIPPP in is a program that was launched to install 17.8GW of electricity generation from renewable sources between 2012 and 2030. Initially, this program was seen to have the purpose to deflect the criticism from South Africa's overly heavy reliance on coal-based energy generation, but recent cost increases in this sector as well as a competitive bidding process have heightened the perceived value of the REIPPPP. At the end of round 3 of the program, the weighted cost of energy has reached a level of 23% below coal-fuelled energy production, as well as 28% below international renewable energy prices (Walwyn & Brent, 2015: 390).

Unlike the cost for fossil fuel, the cost of renewable energy electricity generation has fallen significantly in the last decade and it is predicted that this trend will continue for the next decade coming. Cost of PV panels has reduced remarkably as per figure 3 below:

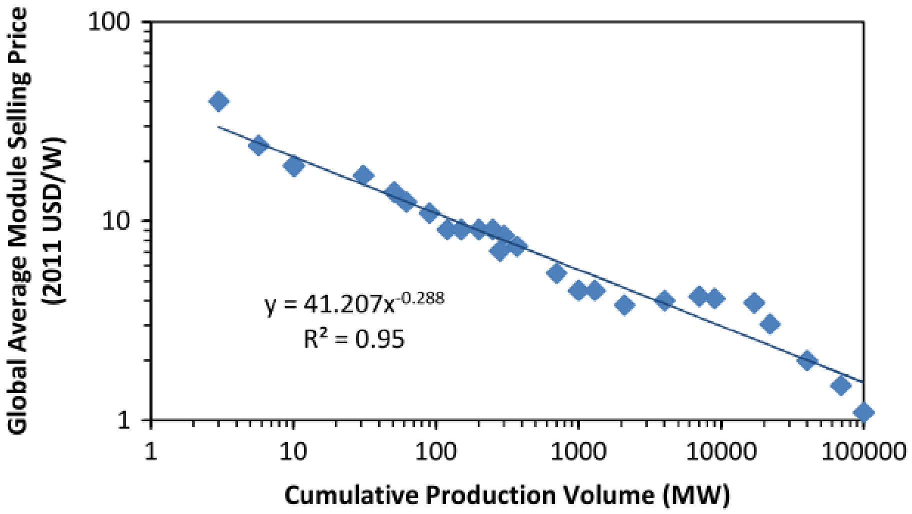


Figure 3: PV module selling prices decrease with cumulative production (Walwyn & Brent, 2015: 391)

The same trend counts for other sources of renewable energy. In terms of the total cost of generation, most renewable energy sources can compete with traditional sources of coal and solar, especially when operation and maintenance costs are concerned (Figure 4). With the trends of fossil fuel prices increasing and the renewable sources decreasing, the difference will become even more pronounced (Figure 5).

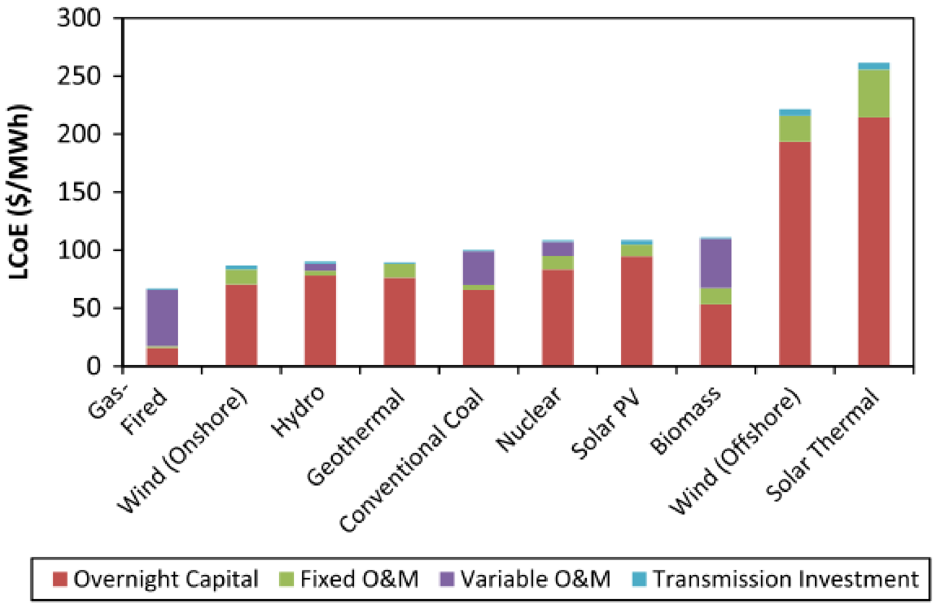


Figure 4: Total cost of generating electricity by technology (Walwyn & Brent, 2015: 391)

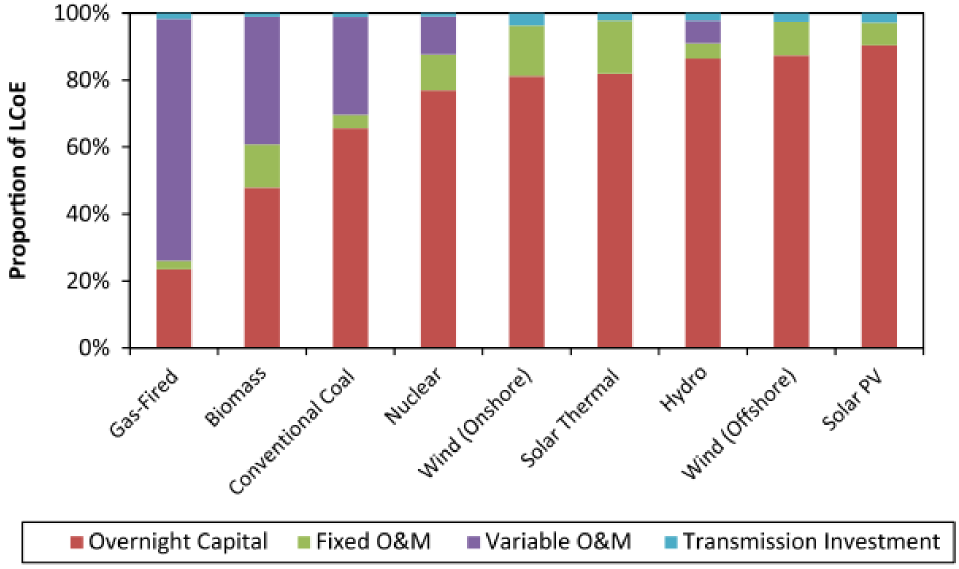


Figure 5: Relative proportions of cost factors to total generation cost (Walwyn & Brent, 2015: 393)

The increased need for skills in this sector has been discussed elsewhere in this report and at this point not enough information is available for the South African market, but predictions suggest that South Africa is in line with predicted high employment rates along the same line as global competitors. Table 6 below gives some indication of the current trends.

Table 6: Direct and indirect jobs in renewable energy technologies (Walwyn & Brent, 2015: 393)

Sub-sector	**Global average (jobs/MW)**	**Number of direct and indirect jobs (thousands)**			
		Global	**China**	**Germany**	**India**
Biofuels	1.9	1379	24	23	35
Solar PV	7.7	1360	300	88	112
Biomass	1.8	753	266	57	58
Wind power	1.7	753	267	118	48
Biogas	6.3	266	90	50	85
Geothermal	2.2	180		14	
Hydropower (small)	2.5	109		7	12
Solar Thermal (CSP)	2.0	53		2	
Total		**4853**	**947**	**359**	**350**

Key success factors for this sector have been identified by Walwyn and Brent (2015). General consensus has been reached over the fact that sustained success of a renewable energy industry is only achievable when a range of factors within the national energy markets are attended to. Local market demand is important, yet it is also essential to look at development and training for sustained market gains. Also important is healthy competition within the sector, as well as government buy-in and legislative support. An indication on the successes of these factors in South Africa can be seen in Table 7 below.

Table 7: South Africa's compliance with the key success factors for a domestic renewable energy sector (Walwyn & Brent, 2015: 395)

Key success factor	Compliance	Comment on South Africa's compliance
Policy		
Clear and consistent government policy	Y	Policy is clearly stated in the IRP 2010–2030 and REI4P (detailed tender documents).
Transparent policy implementation	N	There is limited public information on the implementation of REI4P; some agencies are performing dual functions with clear conflict of interest.
Mix of policy instruments	Y	Specific demand side measures (competitive bidding and supply contracts) and generalised supply side incentives (R&D, human capital).
Enforcement of policies	Partly	Lack of compliance with aspects of local content and other components.
Market and funding		
Balance between stability and adaptability	N	Although investors require stability, especially in terms of price, policies should allow for degression of prices to avoid the risk of overcompensating developers; the tender allows for inflation-adjusted pricing but no degression [38].
Access to affordable capital	Partly	South Africa's cost of capital generally higher than most developed countries; moreover the industry's reliance on the Industrial Development Corporation is considered a weakness.
Public R&D funding for RET	Partly	More R&D funding will be required specifically for RETs if a stronger local industry is planned.
Industry regulations		
Regulations to support investment	Y	The programme has managed to achieve high overall coordination between government departments in establishing the necessary regulatory framework.
Local content requirements	Partly	Local content rules and requirements need tightening to ensure higher levels of localisation and job creation.
Demand-pull and supply-push	Y	Independent power producers are offered a guaranteed market for power supplied to the national grid; further incentives to switch to the most economical means of electricity generation will be required.
Industry standards	Y	Required for consistency in local content, etc. South Africa has quality standards in certain areas such as solar water heating.
Social development		
Government coordinated training in renewable energy technologies	N	Human capital development is adequate in environmental sciences but lacking in more practical training at the technology level.
Stakeholder involvement (local participation and ownership)	Partly	Local communities are mostly disappointed that there are not more local jobs; on the positive side, there is a diverse geographical spread of the IPPs.

When evaluating the REIPPPP it becomes necessary to weigh the listed successes against government assistance of the program. There have been some advances in the goals of the program, but more government support is required. There seems to be a deadlock of implementation at utility-scale and legislative assistance would be required to overcome this. The very strict and well-defined tender process must still be evaluated but successful tenders have been forthcoming (Table 8).

Table 8: Summary of REIIIIP bidding results (Walwyn & Brent, 2015: 396)

Round	Bid closing date	Planned purchase (MW)	Bids received		Bids preferred		Value ($ mill)	Weighted average capital cost ($/MW)
			No	MW	No	MW		
One	04-Nov-11	1416	53	2128	28	1416	46,026	32.52
Two	05-Mar-12	1044	79	3255	19	1044	28,059	26.88
Three	19-Aug-13	1456	93	6023	17	1456	33,810	23.22
Total		3915	225	11,406	64	3915	144,723	

Successes in job creation and integration of previously disadvantaged sector, these results are still out and too early to identify. The targets have been identified and can be benchmarked against global values, but the challenge for these measures is that they must compete with skills shortages, the insourcing of outside expertise lack of R&D in local conditions and the need for an immediate impact on the national power grid. The financing models are also still challenging and more time needs to pass for a verdict to be reached.

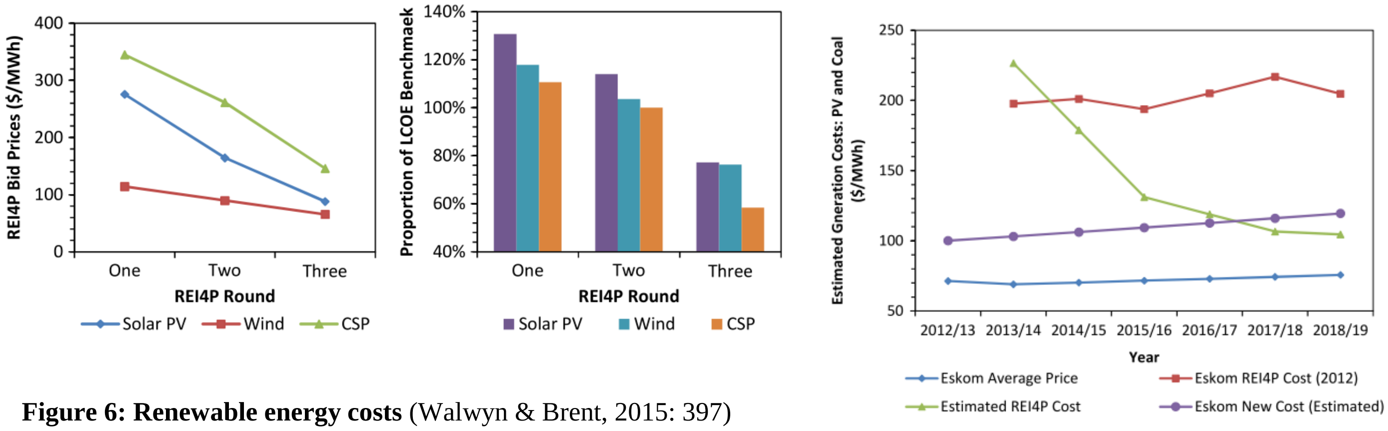


Figure 6: Renewable energy costs (Walwyn & Brent, 2015: 397)

As far as cost of renewable technologies go, the tables above shed light on the situation. Figure 6 (left) indicates a sharp decrease in cost over the different rounds of the REIIIIP. Figure 6 (right) indicates that there is a comparison between power generation cost between traditional coal and PV. Again, the cost at the current stage is in line with contemporary coal production and in some cases even lower. Looking at the trends on all the graphs, the conclusion may be reached that by the projected end of the REIIIIP the cost of renewable energy sources will be significantly lower than traditional and fossil fuel based power generation, making it a definite alternative to be investigated along with the traditional energy sources.

2.3. Feasibility Stage

This report focuses on a study that is conducted at the feasibility stage of a project. The reasons for this are clear when viewed against the phases of a project, where the cost of changes is viewed against the impact they have on the project (Figure 7).

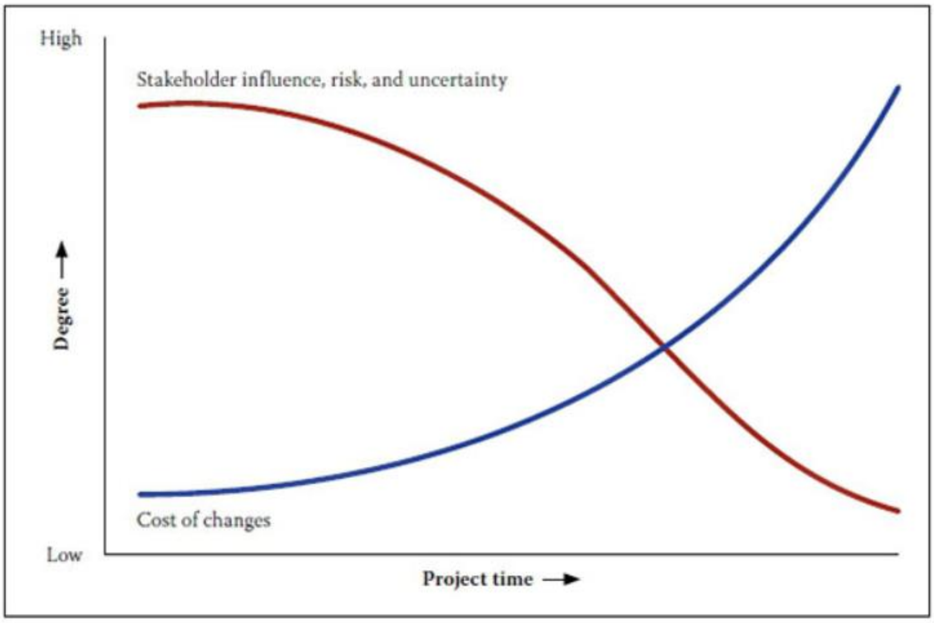


Figure 7: Impact of variables based on project timeline (Ibbs, 1997)

During the early stages of a project, the impact of decisions has a small impact on the cost; whereas the impact on the project on a whole is the most substantial. A feasibility study is conducted at the early stages of a project during the planning phase. It is an analysis that is carried out to determine the ability and likelihood to implement a project successfully. The analysis must include all the relevant factors that influence the project - economic, technological, legal, organisational, environmental and others that are identified (SENTRO, 2008).

As stated at the beginning of this report, the purpose is to develop a measure in which the skills in a project could be measured, both the skills required to complete the project, as well as the potential for skills transfer. The only way in which this information can have an impact on the project is if this knowledge is gained at the early phases of a project. Skills development is in line with much government legislation and should have a higher impact in feasibility studies in the South African electricity sector. When two electricity alternatives have the same scoring in the main components of a feasibility study, the skills value should become a deciding factor between the two.

2.4. The Analytic Hierarchy Process

2.4.1. Background and origin of the AHP

The theory behind the AHP must be investigated to understand the parameters of the model to be developed. Saaty (1987) offers a good primary source introduction to the AHP and the principle of pairwise comparison developed by Saaty between 1971 and 1975. The AHP is a model that aids decision-making in both the physical and psychological domains by offering a non-linear framework that can carry out both deductive and inductive thinking (Saaty, 1987: 161). Saaty also describes some of the underlying mathematical principles of linear algebra and Eigenvector solutions for the weighting and consistency, but these principles will not be discussed in too much depth, focusing rather on the application of them. Saaty refers to the fact that any decision making approach should always be " simple to construct, adaptable, natural to intuition and thinking, encourage compromise and consensus building and not require inordinate specialization to master and communicate" (Saaty, 1994: 20). As stated under the comparisons of various MCDM methods, it is for this reason that the AHP lends itself most to this study.

Saaty states that deductive thinking is not natural and here the AHP aids in breaking down a problem into sub-problems and then aggregating all the solutions to the sub-problems into a conclusion. The AHP is based on the observation that most people possess the innate skill to make sound judgements about smaller problems, the solutions of which then get combined into the solution of the main problem (Saaty, 1994: 20). It is also stated that not all information is useful in improving our understanding and judgement (Saaty, 2008: 83). The measurement of intangible factors has always been problematic and sometimes the basis of over-analysing and over-interpretation. The AHP overcomes this shortcoming by assigning relative values and importance to these sub-problems and by doing this creates some distance to the core problem. Not knowing all the details of a problem should not be debilitating, rather the ability to measure these intangibles through numerical measurement and the relativity between various components should aid in understanding the relations between these variables. This will reduce the complexity and allow the user to engage more effectively with the problem at hand.

2.4.2. Applications of the AHP

Applications of the AHP are varied and one that is particularly pertinent to this study is an example described by Saaty where members of parliament in Finland had to decide which type of power plant had to be built. Some factors that had to be taken into account were the national economy, health, safety and the environment (Saaty 1987: 162). The main criteria were further divided into sub-criteria to eventually arrive at the total hierarchy. The different options are then analysed with this hierarchy in pairwise comparisons. Vargas (1990) points to all the sectors where the AHP can be applied and these range from design to political, social and technological problems This varied scope shows that AHP is definitely also applicable to this study. The same goes for the findings of Vaidya and Kumar (2006), who report on the application of the AHP in sectors ranging from social, to personal, education, manufacturing, industrial and government., whereas Weiss (1987) shows its strength in a dynamic environment and Wind (1987) looks at the dynamic and marketing sectors. This varied background offers a view into the versatility of the applications of the AHP.

In another application close to this study, Pohekar and Ramachandran (2004) report on the ever increasing use of MCDM methods in general and AHP in particular in the sustainable energy planning field. The AHP is the most commonly used MCDM method in this field, followed by PROMETHEE and ELECTRE. They point out that the major advantage of using the AHP in this context is that it “calculates the inconsistency index as a ratio of the decision maker’s inconsistency and randomly generated index” (Pohekar & Ramachandran, 2004: 370), which is important to ensure that the decisions made were consistent and the final result can be trusted. Liu and Xu (1987) look at its application in the Chinese context, where it has been very popular in planning, decision making, forecasting and system analysis (Liu & Xu, 1987: 180). In China it has also been used extensively in energy and resource planning.

Mu and Pereyra-Rojas (2017) look at some current applications of the AHP, in their example of selecting the right car to purchase, explaining the method in which the goals, criteria and alternatives are developed into the model hierarchy. They also employ the traditional Saaty pairwise comparison scale, using both the verbal judgement as well as the related numerical scale. They also explain clearly how the priorities are derived and consistency verified. A solution to the criticism of the rank reversal is suggested by performing a sensitivity analysis.

Ramanathan researched how the AHP has also been used successfully in the Environmental Impact Assessment (EIA) process and has proven to be a widely successful tool in environmental management and in managing multiple criteria, as well as multiple stakeholders. (Ramanathan, 2001: 27). He further suggests that it has the advantages of combining qualitative and quantitative elements and aggregating many expert opinions, often with many disparaging views (Ramanathan, 2001: 30). Active stakeholder engagement is also well managed, which in the South African Energy sector becomes a vital component, looking at the differing backgrounds of all the stakeholders.

Nagesha and Balachandra (2006) give an insight into the situation of acceptance of renewable energy implementation in India, where they applied the AHP to analyse what the main barriers were to implementing these. Six factors were identified that hinder this implementation, namely lack of skills and technology, lack of financial and technical input, lack of financial mechanisms, lack of training and management, lack of rational pricing and lack of information (Nagesha & Balachandra, 2006: 1970). The AHP analysis showed the Financial and Economic barriers to be the most significant hurdle in the implementation of renewable energy sources.

Applying the AHP to deciding between different energy policies applied in Jordan has been proposed by Kablan. Kablan mentions the fact that the AHP has been implemented successfully in Jordan on various governance issues, where complex problems needed to be broken down into easily understandable parts. It has been applied to select the best policies for solar implementation in 1990, measuring business performance (2001) and the decision on using different casting processes (Kablan, 2004: 1152). The hierarchical structure of the model makes it easier for decision makers to understand the links between data and decisions taken and also caters for an interactive approach for groups to decide on the results dynamically (Kablan, 2004: 1151). This group thinking also helps to promote buy-in from all stakeholders involved and take ownership of the decisions made. AHP’s consistency tests aid in screening out inconsistencies in the model.

A study in Malaysia where new sources of renewable energy were to be discussed and evaluated pointed to the fact that decisions that must ensure a steady supply of electricity are complex. The “complexity arises from the interaction of considering long planning horizon, irreversibility of decisions, technology choice, acquisition and deployment delays, resources potential, and uncertainty of future demand.” (Ahmad & Tahar, 2014: 461). In order to deal with the complexity as well as the gravity of the decision, the AHP was employed to determine the criteria that must form part of the hierarchy that is used to compare the different options. The precedents to use the AHP in energy planning and the energy sector in general are significant and many developing countries have employed this method successfully, namely Turkey, India, Crete, and Pakistan. Each of these scenarios have a unique context with unique needs, and the AHP has proven to be robust enough to adapt to each context (Ahmad & Tahar, 2014: 462).

Chatzimouratidis and Pilavachi also used the AHP to determine how different power plant types impact on the living standards of the people that surround them. 10 different types were evaluated, from both traditional nuclear and fossil fuel based to various types of renewable energies (Chatzimouratidis &

Pilavachi, 2007: 1074). The selection of a wind observation station was carried out using the AHP by Aras et al (2003: 1383) who used the AHP as a popular tool in location selection. They evaluated 4 different alternatives with 11 criteria to determine the best location and the results gathered by AHP were in line with expectation.

Even on an HR and staffing level, the AHP has been applied successfully. With this study focusing on skills, there is a definite opportunity to employ the AHP on this level, but this will not form part of this research. Saaty et al (2007) propose a way to apply the AHP to staffing options, to answer the question that often arises in practise: "what is the best combination of alternatives that has the largest sum of priorities and satisfies given constraints? This leads one to consider the interface between the AHP and the combinatorial approach inherent in Linear Programming (LP)" (Saaty et al, 2007: 1). The way organization prioritise resources can be governed by principles of the AHP.

Similarly, Albayrak and Erensal (2004: 491) propose to move away from measuring human performance in terms of efficiency and effectiveness, often relying heavily on KPIs and targets met. The problem of determining skills available and the skills that are necessary to meet the requirements is mostly too vast and complicated for a human resources practitioner or even department to comprehend in its totality that the AHP offers a good aid in building the model by which these complexities can be analysed. There is a definite correlation between human performance and the style of management used within an organization and the AHP is suggested as a possible way to implement a "multiple criteria performance improvement scheme" (Albayrak & Erensal, 2004: 491). This principle can easily be translated in the context of determining skill shortages within an organization and then determining a way in which these shortages can be addressed. The hierarchy and related criteria can be revisited and form a dynamic tool in monitoring the progress to address these skills shortages.

2.4.3. Criticism of the AHP

There has been some criticism of the AHP around for some time that needs investigating. Brunelli (2015) points to two points of criticism that Saaty is also aware of. The first issue pointed out by critics is the phenomenon of rank reversal, where there can be instances that when a new alternative is added to the previous relations between variables this could have an influence on the relation between two already compared variables. This phenomenon can be avoided, though, by aggregating the vectors by taking their component-wise geometric mean and not their convex linear combination (Brunelli, 2015: 18). Again, this study will not seek to validate the findings by complex mathematical theory, but rather take cognisance of this criticism and verify the results by multiple comparisons.

The second criticism pointed out is the different scales that are used in the pairwise comparison. Saaty's original scale was linked to linguistic expressions linked to numerical values. This can have the difficulty of the decision maker having trouble to decide by how much more he preferred one option over the other. The solution proposed is a scale used by Pohjonen, called the balanced scale that also has a verbal judgement attached to it. There still remains a debate on whether this really is an improvement on the Saaty scale, and for the purpose of this study Saaty's original scale will be employed. An aspect where no controversy exists, is the fact that whichever scale used there must be a bounded numerical scale. The one used in the study will be the one proposed by Saaty containing all integers up to 9 (Brunelli, 2015: 20).

Saaty et al (2009) responded to criticism levelled against the AHP. The topics relevant to this study have been listed below:

- Rank reversal: this is a criticism that deals with the changes in the ranking of the different alternatives when the structure of the decisions are changed, be it by leaving out or adding new criteria or alternatives. Critics point to the fact that these sometimes relatively insignificant alterations in the structure of the model cause a reversal of the ranking of the various options, amplified in a manner that is not in line with expected outcomes (Saaty et al, 2009: 1). It comes as a natural consequence that when adding or deleting alternatives in a model where various alternatives are compared with each other according to set criteria, the aggregation of the weights will cause a change in ranking should different alternatives fall away. In its ideal mode the AHP will preserve rank, even when some alternatives get removed, but in reality this will not be possible, nor should it be desirable. A new alternative that is added will naturally influence the rank of itself, as well as the rank of other alternatives, because in the AHP "everything can depend on everything else including itself." In the AHP rank is always allowed to change (Saaty et al, 2009: 4). This should not be viewed as a weakness of the AHP, but rather contribute to the understanding that this model is robust and adaptable in a changing environment, the application this report is investigating.

Where the change in structure occurs due to the adding or deleting of criteria this will consequently lead to a change in the structure and possibly rank reversal. This may be attributed to two reasons. First, criteria may be removed should they be regarded as being irrelevant due to the alternatives having nearly equal priorities under them; or, second, criteria may be added due to similar reasoning as the previous, where new criteria are felt to be necessary. In both these cases it makes little sense to add or remove criteria that seem to be irrelevant or additionally necessary. The proposed way to deal with criteria that seemingly should be added or deleted, according to Saaty, is to either "assign zero priorities to the alternatives and keep that criterion, and in the latter case not to add them or if added to consider this a new decision respecting the influence of added criteria on the final outcome which, as we said above, could lead to different priorities and ranks." (Saaty et al, 2009: 5). Again, the robustness of the model is such that changes in the criteria, as well as possible rank reversal, are not viewed as limiting factors, but rather embraced to adapt to changing conditions and requirements.

- Pareto Optimality and Consistency: Some critics have relied heavily on Pareto optimality in determining whether the results in the analysis create the consistency sought. The challenge is that Pareto optimality "as used in economic and social practice applies to a final ordering of each individual of all the alternatives and not to judgments that obtain that order" (Saaty et al, 2009: 5). In the case of the AHP this process is inherently satisfied when the stated condition is satisfied, since the order preference is based on priorities, rather than an "ordinal statement of preference" (Saaty et al, 2009: 5).

- Altering the Fundamental Scale: This is a general criticism not only levelled at AHP, but many other MCDM models and is based largely on verbal and semantic differences attributed to orders of values. Ma and Zheng (1991) and others have questioned the fundamental 1 – 9 scale, but not enough research of suggested alternatives exists to offer any other way in attributing values to scales of importance in criteria. There have been many researchers that have proposed their own numbers, but again little explanation and validation is offered as to how and why this differing system has been proposed (Saaty et al, 2009: 7). The strength of the judgement scale is that it allows to compare criteria both from a qualitative as well as quantitative background (Ishizaka & Labib 2009: 202). Due to the fact that the AHP uses a ratio scale, compared to other methods that use interval scales, there is no unit required in the comparisons and they are only compared relative to one another without having to assign a more detailed value along with its corresponding to each decision. The use of verbal comparisons is naturally appealing to most partakers in this process, as each person has a natural inclination to scales of relative significance between different criteria. In order to prevent any ambiguities between relative values of verbal scales, these scales must be converted into numerical scales. Most research tends to agree that these scales in conjunction with priorities derivations, consistency matrices, aggregation and sensitivity analysis give consistent and relatively objective results (Ishizaka & Labib 2009: 207).

- Are the Axioms about Comparisons behaviourally meaningful: On a psychological level idea of the pairwise comparison and whether each user attributes the same values to this judgement process have been looked at. Psychologist Arthur Blumenthal describes two types of judgement: "Comparative judgment which is the identification of some relation between two stimuli both present to the observer, and absolute judgment which involves the relation between a single stimulus and some information held in short term memory about some former comparison stimuli or about some previously experienced measurement scale using which the observer rates the single stimulus" (Blumenthal, 1977). This is called relative measurement and absolute measurement in the AHP (Saaty et al, 2009: 7), where in the first process the various alternatives are compared to one another and in the second instance all the various alternatives are compared to the ideal alternative identified and ranked accordingly. The process of the AHP is clear in that the alternatives need to be compared against each other in order to reach the ideal, against which all the other alternatives are to be measured. Comparisons must precede ratings and this process of comparing elements and characteristics with one another lies intrinsically in humans. This is what makes the AHP process so comfortable to all people from varying intellectual, cultural and social backgrounds, seeing that the main analytical tool is naturally inherent in all.

The main underlying principle that governs all the concerns, some of which are definitely valid, is that any finding and analysis need some sort of objective validation of the results received. This is also reiterated by Saaty, who agrees that all subjective comparisons and judgements need to be validated (Saaty et al, 2009: 10). It is suggested that the results in this report also focus on validating the results in order to achieve more objectivity (Whitaker, 2007).

Whitaker points out that much criticism pointed at the AHP is based on results gained from false conclusions and application of the AHP. The AHP is based on clear requirements and only once these requirements are met can a valid conclusion be sought. In reference to a Brazilian study that includes AHP models that lead to wrong results, Whitaker shows that the AHP theory was not applied correctly and that correct application of its principles and processes actually lead to the correct result. The mistake made was that no priorities were set to various criteria, which then invalidates this model, since the links in the hierarchic structure is what links the analysis to real-world data (Whitaker, 2007: 948). The robustness of AHP has been shown in practise by various persons who all developed validation processes using pairwise comparison matrices, hierarchies and networks in examples where they already had knowledge of the answer and then employed these methods to validate the AHP (Whitaker, 2007: 961). For the purpose of this study, the strengths of the AHP definitely outweigh the weaknesses and there are no concerns in applying it to achieve valuable results.

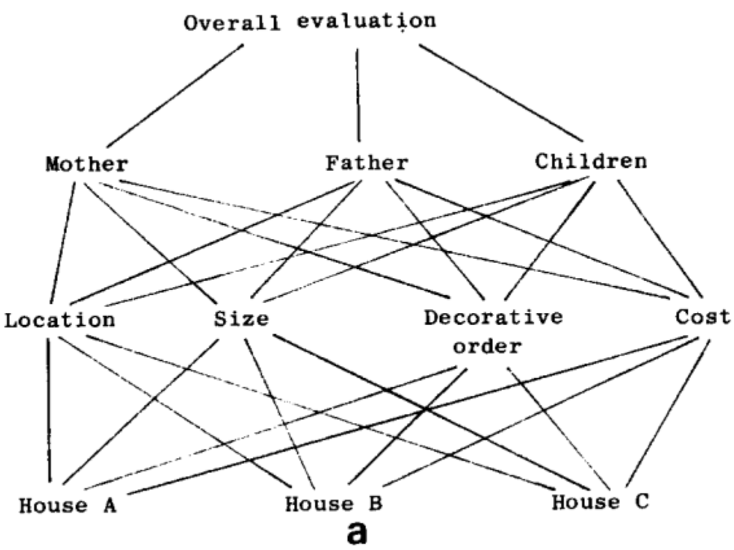
2.4.4. Comparison of the AHP with other MCDM methods

Various different MCDM methods exist and it is prudent to investigate the strengths and weaknesses of each in the application of this particular study being based in the energy sector. Kolios et al (2016) reviewed the weighted sum method (WSM), weighted product method (WPM), the analytical hierarchy process (AHP), the technique for the order of preference by similarity to the ideal solution (TOPSIS), elimination et choix traduisant la realité (ELECTRE) and the preference ranking organization method for enrichment evaluation (PROMETHEE), among others. This particular application looks at the validity and suitability for the decision-making in selecting various suppliers of wind turbine support structures. All the methods compared are used extensively in the energy sector, being useful to aid decision-making in the energy field, new technologies, energy sources and have the strength to include both technical and non-technical attributes (Kolios et al, 2016: 2).

Applying these various MCDM methods to the case study of choosing the best supplier for the wind turbine support structure, 10 alternative support structure types were compared based on 10 different criteria. Most methods ranked similarly in getting to the most appropriate solution. The more sophisticated methods, TOPSIS AND PROMETHEE, scored the most accurate result with the rest of the methods also scoring acceptable results, with the exception of PROMETHEE 1 TYPE V and ELECTRE 1. The purpose of this study being to develop a model that can be applied easily by anyone with a limited background in mathematics, the only options that scored acceptable results and would also be easy enough to apply would be WSM and AHP. When these results were then analysed by performing stochastic expansion through Monte Carlo simulations AHP showed to out-perform WSM slightly (Kolios et al, 2016: 15). That being said, AHP would still be the preferred method to apply in this study as it has the most resources and applications available to use.

MCDM problems can be either continuous or discrete. A continuous problem has an infinite number of feasible solutions, whereas a discrete problem has a finite number of alternatives and criteria (Belton, 1986: 7). This study will be an example of a discrete problem, where we have two alternatives with a list of criteria along which these alternatives are to be evaluated.

Belton (1986) compared the AHP to the Multi-Attribute Value theory as to their efficacy in solving discrete problems from both a theoretical and practical standpoint (Belton, 1986: 8). According to Belton, both of these models have been used extensively and successfully in practise and are based on very similar principles (Belton, 1986: 18). Although these two models have significant shared attributes in theory, there are some differences in the practical implementation. As an example below, the way the criteria are displayed graphically in the two models differs, but the results of the analysis did not portray much difference (Figure 8) (Belton, 1986: 10). It is only in the later analysis phase where the differences between the two models become apparent.



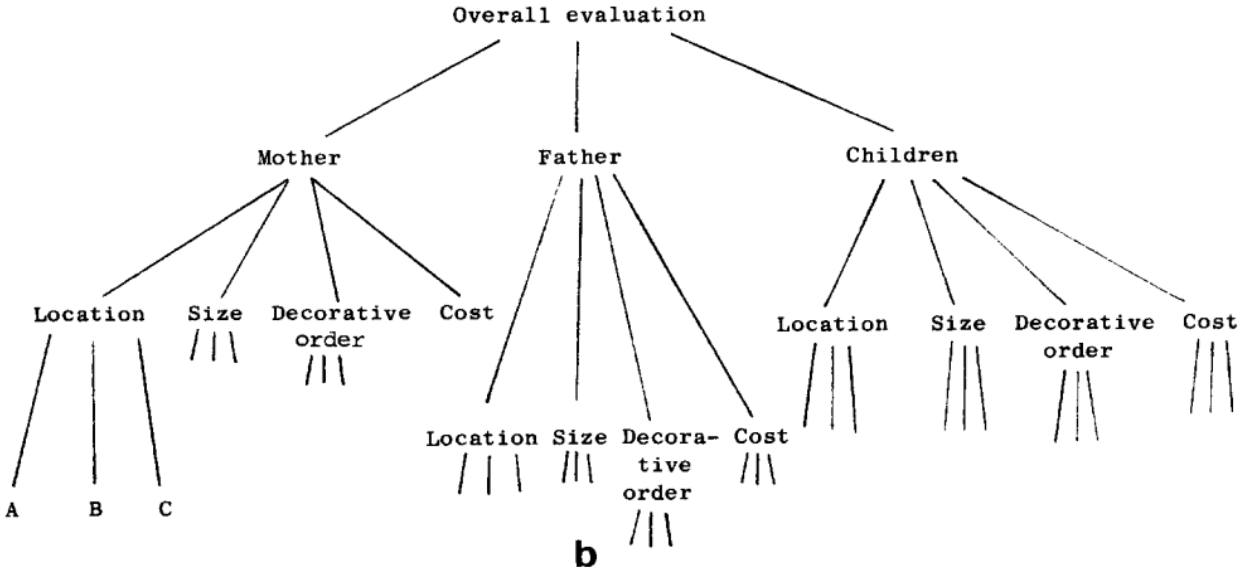


Figure 8: Hierarchical representations of the problem of house purchase. (a) AHP, (b) multi-attribute value function approach (Belton, 1986: 10)

They key differences that were analysed between the models were that the MAV failed to incorporate systematic checks of consistency as the model progressed, whereas Belton suggests that the AHP's reliance on possibly ambiguous weighting of the criteria can present a problem in accuracy of the solution (Belton, 1986: 18). This is a not a unique criticism of the AHP, which is discussed elsewhere along with a proposed solution to mitigate these. The advantages both these models have is that they are easily implementable and understandable by users with limited theoretical knowledge and understanding of the complexities of the problems.

Zanakis et al (1998) also compared several methods for solving multi-attribute decision making problems (MADM). They compared eight methods, namely ELECTRE, TOPSIS, MEW, SAW and four versions of the AHP. The simulation parameters that were used were the number of alternatives, the criteria and their distribution. The different solutions were the analysed according to 12 measures of similarity of performance. The results found that all 4 AHP methods followed similar result as the SAW and TOPSIS methods, with ELECTRE being the furthest removed, followed by MEW (Zanakis et al, 1998: 507). Generally, as the number of alternatives increased, so methods tended to show more similar final weights, yet different final rankings with more rank reversal. All AHP versions showed some rank reversal, but this topic has been discussed elsewhere. This study did not qualify a ranking as to which methods produced the most accurate results; however, it mentioned that all methods were within acceptable tolerances with AHP displaying valuable robustness to deal with the rank reversal (Zanakis et al, 1998: 528).

Again, there are different MCDM methods that have proven to be successful in delivering answers to complex problems, but as can be seen above many of them are more complicated to implement and some of them do not offer many advantages over the AHP. In line with the purpose of this report to make the user part of the model building process and implementation of it, as well as having a method that is robust enough, has proven itself in practise over many years - there is no concern that the AHP is such a method.

2.4.5. Fuzzy AHP

Recent MCDM studies have looked at dealing with the vagueness of human thinking and trying to rationalise and quantify more abstract concepts. Lotfi Zade first introduced the concept of fuzzy set theory (Ertugrul & Karakasoglu, 2009: 784). Fuzzy sets and logic are seen as appropriate tools in modelling abstract and complex concepts and assigning a value to them. Using these fuzzy sets in modelling has "proven to be an effective way for formulating decision problems where the information available is subjective and imprecise" (Ertugrul & Karakasoglu, 2009: 784). Fuzzy logic and numbers also seek to be the link between a linguistic variable as used in the AHP and linking this to a numeric value. Proponents of fuzzy AHP contend that the traditional AHP model cannot reflect the thinking style of the person giving value to the model, seeing that it requires exact values to represent an inexact and complex value set of the expression of the user's vast experience. There is always inherent uncertainty and intuition as part of the pairwise comparison process and Ertugrul and Karakasoglu (2009) argue that Fuzzy AHP is required to address this.

Mosadeghi et al (2014) applied AHP and Fuzzy AHP to an urban design context, where suitable options for land-use planning were to be investigated. The brief was to compare the two with regards to differences in ranking the criteria, differences when the ideal location must be determined, ordering the different options in priorities, overlaying the various analysis and performing a sensitivity analysis (Mosadeghi et al, 2014: 56). The usual process of ranking the criteria in pairwise comparison from values between 1 and 9 was performed by a group of 35 experts from varying backgrounds. These results were fed into a Matlab based computer program and evaluated according to traditional AHP processes. Fuzzy AHP was also employed in this research to deal with uncertainties some of the participants had, where they could specify their attitude as being "optimistic, pessimistic or moderate" (Mosadeghi et al, 2014: 57). These three descriptions would be translated into values of the range of numerical values.

A comparative analysis was carried out to determine the suitability of either approach, alongside a sensitivity analysis. The conclusion reached was that Fuzzy AHP can reach more accurate results in certain environments where the emphasis lies on perceived values and results rely strongly on experience and not so much on measurables (Mosadeghi et al, 2014: 62). Fuzzy AHP can be seen to be less sensitive to weight changes in the criteria. What became apparent, though, is that the traditional AHP might be a bit more sensitive to changes in the criteria rankings, the end result would generally not result in a different option being selected. Traditional AHP will achieve the same result as fuzzy AHP in determining which overall option is to be followed. Fuzzy AHP might assist more in understanding the detail and complexity that the derived option will require after being selected (Mosadeghi et al, 2014: 64).

Fuzzy AHP has been applied by Erensal et al (2006) in technological environments, both in manufacturing and R&D. The challenge they perceived was that many managers did not possess the required technological understanding and skills to comprehend the fast changing environment the companies sit in and to devise adequate strategies (Erensal et al, 2006: 2756). The decision to use fuzzy AHP over traditional AHP was that they felt that fuzzy AHP was more in line with human thinking and that decision makers were more confident to give interval judgment, instead of the singular 1-9 values of the AHP. They point out that fuzziness has always been part of the AHP, with even Saaty having referred to measures of fuzziness. Later on Van Laarhoven and Pedrycz (followed by Buckley) extended on this theory, using fuzzy ratios instead of crisp figures (Erensal et al, 2006: 2760).

Torfi et al (2010) have looked at both AHP, as well as TOPSIS from a fuzzy MCDM approach, citing the reasons that some experts do not feel comfortable in comparing the criteria, sub-criteria and alternatives in the form of exact numbers, but rather in uncertain and fuzzy terms. They suggest to use the fuzzy versions of these in fuzzy environments, where there is fuzzy and inexact data. These kinds of environments rely on intuitive and qualitative data and decision-making and the model employed must reflect the environment and the person within the environment (Torfi et al, 2010: 520). In their research they propose to use fuzzy AHP to determine the final weights of the alternatives and then employ fuzzy TOPSIS in determining the rank of the various alternatives. The strengths of AHP are combined with the strengths of TOPSIS, which is based on identifying the best alternative – being the alternative that is the shortest distance from the positive-ideal alternative (Torfi et al, 2010: 520-521). The conclusion reached by the researchers is that fuzzy AHP and fuzzy TOPSIS can be applied successfully in an environment where the criteria weighting and the performance ratings are vague and not very accurate, as well where the experts used I the comparisons prefer to work with fuzzy values, rather than exact numbers.

Fuzzy MCDM and fuzzy AHP have been proposed by Hsieh et al (2004) in determining tender awards for new buildings. Their assertion is that the selection of the appropriate service provider in the planning and design phase of a project is of critical importance in the success of the project that this decision has to receive the gravity is requires. Again, this decision-making process sit within an environment relying on both qualitative as well as quantitative data, whereas the decision takers come from a varying background of both expertise, education and cultural values (Hsieh et al, 2004: 574). They also propose to use linguistic variables, rather than numerical. Linguistic variables are words or sentences that can easily be understood and used by a participant that does not have a working relationship with numerical values. Hsieh et al (2004) use the following terms when comparing two criteria with one another, rather than the 1 to 9 of the traditional AHP: "absolutely important, very strongly important, essentially important, weakly important and equally important" (Hsieh et al, 2004: 576). These verbal terms then get translated to the traditional AHP scale as indicated below in Figure 9:

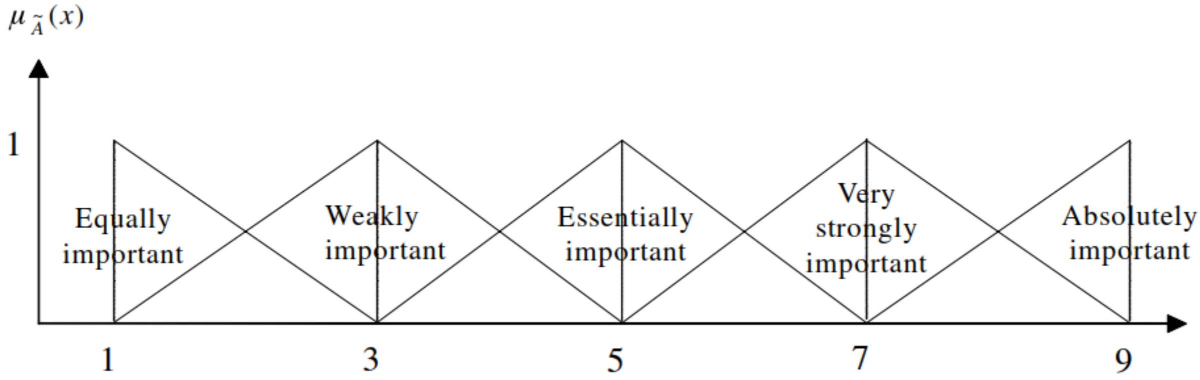


Figure 9: Membership function of linguistics variables for comparing two criteria (Hsieh et al, 2004: 576)

Along with this, linguistic variables are also used when comparing and measuring the performance value of the different alternatives for each criteria. These triangular fuzzy numbers (TFN), as shown in Figure 10, "indicate the membership functions of the expression values" (Hsieh et al, 2004: 576).

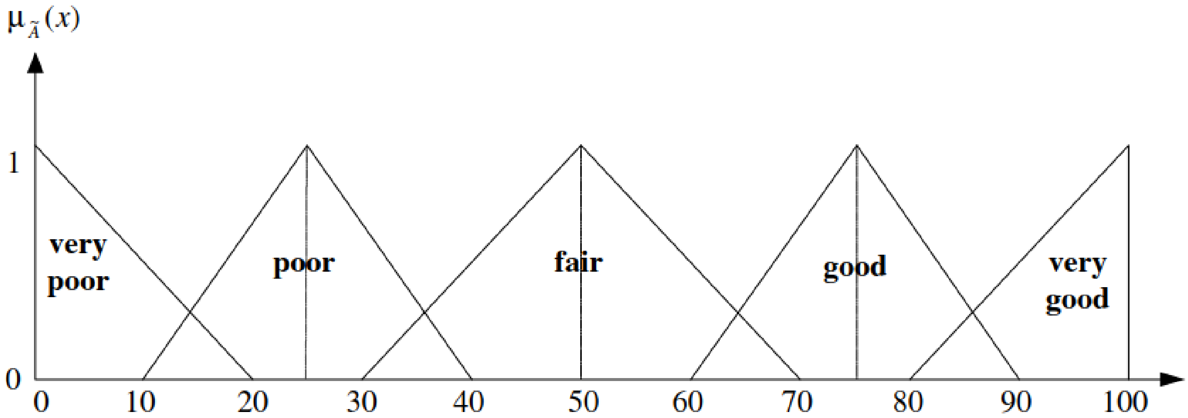


Figure 10: Example of membership functions of linguistic variables for measuring the performance values of alternatives (Hsie et al, 2004: 577)

Generally speaking, fuzzy AHP requires much more computation and analysis, which for this research report was not the goal. Also, the kind of participants chosen in this report all have strong relationships with and feel comfortable in using strong numerical values. There has been little dispute from any AHP practitioners and theorists that fuzzy AHP has a strong position in a fuzzy environment or an environment where the users do not feel comfortable in deciding along clear parameters, but neither do fuzzy AHP advocates deny the value and strength of the traditional AHP.

2.4.6. The AHP Process

To understand the theory behind and the application of the Analytic Hierarchy Process this portion of the study will focus mostly on primary sources as published by the originator of the AHP, Thomas Saaty –

along with some collaborators he directly published with – as well as valuable insights from Matteo Brunelli, who offers substantial and recent commentary on this topic. The first version of the AHP was developed by Saaty in the 1970s, but this has been studied extensively and been refined by Saaty himself as well as other collaborators up to current times. In essence, though, the principles still remain the same.

The premise the AHP is built on is that all humans are decision makers and our lives are composed out of taking decisions in order to survive, from the most basic to the more complex. One of the fallacies is that the more we know the better our decisions are – this will only be true if the information gathered can actually be understood and analysed in such a way as it contributes to making correct decisions (Saaty 2008: 83). Quantity of information only becomes useful if the inherent quality can be distilled and understood. There has always been a drive to measure the world in its physical as well as psychological realms. The tangible and measurable (visible) potion of this realm has for some time been easily measured, it is the intangible and abstract component that has been lagging behind (Saaty 1987: 161). The search has been to find a method in which both these realms can be measured without compromising either of them and this is where Saaty suggests the AHP can satisfy this requirement (Saaty 1987: 161). Saaty suggests that "numerical measurement must be interpreted for meaning and usefulness according to its priority to serve our values in a particular decision. It does not have the same priority for all problems. Its importance is relative." (Saaty 2008: 161).

Saaty asserts that "deductive thinking is not natural" (Saaty 1994: 21) and requires a decision making process to be easy to use, be adaptable to all kinds of users, be natural and easily followed intuitively, aid reaching of consensus and must not need large degrees of specialisation to implement. In practise it has been found that many problems require a vast set of knowledge and expertise to be understood. This level is seldom available by one person and even if this would be the case then to synthesise all this amount of knowledge and derive a solution to the problem does not come naturally (Saaty 1994: 21).

The AHP's main strength is about breaking down this problem into easily analysable portions, coming up with solutions for each sub-set of problems and then aggregating these solutions into a final conclusion. The AHP responds to the natural human ability to make judgements on smaller problems, regardless of the decision takers background and level of education. The AHP is guided by three principles, namely "decomposition, comparative judgements and synthesis of priorities" (Saaty 1987: 163). The decomposition part deals with structuring the problem into the its individual components, working down the structure and having the various elements on the various levels function independently from one another. This breaking down of the structure also points to the dependencies within the problem, being either functional or structural dependencies. The principle of comparative judgement deals with the pairwise comparison of the relative importance of the elements in a certain level with the shared or perceived elements of the level above, thereby creating the matrix that will be shown below. This matrix has its own corresponding principal eigenvector. The third principle is that of synthesizing all the priorities in the matrix by working from the second level downwards and multiplying the local priorities that have been identified for each level by the corresponding criteria in the level above it (Saaty 1987: 166).

The AHP process has been described by Saaty clearly in his 2008 article, which will be quoted below:

1. Define the problem and determine the kind of knowledge sought.

2. Structure the decision hierarchy from the top with the goal of the decision, then the objectives from a broad perspective, through the intermediate levels (criteria on which subsequent elements depend) to the lowest level (which usually is a set of the alternatives).

3. Construct a set of pairwise comparison matrices. Each element in an upper level is used to compare the elements in the level immediately below with respect to it.

4. Use the priorities obtained from the comparisons to weigh the priorities in the level immediately below. Do this for every element. Then for each element in the level below add its weighed values and obtain its overall or global priority. Continue this process of weighing and adding until the final priorities of the alternatives in the bottom most level are obtained. (Saaty 2008: 161)

Point 1 has been covered elsewhere and is easily implemented. Point 2 deals with the process of structuring a hierarchy for the model. This is the creative process of creating the model and the strength of the hierarchy has a direct correlation with the eventual conclusion. When creating the hierarchy of the model, Saaty says this must be guided by the question: “Can I compare elements on a lower level using some or all of the elements on the next higher level as criteria or attributes of the lower level elements?” (Saaty 1994: 22). An easy way in which to structure the hierarchy is to start at the top, with the goal in mind and then move down from there to break it up into more manageable parts until the most basic components that can be adjudicated the easiest are found.

Some suggestions Saaty has in building a strong hierarchy are the following: “(1) Identify the overall goal. What are you trying to accomplish? What is the main question? (2) Identify the subgoals of the overall goal. If relevant, identify time horizons that affect the decision. (3) Identify criteria that must be satisfied to fulfill the subgoals of the overall goal. (4) Identify subcriteria under each criterion. Note that criteria or subcriteria may be specified in terms of ranges of values of parameters or in terms of verbal intensities such as high, medium, low. (5) Identify the actors involved. (6) Identify the actors' goals. (7) Identify the actors' policies. (8) Identify options or outcomes. (9) For yes-no decisions, take the most preferred outcome and compare the benefits and costs of making the decision with those of not making it. (10) Do a benefit/ cost analysis using marginal values. Because we are dealing with dominance hierarchies, ask which alternative yields the greatest benefit; for costs, which alternative costs the most, and for risks, which alternative is more risky." (Saaty 1994: 22).

It is often asked on how much information should be included in the hierarchy and here Saaty suggests that the hierarchy must be complex enough to capture the situation of the problem, but it must also be small and responsive enough to adapt to any changes that might and will occur (Saaty 1987: 163).

An example of what a typical hierarchy could look like when purchasing a car has been put forward by Mu and Pereyra-Rojas (Figure 11). The example used in this report to explain the AHP process is based on this example, using the purchase of a house instead and throughout the discussion this example will be referred to:

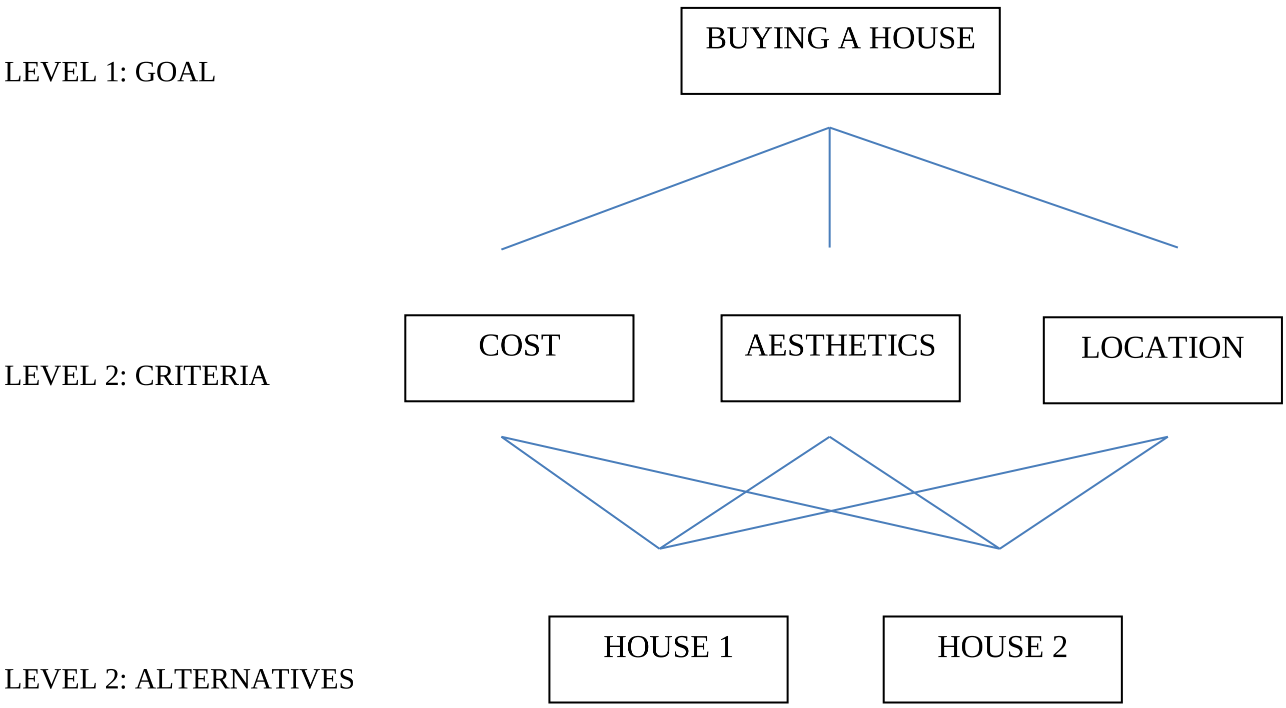


Figure 11: Example of typical hierarchy for decision on buying a house (Based on Mu and Pereyra-Rojas (2017): 8)

A more intricate example of a hierarchy is an example put forward by Saaty in Figure 12:

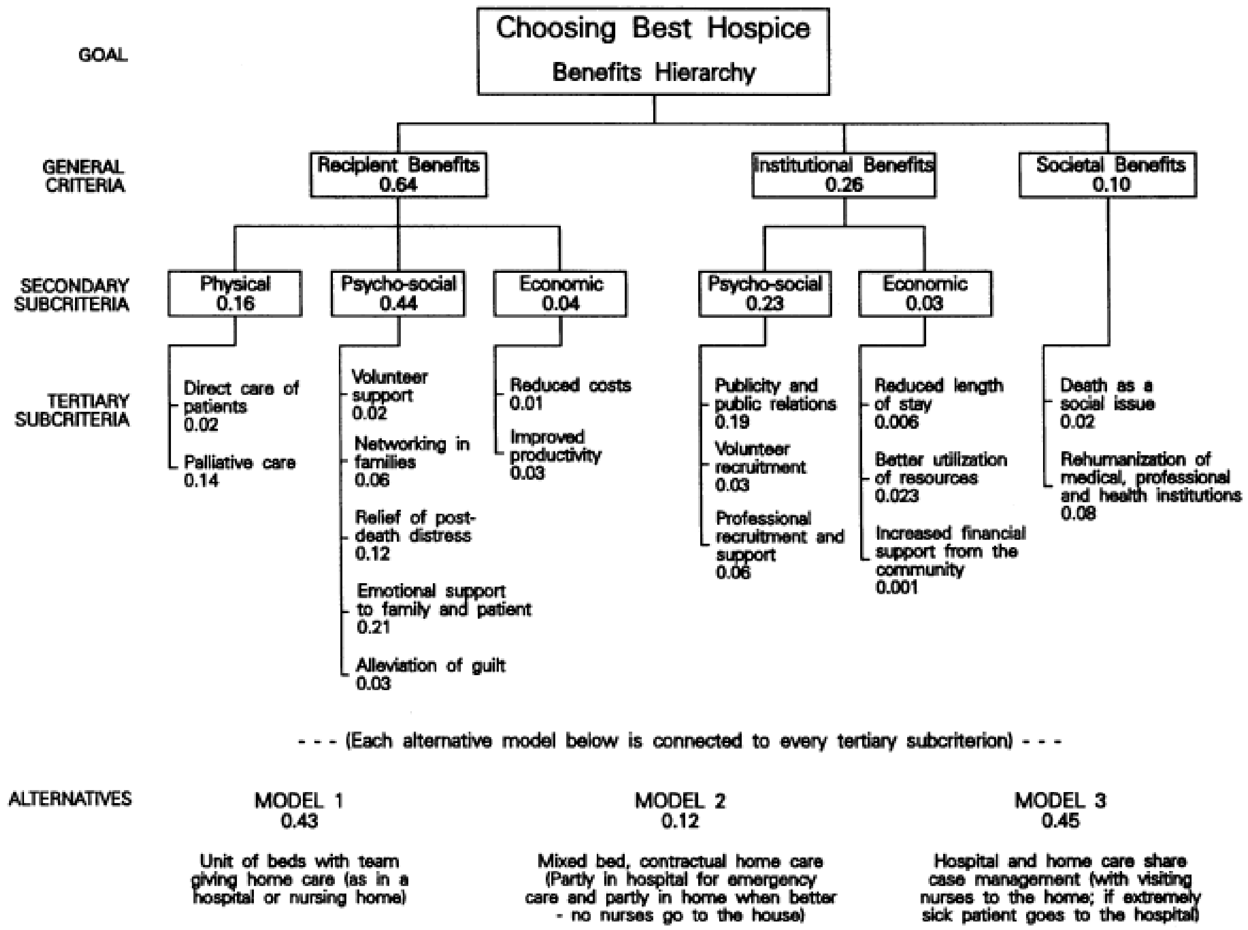


Figure 12: Example of hierarchy for choosing of the best hospice (Saaty 1994: 24)

Both of these hierarchies show how the criteria descend from the more general to the very detailed going down the levels of the alternatives. The nature of the problem determines what amount of levels will be necessary to understand the problem. In more complex problems this is also the step where experts might be consulted in ensuring that the correct amount of detail is added to the hierarchy. The hierarchy is also a graphic representation of the problem and the relationships between the elements.

Point 3 of the AHP process is the process of pairwise comparisons inside the established matrix. In order to make comparisons between two elements or components a numerical scale is suggested to decide how many times more important one element is over the other (Table 9). There have been some suggestions to change this measure, as has been discussed elsewhere in the report.

Table 9: The fundamental scales of absolute numbers (Saaty 2008: 86)

Intensity of Importance	*Definition*	*Explanation*
1	Equal Importance	Two activities contribute equally to the objective
2	Weak or slight	
3	Moderate importance	Experience and judgement slightly favour one activity over another
4	Moderate plus	
5	Strong importance	Experience and judgement strongly favour one activity over another
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favoured very strongly over another; its dominance demonstrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favouring one activity over another is of the highest possible order of affirmation
Reciprocals of above	If activity *i* has one of the above non-zero numbers assigned to it when compared with activity *j*, then *j* has the reciprocal value when compared with *i*	A reasonable assumption
1.1–1.9	If the activities are very close	May be difficult to assign the best value but when compared with other contrasting activities the size of the small numbers would not be too noticeable, yet they can still indicate the relative importance of the activities.

When performing the pairwise comparison of all the criteria identified in the hierarchy, a comparison matrix must be created of all these (Mu & Pareyra-Rojas, 2017: 10) In this process each level of the hierarchy is processed on its own and will form its own weighting. When going through the process of pairwise comparison one always starts with deciding by how much more one element is that the other and then fills in the reciprocal value with the lower ranked version. The process of comparing elements is a numerical representation of the relationship between these 2 elements. Each judgement performed shows the relationship of the dominance of one element over another and also indicates at what magnitude this dominance is viewed by the judge (Saaty, 1994: 22). What is important when doing these comparisons is to always use the lesser element as the unit and then decide by how much the dominant element is more important than itself.

When all the paired comparisons have been completed for the matrix the final step of the AHP process can commence. Not all criteria have the same importance and thus the relative priorities/weights of the criteria need to be established. For the purpose of this report and to explain the process of pairwise comparison more easily, we will refer to an example of buying a house and use Mu and Pareyra-Rojas (2017) process description loosely to develop the model. The detail of this process can be found under Appendix A.

What must be remembered is that the overall priorities will to a large degree be influenced by the weights that were given to the respective criteria. To take this into account and measure by how much the overall result would have changed a process called a sensitivity analysis is carried out. This process is important in determining how robust the model developed is and how trustworthy the final results are. It determines the stability of the inputs of the users, which in nature will always be subjective. In mathematical modelling this analysis looks at how the output of a mathematical model would react to possible variations in the inputs (Brunetti, 2015: 67).

After the process discussed under Appendix A has been completed, the final recommendations can be made. Again, all results must be analysed on whether they fall within the expected parameters and any unexpected results must be analysed and the model interrogated. The sensitivity analysis also gives the results an added advantage to advise under which conditions the lesser favoured alternative could actually become the more desired on. The eventual suggestion must always leave room for interpretation and can also formulate goals that can be worked towards to change the resulted suggestion, should this be required in some situations.

CHAPTER 3
Research Methods

This chapter describes the research methods that were employed to arrive at the objectives of this study. A combination of convenience sampling and snowball sampling was employed to compile the group of specialists, with the focus being on trying to get a diverse group in technical background, demographics and experience. The guided questionnaire process was interactive with feedback to test consistency of answers and consensus amongst respondents built into the process.

The data collected in the guided survey questionnaire process underwent a thematic analysis identifying patterns amongst the responses of participants, both to look for consistencies, as well as finding matrices that were not consistent. Reliability of research was ensured by only one person administering all questions and interviews so that there was no misinterpretation from a third party. The measure to test consistency is inherently built into the AHP process by means of the calculation of the Consistency Ratio, which also aids in ensuring the reliability of the data. Additionally, a Sensitivity Analysis was carried out to verify this.

3.1. Research Design

The way in which this research report was set up was to work towards the eventual goal of answering the critical research question:

How can a model be developed to measure the required skills at the feasibility stage of projects in the energy sector?

In order to reach this goal, the AHP was identified (in chapter 2 sections 4.2 and 4.4) as a possible tool to reach this objective and it was analysed for its strengths and weaknesses, compared to other MCDM methods, its previous applications and methods proposed. The final result was decided that it does fulfil the requirements to reach the objectives of this study. The nature of the AHP being a model that aids decision-making in both the physical and psychological domains by offering a non-linear framework that can carry out both deductive and inductive thinking (Saaty, 1987: 161), there will always be a focus on qualitative and quantitative data collection. Both Saaty's scale and Pohjonen's balanced scale link linguistic expressions to numerical values (Brunelli, 2015: 20), yet the decisions still rely strongly on the values and experience of the decision-maker. The consistency was tested at the end to ensure the accuracy of the decision-maker's choices.

To build this model the process as described by Saaty (1987) was followed, with some additions from Mu and Pereyra-Rojas (2017), in order to develop the hierarchy and its associated components. The first step was to perform a documentary analysis of all the literature that forms part of the study. This research helped to determine the criteria that form part of the AHP model to be developed. Along with the documentary analysis, questionnaires and semi-structured interviews with industry specialists were used to develop the criteria further, construct the pairwise comparison matrices, determine the overall priorities and discus these along with the various alternatives to verify the data and test the model. The final results were also discussed in relation to the expected results and possible future studies.

Graphically, this process can be displayed as follows, showing the overall steps on the one side and the tasks needed to complete each step next to them (Table 10 below):

Table 10: Below: AHP process followed in research report

DEFINE PROBLEM	• refer to CRQ and objectives
STRUCTURE THE DECISION HIERARCHY	• compile list of criteria according to lit review, CRQ and objectives • send guided survey questionnaire to specialists and update criteria if necessary • start with goal and then structure levels of criteria, secondary criteria, etc. • continue hierarchy until it is complex enough to capture the problem, yet small enough to remain responsive
CONSTRUCT PAIRWISE COMPARISON MATRICES	• hold interviews with specialists to determine weighting and priorities of criteria • base weighting both on literature studied, as well as industry specialist • do pairwise comparisons for all levels of the hierarchy
DETERMINE OVERALL PRIORITY	• normalise the comparison matrix • obtain final priorities • present final priorities relative to original matrix • calculate consistency ratios and determine whether it is acceptable
OBTAIN FINAL PRIORITIES OF ALTERNATIVES	• derive local priorities for alternatives • determine overall priorities for each alternative • perform sensitivity analysis • determine final outcome of alternatives
RECOMMEND-ATIONS	• interpret final results • compare results to expected outcomes • formulate goals

3.2. Sampling

3.2.1. Population

The population identified to participate in this study all stems from industry experts with knowledge in the electricity industry, all with professional engineering degrees. The natural inclination would be to invite only electrical engineers, but since all electricity generation projects require a full spectrum of professional services and the skills shortage occurs across all these disciplines.

3.2.2. Sampling Method

Non-probability sampling methods were used – more specifically, a combination of convenience sampling and snowball sampling (referrals) techniques (Babbie & Mouton, 1998: 166). The questionnaires were sent via e-mail or in person, whereas the interviews were conducted either in person or telephone.

For the purpose of this study the choice of participants fell on the following persons on Table 11:

Table 11: Sample that took part in guided survey questionnaire

ID	Job Title	Experience	Sex	Experience Level
1	Electronic Engineer + Project Manager	Electronic + Electrical Engineering expertise, Project Management expertise	Male	Senior
2	Electronic Engineer	Electronic Engineering experience on power plants	Male	Senior
3	Structural Engineer	Structural Engineering experience on power plants	Male	Mid-level
4	Mechatronic Engineer	Mechanical and Electrical Experience	Male	Junior

It was also important to invite a spectrum of ages and experience levels. Unfortunately, this group is not as diversified gender-wise, which was as a result of the non-availability of a mid-level electrical engineer that was identified at an earlier stage. Altuzarra et al (2008) suggest that the population should not exceed 10 participants in order for the process to be fluid and reactive. A minimum number of participants has not been suggested, but the examples in the literature (Saaty, 1987, 1994, 2008) have given acceptable results from 3 participants onwards. The consistency ratio along with the sensitivity analysis ensured that the 4 participant sample size of this study delivered acceptable results.

In any AHP process the problem investigated will determine the mix and characteristic of the participants involved. The balance between enough participants and not having enough always remains important (Basak & Saaty, 1993). For this study the assessment was that four participants should be sufficient, given their varied background and experience levels. The value of the results is as a result of the aggregated results of all participants and not just certain individuals.

There was in initial idea to also rank the participants with regard to how much each participant's decisions should weigh into the overall, with factors such as experience level and experience specific to the problem at hand, but this was decided against. It was felt that the AHP process should compensate for this and this would pre-empt the result too much and possibly influence the final recommendations.

3.3. Instrumentation

The information gathering from the industry specialists comprised of a guided survey questionnaire that was carried out individually with each specialist. This was in the form of a questionnaire that was sent to each individual and then a verbal explanation of the background of the study, the AHP process, what the components are and how the criteria influence this. The answered questionnaires are published in the appendix of this report.

The purpose of this process with the industry specialists was to have them create the link between the literature study and practical experience. The study being composed out of both qualitative and quantitative data, the specialists were looked at homogenising the two. Their input was used to determine the final priorities and weightings of the model and then aggregate these to reach the choice of an alternative.

3.4. Data Collection and Analysis Procedures

3.4.1. Letter of Consent

Ethical clearance had been issued by the faculty prior to this process and the participant information sheet was e-mailed to each participant along with the letter of consent prior to any further engagement. Once the signed letter of consent was received back, either by e-mail or in person, questionnaires was sent to the relevant participant and the guided survey questionnaire process was started.

3.4.2. Definition of the Problem

The problem must be defined to determine what kind of knowledge must be sought to build the model and its associated hierarchy. The critical research question gives some guidance as to what the underlying problem was that had to be solved:

How can a model be developed to measure the required skills at the feasibility stage of projects in the energy sector?

The underlying problem statements that gave rise to this CRQ were derived from the literature by performing a thematic analysis to identify recurring themes amongst the various authors. Other potential problem statements were identified, but only the ones mostly in line with the objectives of this study and scoring the highest number of mentions within the literature were decided to be included. The four statements selected were the following:

Severe skills shortages exist in both the non-renewable and renewable sectors with regards to professional engineers

Lack of skills might mean that these projects are terminated in the feasibility stage of the project because the skills either are not available locally or need to be sourced internationally at an unaffordable rate

Feasibility studies naturally focus mainly on economic factors, but the level of skills is seldom considered

Government institutions need to accept accountability for how they are implementing official policy, also with regards to their targets of skills development

At the core of this lies a need to develop a model that can compare different electricity generating project options with one another, taking into account the skills inherent in each project and to decide which of the options rates the most favourable in that requirement. This is also in response to objective A, which is:

"To determine a list of skill categories inherent in a typical energy construction project to determine the criteria that form part of the model".

Again, a thematic analysis was performed to identify similarities between the various authors. Whereby the initial list was largely influenced by Energy & Utility Skills Limited (2018) and International Labour Office Research Brief (2011) on a general and global level, Lomey and McNamara (2007), McKechnie and Bridgens (2008), Kessides et al (2007), Nijikelana (2012), Reddy (2016), Forsyth (2016) and Baker et al (2015) aided in contextualising it for the South African Energy Sector.

This resultant list of skill categories that was identified also determined the criteria that forms part of the model hierarchy and was tested against the objectives of the study to reduce any research bias. The criteria scoring the highest on both these requirements was determined to be the following:

- Complexity of skill is required to implement a project
- Potential a project has in aiding skill transfer for Small, Medium and Micro-sized Enterprises (SMMEs)
- Potential a project has in providing mentorship to younger engineers
- Potential for skills transfer inherent in a project
- Current availability of skills to implement a project
- Potential a project has in generating new fields of skills at educational institutions
- Potential a project has in supporting students at tertiary institutions, both financially as well as with training, vacation work
- How much inherent potential there is for a project to comply with Government skills development objectives and legislation
- Potential a project has in generating or improve skills at municipal levels
- Potential a project has in generating new types of skills for the electrical industry
- Amount of experts that are currently available in SA to train junior staff and students
- Amount of training facilities currently available in SA to train staff and students
- Potential in providing some opportunities for private sector partnerships and skills transfer with a project
- Potential for a project to drain skills in other vital sectors

These components will be used to structure the criteria and sub-criteria of the hierarchy.

3.4.3. Structure the Decision Hierarchy

The way the hierarchy was developed followed most of the methodology proposed by Saaty (1994), where this was aligned with the overall objectives. Some of the points Saaty suggests refer to fuzzy applications, whereas others are suggestions for multi-level complex hierarchies, which this model is not an example of. As stated, the purpose of the hierarchy was to involve the participants in the process and not to focus on just generating quick answers with heavily computated models. The hierarchy developed is complex enough to capture the problem that is being investigated, but still small enough to be understandable by all and be responsive to their inputs.

Saaty's suggestions that were used in developing the hierarchy were:

3.4.4. Identify the Overall Goal

In this section Saaty suggests to ask the questions: "What are you trying to accomplish? What is the main question?" (Saaty, 1994: 22). For this study various goals were discussed. Depending on the goal, the hierarchy would also change. Depending on the wording of the question and where the emphasis is placed the outcome could change. Based on the purpose of the study, the QRC as well as the underlying problem statements the following was decided to be the goal of the AHP hierarchy (Figure 13):

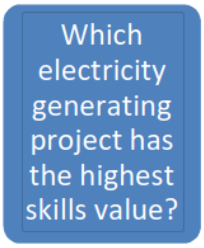


Figure 13: Goal of the AHP hierarchy

The CRQ looks at developing a model that can estimate a project's required skills value at the feasibility stage of a project with the objective of applying this model in a "real-world example by comparing three energy options with each other". In order to fulfil this objective, each of the three energy options must be compared by measuring the skills value of each one of them at tender stage and then determining which one of the options has the highest value. Thus, by searching for the electricity generating project that has the highest skills value, invariably the objective to estimate the required skills at the feasibility stage of a project must be met in order for this goal to be achieved.

3.4.5. Identify the Criteria and Sub-criteria

Here the criteria were identified that had to be satisfied for the main goal to be fulfilled. On the third level of the hierarchy the sub-criteria were identified that fall under each criteria that are used determine the weighting of this criteria.

The criteria identified to form part of this hierarchy have been chosen from the list under 3.4.2, where the skills inherent in a project were based on the categories identified, informed by the literature and specialist opinion. Not all the categories identified formed part of this specific hierarchy, firstly because the hierarchy could not be too complex to lose its interactive and reactive nature and secondly, some of the categories are already contained in the goal formulation, whereas others would form part of the sub-categories. Only the criteria that felt to mostly contribute to the solving of the problem was chosen.

The criteria identified from this list that should form part of the hierarchy are listed below:

- Potential for skills transfer inherent in a project
- Current availability of skills to implement a project
- How much inherent potential there is for this project to comply with Government skills development objectives and legislation
- Potential a project has in generating new fields of skills for the electrical industry

The criteria will be represented graphically as follows, also indicating the dependencies between the levels with the lines between the different elements:

Figure 14: Criteria of the AHP hierarchy

The process to determine the sub-criteria that fall under these criteria can be guided by the question "Can I compare elements on a lower level using some or all of the elements on the next higher level as criteria or attributes of the lower level elements?" (Saaty, 1994: 22). The principle of comparative judgement deals with the pairwise comparison of the relative importance of the elements in a certain level with the shared or perceived elements of the level above, which will lead to the homogenous matrix that will represent the hierarchy, composed out of all qualitative and quantitative data that forms part of the goal. Also, here an item was introduced whereby sub-criteria can also be in the form of a value judgement and not only a specific criteria. This can be found under the last criterion listed.

Again, different sub-criteria could have been chosen, but in line with the rationale for choosing the specific criteria the eventual sub-criteria decided on represented the core components the literature and specialists perceive to be part of the problem. Sub-criteria that fall under the main criteria are listed below, each sub-criteria also having an abbreviation that was used in the matrices developed (Figure 15).

Potential for skills transfer inherent in a project

- potential for this project in aiding skill transfer for SMMEs (ST)
- potential for portable skills that can be generated by this project that can then be applied in different sectors (PS)
- potential for this project in providing mentorship to younger engineers (MJ)

Current availability of skills to implement this project

- current availability of senior skills for this project in SA (SS)
- current availability of junior skills for this project in SA (JS)
- necessity to import senior skills internationally (IS)

How much inherent potential there is for this project to comply with Government skills development objectives and legislation

- Skills Development Act, Accelerated and Shared Growth Initiative for South Africa and the Joint Initiative on Priority Skills Acquisition (LA)
- involvement of local community, focusing on skills transfer to take place, not financial benefit (LC)

Potential this project has in generating new types of skills for the electrical industry

- o High likelihood (HL)
- o Low likelihood (LL)

Figure 15: Sub-criteria of the AHP hierarchy

3.4.6. Identify the Alternatives

For the purpose of this study three typical alternatives were selected that were based on the expertise of the specialists that formed part of this study (Figure 16):

- Coal-fired Power

- Nuclear Power
- Wind Power

Figure 16: Alternatives of the AHP hierarchy

3.4.7. Compile Final Hierarchy

Combining all the separate levels that form part of the hierarchy yields its final form (Figure 17). It is a homogenous structure showing dependencies and relationships between the various elements in the model, showing how the criteria descend from the more general to the very detailed going down the levels of the alternatives. The nature of the problem determines what amount of levels will be necessary to understand the problem, ensuring that the correct amount of detail is added to the hierarchy. It is complex enough to understand the problem, yet simple enough to remain responsive.

It responds to the four AHP axioms of reciprocal judgments, homogeneous elements, hierarchic or feedback dependent structure, and rank order expectations (Saaty, 1986). The homogeneity requirement of the AHP requires elements that have different orders of magnitude that must be grouped together and then linked with each other in order to compare them. One would not compare elements of very differing magnitude directly with one another, but rather in gradual steps along a logically formed path that links them.

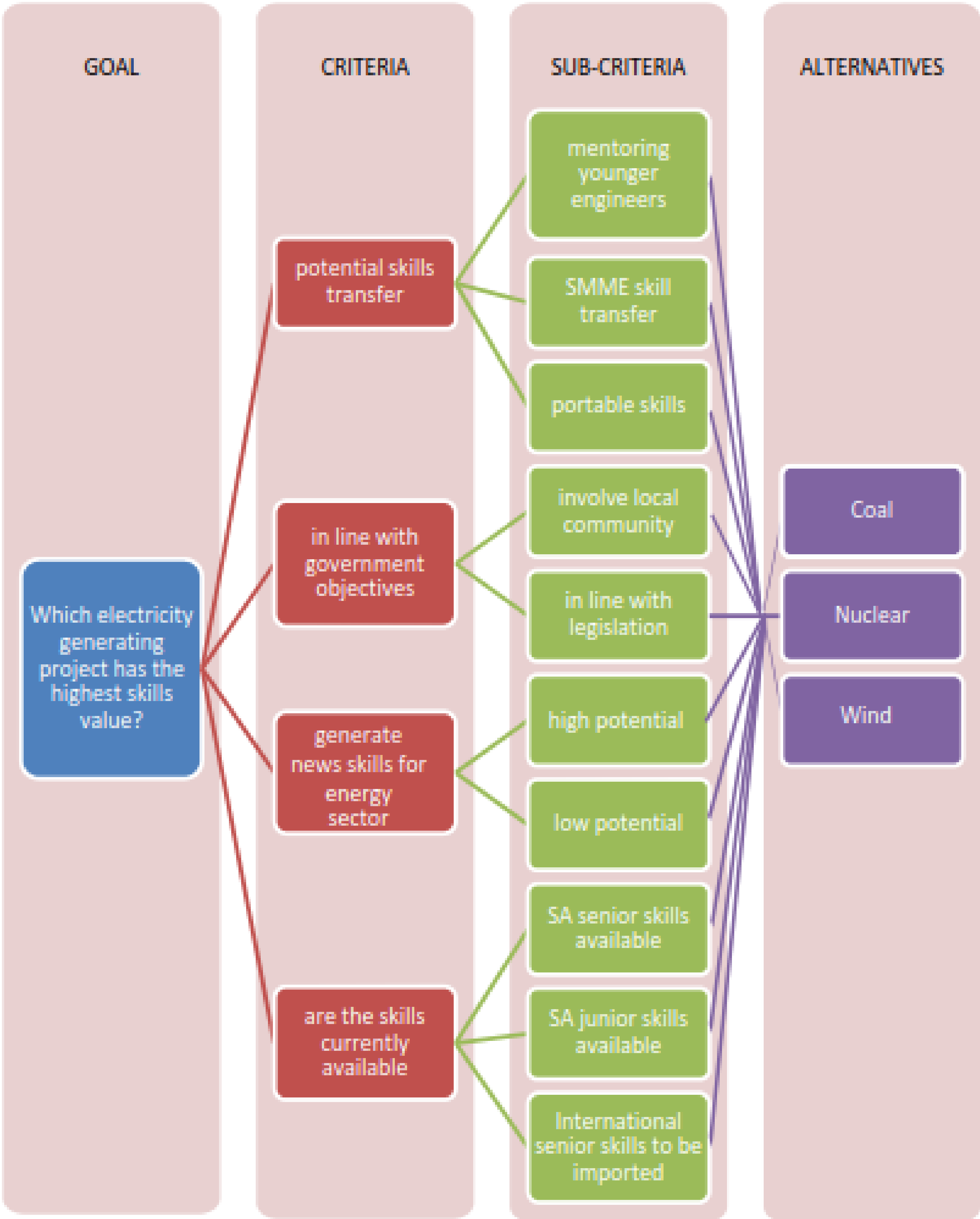


Figure 17: Final AHP hierarchy that was used in this study

3.4.8. Design of Spreadsheets

When the decision had to be made in which form the AHP process would take on, the main criteria was which software design was appropriate to deliver the process acceptably. Various software packages exist that are based on the AHP process, ranging from expensive software such as Expert Choice and MakeItRational, to lighter on-line versions like Sourceforge. Thomas Saaty's company has also developed a software called "Super Decisions", which turned out to be very cumbersome. What all of these software packages had in common is that they were not transparent enough and generally had a discord between entering of the criteria and the pairwise comparison process and evolving at the final answer. There was no way of interrogating the results, looking for consistencies between participants and carrying out a useful CR exercise. Especially in this study where the process to arrive at the eventual answer was equally important as reaching the final rankings a different approach had to be followed that allowed input and analysis all along the way

It was thus decided that the correct way was to create a set of spreadsheets based on Goepel's AHP spreadsheet (Goepel, 2013) and spreadsheets created by the researcher. This process had the advantage of creating a matrix for each pairwise comparison that could accept multiple users and create an aggregated matrix. The aggregation of the individual judgements was done by using the weighted geometric mean of the elements of the individual matrices. The parameters that were important for this study that could be read from this spreadsheet were:

- **Consistency Ratio**: the CR was first calculated for each individual set of pairwise comparisons for every participant. The separate CRs were then aggregated into a combined CR and indicated whether this aggregated value fell below the 0.10 acceptable value. By calculating the individual CRs per participant made it easy to understand which of the participants contributed the greatest should the aggregated CR fall beyond the acceptable parameters. This then made it possible to revisit those comparisons and determine whether they have been inserted correctly by that participant or whether the weightings are accurate. It was important to only be guided of where to investigate, but not on how to change the values to fall inside the 0.10 threshold. If the CR still remained above the 0.10 value then this would be accepted as such and worked into the model, the CR is not an indicator of the accuracy of the data.

- **Consensus**: The spreadsheet had the ability to indicate the consensus between all the participants and is calculated based on the row geometric mean method results using Shannon alpha and beta entropy. A consensus indicator of between 75% and 85% is considered high, whereas anything above 85% very high. This was also a sign of consistency of responses and whether that particular matrix could be considered accurate and valid.

- **Weights**: The weights for every criterion used to compare against each other are indicated on the summary sheet as percentage. This is important in already identifying at an early stage which of the criteria are the most important for that particular matrix, as well as globally. This was evaluated against what the expected result should be and any deviation would result either in re-evaluating the expected result or the possible re-evaluation of the weighting.

After this process was completed a set of 15 consistent weighted matrices was inserted into a spreadsheet indicating the hierarchy and the local priorities of each element on that hierarchy. This was linked to another spreadsheet indicating the global priorities of all the sub-criteria. These global priorities were derived by multiplying the local priorities of the sub-criteria with the priorities of the criteria directly above on the hierarchy. Then there was a set of 10 tables indicating each alternative compared to all the sub-criteria. Again, each table indicated the local and global priorities, derived in the same fashion as previously explained.

All of these tables were then linked to the final spreadsheet that summarised all the other spreadsheets and tables. The final ranking of the 3 alternatives was achieved by aggregating all the derived global priorities for every alternative compared to the sub-criteria. For the sensitivity analysis this sheet was duplicated and through the linking of all the values this analysis could be carried out quickly and responsively.

The advantage of this process described above is that the user has the ability to analyse and guide the process along the whole way. Conversely to some of the more automated software, this process is transparent and does not derive a solution blindly without being able to interrogate bit. This is essential in arriving at consistent and valid answers whose accuracy can be determined at every step.

3.4.9. Guided Survey Questionnaire

3.4.9.1. Questionnaire Development

The guided survey questionnaire (see Appendix D) was developed to directly reflect the hierarchy that was developed, taking into account the overall objective and the criteria and sub-criteria against which the three alternatives are being compared. It converts the process of pairwise comparisons into a set questions, where the person answering the question does not need to know the overall AHP process of where the particular question fits in, but only has to focus on a particular question at a time in isolation.

The questionnaire starts off with an explanation of the background of the study and a brief description of the AHP process. This is followed by an explanation of the fundamental scale with a practical example of how this must be applied. Question 1 compares all criteria identified in 3.4.5 with one another to determine their relative importance with one another. These weightings can easily be converted to local priorities of each of the criteria in the AHP model. Questions 2 to 5 relate directly to the process of comparing all identified sub-criteria as per 3.4.5 with each other relative to their importance towards the criteria directly above them. Again, the values derived in this process can be used directly to calculate the local priorities amongst the sub-criteria. Questions 6 to 15 are a direct translation of the pairwise comparison process of comparing the three alternatives with their relative importance in relation to the sub-criteria to derive at the local priorities.

3.4.9.2. Questionnaire Administration

The questionnaire that was sent out to every specialist participant is included under Appendix D. This questionnaire was accompanied by a verbal explanation of the AHP process and any the manner in which each question was to be answered. The fundamental scale was also discussed, along with examples on how to apply it. At every question the key comparisons were once again pointed out and what the focus of that particular question was. This process proved to be very effective with acceptable results. No participant seemed to have any difficulty in understanding the requirements and the answers confirmed this observation. All filled in questionnaires are included in the appendix as follows:

- Participant 1: Appendix T
- Participant 2: Appendix U
- Participant 3: Appendix V
- Participant 4: Appendix W

3.4.9.3. Survey Process

The guided survey questionnaire was sent out electronically, accompanied by a telephonic or face-to-face brief to the industry specialist as to the background of the study, the principles of the AHP and where the data sought from them fits into the model. Any questions that were asked were answered immediately to ensure that the brief was understood completely. This process ensured that the interactive part was well prepared and each participant was well prepared for the next process.

Two days after the sent questionnaire and preparation material, this was followed up by going through the questionnaire and deciding whether all the criteria were in line with the specialist's opinion. This was done either in person with the specialist or telephonically. After the hierarchy was discussed and the principles of the process discussed, the process of the pairwise comparisons was completed throughout the hierarchy and eventually the alternatives compared to one another and the synthesizing of the group decisions completed as per discussion about the group decision process. At every question the overall objective of the study was discussed and then how this particular matrix fits into the overall goal.

When the consistency ratio of a particular matrix turned out to be outside the accepted 0.1 value, this question was identified and the key inconsistencies sought out. These were then discussed with the relevant participant to decide whether the answers in questions were filled in correctly or there might have been some misunderstandings. At no point were the participants overruled or not consulted. Where they reviewed their answers and decided that they would want to adjust them, these were marked in red on their original answer sheets, the corrections noted and the signed and dated. All these changes are included on the answered question sheets as part of the appendix.

Various options on conducting the pairwise comparison process were considered. At this point the AHP model spreadsheet and calculations had already been developed based on the hierarchy. This would make it possible to key in the weightings and derive the matrices as the criteria are developed, but this option was decided against for two reasons. Firstly, it seemed important to distance the specialist from the weighting process, both in order to not influence any future decisions, as well as taking the focus off the actual question at hand and be distracted by the secondary process. Secondly, the flow of conducting the questionnaire process would be broken by the interruptions between the two programs that the feeling was that this would influence consistency somewhat.

3.4.10. Group Decision Process

The decision on which type of group interaction to use was based on a couple of factors. Basak and Saaty (1993) refer to three types of consensus when group decision-making is involved, namely "spontaneous, emergent and manipulated" (Basak & Saaty, 1993: 109) and suggest a way in which to synthesize group judgements, both in a stochastic, as well as statistical way. The statistical approach would be applied for large groups of people dispersed over vast distances and where the individual decision needs to be weighed against a large volume of other decisions. In this study it was decided to make use of a small group of specialists that would not be linked in a single geographic location and would, thus, give inputs into the model individually. Initially, the possibility for a focus group was considered, but the fact that the specialists were from diverging backgrounds made the risk of manipulated consensus results too large that the individually aggregated approach was followed.

Altuzarra et al (2008) suggest a statistical Bayesian model to analyse disagreements between the different opinions of the participants in order to identify agreement and disagreement zones in the process of consensus building, but this approach would only be necessary for a larger sample of participants.

The approach of synthesizing the group decisions in this particular study followed an approach proposed by Hummel et al (2014). In a context where the most relevant criteria that informs the structuring of the decision hierarchy, with goals, criteria and alternatives that can be found in literature, the suggestion is that the structure is prepared prior to the group session. The same approach was taken in this study with the relevant specialists being invited to add criteria, should they find any lacking in the proposed hierarchy.

For the pairwise comparison process, the specialists were guided by the study leader through the various matrices that were developed from the criteria and compared all criteria and sub-criteria as per AHP method. There are 2 methods to aggregate the results of the group decisions, either aggregating during the pairwise comparison stage or later at the final decision-making stage. There is not much difference in accuracy of these two methods. The first method was chosen, where the results were aggregated for every matrix and the aggregated priority derived for each of them. Here the weights and priorities of the individual decisions were averaged by using the arithmetic mean.

3.4.11. Qualitative and Quantitative Analysis

The data collected in the guided survey questionnaires underwent a thematic analysis to look for patterns amongst the responses of participants, both to look for consistencies, as well as finding matrices that were not consistent. Each matrix had its own Consistency Ratio calculated and where this index exceeded the acceptable parameters that particular matrix was investigated further. Again, the Consistency Ratio is not a measure of accuracy of results, but does offer some guidance on the validity of the data. The matrices in this particular study that were outside the accepted parameters will be discussed later.

Also contained in the spreadsheets used was a measure to determine the consensus between the participants' answers. This was calculated based on the row geometric mean method results using Shanon alpha and beta entropy. A consensus indicator of between 75% and 85% is considered high, whereas anything above 85% very high. Consensus is important to determine the validity and strength of the answer.

The data in the guided survey questionnaires was easily transferred to the study's hierarchy. A set of spreadsheets based on Business Performance Management Singapore's Klaus Goepel's AHP spreadsheet (Goepel, 2013) was created, which made provision for all the different participants' answers to be simultaneously added in the same spreadsheet. Each spreadsheet reprinted one comparison matrix of the complete hierarchy. The further steps of aggregating all the priorities of the matrices, leading up to the final results was done in separate spreadsheets. All sheets were interactive and any changes, either by finding the Consistency Ratio shortfalls, as well as the validity analysis were easily conducted with accurate results. The interactive nature was also important for the sensitivity analysis.

3.5. Reliability and Validity

3.5.1. Reliability

Reliability of research was ensured by only one person administering all questions and interviews so that there was no misinterpretation from a third party. The consistency of the respondents' answers was tested along the way, as discussed in chapter 4, to ensure the reliability of the decision-makers choices. The sensitivity analysis further ensured that no rank reversal would take place. The measures for these parameters are inherently built into the AHP process, with various stops along the way to offer opportunities to interrogate them. If the AHP process is followed as it was designed, it will naturally result in reliable results.

3.5.2. Consistency Ratio

The main tool built into the AHP to test and ensure reliability of the data is the Consistency Ratio (CR). There will always be some measure of inconsistency in an AHP model, which is often not easily known by the decision maker, but the AHP can show in sequential order which judgments are the most inconsistent.

What must be understood is that this increased consistency will not lead to a more accurate set of priorities and accuracy can only be changed by gathering more information and possibly changing the framework of the matrix (Saaty, 1994: 28).

The Consistency Ratio is defined as CR, where CR = CI/RI where CI = Consistency Index and RI = Consistency Index of a random-like matrix. Saaty (1994) has shown that a CR of 0.10 or less is acceptable and one can freely continue with the AHP analysis. Should the ratio be more than that the hierarchy needs to be refined more, in parameters that are still acceptable. To improve the Consistency Ratio, the process proposed by Saaty (1994) was to revisit these matrices along with the participants and go through in detail whether all the answers given were still the ones that the various specialists would give upon further inspection. It could easily be that there were mistakes in filling in the forms or in transferring the information into the model that can influence the consistency.

3.5.2.1. Sensitivity Analysis

When discussing the criticism of the AHP one of the main points of criticism that challenges the reliability of the AHP phenomenon of rank reversal (Brunelli, 2015). Along with this it must be remembered that the overall priorities will to a large degree be influenced by the weights that were given to the respective criteria. To take this into account and measure by how much the overall result could have changed, a process called a sensitivity analysis was carried out. This process is important in determining how robust the model developed is and how trustworthy the final results are. It also determines the stability of the inputs of the participants. The sensitivity analysis formed part of the AHP process of this particular study and is discussed in more detail in the analysis section.

3.5.3. Validity

Validity is also ensured by using a method that has been developed in a framework that already exists and tested over time. Some criticism towards this method has been acknowledged (Kolios et al, 2016) and, where possible, addressed in the study. This also allows for a context-specific generalizability where the results can be applied to contexts similar to the one this study was conducted in.

To ensure that this particular study is actually studying the intended purpose of the study. it was important to form various triangulations with the methodologies employed to ensure that the overlapping areas of the methods employed would point to any possible discrepancies. Again, these measures are mostly built into the AHP process with checks along the way. This process, along with literature and the expert input ensured the validity along the way.

To ensure the validity of the data received, a proper briefing was held with each specialist to ensure that all questions are understood correctly and in the way they were formulated and any shortcomings corrected. If the responses are returned in the way that it was expected then the responses can be trusted. Any results that did not fall within the expected results were analysed further and their validity determined.

3.6. Ethical Clearance

Ethics Clearance for this research report was applied for through the School Ethics Committee and approval was granted with the ethics clearance number MIAEC 119/18.

All guidelines and processes were duly followed in getting approval from all participants prior to any formal engagement in the study. Examples of the letter of consent (Appendix A) and the participant information sheet (Appendix B) are included in the appendices.

All the participants agreed to partake in the study freely, and did not request their identities to remain unknown.

CHAPTER 4

Data Analysis and Results

This chapter analyses the results received from the questionnaires and describes how these results are to be interpreted. It also follows the process of assigning priorities to these results and how the final recommendations are derived.

4.1. Hierarchy Matrices

As described in Chapter 3 Section 4.9 the process of questionnaire administration was a direct representation of the hierarchy that was developed and the related pairwise comparison process. All the results were read into the spreadsheets that were developed and the local priorities calculated. Where results turned out to have a low level of consistency or consensus the process was further interrogated and where necessary the specialist were approached to verify certain answers. In this study there were 3 out of 15 matrices where the outside the 0.10 threshold, which necessitated further investigation.

The consensus between the parties was also monitored for obvious inconsistencies that could point to possible mistakes by a participant in answering a question. This process was followed and one participant immediately realised that he had filled in his one question incorrectly. In this instance all other participants were fully agreeing on all three comparison options – not just difference in weighting - for that particular question, which made it necessary to understand whether the one participant that had a different dominance did so out of mistake or intent. The details of how this and other discrepancies were approached are described below at the relevant matrices.

Below is the summary of each matrix that as developed and the resultant data received. Matrix 1 is published in its entirety, with the other matrices attached under appendices E to R.

4.1.1. Matrix 1

In Matrix 1 (Table 12) the results are displayed when the criteria of the study are compared to one another in relation to the goal. It shows a very high consensus between the participants (91.7%) and a very acceptable CR (6.5%). The results were as expected, with the criteria of “availability of skills” being weighted the highest (46.3%) and “in line with government objectives” the lowest (2%).

With all these in mind and looking at the individual participants’ weightings, there was no need to investigate this further.

Table 12: Matrix 1 – Criteria compared to Goal

n= 4 Number of criteria (2 to 10) Scale: 1 AHP 1-9

N= 4 Number of Participants (1 to 20) α: 0.1 Consensus: 91.7%

p= 0 selected Participant (0=consol.) 2 7 Consolidated

Objective: which of these criteria should be the more important to consider when evaluating a project based on the inherent value of skill it has

Author

Date Thresh: 1E-08 Iterations: 6 EVM check: 9.8E-09

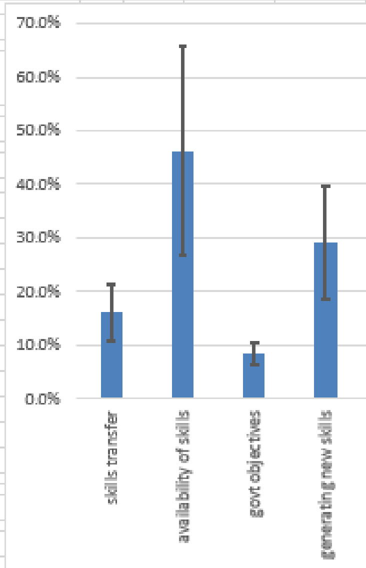
Table

	Criterion	Comment	Weights	+/-
1	skills transfer		16.1%	5.1%
2	availability of skills		46.3%	19.6%
3	govt objectives		8.5%	2.0%
4	generating new s		29.1%	10.5%
5			0.0%	0.0%
6			0.0%	0.0%
7			0.0%	0.0%
8			0.0%	0.0%
9		for 9&10 unprotect the input sheets and expand the	0.0%	0.0%
#		question section ("+" in row 66)	0.0%	0.0%

Result

Eigenvalue Lambda: 4.178 MRE: 34.2%

Consistency Ratio 0.37 GCI: 0.23 Psi: 8.3% CR: 6.5%



Matrix		skills transfer	availability of skills	govt objectives	generating new skills	0	0	0	0	0	0	normalized principal Eigenvector
		1	2	3	4	5	6	7	8	9	10	
skills transfer	1	1	1/5	2 3/5	2/3	-	-	-	-	-	-	16.11%
availability of skills	2	4 4/5	1	4 4/5	1	-	-	-	-	-	-	46.27%
govt objectives	3	2/5	1/5	1	2/5	-	-	-	-	-	-	8.53%
generating new skills	4	1 1/2	1	2 3/5	1	-	-	-	-	-	-	29.09%
0	5	-	-	-	-	1	-	-	-	-	-	0.00%
0	6	-	-	-	-	-	1	-	-	-	-	0.00%

4.1.2. Matrix 2

In Matrix 2 (Appendix E, Table 39) the sub-criteria relating to “skills transfer” were compared to one another. The consensus between the participants was slightly lower, but at 80.1 and still “good”. The CR of 6.0% was again acceptable and no concerns could be raised by looking at the individual participants’ weightings. The results were as expected, although the magnitude of the 56.1% for “mentorship of young engineers” was slightly larger than expected compared to the other two sub-criteria.

Nevertheless, there was no reason to not accept the results as they were.

4.1.3. Matrix 3

Matrix 3 (Appendix F, Table 40) was the first matrix where there were some results that required further investigation. The initial results gave a consensus of 73.1%, which is lower than ideal. This on its own would still be acceptable, but the CR of 17.7% was not within the range required to form part of the overall hierarchy and still yield acceptable results.

Further investigation into the results of each participant showed that participant 1 showed both a high CR (14%) (Appendix F, Table 41), as well as little consensus with the other participants. The low consensus led the analysis to believe that there could have been a mistake in the input of data. A further discussion with participant 1 revealed this to be the case and he realised that the wrong criteria of the 2 was chosen as being the more dominant. The revised weighting can be seen in (Appendix F, Table 42, which now shows a CR of 0%.

The other participant identified for further interaction was participant 4, whose answers showed a very high CR of 59% (Appendix F, Table 43). What was immediately evident was the comparison between “senior skills available” and “junior skills available”, whose weighting of 9 in favour of the former was not in line with any of the other participants. Participant 2 was asked to re-evaluate the weightings on that particular matrix and did revise the weighting on that particular comparison, albeit only by 2 (Appendix F, Table 44). This still gave that particular matrix a high CR of 45%, nevertheless the revised overall matrix (Appendix F, Table 45) with all participants aggregated was now acceptable with a very high consensus of 96%, as well as a CR of 9.2%.

All revisions that the participants made to their original weightings can be seen in the appendix. Every change was corrected in red ink and was signed by the participant who adjusted their inputs.

4.1.4. Matrix 4

In Matrix 4 (Appendix G, Table 46) the sub-criteria relating to “government objectives” were compared to one another. The consensus between the participants was low to moderate at 64.5%, but a CR of 0% was very good. There could have been a case for looking for more consensus between the participants, but this would have impacted on the CR, which will mostly supersede the search for consensus.

The results were as expected, with a favouring of the sub-criteria of “in line with government legislation and objectives” and also the magnitude of this over the other sub-criteria was deemed acceptable and no further investigation was warranted.

4.1.5. Matrix 5

Matrix 5 (Appendix H, Table 47) immediately showed that there was no need to investigate it further, with a very high consensus of 92.4% and a CR of 0%. The results were also completely as expected with an overall 80.2% weighting in favour of "high likelihood".

4.1.6. Matrix 6

Matrix 6 (Appendix I, Table 48) was the first matrix that compared the different alternatives to one another, this particular matrix comparing them in relation to "skills transfers for SMMEs". The consensus was very high at 99.1%, but the CR was very close to unacceptable values at 9.2%.

The individual scores were reviewed and no major concerns were identified. This, along with a very expected result of the weightings meant that no further engagement with the participants was necessary to refine the answers.

4.1.7. Matrix 7

Matrix 7 (Appendix J, Table 49) displayed a high consensus of 89.3% and a very good CR of 0.6%, nevertheless a detailed view of all the participants weighting indicated that both participants 2 and 3 had an individual CR of 14%, with both rating nuclear power over wind power, conversely to participants 1 and 4. The dominance chosen was only a 3 on both choices, which did not mean that this would influence the overall CR significantly. Therefore it was decided that no further interaction with the participants on this matrix would be necessary.

4.1.8. Matrix 8

Matrix 8 (Appendix K, Table 50) compared the various alternatives to the sub-criteria of "mentorship to young engineers" and displayed a very good consensus between the participants of 87.9%. Participants 2 and 4 displayed individual CRs of 14%, but the aggregated CR of 1.9% was completely acceptable and satisfactory.

The results were as expected and when looking in detail at participant 2 and 4, the higher CR is derived by low dominances of elements over one another (1 and 3 values), which does not necessitate any further investigations.

4.1.9. Matrix 9

Matrix 9 (Appendix L, Table 51) compared the various alternatives to the sub-criteria of "current availability of senior skills" and displayed a very good consensus between the participants of 98.6%. The CR of 7.5% is slightly elevated, yet still within accepted parameters. When looking at the individual weightings it is observable that 3 participants display slightly increased CRs, but with participant 2 at 14% and participants 3 and 4 at 7% these values are not of much concern.

The overall results were as expected and no further investigation was deemed necessary.

4.1.10. Matrix 10

Matrix 10 (Appendix M, Table 52) compared the various alternatives to the sub-criteria of "current availability of junior skills". The consensus was very good amongst the participants, but a look at the individual weightings show that all four participants display a high CR. Participants 1 (19%), 2 (41%), 3 (7%) and 4 (31%) all have high CRs, but their aggregated value of 2.3% gives the overall matrix an acceptable result.

Nevertheless, the participants were asked to review their answers and look if there was a need to change anything. None of them decided to alter their weightings and the result stayed as it was. In aggregation everything was still acceptable and the final results were as expected.

4.1.11. Matrix 11

Matrix 11 (Appendix N, Table 53) turned out to be a matrix that required a more intensive evaluation. The consensus of 99.4% was very high, but the aggregated CR of 12.6% was too high. A look at the individual weightings show that all four participants display a high CR. Participants 1 (12%), 2 (14%), 3 (19%) and 4 (7%) all have high CRs and again the participants were asked to re-evaluate their individual weightings. Participant 3 decided to change the weighting on the comparison between coal and wind power from a 5 (Appendix N, Table 54) to a 3 (Appendix N, Table 55). This changed the individual CR from 19% to 7%, which also changed the overall CR to 9.7% (Appendix N, Table 56).

The other participants were still satisfied with their original weightings, but with the CR now in acceptable dimensions and the consensus at 99.6% it was decided that no further re-evaluation was necessary.

4.1.12. Matrix 12

Matrix 12 (Appendix O, Table 57) compared the various alternatives to the sub-criteria of "potential of skills transfer". The consensus was good at 81.1%, but a look at the individual weightings show that there were some individual high CRs. Participants 1 (22%), 3 (14%) and 4 (14%) all have high CRs, but their aggregated value of 1.3% gives the overall matrix an acceptable result.

These 3 participants were asked to review their answers and look if there was a need to change anything. None of them decided to alter their weightings and the result stayed as it was. In aggregation everything was still acceptable and the final results were as expected.

4.1.13. Matrix 13

Matrix 13 (Appendix P, Table 58) had similar results to Matrix 12. It compared the various alternatives to the sub-criteria of “involvement of local community”. The consensus was good at 86.9%, but a look at the individual weightings show that there were some individual high CRs. Participants 1 (19%), 3 (14%) and 4 (31%) all have high CRs, but their aggregated value of 2.3% gives the overall matrix an acceptable result.

Again, these 3 participants were asked to review their answers and look if there was a need to change anything. None of them decided to alter their weightings and the result stayed as it was, still acceptable as was matrix 12.

4.1.14. Matrix 14

Matrix 14 (Appendix Q, Table 59) was another matrix that required a more intensive evaluation, with an aggregated CR of 11%. The consensus of 98.7% was very high, but the aggregated CR necessitated a more focused evaluation. A look at the individual weightings show that all four participants display a high CR. Participants 1 (14%), 3 (14%) and 4 (14%) all have higher CRs, but looking at the weightings in detail showed that the values entered were still close to one another to make the results acceptable. Nevertheless, the heightened aggregated CR necessitated that the participants re-evaluate their individual weightings.

Participant 4 decided to change the weighting on the comparison between nuclear and wind power from a 5 (Appendix Q, Table 60) to a 3 (Appendix Q, Table 61). This changed the individual CR from 14% to 4%, which also changed the overall CR to 8.3% (Appendix Q, Table 62).

The other participants were still satisfied with their original weightings, but with the CR now in acceptable dimensions and the consensus at 99.6% it was decided that no further re-evaluation was necessary.

4.1.15. Matrix 15

Matrix 15 (Appendix R, Table 63) compared the various alternatives to the sub-criteria of “likelihood of generating new skills”. The CR was good at 4.9%, but the consensus was low at 63.4%. This warranted a further look at the individual weightings and turned out that participants 1, 2 and 3 had exactly the same weightings for all 3 comparisons, but participant 4 had picked the opposite to the other 3. In this situation is was decided to still accept this result without further evaluation, since participant 4’s individual CR was only at 6% and with an aggregated CR of 4.9% the results were still consistent and accurate enough to continue with them.

This is an example of the fact that a low CR will not necessarily result in more accurate data, nevertheless compared to the three other completely identical participants the low consensus could be negated.

4.2. Determine Local and Global Priorities

As described in 4.1 the 15 matrices that were interrogated and re-evaluated where necessary were inserted into the spreadsheet indicating the hierarchy and the local priorities of each element on that hierarchy (Table 13). This was linked to another spreadsheet indicating the global priorities of all the sub-criteria (Table 14). These global priorities were derived by multiplying the local priorities of the sub-criteria with the priorities of the criteria directly above on the hierarchy

Table 13: Local Priorities of elements in hierarchy

AHP Hierarchy, indicating the pairwise comparisons summary - Local Priorities

GOAL	PROJECT WITH HIGHEST SKILLS VALUE									
PRIORITY (LOCAL)	1									
CRITERIA	POTENTIAL SKILLS TRANSFER			CURENT SKILLS AVAILABLE			GOVT OBJECTIVES		NEW SKILLS	
PRIORITY (LOCAL)	0,161			0,463			0,085		0,291	
SUB-CRITERIA	ST	PS	MJ	SS	JS	IS	LA	LC	HL	LL
PRIORITY (LOCAL)	0,184	0,255	0,561	0,65	0,208	0,142	0,663	0,337	0,802	0,198

Table 14: Global Priorities of elements in hierarchy

AHP Hierarchy, indicating the pairwise comparisons summary - Global Priorities

GOAL	PROJECT WITH HIGHEST SKILLS VALUE									
PRIORITY (GLOBAL)										
CRITERIA	POTENTIAL SKILLS TRANSFER			CURENT SKILLS AVAILABLE			GOVT OBJECTIVES		NEW SKILLS	
PRIORITY (GLOBAL)										
SUB-CRITERIA	ST	PS	MJ	SS	JS	IS	LA	LC	HL	LL
PRIORITY (GLOBAL)	0,030	0,041	0,090	0,301	0,096	0,066	0,056	0,029	0,233	0,058

Then there was a set of tables (Tables 64 to 72) indicating each alternative compared to all the sub-criteria. Again, each table indicated the local and global priorities, derived in the same fashion as previously explained. Table 15 is displayed below, tables 64 to 72 are referenced under Appendix S.

Table 15: Local and global priorities of alternatives compared to ST

PRIORITIES OF ALTERNATIVES / ST = 0.030

SUB-CRITERIA	ALTERNATIVE	LOCAL PRIORITY	GLOBAL PRIORITY
ST	COAL	0,674	0,020
ST	NUCLEAR	0,092	0,003
ST	WIND	0,234	0,007

4.3. Obtain Final Hierarchy with all Priorities and Rankings

All of these tables were then linked to the final spreadsheet that summarised all the other spreadsheets (Table 16) and tables. The final ranking of the 3 alternatives was achieved by aggregating all the derived global priorities for every alternative compared to the sub-criteria. For the sensitivity analysis this sheet was duplicated and through the linking of all the values this analysis could be carried out quickly and responsively.

The result was that the alternative of coal was ranked in first place with a priority of 0,493, followed by nuclear (0,285) and wind (0,221). Again, the result of coal ranking in first place was as expected, with the other two alternatives lying close to one another in the ranks after.

The advantage of this process described above is that the user has the ability to analyse and guide the process along the whole way. Conversely to some of the more automated software, this process is transparent and does not derive a solution blindly without being able to interrogate it. This is essential in arriving at consistent and valid answers whose accuracy can be determined at every step.

Table 16: Summary of AHP Model, indicating all results

AHP Hierarchy, Summary of Model

AHP Hierarchy, Summary of Model		GOAL	PROJECT WITH HIGHEST SKILLS VALUE										TOTAL	RANK
		CRITERIA	POTENTIAL SKILLS TRANSFER			CURENT SKILLS AVAILABLE			GOVT OBJECTIVES		NEW SKILLS			
		SUB-CRITERIA	ST	PS	MJ	SS	JS	IS	LA	LC	HL	LL		
		COMPARISON OF ALTERNATIVES WITH SUB-CRITERIA												
		COAL	0,020	0,025	0,049	0,216	0,070	0,005	0,035	0,019	0,028	0,027	0,493	1
		NUCLEAR	0,003	0,007	0,022	0,026	0,010	0,049	0,009	0,003	0,143	0,014	0,285	2
		WIND	0,007	0,009	0,019	0,059	0,017	0,012	0,012	0,007	0,063	0,017	0,221	3
TOTALS	GLOBAL		0,030	0,041	0,090	0,301	0,096	0,066	0,056	0,029	0,233	0,058	1,000	
	GLOBAL		0,161			0,463			0,085		0,291		1,000	
	TOTAL	1												

4.4. Sensitivity Analysis

In order to test the final model and the rankings of the alternatives it derived a sensitivity analysis was carried out. This was to test one of the criticism levelled against the AHP that rank reversal can happen, which will challenge the reliability of the data and the results. It must be remembered that the overall priorities were to a large degree influenced by the weights that were given by the specialists to the respective criteria. The consensus and consistency have been tested as the weighting of the overall hierarchy was carried out, but the final results must still be interrogated to ensure the overall reliability and validity.

To take this into account and measure by how much the overall result could have changed if the weightings were given differently, the sensitivity analysis was carried out. This process was also important in determining how robust the model developed is and how trustworthy the final results are. It also determines the stability of the inputs of the participants.

Two scenarios were tested in this analysis, namely one scenario where all the sub-criteria were given equal priorities and another where one sub-criteria received a higher priority and all other criteria were made equally small. The first scenario is indicated on Table 17, where all sub-criteria were given the same global priority of 0,100. It must be noted that horizontally aggregated all these priorities must still amount to 1. The results of this analysis resulted in the same ranking as the original ranking, with coal gaining slightly in its priority (0,521) and the other two alternatives decreasing slightly.

Table 17: Sensitivity Analysis - all global priorities of sub-criteria equal

AHP Hierarchy, Summary of Model - Sensitivity Analysis all GP Equal

AHP Hierarchy, Summary of Model	GOAL	PROJECT WITH HIGHEST SKILLS VALUE										TOTAL	RANK
	CRITERIA	POTENTIAL SKILLS TRANSFER			CURENT SKILLS AVAILABLE			GOVT OBJECTIVES		NEW SKILLS			
	SUB-CRITERIA	ST	PS	MJ	SS	JS	IS	LA	LC	HL	LL		
	COMPARISON OF ALTERNATIVES WITH SUB-CRITERIA												
	COAL	0,067	0,062	0,055	0,072	0,072	0,007	0,062	0,066	0,012	0,046	0,521	1
	NUCLEAR	0,009	0,017	0,024	0,009	0,010	0,074	0,016	0,012	0,061	0,024	0,257	2
	WIND	0,023	0,021	0,021	0,020	0,018	0,019	0,022	0,023	0,027	0,030	0,222	3
TOTALS	GLOBAL	0,100	0,100	0,100	0,100	0,100	0,100	0,100	0,100	0,100	0,100	1,000	
	GLOBAL	0,161			0,463			0,085		0,291		1,000	
	TOTAL	1											

For the second sensitivity analysis (Table 18) it was decided to increase the priority of the sub-criteria of "mentorship of junior engineers" from the original value of 0,090 to 0,300 and then divide the remaining 0,700 among the other sub-criteria (0,078). The results again kept to the same ranking as the originally weighted model with final priorities of the alternatives very similar to the previous sensitivity analysis (1 = 0,527; 2 = 0,254; 3 = 0,220).

Table 18: Sensitivity Analysis - all global priorities of sub-criteria equal, except MJ = 0,30

AHP Hierarchy, Summary of Model - Sensitivity Analysis MJ = 0.30

AHP Hierarchy, Summary of Model	GOAL	PROJECT WITH HIGHEST SKILLS VALUE										TOTAL	RANK
	CRITERIA	POTENTIAL SKILLS TRANSFER			CURENT SKILLS AVAILABLE			GOVT OBJECTIVES		NEW SKILLS			
	SUB-CRITERIA	ST	PS	MJ	SS	JS	IS	LA	LC	HL	LL		
	COMPARISON OF ALTERNATIVES WITH SUB-CRITERIA												
	COAL	0,052	0,048	0,164	0,056	0,056	0,006	0,048	0,051	0,009	0,036	0,527	1
	NUCLEAR	0,007	0,013	0,073	0,007	0,008	0,058	0,013	0,009	0,048	0,019	0,254	2
	WIND	0,018	0,016	0,063	0,015	0,014	0,014	0,017	0,018	0,021	0,023	0,220	3
TOTALS GLOBAL		0,078	0,078	0,300	0,078	0,078	0,078	0,078	0,078	0,078	0,078	1,000	
TOTALS GLOBAL		0,161			0,463			0,085		0,291		1,000	
TOTALS TOTAL	1												

4.5. Final Results

Having gone through the process of pairwise comparison of all the elements of the AHP hierarchy developed for this study with the goal of finding the electricity generating project that has the highest skills value the following results can be put forward, based on the judgments of a panel of 4 specialists:

1. Coal-fired Power (49,3%)
2. Nuclear Power (28,5%)
3. Wind power (22,1%)

This means that the specialists judged that a typical coal-fired power electricity generating project has the highest potential in addressing all the criteria and sub-criteria successfully that have been developed under objective A. These criteria have been identified to form part of a measure in determining the skills value a project has at the feasibility stage and through the AHP process these criteria have been weighted to determine at what magnitude each of them contributes to the overall result. The project that satisfies the most important criteria and sub-criteria the best will be the one that will rank the highest.

These results have undergone tests of consensus among the participants' decisions, consistency of the weightings and priorities, validity and reliability of the results and it can deduced from this that these results are accurate and the model developed can be trusted. To put these results into perspective with regard to the overall objective of this study they must be analysed in how they can be applied in a more general sense in a specific real-world example. The following section will comment on this.

CHAPTER 5

Discussion

This chapter discusses the results gained, looking at whether they have met the objectives of the study. The results gained in the previous session must be put into context to understand their universal validity in applying this model developed in the electrical distribution sector in general. It must also be decided whether the theoretical framework and requirements suggested by the literature have been met and whether this model developed offers some potential in being applied in other scenarios.

5.1. The AHP as a tool in aiding decision-making in the SA electric power industry

To understand the validity of these results and their support in achieving the objectives of this study a review of these objectives is necessary.

The objectives of this research were:

A. To determine a list of skill categories inherent in a typical energy construction project to determine the criteria that form part of the model;
B. To develop a model based on the Analytic Hierarchy Process with which to measure skills in the energy sector; and
C. To apply this tool in a real-world example by comparing three energy options with each other.

How these objectives were met will be discussed in the next section.

5.1.1. Objective A: Determine list of skill categories

The list of skill categories developed under 3.4.2 and 3.4.5 was based on the literature and represented the criteria and sub-criteria that formed part of the model. These criteria have been identified to form part of a measure in determining the skills value a project has at the feasibility stage and thus were included in the AHP model. This list is neither exhaustive, nor does it try to offer a universal applicability. It is a measure of the recurring themes that were presented by the chosen literature sources for this particular study. These sources were chose in response to an investigation into skills in the energy sector in general and applied in the South African context specifically. Should the focus of the study change, this list will naturally change to be in line with a different topic researched.

The intention of this objective was to demonstrate that it is possible to determine a list of criteria and sub-criteria based on literature that has been sourced to form part of a study and have this criteria contribute successfully to the model hierarchy. A thematic analysis will always contain a measure of subjectivity in selecting which categories must form part of the list and a more detailed content analysis could be considered. For the purpose of this study this was felt not necessary and the responses from the specialists and questionnaire process did not warrant any further investigation. The nature of the AHP process is such that it can adapt as different criteria is chosen to form part of it and this study allowed for this.

5.1.2. Objective B: Develop model based on the AHP

Once objective A has been met, the natural step is to construct the model hierarchy, which is a reflection of the criteria and sub-criteria identified. This process has been described by the literature on the AHP process and in this particular study has been described in 3.4. Once the overall goal of the AHP hierarchy had been determined to be "which electricity generating project has the highest skills value" (as per 3.4.4), the structure of the final hierarchy was easily developed according to the criteria, sub-criteria and alternatives developed as part of objective A. The AHP process is robust enough to adapt to many different objectives and goals and this study was easily adapted along these guidelines. Saaty's AHP process as indicated on table 10 in 3.1 was followed in this research report and the theoretical framework and processes this table is based on is backed by the vast literature that testifies of its strengths.

The objective of this model was to measure skills in the energy sector and it was necessary to decide which criteria were essential in the formation of this model and not include all the elements identified. The goal of the study – to determine the skills value a typical project has – was the guiding measure against which the inclusion of a particular criteria as part of the hierarchy was decided. Thus, by searching for the electricity generating project that has the highest skills value, invariably the objective to estimate the required skills at the feasibility stage of a project must be met in order for this goal to be achieved. This requirement is built into the model developed as part of objective B.

5.1.3. Objective C: Apply the model in real-world example

The final objective sought to apply this model in a real-world example by comparing three energy generating options with one another to decide which of these options offers the highest skills value. This was done by comparing typical projects in the coal, nuclear and wind energy sectors by applying the already developed AHP process and hierarchy in comparing them with one another according to the priorities gained. The alternatives were not directly dependant on the criteria and sub-criteria chosen and different alternatives within the electrical power generating sector could equally be used to derive at a valid result.

The application of the model followed the pairwise comparison process as described in 2.4.6 and was easily applied to the real-world example of this study. The interactive nature of this process allowed interrogation of result along the way, with the built-in measures ensuring accuracy of results. These results underwent tests of consensus among the participants' decisions, consistency of the weightings and priorities, validity and reliability of the results and it can deduced from this that these results are accurate and the model developed can be trusted.

Cognisance was taken of the criticism of the AHP as described in 2.4.3 with rank reversal and consistency being addressed in the tests described above. The criticism of the use of the fundamental scale did not present any problems, since the participants chosen could easily relate to the numerical values described in this scale.

Not only was this model successfully applied to a real-world example, it is easily possible to adapt the same structure and include different criteria or alternatives. This would be guided by the overall goal of the topic being investigated.

5.2. The AHP as a tool in aiding decision-making in the SA electric power industry

The literature that was studied suggested that the Analytic Hierarchy Process was a widely used multi-criteria decision making method in successful problem-solving. It has the advantage of breaking down the problem into easier identifiable elements that were then compared to each other to derive their overall importance within the hierarchy of the model. The advantage it has is that it can reduce complexity and allow the participant to engage with the smaller portion at hand without needing the understanding of the overall picture. This has the advantage of participants of differing cultural and educational backgrounds able to partake in this process and deliver equally valid inputs, something that would be necessary for the application in the SA electricity sector.

Moving away from the literature, in practice the AHP process also proved to be successful and valuable in delivering the required results. This particular study applied it on a specific problem, which this process solved adequately. The AHP process had the advantage of engaging with the process along the way and analysing and evaluating the data along the way. No process should be trusted blindly in delivering a result, it should be interrogated along the way to ensure the results are consistent, accurate and valid. This study reiterated this issue by specifically deciding to manually guide this process along, instead of employing software that could derive the solutions automatically. As the literature showed, the AHP can also derive solutions that are not accurate and the necessary understanding of this - as well as the built-in measures along the way - are necessary to minimize this possibility.

It is the author’s opinion that this process should not be automated completely, with enough room for input from the person leading the process and enough feedback to and from all participants. If this process is followed as described there should be no concern about employing the AHP method in the SA electric power industry.

5.3. Choice of participants

Any results and suggestions gained using the AHP method are as strong and accurate as the inputs from the participants. The priorities are derived by asking a participant which of the two elements is dominant in relation to the other and then by how much this is the case. In order for the participant to make this decision he needs to rely on experience on all these aspects to make this decision informed and valid. After the experience comes the necessity to measure the weight of the dominance between the two options in numerical fashion. It thus becomes necessary for the leader of the study to decide on the correct mixture of specialist asked to give their inputs to the study.

As a general rule it is always advantageous to keep the group of specialists as diverse as possible. This relates to experience levels, age, gender, area of specialisation. Depending on the subject matter it could also be required to have diversity of social and cultural characteristics too. There must also be a conscious decision between a process of individual or group engagement. Both of these have their own dynamics and will change the process followed in the pairwise comparison process. The nature of the problem at hand and the results wanted will determine the mix of participants and the engagement type. It must be a conscious decision and not happen naturally.

In this particular study the group of specialists assembled represented a small spread of varied experience in the SA electricity sector, both in type of experience, as well as magnitude. The reality is that there will never be a group of participants large and varied enough to represent complete experience in every component of expertise that particular problem requires. It is also goes without saying that a different group of specialists might have come up with a different solution, probably not in changing the number one ranked alternative, but possibly between two and three, which were closer together in their weightings. The solution sought must always inform the type of specialist to include in the AHP process.

The advantages of the AHP are that it can compensate for this by aggregating the knowledge between the participants and deriving the average of all the inputs across the group. Added to this is the information that is informed by research and literature independent of the specialists that forms part of the hierarchy, which also acts as a guidance of what kind of results might be expected. In the AHP process in this research report all the checks and analysis opportunities built into the AHP model ensured that the derived priorities were in line with the expected results. When there were situations where there seemed to be some lack of consensus amongst the participants or the CR was above the allowed parameters, these situation warranted further investigation. The final suggestions did not offer any concerns that the group of participants was not adequately integrated into the solution by the AHP process.

5.4. How to structure the hierarchy

The process of structuring the hierarchy is arguably the most important factor in arriving at an accurate and valid solution. The nature of the problem determines what amount of levels will be necessary to understand the problem. The hierarchy is a graphic representation of the problem and the relationships between the elements. It must make the participants involved in the process and not focus on just generating quick answers with heavily computated models. The hierarchy develop must be complex enough to capture the problem that is being investigated, but still small enough to be understandable by all and be responsive to their inputs.

The hierarchy developed for this particular study was informed by two main components: the literature and the specialists. The literature firstly aided in providing examples of how different hierarchies were structured in response to different problems. There are many solutions to a problem and this also counts for this study. The hierarchy will look differently depending on where the focus of the problem is and the path chosen to follow this solution. In essence, a hierarchy consists of all the components deemed to form part of a problem, all the criteria used to describe to problem or components of it and the relationships between all these components. The final arrangement may differ, depending on where the study leader places to focus of the study.

The literature also informed what the criteria might be that must form part of the hierarchy. The state of the SA electric power industry informed the criteria that must form part, the level of skills and associated challenges another. Case studies looking at global and African trends and challenges formed another component and the section on renewable energies confirmed that the wind power as an alternative deserves to form part of the hierarchy. The literature on criticism of the AHP informed the fact that the sensitivity analysis formed part of this AHP process and the guidance on how to structure a hierarchy had an impact on the eventual shape it took on.

In some instances – when the nature of the subject matter that it studies contains enough empirical and measurable data – this literature will suffice in generating the hierarchy and also completing its pairwise comparisons. In this particular study the hierarchy also relied on qualitative elements to inform it structure and the dependencies between the elements. In response to this the industry specialists were required to add value to the hierarchy, decide whether some elements should not form part of the hierarchy or whether others were left out. They were also employed later to analyse all of these elements going down the hierarchy in the pairwise comparisons already discussed.

The hierarchy for this study can be judged to have successfully captured the essence of the problem, showing all the elements chosen to form part of it and the relationships between these elements. It allowed for enough complexity to include adequate criteria, yet was also simple enough to make it still responsive and perform the required tests along the way. The manner in which this hierarchy was developed can easily be applied to similar skills related questions when comparing different electricity generating projects in the SA electric power industry.

5.5. Questionnaire effectiveness

Different ways in which to gather the data from the industry specialists were discussed. There could have been the option of an interview or a session – either individually or with the whole group present – where the information would be fed live into the spreadsheets. In the end it was decided to rather employ a questionnaire for this purpose.

The questionnaire had some advantages: firstly, it seemed important to distance the specialist from the weighting process, both in order to not influence any future decisions, as well as eliminating the risk of distraction, by taking the focus off the actual question at hand. Secondly, the flow of conducting the questionnaire process would be broken by the interruptions between the two programs that the feeling was that this would influence consistency somewhat. The questionnaire was also administered in hard copy with each participant writing the answers on the question sheets. This had the advantage of tracking the history of all the answers given and also recording any changes that were either prompted by the participant himself or by the AHP process where inconsistencies were discovered. The hard copy was also considered to be advantageous for ethical reasons, ensuring all data is kept safe and offers the least chance of being manipulated.

To decide whether the questionnaire works better than other methods to record the participants answers is difficult to do. The merit of other methods will not be disregarded, but this particular method chosen for this study has its merits and can be put forward as a possible component in the successful administration of the AHP process in the SA electric power industry.

5.6. Type of problem chosen and alternatives

This study attempted to develop a method in comparing three alternative power generating projects and determining the skills values inherent in them. It must be noted that these three alternatives were generic project descriptions of power generating types. In real-world applications these projects would have much more detailed information connected to them, like the size of the project, location, budget and other parameters necessary to initiate a project. In general, the more detail is available the more accurate the answer will be. The more detail can be added to the hierarchy, the more accurate the comparisons will be. The other advantage is that a real-word problem should inherently have more quantitative data, making the comparisons between the criteria easier to judge.

The conclusion gained from this is that this study – using more generic data than a real-world study would employ – still delivers accurate and valid results. The application in the SA power generating industry should be even more effective if the data used can be even more easily applied in practise.

5.7. AHP Process Administration

The administration of the AHP process is important in ensuring consistency of the overall process and the results. Certain steps are inherently given by the process, but others will be unique for each application. The person chosen to administer this process must be completely aware of the underlying principles behind the AHP as well as have sufficient knowledge about the subject matter it is applied to.

This study has shown that if the AHP is to be applied in the SA power generating industry in the manner that is suggested, the process to derive the final ranks is an interactive one with constant analysis of the results given by the specialist participants. The administrator of this process must understand what the measures are that are sought and how consistency is guaranteed. Only when these components are understood can they be actively managed.

5.8. Application during the feasibility stage

The purpose of this study was to develop a model that can measure the skills value of projects in the SA electric power industry at the feasibility stage of a project. The reason for this has been discussed as during the early stages of a project, the impact of decisions has a small impact on the cost; whereas the impact on the project on a whole is the most substantial. The need for an accurate decision making method is thus warranted for this stage.

For that purpose, a model had to be developed that can determine the skills value of a project at an early stages of a project The only way in which this information can have an impact on the project is if this knowledge is gained at the early phases of a project and compare this to other projects that are also considered for implementation. When two electricity alternatives have the same scoring in the main components of a feasibility study, the skills value should become a deciding factor between the two. The model developed in this study delivered reliable results in ranking three different energy type projects, giving recommendations on which of them should be considered when focusing on the skills value only. These results can easily be replicated in a real-world feasibility study in the SA electric power industry.

5.9. Reliability and Validity

As a final discussion point, the validity and reliability of the results must be summarised.

As intended, reliability of research was ensured by only one person administering all questions and interviews so that there was no misinterpretation from a third party. The consistency of the respondents' answers was tested along the way and the sensitivity analysis further ensured that no rank reversal would take place. The AHP process inherently ensures that measures for these parameters are followed when this process is carried out as designed. It must be remembered that the overall priorities will to a large degree be influenced by the weights that were given to the respective criteria. To take this into account and measure by how much the overall result could have changed the sensitivity analysis was carried out to determine how robust the model developed is and how trustworthy the final results are. It also determined the stability of the inputs of the participants. The results for the sensitivity analysis were satisfactory to determine that no rank reversal took place, meaning that the data and results are reliable.

The other primary tool built into the AHP to test and ensure reliability of the data is the Consistency Ratio, which ensured that any inconsistency in an AHP model and the results were quickly identified to be acted upon. To improve the Consistency Ratio at a specific matrix that has indicated values outside the accepted parameters, the process proposed by Saaty (1994) was employed successfully to revisit these matrices along with the participants and go through in detail whether all the answers given were still the ones that the various specialists would give upon further inspection. It could easily be that there were mistakes in filling in the forms or in transferring the information into the model that can influence the consistency. As shown in section 4.1, there were some instances where there were both mistakes in filling in the questionnaire, as well as instances where the participant was asked to re-evaluate a decision. The process proved to successfully point out inconsistencies and then guide the results to more consistent values. It must be noted that nowhere should the process automatically revise measures to increase the reliability of data, but only guide the administrator of the process in a direction to interrogate the data further to possibly increase the reliability.

Validity of the data and results was ensured by using a method that has been developed in a framework that already exists and has been comprehensively tested over time. Cognisance was taken of the criticism directed at the AHP and responses to this criticism were built into the model developed and the process to administer it, as was already discussed under the reliability section.

Various triangulations within the methodologies ensured that the overlapping areas of the methods employed would point to any possible discrepancies and ensure that this particular study is actually focusing on the intended purpose of the study. Again, these measures are mostly built into the AHP process with checks along the way. This process, along with literature and the expert input ensured the validity along the way. The full briefing session held with each specialist ensured that all questions were understood correctly and in the way they were formulated and any shortcomings could be easily identified and corrected. Any results that did not fall within the expected results were analysed further and their validity determined.

The process developed in this research report allows for a context-specific generalizability, where the model can be applied to other contexts as discussed in 6.2. Reliability and validity of the data have been proven possible if this process is followed as intended, guided by the administrator of the process and supported by all the processes built into it.

CHAPTER 6

Conclusion and Recommendations

The final chapter of this research report draws conclusions from the results gained in previous chapters and measures them against the goals and objectives of this study. It also offers some suggestions for further study and applying this model in other contexts.

6.1. Goals and objectives of the study

The way in which this study responds to its objectives has been described in more detail in 5.1. Tying this response to the CRQ, the goal was to develop a model that can estimate a project's required skills value at the feasibility stage of a project with the objective of applying this model in a "real-world example by comparing three energy options with each other". In order to fulfil this goal, each of the three energy options was compared by measuring the skills value of each one of them at tender stage and then determining which one of the options has the highest value. This process is based on comparing the criteria and sub-criteria identified to form part of a measure in determining the skills value a project has at the feasibility stage. Through the AHP process these criteria have been weighted to determine at what magnitude each of them contributes to the overall result. The project that satisfies the most important criteria and sub-criteria the best will be the one that will rank the highest. The rank also signifies the skills value of the project - the higher the skills value, the higher the rank.

The way in which the criteria and sub-criteria were defined looked at the potential each project has in fulfilling these and thus become a measure of how much inherent potential the project has to support improvements in skills values. This was also represented in the questionnaire, where each participant was asked which of the three alternatives had the highest potential in meeting a particular criteria's requirements. Again, the higher the rank an alternative reached the higher the potential for improving the skills value in a project.

It can be confidently concluded that this study achieved its objectives and answered the questions it sought to answer. With this in mind, possible applications of this model in other settings will be discussed in the next section.

6.2. Recommendations for further study

The ability of this model to be applied in measuring the skills value of projects at the feasibility stage has been demonstrated. The next step would be to apply this model on actual projects that have more specific parameters and criteria that can be added into the model. Given the scenario painted of the need South Africa has for advancement of skills along all levels of the social fabric, the need to approach this problem strategically can only be met over the long term with accurate and consistent data. As mentioned in the previous section the focus of this study was on looking at the skills value of a project, which also included the measure a project has in the potential to meet or improve skills within and through the project. It is a measure of the inherent skills value this project has and the potential it has to generate new skills. This was as a result of the criteria that was chosen, where a strong focus was on potential skills development. Depending on the final application and the intended goal, the criteria can also be altered to shift the focus to different areas and the specialists selected to weight the criteria might shift the focus due to their background and the values they bring with them.

There is also no reason why this model cannot be applied in other industries, seeing that the whole infrastructure sector in South Africa is hampered by severe skills shortages and many projects are not completed on time or at all due to the lack of implementation capacity. In all of these applications the AHP can be employed to aid in determining the skills value and thereby offer strategic support to decision making.

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Appendices

Appendix A – AHP Example of buying a house

The following is an example of the AHP process, based on Mu & Preyra-Rojas (2017) example of buying a house.

Table 19: Matrix of buying a car, indicating the goal and its criteria (based on Mu & Preyra-Rojas, 2017)

Buying a house	Cost	Aesthetics	Location
Cost	1	7	3
Aesthetics	1/7	1	1/3
Location	1/3	3	1

There are two methods to calculate this weighting, namely the exact method or the approximate methods. Both of these methods offer valid and reliable results and for the purpose of this report the approximate method will be employed due to its simple implementation, making it easy for all participants to follow the process and partake in the final results. It must be noted, though, that the approximate method provides a more valid result when the matrix has a low inconsistency.

The process involved is described in Table 20. The approximate method requires the normalization of the comparison matrix by adding the values that have been identified in each column.

Table 20: Approximate comparison matrix (based on Mu & Preyra-Rojas, 2017)

Buying a house	Cost	Aesthetics	Location
Cost	1.000	7.000	3.000
Aesthetics	0.143	1.000	0.333
Location	0.333	3.000	1.000
Sum	1.476	11.000	4.333

The next step is to divide each cell by the total that has been calculated for the entire column, which then gives us the normalized matrix.

Table 21: Normalized matrix (based on Mu & Preyra-Rojas, 2017)

Buying a house	Cost	Aesthetics	Location
Cost	0.677	0.636	0.692
Aesthetics	0.097	0.091	0.077
Location	0.226	0.273	0.231

Once this normalised matrix has been obtained the final priorities can be calculated by calculating the averages of each row (Table 22).

Table 22: Final priorities (based on Mu & Preyra-Rojas, 2017)

Buying a house	Cost	Aesthetics	Location	Priority
Cost	0.677	0.636	0.692	0.669
Aesthetics	0.097	0.091	0.077	0.088
Location	0.226	0.273	0.231	0.243

The results in gained in the table above can then be presented relative to original matrix (Table 23) and the recommendations become apparent. In this example the criteria of cost should hold a 66.9% importance in the overall decision of which house to buy, whereas location and aesthetics only account to 24.3% and 8.8% respectively.

Table 23: Final priorities relative to original matrix (based on Mu & Preyra-Rojas, 2017)

Buying a house	Cost	Aesthetics	Location	Priority
Cost	1.000	7.000	3.000	0.669
Aesthetics	0.143	1.000	0.333	0.088
Location	0.333	3.000	1.000	0.243

After this adjudication has been reached it is important to determine whether the results are consistent with what can be expected. There will always be some measure of inconsistency in an AHP model, which is often not easily known by the decision maker, but the AHP can show in sequential order which judgments are the most inconsistent. What must be understood is that this increased consistency will not lead to a more accurate set of priorities and accuracy can only be changed by gathering more information and possibly changing the framework of the matrix (Saaty 1994: 28). Each matrix must come with its own Consistency ratio (CR) and for this ratio the set of judgements must be compared to acceptable values were this matrix be taken at random. The CR in AHP is calculated by comparing the consistency index (CI) of the matrix developed with the CI of a random-like matrix (RI), a matrix where the judgements have been randomly entered and as such will be highly inconsistent or in more detail as per Table 24

Table 24: Consistency Ratio (Mu and Pereyra-Rojas, 2017: 12)

N	3	4	5	6
RI	0.58	0.9	1.12	1.24

The CR is thus defined as CR, where CR = CI/RI. Saaty has shown that a CR of 0.10 or less is acceptable and can one continue with the AHP analysis. Should the ratio be more than that the hierarchy needs to be refined more, in parameters that are still acceptable. Now the process for calculating the CR for our example can start. It must be mentioned again that this will be a simplified version of Saaty's Eigenvector solution, but this is in line with the requirements to keep the process interactive and make the participants part of the process. The results will still remain acceptable. The other alternative would be to employ computer software that is readily available to aid in the AHP process, but again this would defeat the purpose of this study.

The first step in calculating the CR is to use the weights for each column and multiplying each cell with its associated priority, displayed in the last column, which will give us Table 25 below:

Table 25: Weights multiplied by their associated priorities (based on Mu & Preyra-Rojas, 2017)

Buying a house	Cost	Aesthetics	Location
Cost	0.669	0.617	0.729
Aesthetics	0.096	0.088	0.081
Location	0.223	0.265	0.243

In order to obtain the weighted sum, all the values in a row must be added up as follows on Table 26:

Table 26: Weighted sums (based on Mu & Preyra-Rojas, 2017)

Buying a house	Cost	Aesthetics	Location	Weighted sum
Cost	0.669	0.617	0.729	2.015
Aesthetics	0.096	0.088	0.081	0.265
Location	0.223	0.265	0.243	0.731

The elements on the weighted sum vector must now be divided by the corresponding priority. The average of these priorities is called λmax, the value of which is (Table 27):

Table 27: λmax of priorities (based on Mu & Preyra-Rojas, 2017)

Weighted sum	Priority	
2.015/	0.669 =	3.014
0.265/	0.088 =	3.002
0.731/	0.243 =	3.005
	Total	9.021
	/3 to get λmax	3.007

The consistency index is calculated according to the formula

CI = (λmax-n)/(n-1), where n denotes the number of elements that are compared (3)

Therefore CI = (3.007-3)/(3-1) = 0.004

Since CR = CI/RI we get 0.004/0.58 = 0.006

This value is below the 0.10 threshold, which means that this model is consistent enough to continue with the AHP decision making process. (Mu and Pereyra-Rojas 2017: 15).

The next step is to derive the local priorities or preferences for the alternatives. This means to find the priorities for each of the elements and see where the main suggestions could lie. Since these will only at this stage be calculated for each criterion, these are still local priorities, which will later be aggregated to the overall priorities of the model. In the example cited there are only 2 alternatives, along with three criteria. For each of the criteria the two alternatives must now be compared in pairwise comparison as already displayed in comparing the criteria previously. This could give us the following results in Tables 28 to 30:

Table 28: Comparison with respect to cost (based on Mu & Preyra-Rojas, 2017)

Cost	House 1	House 2
House 1	1.000	7.000
House 2	0.143	1.000
Sum	1.143	8.000

Table 29: Preference with respect to cost (based on Mu & Preyra-Rojas, 2017)

Cost	House 1	House 2	Priority
House 1	0.875	0.875	0.0875
House 2	0.125	0.125	0.125

Table 30: Results with respect to cost (based on Mu & Preyra-Rojas, 2017)

Cost	House 1	House 2	Priority
House 1	1.000	7.000	0.875
House 2	0.143	1.000	0.125

These same processes must be repeated for the other 2 criteria, namely comfort and safety. What will be noticed here is that if only 2 elements are compared then the CR will always be consistent and does not need to be checked. For 3 or more elements the CR must be calculated to make sure it falls within the required criteria. Again, these priorities are still only local priorities, seeing that they are not compared to the overall model where the other criteria are evaluated according to the 2 alternatives (Table 31).

Table 31: Local priorities of alternatives (based on Mu & Preyra-Rojas, 2017)

Alternatives	Cost	Aesthetics	Location
House 1	0.875	0.167	0.100
House 2	0.125	0.833	0.900

To get the overall picture of how these local priorities compare with each other the overall priorities need to be determined. This step of the process is called model synthesis and brings together all the previous values and priorities already calculated in order to formulate a coherent and concise way forward (Tables 32 to 35).

The overall priority is calculated by using the local priorities previously calculated and applying the weighting that was previously determined (Table 32):

Table 32: Local priorities table as base (based on Mu & Preyra-Rojas, 2017)

	Cost	Aesthetics	Location
House 1	0.875	0.167	0.100
House 2	0.125	0.833	0.900

Table 33: Preparation for weighting priorities (based on Mu & Preyra-Rojas, 2017)

	Cost	Aesthetics	Location
Criteria weights	0.669	0.088	0.243
House 1	0.875	0.167	0.100
House 2	0.125	0.833	0.900

Table 34: Calculation of overall priorities (based on Mu & Preyra-Rojas, 2017)

	Cost	Aesthetics	Location	Overall priority
Criteria weights	0.669	0.088	0.243	
House 1	0.585	0.015	0.024	0.624
House 2	0.084	0.074	0.219	0.376

Table 35: Synthesis of the model (based on Mu & Preyra-Rojas, 2017)

	Cost	Aesthetics	Location	Overall priority
Criteria weights	0.669	0.088	0.243	
House 1	0.875	0.167	0.100	0.624
House 2	0.125	0.833	0.900	0.376

By adding all the results in Table 36, the overall priority for each car is calculated. This must then be repeated for all the different alternatives to arrive at the overall priority, by multiplying each of the local priorities with the criteria weighting and adding all together.

Table 36: Overall priorities of the two alternatives (based on Mu & Preyra-Rojas, 2017)

Alternatives	Overall Priority
House 1	0.624
House 2	0.376

This result means that, according to the importance and weighting of each criteria identified, House 1 is preferred (Mu & Pereyra-Rojas, 2017: 20).

In our example it can be seen that cost has been given a very high priority, which along with House 1's local priority for this criteria as also very high the question must be asked what would happen if the importance of this criteria is changed, what would happen if all criteria receive the same weighting or if the weighting is changed completely toward a different criteria not initially sought out? For this study 2 different scenarios will be investigated as per Tables 37 and 38:

Table 37: Scenario: all criteria have the same weight (based on Mu & Preyra-Rojas, 2017)

	Cost	Aesthetics	Location	Overall priority
Criteria weights	0.333	0.333	0.333	
House 1	0.875	0.167	0.100	0.380
House 2	0.125	0.833	0.900	0.619

Table 38: Scenario: cost weight leading to equal preferences of the alternatives (based on Mu & Preyra-Rojas, 2017)

	Cost	Aesthetics	Location	Overall priority
Criteria weights	0.500	0.250	0.250	
House 1	0.875	0.167	0.100	0.504
House 2	0.125	0.833	0.900	0.496

In the first scenario, all 3 criteria have been given the same weight. The result means that now House 2 is the preferred option, which points to the fact that because cost was given such a strong weighting this criteria has dominated all the other criteria. Should Aesthetics and Location have been given higher weightings at the earlier stages, House 2 would have been a feasible option. At this stage it always become valuable to possible review the weightings and determine whether they might not have clouded the final results to severely. The second scenario seeks to find the break-even point at which weighting there is little to choose between the 2 houses. This again can help in determining whether the weighting and importance of criteria are still in line with expected results (Mu and Pereyra-Rojas, 2017: 21)

Appendix B – Letter of Consent

Letter of Consent

I, ____, agree to participate in the MSc research entitled ***A skills measurement model for the South African Energy Sector: applying the Analytic Hierarchy Process to the SA electric power industry***, to be undertaken by Markus Meyer under the supervision of Ms Bernadette Sunjka, and certify that I have received a copy of this letter of consent.

I acknowledge that the research has been explained to me and I understand what it entails, as follows:

1. There will be one verbal interview, either in person or telephonically, which is expected to take no more than 1.5 hours.
2. At a later stage a guided survey questionnaire will be filled in.
3. The interviews will be audio taped and transcribed for analysis by the researcher.
4. I have the right to withdraw my assistance from this project at any time without penalty, even after signing the letter of consent.
5. I have the right to refuse to answer one or more of the questions without penalty and may continue to be a part of the study.
6. I may request a report summary, which will come as a result of this study.
7. I am entirely free to discuss issues and will not be in any way coerced into providing information that is confidential or of a sensitive nature.
8. Pseudonyms will be used to conceal my identity, and that of my company, my employees, my suppliers and my customers. The information disclosed in the interviews will be confidential.
9. Audio-tapes and transcripts will be kept securely stored during the research and after the research has been completed.
10. This project was approved by the Faculty of Engineering and the Built Environment of the University of the Witwatersrand and the School of Mechanical, Industrial and Aeronautical Research Ethics Committee (non-medical) of the University.
11. If I have any questions or concerns about my rights or treatment as a participant, I may contact the Chair of the School of Mechanical, Industrial and Aeronautical Research Ethics Committee (non-medical) Dr Bruno Emwanu at 011 717 7343 or bruno.emwanu@wits.ac.za.

Signed: ____

Date: ____

Questions concerning the study can be directed to:

Markus Meyer

Tel: 083 251 1000 and Email: aurelius.meyer@gmail.com

Supervisor: Tel: 011 717 7367   Email: Bernadette.Sunjka@wits.ac.za

Appendix C – Participant Information Sheet

Date

Dear …..,

Re: Participation in Research on skills in the South African Energy Sector

Thank you for offering to participate in this research report.

I am a part-time MSc student in the School of Mechanical, Industrial and Aeronautical Engineering at the University of the Witwatersrand, under the supervision of Ms Bernadette Sunjka. My MSc title is: *A skills measurement model for the South African Energy Sector: applying the Analytic Hierarchy Process to the SA electric power industry*.

I would like to formally invite you to participate in this research report. As an industry specialist in the energy sector in South Africa, your knowledge and experience would contribute significantly. The aim of this research report is to understand the skills inherent in projects in the energy sector and develop a model to measure these skills in pairwise comparisons and thus being able to evaluate projects with regards to their inherent skill values.

The research will be conducted between November 2018 and February 2019. Your involvement would entail one (1) guided survey questionnaire towards the end of the research phase (of around 30 - 60 minutes duration). The guided survey questionnaire will be used to firstly assist in determining the criteria that form part of the model and then to validate this model with a pairwise comparison process.

Participation in the study is voluntary, and you may withdraw at any time. Anonymity (regarding company name and any owner/manager/employee names) and confidentiality of information provided will be assured and respected. I would like to record the interviews, so I can later transcribe them. Your consent at the time of the interview will be requested. If you do not wish the interviews to be recorded this will be respected.

The results of the study will form part of my MSc research report and may also be reported in academic papers and at conferences. A summary of the results of the research will be made available to you on request.

Please contact me if you have any questions regarding the research and your participation. If you have any questions or concerns about your rights or treatment as a participant, you may contact the Chair of the School of Mechanical, Industrial and Aeronautical Research Ethics Committee (non-medical) Dr Bruno Emwanu at 011 717 7343 or bruno.emwanu@wits.ac.za.

I look forward to hearing from you.

Yours faithfully

Markus Meyer

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Appendix D – Questionnaire

A skills measurement model for the South African Energy Sector: applying the Analytic Hierarchy Process to the SA electric power industry

Thank you for agreeing to partake in this questionnaire. This study seeks to develop a model based on the Analytic Hierarchy Process (AHP), developed by Thomas Saaty, to measure skills in the energy sector in pairwise comparisons and thus being able to evaluate projects with regards to their inherent skill values.
The AHP process consist of a hierarchy of relationships between the goal of the study, the criteria the goal relies on, as well as 3 options that are compared to one another in their relative strengths of fulfilling the goals.

Below you will find a list of questions where 2 criteria will be compared to one another relating to a criteria on a higher level. For each question, please answer the following 2 points:

1. which of the 2 criteria is more important than the other
2. by how much more important is it than the other

The first answer will be a simple "A" or "B" answer, for the second part please refer to the following table and then assign a number between 1 and 9, indicating the magnitude of dominance of the one over the other.

Intensity of Importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
2	Weak or slight importance	
3	Moderate importance	Experience and judgement slightly favour one activity over another
4	Moderate plus importance	
5	Strong importance	Experience and judgement strongly favour one activity over another
6	Strong plus importance	
7	Very strong or demonstrated importance	An activity is favoured very strongly over another; its dominance is demonstrated in practise
8	Very, very strong importance	
9	Extremely strong importance	The evidence favouring one activity over another is of the highest possible order of affirmation

An example: in a study that is looking at buying a car the two criteria of safety and cost need to be compared to one another, the question is asked: Which of these 2 criteria is more important when considering to buy a car and by how much is the one more important than the other?

Objective of buying a car		Which Criteria is more important? A or B	By what magnitude is it more important? 1 to 9
A	B		
safety	cost	A	3

i.e. when considering to buy a car, the criteria of "safety" cost is moderately more important (value 3 from table) than the criteria of "cost".

With this in mind, please answer the following to the best of your ability and experience. Some topics might be less known to you than others, but a decision based on your experience will still be valid.

Questions:

1 **Comparing these criteria with each other, which of these criteria should be the more important to consider when evaluating a project based on the inherent value of skill it has:**

- potential for skills transfer inherent in this project
- current availability of skills to implement this project
- how much inherent potential there is for this project to comply with Government skills development objectives and legislation
- potential this project has in generating new types of skills for the electrical industry

Objective of determining the skill value in a project		Which Criteria is more important? A or B	By what magnitude is it more important? 1 to 9
A	B		
Potential for skills transfer in project	Current availability of skills		
Potential for skills transfer in project	In line with government skills objectives		
Potential for skills transfer in project	Potential to generate new skills for the energy sector		
In line with government skills objectives	Potential to generate new skills for the energy sector		
In line with government skills objectives	Current availability of skills		
Potential to generate new skills for the energy sector	Current availability of skills		

2 **When analysing the potential for skills transfer inherent in this project, please compare the following criteria with one another for their importance**

- potential for this project in aiding skill transfer for SMMEs (ST)

- potential for portable skills that can be generated by this project that can then be applied in different sectors (PS)
- potential for this project in providing mentorship to younger engineers (MJ)

Criteria to analyse the potential for skills transfer in a project		Which Criteria is more important? A or B	By what magnitude is it more important? 1 to 9
A	B		
Potential in aiding skills transfer for SMMEs	Potential for portable skills		
Potential in aiding skills transfer for SMMEs	Potential to provide mentorship to junior engineers		
Potential for portable skills	Potential to provide mentorship to junior engineers		

3 <u>When analysing the current availability of skills to implement this project, please compare the following criteria with one another for their importance</u>

- current availability of senior skills for this project in SA (SS)
- current availability of junior skills for this project in SA (JS)
- necessity to import senior skills internationally (IS)

Criteria to analyse the current availability of skills to implement this project		Which Criteria is more important? A or B	By what magnitude is it more important? 1 to 9
A	B		
Current availability of senior skills in SA	Current availability of junior skills in SA		
Current availability of senior skills in SA	Necessity to import senior skills internationally		
Current availability of junior skills in SA	Necessity to import senior skills internationally		

4 <u>When analysing how much inherent potential there is for this project to comply with Government skills development objectives and legislation, please compare the following criteria with one another for their importance</u>

- Skills Development Act, Accelerated and Shared Growth Initiative for South Africa and the Joint Initiative on Priority Skills Acquisition (LA)
- involvement of local community, focusing on skills transfer to take place, not financial benefit (LC)

Criteria to analyse the inherent potential there is for this project to comply with Government skills development objectives and legislation		Which Criteria is more important? A or B	By what magnitude is it more important? 1 to 9
A	B		
In line with govt skills legislation	Involvement of local community		

5 **When analysing how much potential this project has in generating new types of skills for the electrical industry, please compare the following criteria with one another for their importance**

- High likelihood (HL)
- Low likelihood (LL)

Criteria to analyse the potential in generating new types of skills for the electrical industry		Which Criteria is more important? A or B	By what magnitude is it more important? 1 to 9
A	B		
High likelihood	Low likelihood		

Now, three possible energy generating projects will be compared to one another in how they compare with each other in importance against the criteria previously mentioned. The three types of projects are:

- Coal-fired Power Station
- Nuclear Powered Power Station
- Wind Powered Power Station

6 **When comparing each energy generating project type, please compare the following alternatives with one another for their potential in aiding skills transfer for SMMEs**

Potential in aiding skills transfer for SMMEs		Which Alternative has the higher potential? A or B	By what magnitude is the potential more than the other alternative? 1 to 9
A	B		
Coal-fired Power Station	Nuclear Powered Power Station		
Coal-fired Power Station	Wind Power Station		
Nuclear Powered Power Station	Wind Power Station		

7 **When comparing each energy generating project type, please compare the following alternatives with one another for their potential in generating portable skills that can then be applied in different sectors**

Potential for portable skills		Which Alternative has the higher potential? A or B	By what magnitude is the potential more than the other alternative? 1 to 9
A	B		
Coal-fired Power Station	Nuclear Powered Power Station		
Coal-fired Power Station	Wind Power Station		
Nuclear Powered Power Station	Wind Power Station		

8 **<u>When comparing each energy generating project type, please compare the following alternatives with one another for their potential in providing mentorship to younger engineers</u>**

Potential to provide mentorship to junior engineers		Which Alternative has the higher potential? A or B	By what magnitude is the potential more than the other alternative? 1 to 9
A	B		
Coal-fired Power Station	Nuclear Powered Power Station		
Coal-fired Power Station	Wind Power Station		
Nuclear Powered Power Station	Wind Power Station		

9 **<u>When comparing each energy generating project type, please compare the following alternatives with one another for their current availability of senior skills to implement this project</u>**

Current availability of senior skills in SA		Which Alternative has the higher potential? A or B	By what magnitude is the potential more than the other alternative? 1 to 9
A	B		
Coal-fired Power Station	Nuclear Powered Power Station		
Coal-fired Power Station	Wind Power Station		
Nuclear Powered Power Station	Wind Power Station		

10 **<u>When comparing each energy generating project type, please compare the following alternatives with one another for their current availability of junior skills to implement this project</u>**

Current availability of junior skills in SA		Which Alternative has the higher potential? A or B	By what magnitude is the potential more than the other alternative? 1 to 9
A	B		
Coal-fired Power Station	Nuclear Powered Power Station		
Coal-fired Power Station	Wind Power Station		
Nuclear Powered Power Station	Wind Power Station		

11 **<u>When comparing each energy generating project type, please compare the following alternatives with one another for their current need to import skills to implement this project</u>**

Necessity to import senior skills internationally		Which Alternative has the higher potential? A or B	By what magnitude is the potential more than the other alternative? 1 to 9
A	B		
Coal-fired Power Station	Nuclear Powered Power Station		
Coal-fired Power Station	Wind Power Station		
Nuclear Powered Power Station	Wind Power Station		

12 **<u>When comparing each energy generating project type, please compare the following alternatives with one another for their potential of skills transfer in line with government legislation for this project</u>**

Skills transfer in line with govt skills legislation		Which Alternative has the higher potential? A or B	By what magnitude is the potential more than the other alternative? 1 to 9
A	B		
Coal-fired Power Station	Nuclear Powered Power Station		
Coal-fired Power Station	Wind Power Station		
Nuclear Powered Power Station	Wind Power Station		

13 **<u>When comparing each energy generating project type, please compare the following alternatives with one another for their potential of involvement of local community, focusing on skills transfer to take place, not financial benefit, in this project</u>**

Involvement of local community, focusing on		Which Alternative has	By what magnitude is the

skills transfer to take place, not financial benefit		the higher potential? A or B	potential more than the other alternative? 1 to 9
A	B		
Coal-fired Power Station	Nuclear Powered Power Station		
Coal-fired Power Station	Wind Power Station		
Nuclear Powered Power Station	Wind Power Station		

14 **<u>When comparing each energy generating project type, please compare the following alternatives with one another for their potential of a high likelihood in generating new types of skills for the electrical industry in this project</u>**

High likelihood in generating new types of skills for the electrical industry		Which Alternative has the higher potential? A or B	By what magnitude is the potential more than the other alternative? 1 to 9
A	B		
Coal-fired Power Station	Nuclear Powered Power Station		
Coal-fired Power Station	Wind Power Station		
Nuclear Powered Power Station	Wind Power Station		

15 **<u>When comparing each energy generating project type, please compare the following alternatives with one another for their potential of a low likelihood in generating new types of skills for the electrical industry in this project</u>**

Low likelihood in generating new types of skills for the electrical industry		Which Alternative has the higher potential? A or B	By what magnitude is the potential more than the other alternative? 1 to 9
A	B		
Coal-fired Power Station	Nuclear Powered Power Station		
Coal-fired Power Station	Wind Power Station		
Nuclear Powered Power Station	Wind Power Station		

Appendix E – Matrix 2

Table 39: Matrix 2 - Sub-criteria compared to skills transfer

n=	3	Number of criteria (2 to 10)	Scale: 1		AHP 1-9
N=	4	Number of Participants (1 to 20)	α: 0.1	Consensus:	80.1%
p=	0	selected Participant (0=consol.)	2 7		Consolidated

Objective which of these sub-criteria should be the more important to consider when evaluating the criteria of skills transfer in this project

Author

Date

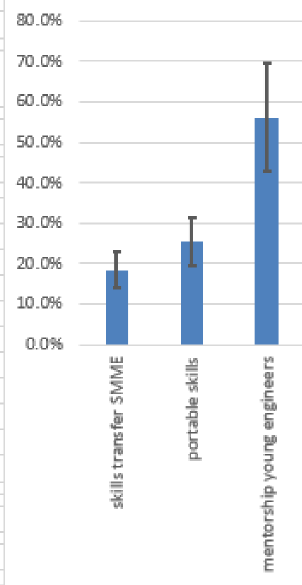
Thresh: 1E-08 Iterations: 9 EVM check: 1.6E-09

Table

	Criterion	Comment	Weights	+/-
1	skills transfer SM		18.4%	4.4%
2	portable skills		25.5%	6.1%
3	mentorship youn		56.1%	13.4%
4			0.0%	0.0%
5			0.0%	0.0%
6			0.0%	0.0%
7			0.0%	0.0%
8			0.0%	0.0%
9		for 9&10 unprotect the input sheets and expand the	0.0%	0.0%
#		question section ("+" in row 66)	0.0%	0.0%

Result

Eigenvalue				Lambda:	3.058	MRE: 23.8%
Consistency Ratio	0.37	GCI: 0.17	Psi: 0.0%	CR:	6.0%	



Matrix

		skills transfer SMME	portable skills	mentorship young	0	0	0	0	0	0	0	normalized principal Eigenvector
		1	2	3	4	5	6	7	8	9	10	
skills transfer	1	1	1	1/4	-	-	-	-	-	-	-	18.42%
portable skills	2	1	1	4/7	-	-	-	-	-	-	-	25.48%
mentorship young	3	3 7/8	1 3/4	1	-	-	-	-	-	-	-	56.11%
0	4	-	-	-	1	-	-	-	-	-	-	0.00%
0	5	-	-	-	-	1	-	-	-	-	-	0.00%

Appendix F – Matrix 3

Table 40: Matrix 3 - Sub-criteria compared to current availability of skills

n=	3	Number of criteria (2 to 10)	Scale:	1	AHP 1-9
N=	4	Number of Participants (1 to 20)	α:	0.1	Consensus: 73.1%
p=	0	selected Participant (0=consol.)	2	7	Consolidated

Objective which of these sub-criteria should be the more important to consider when evaluating the criteria of analysing the current availability of skills to implement this project

Author

Date

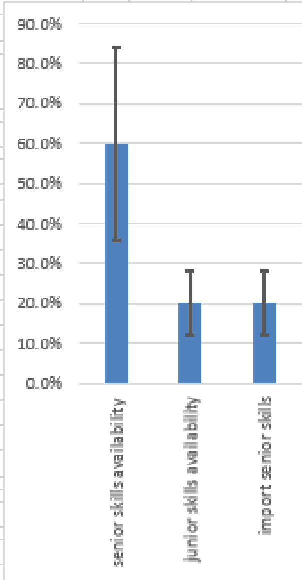
Thresh: 1E-08 Iterations: 8 EVM check: 8.7E-09

Table

	Criterion	Comment	Weights	+/-
1	senior skills availat		59.8%	23.9%
2	junior skills availab		20.1%	8.0%
3	import senior skills		20.2%	8.1%
4			0.0%	0.0%
5			0.0%	0.0%
6			0.0%	0.0%
7			0.0%	0.0%
8			0.0%	0.0%
9		for 9&10 unprotect the input sheets and expand the	0.0%	0.0%
#		question section ("+" in row 66)	0.0%	0.0%

Result

Eigenvalue			Lambda:	3.169		MRE:	40.0%
Consistency Ratio	0.37	GCI:	0.50	Psi:	33.3%	CR:	17.7%



Matrix

		senior skills availability	junior skills availability	import senior skills	0	0	0	0	0	0	0	normalized principal Eigenvector
		1	2	3	4	5	6	7	8	9	10	
senior skills availabilitu	1	1	4 1/2	2	-	-	-	-	-	-	-	59.77%
junior skills availabilitu	2	2/9	1	1 1/2	-	-	-	-	-	-	-	20.05%
import senior skills	3	1/2	2/3	1	-	-	-	-	-	-	-	20.18%
0	4	-	-	-	1	-	-	-	-	-	-	0.00%
0	5	-	-	-	-	1	-	-	-	-	-	0.00%

Name	Weight	Date	α:	Consistency Ratio
Participant 1	1		0.1	CR: 14%

i	j	Criteria A	B	more important ? A or B	Scale (1-9)		
1	2	senior skills availability	junior skills availability	A	3	3	A2
1	3		import senior skills	B	3	2	B2
1	4						
1	5						
1	6						
1	7						
1	8						
2	3	junior skills availability	import senior skills	B	3	1	B4
2	4						
2	5						
2	6						
2	7						
2	8						
3	4						

Table 41: Participant 1 - Original weightings

Participant 1	1			α:	0.1	CR:	0%
Name	Weight	Date				Consistency Ratio	

		Criteria		more important ?	Scale
i	j	A	B	A or B	(1-9)
1	2	senior skills availability	junior skills availability	A	3
1	3		import senior skills	a	3
1	4				
1	5				
1	6				
1	7				
1	8				
2	3	junior skills availability	import senior skills	a	1
2	4				
2	5				
2	6				
2	7				
2	8				
3	4				

Table 42: Participant 1 - Revised weightings

Participant 4	1			α:	0.1	CR:	59%
Name	Weight	Date				Consistency Ratio	

		Criteria		more important ?	Scale	
i	j	A	B	A or B	(1-9)	
1	2	senior skills availability	junior skills availability	A	9	1
1	3		import senior skills	A	5	
1	4					
1	5					
1	6					
1	7					
1	8					
2	3	junior skills availability	import senior skills	A	5	1
2	4					
2	5					
2	6					
2	7					
2	8					

Table 43: Participant 4 - Original weightings

Participant 4	1			α:	0.1	CR:	45%
Name	Weight	Date				Consistency Ratio	

		Criteria		more important ?	Scale	
i	j	A	B	A or B	(1-9)	
1	2	senior skills availability	junior skills availability	A	7	1
1	3		import senior skills	A	5	
1	4					
1	5					
1	6					
1	7					
1	8					
2	3	junior skills availability	import senior skills	A	5	1
2	4					
2	5					
2	6					
2	7					
2	8					

Table 44: Participant 4 - Revised weightings

Table 45: Matrix 3 – Updated sub-criteria compared to current availability of skills

n=	3	Number of criteria (2 to 10)	Scale: 1		AHP 1-9
N=	4	Number of Participants (1 to 20)	α: 0.1	Consensus:	96.0%
p=	0	selected Participant (0=consol.)	2 7		Consolidated

Objective which of these sub-criteria should be the more important to consider when evaluating the criteria of analysing the current availability of skills to implement this project

Author

Date

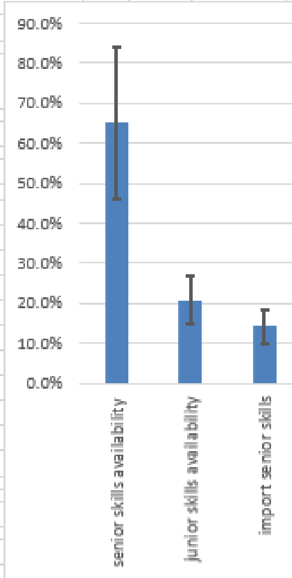
Thresh: 1E-08 Iterations: 9 EVM check: 1.1E-09

Table

	Criterion	Comment	Weights	+/-
1	senior skills availat		65.0%	19.1%
2	junior skills availab		20.8%	6.1%
3	import senior skills		14.2%	4.2%
4			0.0%	0.0%
5			0.0%	0.0%
6			0.0%	0.0%
7			0.0%	0.0%
8			0.0%	0.0%
9		for 9&10 unprotect the input sheets and expand the	0.0%	0.0%
#		question section ("+" in row 66)	0.0%	0.0%

Result

Eigenvalue			Lambda:	3.088	MRE:	29.3%
Consistency Ratio	0.37	GCI: 0.26	Psi: 33.3%	CR: 9.2%		



Matrix

		senior skills availability	junior skills availability	import senior skills	0	0	0	0	0	0	0	normalized principal Eigenvector
		1	2	3	4	5	6	7	8	9	10	
senior skills availability	1	1	4 1/5	3 2/5	-	-	-	-	-	-	-	65.05%
junior skills availability	2	1/4	1	2	-	-	-	-	-	-	-	20.76%
import senior skills	3	2/7	1/2	1	-	-	-	-	-	-	-	14.19%
0	4	-	-	-	1	-	-	-	-	-	-	0.00%
0	5	-	-	-	-	1	-	-	-	-	-	0.00%

Appendix G – Matrix 4

Table 46: Matrix 4 – Sub-criteria compared to government objectives and legislation

n=	2	Number of criteria (2 to 10)	Scale:	1	AHP 1-9
N=	4	Number of Participants (1 to 20)	α:	0.1	Consensus: 64.5%
p=	0	selected Participant (0=consol.)	2	7	Consolidated

Objective which of these sub-criteria should be the more important to consider when evaluating the criteria of complying with govt skills development objectives and legislation in this project

Author

Date

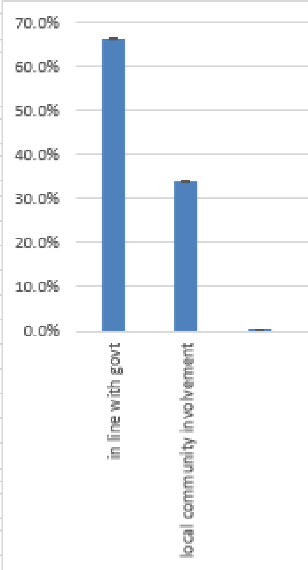
Thresh: 1E-08 Iterations: 14 EVM check: 8.1E-09

Table

	Criterion	Comment	Weights	+/-
1	in line with govt		66.3%	0.0%
2	local community inv		33.7%	0.0%
3			0.0%	0.0%
4			0.0%	0.0%
5			0.0%	0.0%
6			0.0%	0.0%
7			0.0%	0.0%
8			0.0%	0.0%
9		for 9&10 unprotect the input sheets and expand the	0.0%	0.0%
#		question section ("+" in row 66)	0.0%	0.0%

Result

Eigenvalue		Lambda: 2.000		MRE: 0.0%
Consistency Ratio	0.37 GCI: n/a	Psi: n/a	CR: 0.0%	0.0%



Matrix

			in line with govt	local community	0	0	0	0	0	0	0	0	normalized principal Eigenvector
			1	2	3	4	5	6	7	8	9	10	
in line with govt	1		1	2	-	-	-	-	-	-	-	-	66.31%
local community	2		1/2	1	-	-	-	-	-	-	-	-	33.69%
0	3		-	-	1	-	-	-	-	-	-	-	0.00%
0	4		-	-	-	1	-	-	-	-	-	-	0.00%
0	5		-	-	-	-	1	-	-	-	-	-	0.00%

Appendix H – Matrix 5

Table 47: Matrix 5 – Sub-criteria compared to gaining new skills for electrical industry

n=	2	Number of criteria (2 to 10)	Scale:	1	AHP 1-9
N=	4	Number of Participants (1 to 20)	α: 0.1	Consensus:	92.4%
p=	0	selected Participant (0=consol.)	2 7		Consolidated

Objective which of these sub-criteria should be the more important to consider when evaluating the criteria of genrating new skills for the elctrical industry in this project

Author

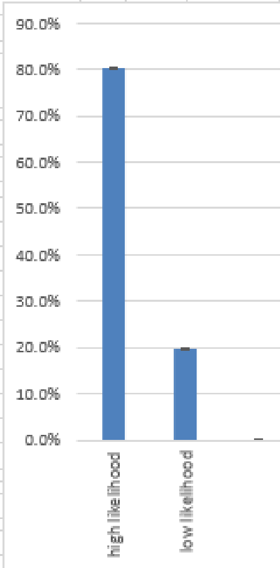
Date Thresh: 1E-08 Iterations: 14 EVM check: 4.8E-09

Table

	Criterion	Comment	Weights	+/-
1	high likelihood		80.2%	0.0%
2	low likelihood		19.8%	0.0%
3			0.0%	0.0%
4			0.0%	0.0%
5			0.0%	0.0%
6			0.0%	0.0%
7			0.0%	0.0%
8			0.0%	0.0%
9		for 9&10 unprotect the input sheets and expand the	0.0%	0.0%
#		question section ("+" in row 66)	0.0%	0.0%

Result

Eigenvalue		Lambda: 2.000	MRE:	0.0%
Consistency Ratio	0.37 GCI: n/a	Psi: n/a	CR: 0.0%	0.0%



Matrix

			high likelihood 1	low likelihood 2	0 3	0 4	0 5	0 6	0 7	0 8	0 9	0 10	normalized principal Eigenvector
high likelihood	1		1	4	-	-	-	-	-	-	-	-	80.21%
low likelihood	2		1/4	1	-	-	-	-	-	-	-	-	19.79%
0	3		-	-	1	-	-	-	-	-	-	-	0.00%
0	4		-	-	-	1	-	-	-	-	-	-	0.00%
0	5		-	-	-	-	1	-	-	-	-	-	0.00%
0	6		-	-	-	-	-	1	-	-	-	-	0.00%

Appendix I – Matrix 6

Table 48: Matrix 6 – Alternatives compared to aiding skills transfer for SMMEs

n=	3	Number of criteria (2 to 10)	Scale:	1	AHP 1-9
N=	4	Number of Participants (1 to 20)	α:	0.1	Consensus: 99.1%
p=	0	selected Participant (0=consol.)	2	7	Consolidated

Objective When comparing each energy generating project type, please compare the following alternatives with one another for their potential in aiding skills transfer for SMMEs

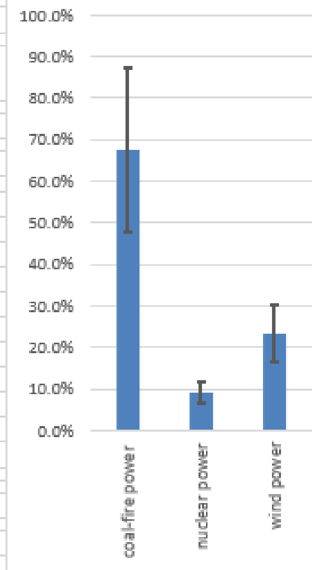
Author

Date

Thresh: 1E-08 Iterations: 8 EVM check: 7.1E-09

Table

	Criterion	Comment	Weights	+/-
1	coal-fire power		67.4%	19.7%
2	nuclear power		9.2%	2.7%
3	wind power		23.4%	6.8%
4			0.0%	0.0%
5			0.0%	0.0%
6			0.0%	0.0%
7			0.0%	0.0%
8			0.0%	0.0%
9		for 9&10 unprotect the input sheets and expand the	0.0%	0.0%
#		question section ("+" in row 66)	0.0%	0.0%



Result

Eigenvalue				Lambda:	3.088	MRE:	29.2%
Consistency Ratio	0.37	GCI:	0.26	Psi:	0.0%	CR:	9.2%

Matrix

		coal-fire power 1	nuclear power 2	wind power 3	0 4	0 5	0 6	0 7	0 8	0 9	0 10	normalized principal Eigenvector
coal-fire power	1	1	5 4/9	3 7/8	-	-	-	-	-	-	-	67.39%
nuclear power	2	1/5	1	2/7	-	-	-	-	-	-	-	9.22%
wind power	3	1/4	3 2/5	1	-	-	-	-	-	-	-	23.39%
0	4	-	-	-	1	-	-	-	-	-	-	0.00%
0	5	-	-	-	-	1	-	-	-	-	-	0.00%

Appendix J – Matrix 7

Table 49: Matrix 7 – Alternatives compared to generating portable skills

n=	3	Number of criteria (2 to 10)	Scale:	1		AHP 1-9
N=	4	Number of Participants (1 to 20)	α:	0.1	Consensus:	89.3%
p=	0	selected Participant (0=consol.)	2	7		Consolidated

Objective When comparing each energy generating project type, please compare the following alternatives with one another for their potential in generating portable skills that can then be

Author

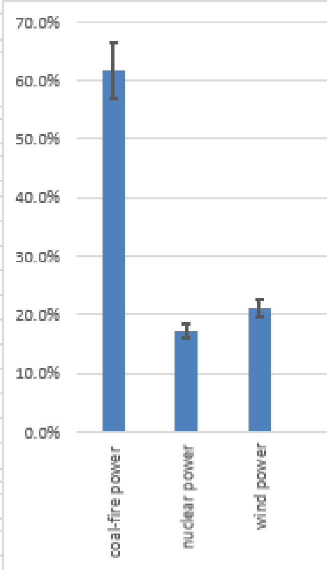
Date Thresh: 1E-08 Iterations: 9 EVM check: 2.0E-09

Table

	Criterion	Comment	Weights	+/-
1	coal-fire power		61.7%	4.7%
2	nuclear power		17.2%	1.3%
3	wind power		21.1%	1.6%
4			0.0%	0.0%
5			0.0%	0.0%
6			0.0%	0.0%
7			0.0%	0.0%
8			0.0%	0.0%
9		for 9&10 unprotect the input sheets and expand the	0.0%	0.0%
#		question section ("+" in row 66)	0.0%	0.0%

Result

Eigenvalue				Lambda:	3.006	MRE:	7.6%
Consistency Ratio	0.37	GCI:	0.02	Psi:	0.0%	CR:	0.6%



Matrix

		coal-fire power 1	nuclear power 2	wind power 3	0 4	0 5	0 6	0 7	0 8	0 9	0 10	normalized principal Eigenvector
coal-fire power	1	1	3 7/8	2 5/7	-	-	-	-	-	-	-	61.71%
nuclear power	2	1/4	1	7/8	-	-	-	-	-	-	-	17.20%
wind power	3	3/8	1 1/7	1	-	-	-	-	-	-	-	21.09%
0	4	-	-	-	1	-	-	-	-	-	-	0.00%
0	5	-	-	-	-	1	-	-	-	-	-	0.00%

Appendix K – Matrix 8

Table 50: Matrix 8 – Alternatives compared to providing mentorship to young engineers

n=	3	Number of criteria (2 to 10)	Scale:	1	AHP 1-9
N=	4	Number of Participants (1 to 20)	α: 0.1	Consensus:	87.9%
p=	0	selected Participant (0=consol.)	2 7		Consolidated

Objective When comparing each energy generating project type, please compare the following alternatives with one another for their potential in providing mentorship to younger engineers

Author

Date

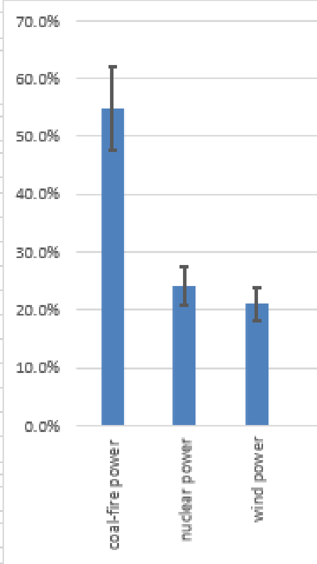
Thresh: 1E-08 Iterations: 9 EVM check: 2.2E-09

Table

	Criterion	Comment	Weights	+/-
1	coal-fire power		54.8%	7.3%
2	nuclear power		24.2%	3.2%
3	wind power		21.0%	2.8%
4			0.0%	0.0%
5			0.0%	0.0%
6			0.0%	0.0%
7			0.0%	0.0%
8			0.0%	0.0%
9		for 9&10 unprotect the input sheets and expand the	0.0%	0.0%
#		question section ("+" in row 66)	0.0%	0.0%

Result

Eigenvalue			Lambda: 3.018		MRE: 13.4%
Consistency Ratio	0.37	GCI: 0.05	Psi: 33.3%	CR: 1.9%	



Matrix

		coal-fire power 1	nuclear power 2	wind power 3	0 4	0 5	0 6	0 7	0 8	0 9	0 10	normalized principal Eigenvector
coal-fire power	1	1	2 3/5	2 2/7	-	-	-	-	-	-	-	54.79%
nuclear power	2	2/5	1	1 1/3	-	-	-	-	-	-	-	24.19%
wind power	3	4/9	3/4	1	-	-	-	-	-	-	-	21.02%
0	4	-	-	-	1	-	-	-	-	-	-	0.00%
0	5	-	-	-	-	1	-	-	-	-	-	0.00%

Appendix L – Matrix 9

Table 51: Matrix 9 – Alternatives compared to current availability of senior skills

n=	3	Number of criteria (2 to 10)	Scale:	1	AHP 1-9
N=	4	Number of Participants (1 to 20)	α:	0.1	Consensus: 98.6%
p=	0	selected Participant (0=consol.)	2	7	Consolidated

Objective When comparing each energy generating project type, please compare the following alternatives with one another for their current availability of senior skills to implement this

Author

Date

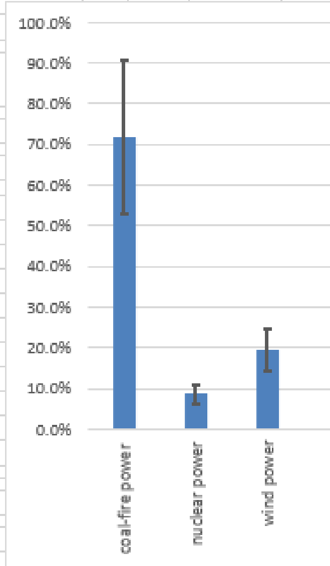
Thresh: 1E-08 Iterations: 8 EVM check: 6.8E-09

Table

	Criterion	Comment	Weights	+/-
1	coal-fire power		71.8%	19.1%
2	nuclear power		8.5%	2.3%
3	wind power		19.6%	5.2%
4			0.0%	0.0%
5			0.0%	0.0%
6			0.0%	0.0%
7			0.0%	0.0%
8			0.0%	0.0%
9		for 9&10 unprotect the input sheets and expand the	0.0%	0.0%
#		question section ("+" in row 66)	0.0%	0.0%

Result

Eigenvalue				Lambda:	3.072	MRE:	26.5%
Consistency Ratio	0.37	GCI: 0.21	Psi: 0.0%	CR:	7.5%		



Matrix

		coal-fire power 1	nuclear power 2	wind power 3	0 4	0 5	0 6	0 7	0 8	0 9	0 10	normalized principal Eigenvector
coal-fire power	1	1	6 3/7	4 4/5	-	-	-	-	-	-	-	71.84%
nuclear power	2	1/6	1	1/3	-	-	-	-	-	-	-	8.54%
wind power	3	1/5	3	1	-	-	-	-	-	-	-	19.61%
0	4	-	-	-	1	-	-	-	-	-	-	0.00%
0	5	-	-	-	-	1	-	-	-	-	-	0.00%

Appendix M – Matrix 10

Table 52: Matrix 10 – Alternatives compared to current availability of junior skills

n=	3	Number of criteria (2 to 10)	Scale: 1	AHP 1-9
N=	4	Number of Participants (1 to 20)	α: 0.1	Consensus: 91.0%
	3 9			
p=	0	selected Participant (0=consol.)	2 7	Consolidated

Objective When comparing each energy generating project type, please compare the following alternatives with one another for their current availability of junior skills to implement this project

Author

Date

Thresh: 1E-08 Iterations: 9 EVM check: 1.1E-09

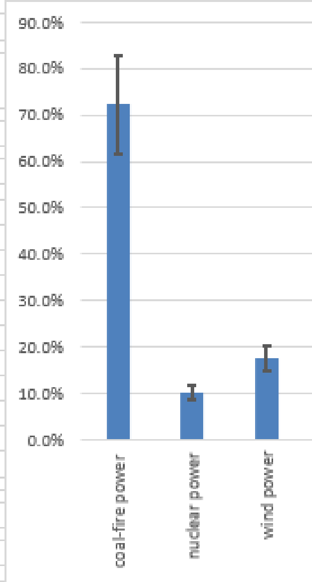
Table

	Criterion	Comment	Weights	+/-
1	coal-fire power		72.2%	10.7%
2	nuclear power		10.3%	1.5%
3	wind power		17.5%	2.6%
4			0.0%	0.0%
5			0.0%	0.0%
6			0.0%	0.0%
7			0.0%	0.0%
8			0.0%	0.0%
9		for 9&10 unprotect the input sheets and expand the	0.0%	0.0%
#		question section ("+" in row 66)	0.0%	0.0%

Result

Eigenvalue Lambda: 3.022 MRE: 14.8%

Consistency Ratio 0.37 GCI: 0.07 Psi: 0.0% CR: 2.3%



Matrix

		coal-fire power 1	nuclear power 2	wind power 3	0 4	0 5	0 6	0 7	0 8	0 9	0 10	normalized principal Eigenvector
coal-fire power	1	1	6	4 4/5	-	-	-	-	-	-	-	72.19%
nuclear power	2	1/6	1	1/2	-	-	-	-	-	-	-	10.32%
wind power	3	1/5	2	1	-	-	-	-	-	-	-	17.50%
0	4	-	-	-	1	-	-	-	-	-	-	0.00%

Appendix N – Matrix 11

Table 53: Matrix 11 – Alternatives compared to need to import skills

n=	3	Number of criteria (2 to 10)	Scale:	1	AHP 1-9
N=	4	Number of Participants (1 to 20)	α:	0.1	Consensus: 99.4%
	3 9				
p=	0	selected Participant (0=consol.)	2	7	Consolidated

Objective When comparing each energy generating project type, please compare the following alternatives with one another for their current need to import skills to implement this project

Author

Date

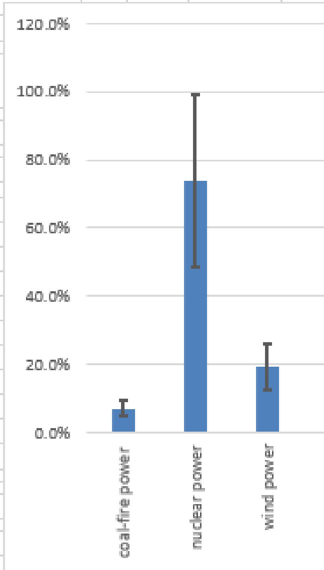
Thresh: 1E-08 Iterations: 8 EVM check: 4.3E-09

Table

	Criterion	Comment	Weights	+/-
1	coal-fire power		7.0%	2.4%
2	nuclear power		73.8%	25.2%
3	wind power		19.2%	6.5%
4			0.0%	0.0%
5			0.0%	0.0%
6			0.0%	0.0%
7			0.0%	0.0%
8			0.0%	0.0%
9		for 9&10 unprotect the input sheets and expand the	0.0%	0.0%
#		question section ("+" in row 66)	0.0%	0.0%

Result

Eigenvalue				Lambda:	3.121	MRE:	34.1%
Consistency Ratio	0.37	GCI:	0.36	Psi:	0.0%	CR:	12.6%



Matrix

		coal-fire power	nuclear power	wind power	0	0	0	0	0	0	0
		1	2	3	4	5	6	7	8	9	10
coal-fire power	1	1	1/7	1/4	-	-	-	-	-	-	-
nuclear power	2	7 4/9	1	5 4/9	-	-	-	-	-	-	-
wind power	3	3 7/8	1/5	1	-	-	-	-	-	-	-
0	4	-	-	-	1	-	-	-	-	-	-
0	5	-	-	-	-	1	-	-	-	-	-

normalized principal Eigenvector

7.00%
73.81%
19.19%
0.00%
0.00%

Participant 3	1		α:	0.1	CR: 19%
Name	Weight	Date			Consistency Ratio

i	j	A	B	more important ? A or B	Scale (1-9)		
1	2	coal-fire power	nuclear power	b	7		
1	3		wind power	b	5	2	B3
1	4						
1	5						
1	6						
1	7						
1	8						
2	3	nuclear power	wind power	a	5	1	A3
2	4						
2	5						
2	6						
2	7						
2	8						
3	4						

Table 54: Participant 3 - Original weightings

Participant 3	1		α: 0.1	CR: 7%
Name	Weight	Date		Consistency Ratio

i	j	Criteria A	B	more important ? A or B	Scale (1-9)
1	2	coal-fire power	nuclear power	b	7
1	3		wind power	b	3
1	4				
1	5				
1	6				
1	7				
1	8				
2	3	nuclear power	wind power	a	5
2	4				
2	5				
2	6				
2	7				
2	8				
3	4				

Table 55: Participant 3 - Revised weightings

n=	3	Number of criteria (2 to 10)	Scale: 1		AHP 1-9
N=	4	Number of Participants (1 to 20)	α: 0.1	Consensus:	99.6%
p=	0	selected Participant (0=consol.)	2 7		Consolidated

Objective When comparing each energy generating project type, please compare the following alternatives with one another for their current need to import skills to implement this project

Author

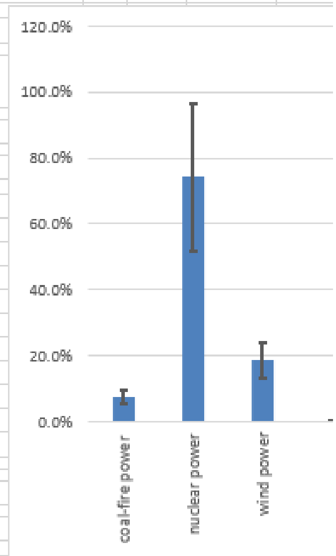
Date Thresh: 1E-08 Iterations: 8 EVM check: 5.1E-09

Table

	Criterion	Comment	Weights	+/-
1	coal-fire power		7.3%	2.2%
2	nuclear power		74.2%	22.3%
3	wind power		18.5%	5.5%
4			0.0%	0.0%
5			0.0%	0.0%
6			0.0%	0.0%
7			0.0%	0.0%
8			0.0%	0.0%
9		for 9&10 unprotect the input sheets and expand the	0.0%	0.0%
#		question section ("+" in row 66)	0.0%	0.0%

Result

Eigenvalue			Lambda: 3.093		MRE: 30.0%
Consistency Ratio	0.37	GCI: 0.28	Psi: 0.0%	CR: 9.7%	



Matrix

		coal-fire power 1	nuclear power 2	wind power 3	0 4	0 5	0 6	0 7	0 8	0 9	0 10	normalized principal Eigenvector
coal-fire power	1	1	1/7	2/7	-	-	-	-	-	-	-	7.34%
nuclear power	2	7 4/9	1	5 4/9	-	-	-	-	-	-	-	74.18%
wind power	3	3 2/5	1/5	1	-	-	-	-	-	-	-	18.48%
0	4	-	-	-	1	-	-	-	-	-	-	0.00%
0	5	-	-	-	-	1	-	-	-	-	-	0.00%

Table 56: Matrix 11 – Updated alternatives compared to need to import skills

Appendix O – Matrix 12

Table 57: Matrix 12 – Alternatives compared to government objectives and legislation

n=	3	Number of criteria (2 to 10)	Scale: 1	AHP 1-9
N=	4	Number of Participants (1 to 20)	α: 0.1	Consensus: 81.1%
p=	0	selected Participant (0=consol.)	2 7	Consolidated

Objective When comparing each energy generating project type, please compare the following alternatives with one another for their potential of skills transfer in line with government

Author

Date

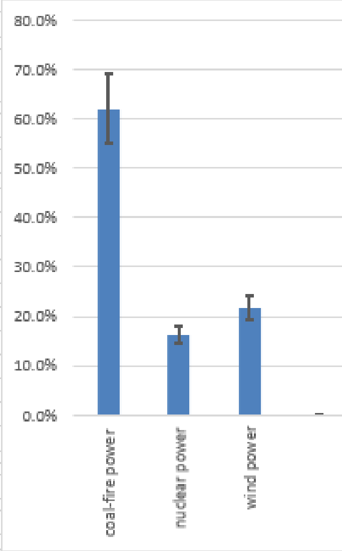
Thresh: 1E-08 Iterations: 9 EVM check: 1.8E-09

Table

	Criterion	Comment	Weights	+/-
1	coal-fire power		62.0%	7.0%
2	nuclear power		16.3%	1.8%
3	wind power		21.7%	2.5%
4			0.0%	0.0%
5			0.0%	0.0%
6			0.0%	0.0%
7			0.0%	0.0%
8			0.0%	0.0%
9		for 9&10 unprotect the input sheets and expand the	0.0%	0.0%
#		question section ("+" in row 66)	0.0%	0.0%

Result

Eigenvalue			Lambda: 3.013		MRE: 11.3%
Consistency Ratio	0.37	GCI: 0.04	Psi: 0.0%	CR: 1.3%	



Matrix

		coal-fire power 1	nuclear power 2	wind power 3	0 4	0 5	0 6	0 7	0 8	0 9	0 10	normalized principal Eigenvector
coal-fire power	1	1	3 2/5	3 1/5	-	-	-	-	-	-	-	62.04%
nuclear power	2	2/7	1	2/3	-	-	-	-	-	-	-	16.25%
wind power	3	1/3	1 1/2	1	-	-	-	-	-	-	-	21.70%
0	4	-	-	-	1	-	-	-	-	-	-	0.00%
0	5	-	-	-	-	1	-	-	-	-	-	0.00%

Appendix P – Matrix 13

Table 58: Matrix 13 – Alternatives compared to involvement of local community

n=	3	Number of criteria (2 to 10)	Scale: 1	AHP 1-9
N=	4	Number of Participants (1 to 20)	α: 0.1	Consensus: 86.9%
p=	0	selected Participant (0=consol.)	2 7	Consolidated

Objective When comparing each energy generating project type, please compare the following alternatives with one another for their potential of involvement of local community, focusing on

Author

Date

Thresh: 1E-08 Iterations: 9 EVM check: 1.4E-09

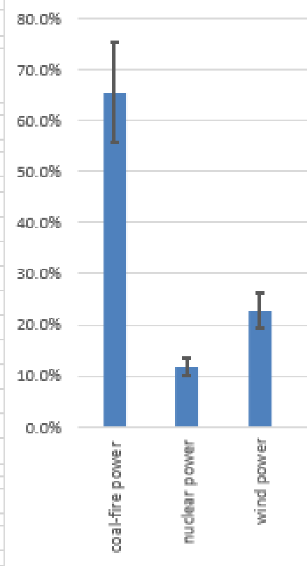
Table

	Criterion	Comment	Weights	+/-
1	coal-fire power		65.5%	9.7%
2	nuclear power		11.8%	1.7%
3	wind power		22.7%	3.4%
4			0.0%	0.0%
5			0.0%	0.0%
6			0.0%	0.0%
7			0.0%	0.0%
8			0.0%	0.0%
9		for 9&10 unprotect the input sheets and expand the	0.0%	0.0%
#		question section ("+" in row 66)	0.0%	0.0%

Result

Eigenvalue Lambda: 3.022 MRE: 14.8%

Consistency Ratio 0.37 GCI: 0.07 Psi: 0.0% CR: 2.3%



Matrix

		coal-fire power 1	nuclear power 2	wind power 3	0 4	0 5	0 6	0 7	0 8	0 9	0 10	normalized principal Eigenvector
coal-fire power	1	1	4 4/5	3 1/3	-	-	-	-	-	-	-	65.49%
nuclear power	2	1/5	1	4/9	-	-	-	-	-	-	-	11.79%
wind power	3	2/7	2 1/4	1	-	-	-	-	-	-	-	22.72%
0	4	-	-	-	1	-	-	-	-	-	-	0.00%

Appendix Q – Matrix 14

Table 59: Matrix 14 – Alternatives compared to high likelihood of generating new skills

n=	3	Number of criteria (2 to 10)	Scale:	1	AHP 1-9
N=	4	Number of Participants (1 to 20)	α:	0.1	Consensus: 98.7%
p=	0	selected Participant (0=consol.)	2	7	Consolidated

Objective When comparing each energy generating project type, please compare the following alternatives with one another for their potential of a high likelihood in generating new types of

Author

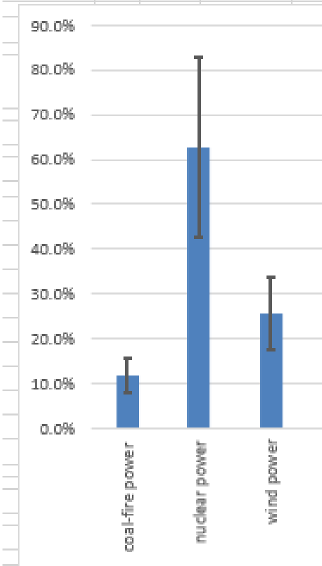
Date Thresh: 1E-08 Iterations: 8 EVM check: 8.5E-09

Table

	Criterion	Comment	Weights	+/-
1	coal-fire power		11.7%	3.7%
2	nuclear power		62.8%	20.1%
3	wind power		25.5%	8.1%
4			0.0%	0.0%
5			0.0%	0.0%
6			0.0%	0.0%
7			0.0%	0.0%
8			0.0%	0.0%
9		for 9&10 unprotect the input sheets and expand the	0.0%	0.0%
#		question section ("+" in row 66)	0.0%	0.0%

Result

Eigenvalue		Lambda: 3.106		MRE: 31.9%
Consistency Ratio	0.37	GCI: 0.31	Psi: 0.0%	CR: 11.0%



Matrix

		coal-fire power 1	nuclear power 2	wind power 3	0 4	0 5	0 6	0 7	0 8	0 9	0 10
coal-fire power	1	1	1/4	1/3	-	-	-	-	-	-	-
nuclear power	2	3 7/8	1	3 2/5	-	-	-	-	-	-	-
wind power	3	3	2/7	1	-	-	-	-	-	-	-
0	4	-	-	-	1	-	-	-	-	-	-

normalized principal Eigenvector

11.73%
62.80%
25.47%
0.00%

Participant 4	1		α: 0.1	CR: 14%
Name	Weight	Date		Consistency Ratio

i	j	Criteria A	B	more important? A or B	Scale (1-9)	
1	2	coal-fire power	nuclear power	b	5	3
1	3		wind power	b	3	2
1	4					
1	5					
1	6					
1	7					
1	8					
2	3	nuclear power	wind power	a	5	1
2	4					
2	5					
2	6					
2	7					
2	8					

Table 60: Participant 4 - Original weightings

Participant 4	1		α: 0.1	CR: 4%
Name	Weight	Date		Consistency Ratio

i	j	A	B	more important ? A or B	Scale (1-9)
1	2	coal-fire power	nuclear power	b	5
1	3		wind power	b	3
1	4				
1	5				
1	6				
1	7				
1	8				
2	3	nuclear power	wind power	a	3
2	4				
2	5				
2	6				
2	7				
2	8				

Table 61: Participant 4 - Revised weightings

n= 3 Number of criteria (2 to 10) Scale: 1 AHP 1-9

N= 4 Number of Participants (1 to 20) α: 0.1 Consensus: 99.6%

p= 0 selected Participant (0=consol.) 2 7 Consolidated

Objective When comparing each energy generating project type, please compare the following alternatives with one another for their potential of a high likelihood in generating new types of

Author

Date Thresh: 1E-08 Iterations: 8 EVM check: 9.8E-09

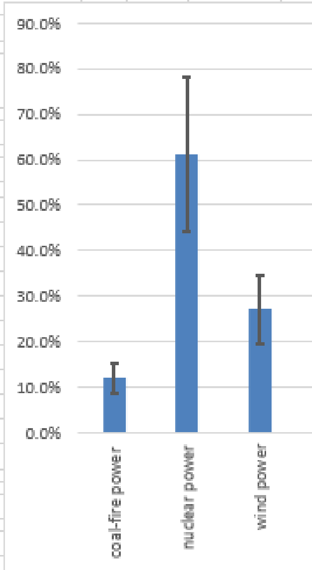
Table

	Criterion	Comment	Weights	+/-
1	coal-fire power		11.9%	3.3%
2	nuclear power		61.1%	17.0%
3	wind power		27.0%	7.5%
4			0.0%	0.0%
5			0.0%	0.0%
6			0.0%	0.0%
7			0.0%	0.0%
8			0.0%	0.0%
9		for 9&10 unprotect the input sheets and expand the	0.0%	0.0%
#		question section ("+" in row 66)	0.0%	0.0%

Result

Eigenvalue Lambda: 3.080 MRE: 27.8%

Consistency Ratio 0.37 GCI: 0.24 Psi: 0.0% CR: 8.3%



Matrix

		coal-fire power 1	nuclear power 2	wind power 3	0 4	0 5	0 6	0 7	0 8	0 9	0 10	normalized principal Eigenvector
coal-fire power	1	1	1/4	1/3	-	-	-	-	-	-	-	11.91%
nuclear power	2	3 7/8	1	3	-	-	-	-	-	-	-	61.11%
wind power	3	3	1/3	1	-	-	-	-	-	-	-	26.98%
0	4	-	-	-	1	-	-	-	-	-	-	0.00%
0	5	-	-	-	-	1	-	-	-	-	-	0.00%

Table 62: Matrix 14 – Updated alternatives compared to high likelihood of generating new skills

Appendix R – Matrix 15

Table 63: Matrix 15 – Alternatives compared to low likelihood of generating new skills

n=	3	Number of criteria (2 to 10)	Scale: 1		AHP 1-9
N=	4	Number of Participants (1 to 20)	α: 0.1	Consensus:	63.4%
p=	0	selected Participant (0=consol.)	2 7		Consolidated

Objective: When comparing each energy generating project type, please compare the following alternatives with one another for their potential of a low likelihood in generating new types of

Author

Date

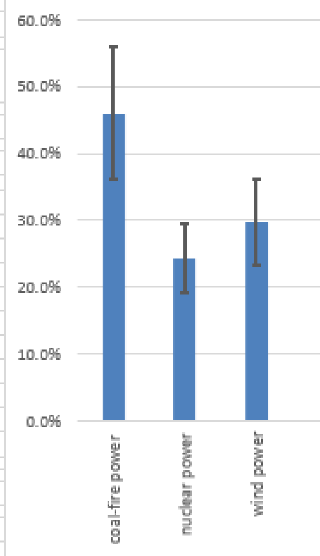
Thresh: 1E-08 Iterations: 9 EVM check: 2.1E-09

Table

	Criterion	Comment	Weights	+/-
1	coal-fire power		46.0%	9.9%
2	nuclear power		24.3%	5.2%
3	wind power		29.8%	6.4%
4			0.0%	0.0%
5			0.0%	0.0%
6			0.0%	0.0%
7			0.0%	0.0%
8			0.0%	0.0%
9		for 9&10 unprotect the input sheets and expand the	0.0%	0.0%
#		question section ("+" in row 66)	0.0%	0.0%

Result

Eigenvalue		Lambda: 3.047		MRE: 21.6%
Consistency Ratio	0.37	GCI: 0.14	Psi: 33.3%	CR: 4.9%



Matrix

		coal-fire power	nuclear power	wind power	0	0	0	0	0	0	0	normalized principal Eigenvector
		1	2	3	4	5	6	7	8	9	10	
coal-fire power	1	1	1 1/2	2	-	-	-	-	-	-	-	45.95%
nuclear power	2	2/3	1	2/3	-	-	-	-	-	-	-	24.27%
wind power	3	1/2	1 1/2	1	-	-	-	-	-	-	-	29.78%
0	4	-	-	-	1	-	-	-	-	-	-	0.00%

Appendix S – Tables 64 to 72 of Priorities of Alternatives

Table 64: Local and global priorities of alternatives compared to PS

PRIORITIES OF ALTERNATIVES / PS = 0.041

SUB-CRITERIA	ALTERNATIVE	LOCAL PRIORITY	GLOBAL PRIORITY
PS	COAL	0,617	0,025
PS	NUCLEAR	0,172	0,007
PS	WIND	0,211	0,009

Table 65: Local and global priorities of alternatives compared to MJ

PRIORITIES OF ALTERNATIVES / MJ = 0.090

SUB-CRITERIA	ALTERNATIVE	LOCAL PRIORITY	GLOBAL PRIORITY
MJ	COAL	0,548	0,049
MJ	NUCLEAR	0,242	0,022
MJ	WIND	0,21	0,019

Table 66: Local and global priorities of alternatives compared to SS

PRIORITIES OF ALTERNATIVES / SS = 0.301

SUB-CRITERIA	ALTERNATIVE	LOCAL PRIORITY	GLOBAL PRIORITY
SS	COAL	0,718	0,216
SS	NUCLEAR	0,085	0,026
SS	WIND	0,196	0,059

Table 67: Local and global priorities of alternatives compared to JS

PRIORITIES OF ALTERNATIVES / JS = 0.096

SUB-CRITERIA	ALTERNATIVE	LOCAL PRIORITY	GLOBAL PRIORITY
JS	COAL	0,722	0,070
JS	NUCLEAR	0,103	0,010
JS	WIND	0,175	0,017

Table 68: Local and global priorities of alternatives compared to IS

PRIORITIES OF ALTERNATIVES / IS = 0.066

SUB-CRITERIA	ALTERNATIVE	LOCAL PRIORITY	GLOBAL PRIORITY
IS	COAL	0,073	0,005
IS	NUCLEAR	0,742	0,049
IS	WIND	0,185	0,012

Table 69: Local and global priorities of alternatives compared to LA

PRIORITIES OF ALTERNATIVES / LA = 0.056

SUB-CRITERIA	ALTERNATIVE	LOCAL PRIORITY	GLOBAL PRIORITY
LA	COAL	0,62	0,035
LA	NUCLEAR	0,163	0,009
LA	WIND	0,217	0,012

Table 70: Local and global priorities of alternatives compared to LC

PRIORITIES OF ALTERNATIVES / LC = 0.029

SUB-CRITERIA	ALTERNATIVE	LOCAL PRIORITY	GLOBAL PRIORITY
LC	COAL	0,655	0,019
LC	NUCLEAR	0,118	0,003
LC	WIND	0,227	0,007

Table 71: Local and global priorities of alternatives compared to HL

PRIORITIES OF ALTERNATIVES / HL = 0.233

SUB-CRITERIA	ALTERNATIVE	LOCAL PRIORITY	GLOBAL PRIORITY
HL	COAL	0,119	0,028
HL	NUCLEAR	0,611	0,143
HL	WIND	0,27	0,063

Table 72: Local and global priorities of alternatives compared to LL

PRIORITIES OF ALTERNATIVES / LL = 0.058

SUB-CRITERIA	ALTERNATIVE	LOCAL PRIORITY	GLOBAL PRIORITY
LL	COAL	0,46	0,027
LL	NUCLEAR	0,243	0,014
LL	WIND	0,298	0,017

Appendix T – Filled-in Questionnaire Candidate 1

Survey Questionnaire for the study

A skills measurement model for the South African Energy Sector: applying the Analytic Hierarchy Process to the SA electric power industry

Thank you for agreeing to partake in this questionnaire. This study seeks to develop a model based on the Analytic Hierarchy Process (AHP), developed by Thomas Saaty, to measure skills in the energy sector in pairwise comparisons and thus being able to evaluate projects with regards to their inherent skill values.

The AHP process consist of a hierarchy of relationships between the goal of the study, the criteria the goal relies on, as well as 3 options that are compared to one another in their relative strengths of fulfilling the goals.

Below you will find a list of questions where 2 criteria will be compared to one another relating to a criteria on a higher level. For each question, please answer the following 2 points:

1. which of the 2 criteria is more important than the other
2. by how much more important is it than the other

The first answer will be a simple "A" or "B" answer, for the second part please refer to the following table and then assign a number between 1 and 9, indicating the magnitude of dominance of the one over the other.

Intensity of Importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
2	Weak or slight importance	
3	Moderate importance	Experience and judgement slightly favour one activity over another
4	Moderate plus importance	
5	Strong importance	Experience and judgement strongly favour one activity over another
6	Strong plus importance	
7	Very strong or demonstrated importance	An activity is favoured very strongly over another; its dominance is demonstrated in practise
8	Very, very strong importance	
9	Extremely strong importance	The evidence favouring one activity over another is of the highest possible order of affirmation

An example: in a study that is looking at buying a car the two criteria of safety and cost need to be compared to one another, the question is asked: Which of these 2 criteria is more important when considering to buy a car and by how much is the one more important than the other?

Objective of buying a car		Which Criteria is more important? A or B	By what magnitude is it more important? 1 to 9
A	B		
safety	cost	A	3

i.e. when considering to buy a car, the criteria of "safety" cost is moderately more important (value 3 from table) than the criteria of "cost".

With this in mind, please answer the following to the best of your ability and experience. Some topics might be less known to you than others, but a decision based on your experience will still be valid.

Questions:

1 **Comparing these criteria with each other, which of these criteria should be the more important to consider when evaluating a project based on the inherent value of skill it has:**

- potential for skills transfer inherent in this project
- current availability of skills to implement this project
- how much inherent potential there is for this project to comply with Government skills development objectives and legislation
- potential this project has in generating new types of skills for the electrical industry

Objective of determining the skill value in a project		Which Criteria is more important? A or B	By what magnitude is it more important? 1 to 9
A	B		
Potential for skills transfer in project	Current availability of skills	B	3
Potential for skills transfer in project	In line with government skills objectives	B	1
Potential for skills transfer in project	Potential to generate new skills for the energy sector	A	1
In line with government skills objectives	Potential to generate new skills for the energy sector	A	1
In line with government skills objectives	Current availability of skills	B	3
Potential to generate new skills for the energy sector	Current availability of skills	B	3

2 **When analysing the potential for skills transfer inherent in this project, please compare the following criteria with one another for their importance**

- potential for this project in aiding skill transfer for SMMEs (ST)
- potential for portable skills that can be generated by this project that can then be applied in different sectors (PS)
- potential for this project in providing mentorship to younger engineers (MJ)

Criteria to analyse the potential for skills transfer in a project		Which Criteria is more important? A or B	By what magnitude is it more important? 1 to 9
A	B		
Potential in aiding skills transfer for SMMEs	Potential for portable skills	A	3
Potential in aiding skills transfer for SMMEs	Potential to provide mentorship to junior engineers	B	3
Potential for portable skills	Potential to provide mentorship to junior engineers	B	3

3 **When analysing the current availability of skills to implement this project, please compare the following criteria with one another for their importance**

- current availability of senior skills for this project in SA (SS)
- current availability of junior skills for this project in SA (JS)
- necessity to import senior skills internationally (IS)

Criteria to analyse the potential for skills transfer in a project		Which Criteria is more important? A or B	By what magnitude is it more important? 1 to 9
A	B		
Current availability of senior skills in SA	Current availability of junior skills in SA	A	3
Current availability of senior skills in SA	Necessity to import senior skills internationally	B	3
Current availability of junior skills in SA	Necessity to import senior skills internationally	B	3

4 **When analysing how much inherent potential there is for this project to comply with Government skills development objectives and legislation, please compare the following criteria with one another for their importance**

- Skills Development Act, Accelerated and Shared Growth Initiative for South Africa and the Joint Initiative on Priority Skills Acquisition (LA)

- involvement of local community, focusing on skills transfer to take place, not financial benefit (LC)

Criteria to analyse the potential for skills transfer in a project		Which Criteria is more important? A or B	By what magnitude is it more important? 1 to 9
A	B		
In line with govt skills legislation	Involvement of local community	A	5

5 **When analysing how much potential this project has in generating new types of skills for the electrical industry, please compare the following criteria with one another for their importance**

- High likelihood (HL)
- Low likelihood (LL)

Criteria to analyse the potential for skills transfer in a project		Which Criteria is more important? A or B	By what magnitude is it more important? 1 to 9
A	B		
High likelihood	Low likelihood	A	3

Now, three possible energy generating projects will be compared to one another in how they compare with each other in importance against the criteria previously mentioned. The three types of projects are:

- Coal-fired Power Station
- Nuclear Powered Power Station
- Wind Powered Power Station

6 **When comparing each energy generating project type, please compare the following alternatives with one another for their potential in aiding skills transfer for SMMEs**

Potential in aiding skills transfer for SMMEs		Which Alternative has the higher potential? A or B	By what magnitude is the potential more than the other alternative? 1 to 9
A	B		
Coal-fired Power Station	Nuclear Powered Power Station	A	5
Coal-fired Power Station	Wind Power Station	A	3
Nuclear Powered Power Station	Wind Power Station	B	3

7 **When comparing each energy generating project type, please compare the following alternatives with one another for their potential in generating portable skills that can then be applied in different sectors**

Potential for portable skills		Which Alternative has the higher potential? A or B	By what magnitude is the potential more than the other alternative? 1 to 9
A	B		
Coal-fired Power Station	Nuclear Powered Power Station	A	5
Coal-fired Power Station	Wind Power Station	A	3
Nuclear Powered Power Station	Wind Power Station	B	3

8 **When comparing each energy generating project type, please compare the following alternatives with one another for their potential in providing mentorship to younger engineers**

Potential to provide mentorship to junior engineers		Which Alternative has the higher potential? A or B	By what magnitude is the potential more than the other alternative? 1 to 9
A	B		
Coal-fired Power Station	Nuclear Powered Power Station	A	5
Coal-fired Power Station	Wind Power Station	A	3
Nuclear Powered Power Station	Wind Power Station	B	3

9 **When comparing each energy generating project type, please compare the following alternatives with one another for their current availability of senior skills to implement this project**

Current availability of senior skills in SA		Which Alternative has the higher potential? A or B	By what magnitude is the potential more than the other alternative? 1 to 9
A	B		
Coal-fired Power Station	Nuclear Powered Power Station	A	5
Coal-fired Power	Wind Power Station	A	3

Station			
Nuclear Powered Power Station	Wind Power Station	B	3

10 When comparing each energy generating project type, please compare the following alternatives with one another for their current availability of junior skills to implement this project

Current availability of junior skills in SA		Which Alternative has the higher potential? A or B	By what magnitude is the potential more than the other alternative? 1 to 9
A	B		
Coal-fired Power Station	Nuclear Powered Power Station	A	7
Coal-fired Power Station	Wind Power Station	A	5
Nuclear Powered Power Station	Wind Power Station	B	5

11 When comparing each energy generating project type, please compare the following alternatives with one another for their current need to import skills to implement this project

Necessity to import senior skills internationally		Which Alternative has the higher potential? A or B	By what magnitude is the potential more than the other alternative? 1 to 9
A	B		
Coal-fired Power Station	Nuclear Powered Power Station	B	9
Coal-fired Power Station	Wind Power Station	B	5
Nuclear Powered Power Station	Wind Power Station	A	5

12 When comparing each energy generating project type, please compare the following alternatives with one another for their potential of skills transfer in line with government legislation for this project

Skills transfer in line with govt skills legislation		Which Alternative has the higher potential? A or B	By what magnitude is the potential more than the other alternative? 1 to 9
A	B		

Coal-fired Power Station	Nuclear Powered Power Station	A	9
Coal-fired Power Station	Wind Power Station	A	7
Nuclear Powered Power Station	Wind Power Station	B	5

13 **When comparing each energy generating project type, please compare the following alternatives with one another for their potential of involvement of local community, focusing on skills transfer to take place, not financial benefit, in this project**

Involvement of local community, focusing on skills transfer to take place, not financial benefit		Which Alternative has the higher potential? A or B	By what magnitude is the potential more than the other alternative? 1 to 9
A	B		
Coal-fired Power Station	Nuclear Powered Power Station	A	7
Coal-fired Power Station	Wind Power Station	A	5
Nuclear Powered Power Station	Wind Power Station	B	5

14 **When comparing each energy generating project type, please compare the following alternatives with one another for their potential of a high likelihood in generating new types of skills for the electrical industry in this project**

High likelihood in generating new types of skills for the electrical industry		Which Alternative has the higher potential? A or B	By what magnitude is the potential more than the other alternative? 1 to 9
A	B		
Coal-fired Power Station	Nuclear Powered Power Station	B	3
Coal-fired Power Station	Wind Power Station	B	3
Nuclear Powered Power Station	Wind Power Station	A	3

15 **When comparing each energy generating project type, please compare the following alternatives with one another for their potential of a low likelihood in generating new types of skills for the electrical industry in this project**

Low likelihood in generating new types of skills for the electrical industry		Which Alternative has the higher potential? A or B	By what magnitude is the potential more than the other alternative? 1 to 9
A	B		
Coal-fired Power Station	Nuclear Powered Power Station	A	3
Coal-fired Power Station	Wind Power Station	A	3
Nuclear Powered Power Station	Wind Power Station	B	3

Name: WITHHELD

Date: 15/01/2019

Signature: WITHHELD

Appendix U – Filled-in Questionnaire Candidate 2

Survey Questionnaire for the study

<u>A skills measurement model for the South African Energy Sector: applying the Analytic Hierarchy Process to the SA electric power industry</u>

Thank you for agreeing to partake in this questionnaire. This study seeks to develop a model based on the Analytic Hierarchy Process (AHP), developed by Thomas Saaty, to measure skills in the energy sector in pairwise comparisons and thus being able to evaluate projects with regards to their inherent skill values.

The AHP process consist of a hierarchy of relationships between the goal of the study, the criteria the goal relies on, as well as 3 options that are compared to one another in their relative strengths of fulfilling the goals.

Below you will find a list of questions where 2 criteria will be compared to one another relating to a criteria on a higher level. For each question, please answer the following 2 points:

1. which of the 2 criteria is more important than the other
2. by how much more important is it than the other

The first answer will be a simple "A" or "B" answer, for the second part please refer to the following table and then assign a number between 1 and 9, indicating the magnitude of dominance of the one over the other.

Intensity of Importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
2	Weak or slight importance	
3	Moderate importance	Experience and judgement slightly favour one activity over another
4	Moderate plus importance	
5	Strong importance	Experience and judgement strongly favour one activity over another
6	Strong plus importance	
7	Very strong or demonstrated importance	An activity is favoured very strongly over another; its dominance is demonstrated in practise
8	Very, very strong importance	
9	Extremely strong importance	The evidence favouring one activity over another is of the highest possible order of affirmation

An example: in a study that is looking at buying a car the two criteria of safety and cost need to be compared to one another, the question is asked: Which of these 2 criteria is more important when considering to buy a car and by how much is the one more important than the other?

Objective of buying a car		Which Criteria is more important? A or B	By what magnitude is it more important? 1 to 9
A	B		
safety	cost	A	3

i.e. when considering to buy a car, the criteria of "safety" cost is moderately more important (value 3 from table) than the criteria of "cost".

With this in mind, please answer the following to the best of your ability and experience. Some topics might be less known to you than others, but a decision based on your experience will still be valid.

Questions:

1 **<u>Comparing these criteria with each other, which of these criteria should be the more important to consider when evaluating a project based on the inherent value of skill it has:</u>**

- potential for skills transfer inherent in this project
- current availability of skills to implement this project
- how much inherent potential there is for this project to comply with Government skills development objectives and legislation
- potential this project has in generating new types of skills for the electrical industry

Objective of determining the skill value in a project		Which Criteria is more important? A or B	By what magnitude is it more important? 1 to 9
A	B		
Potential for skills transfer in project	Current availability of skills	B	7
Potential for skills transfer in project	In line with government skills objectives	A	3
Potential for skills transfer in project	Potential to generate new skills for the energy sector	B	5
In line with government skills objectives	Potential to generate new skills for the energy sector	B	3
In line with government skills objectives	Current availability of skills	B	7
Potential to generate new skills for the energy sector	Current availability of skills	B	1

2 **When analysing the potential for skills transfer inherent in this project, please compare the following criteria with one another for their importance**

- potential for this project in aiding skill transfer for SMMEs (ST)
- potential for portable skills that can be generated by this project that can then be applied in different sectors (PS)
- potential for this project in providing mentorship to younger engineers (MJ)

Criteria to analyse the potential for skills transfer in a project		Which Criteria is more important? A or B	By what magnitude is it more important? 1 to 9
A	B		
Potential in aiding skills transfer for SMMEs	Potential for portable skills	B	7
Potential in aiding skills transfer for SMMEs	Potential to provide mentorship to junior engineers	B	5
Potential for portable skills	Potential to provide mentorship to junior engineers		1

3 **When analysing the current availability of skills to implement this project, please compare the following criteria with one another for their importance**

- current availability of senior skills for this project in SA (SS)
- current availability of junior skills for this project in SA (JS)
- necessity to import senior skills internationally (IS)

Criteria to analyse the potential for skills transfer in a project		Which Criteria is more important? A or B	By what magnitude is it more important? 1 to 9
A	B		
Current availability of senior skills in SA	Current availability of junior skills in SA	A	3
Current availability of senior skills in SA	Necessity to import senior skills internationally	A	5
Current availability of junior skills in SA	Necessity to import senior skills internationally	A	3

4 **When analysing how much inherent potential there is for this project to comply with Government skills development objectives and legislation, please compare the following criteria with one another for their importance**

- Skills Development Act, Accelerated and Shared Growth Initiative for South Africa and the Joint Initiative on Priority Skills Acquisition (LA)

- involvement of local community, focusing on skills transfer to take place, not financial benefit (LC)

Criteria to analyse the potential for skills transfer in a project		Which Criteria is more important? A or B	By what magnitude is it more important? 1 to 9
A	B		
In line with govt skills legislation	Involvement of local community	A	3

5 **<u>When analysing how much potential this project has in generating new types of skills for the electrical industry, please compare the following criteria with one another for their importance</u>**

- High likelihood (HL)
- Low likelihood (LL)

Criteria to analyse the potential for skills transfer in a project		Which Criteria is more important? A or B	By what magnitude is it more important? 1 to 9
A	B		
High likelihood	Low likelihood	A	5

Now, three possible energy generating projects will be compared to one another in how they compare with each other in importance against the criteria previously mentioned. The three types of projects are:

- Coal-fired Power Station
- Nuclear Powered Power Station
- Wind Powered Power Station

6 **<u>When comparing each energy generating project type, please compare the following alternatives with one another for their potential in aiding skills transfer for SMMEs</u>**

Potential in aiding skills transfer for SMMEs		Which Alternative has the higher potential? A or B	By what magnitude is the potential more than the other alternative? 1 to 9
A	B		
Coal-fired Power Station	Nuclear Powered Power Station	A	5
Coal-fired Power Station	Wind Power Station	A	3
Nuclear Powered Power Station	Wind Power Station	B	3

7 When comparing each energy generating project type, please compare the following alternatives with one another for their potential in generating portable skills that can then be applied in different sectors

Potential for portable skills		Which Alternative has the higher potential? A or B	By what magnitude is the potential more than the other alternative? 1 to 9
A	B		
Coal-fired Power Station	Nuclear Powered Power Station	A	3
Coal-fired Power Station	Wind Power Station	A	3
Nuclear Powered Power Station	Wind Power Station	A	3

8 When comparing each energy generating project type, please compare the following alternatives with one another for their potential in providing mentorship to younger engineers

Potential to provide mentorship to junior engineers		Which Alternative has the higher potential? A or B	By what magnitude is the potential more than the other alternative? 1 to 9
A	B		
Coal-fired Power Station	Nuclear Powered Power Station	A	3
Coal-fired Power Station	Wind Power Station		1
Nuclear Powered Power Station	Wind Power Station		1

9 When comparing each energy generating project type, please compare the following alternatives with one another for their current availability of senior skills to implement this project

Current availability of senior skills in SA		Which Alternative has the higher potential? A or B	By what magnitude is the potential more than the other alternative? 1 to 9
A	B		
Coal-fired Power Station	Nuclear Powered Power Station	A	7
Coal-fired Power	Wind Power Station	A	7

Station			
Nuclear Powered Power Station	Wind Power Station	B	3

10 **When comparing each energy generating project type, please compare the following alternatives with one another for their current availability of junior skills to implement this project**

Current availability of junior skills in SA		Which Alternative has the higher potential? A or B	By what magnitude is the potential more than the other alternative? 1 to 9
A	B		
Coal-fired Power Station	Nuclear Powered Power Station	A	9
Coal-fired Power Station	Wind Power Station	A	7
Nuclear Powered Power Station	Wind Power Station	B	5

11 **When comparing each energy generating project type, please compare the following alternatives with one another for their current need to import skills to implement this project**

Necessity to import senior skills internationally		Which Alternative has the higher potential? A or B	By what magnitude is the potential more than the other alternative? 1 to 9
A	B		
Coal-fired Power Station	Nuclear Powered Power Station	B	7
Coal-fired Power Station	Wind Power Station	B	3
Nuclear Powered Power Station	Wind Power Station	A	7

12 **When comparing each energy generating project type, please compare the following alternatives with one another for their potential of skills transfer in line with government legislation for this project**

Skills transfer in line with govt skills legislation		Which Alternative has the higher potential? A or B	By what magnitude is the potential more than the other alternative? 1 to 9
A	B		

Coal-fired Power Station	Nuclear Powered Power Station		1
Coal-fired Power Station	Wind Power Station		1
Nuclear Powered Power Station	Wind Power Station		1

13 **When comparing each energy generating project type, please compare the following alternatives with one another for their potential of involvement of local community, focusing on skills transfer to take place, not financial benefit, in this project**

Involvement of local community, focusing on skills transfer to take place, not financial benefit		Which Alternative has the higher potential? A or B	By what magnitude is the potential more than the other alternative? 1 to 9
A	B		
Coal-fired Power Station	Nuclear Powered Power Station	A	3
Coal-fired Power Station	Wind Power Station		1
Nuclear Powered Power Station	Wind Power Station	B	3

14 **When comparing each energy generating project type, please compare the following alternatives with one another for their potential of a high likelihood in generating new types of skills for the electrical industry in this project**

High likelihood in generating new types of skills for the electrical industry		Which Alternative has the higher potential? A or B	By what magnitude is the potential more than the other alternative? 1 to 9
A	B		
Coal-fired Power Station	Nuclear Powered Power Station	B	5
Coal-fired Power Station	Wind Power Station	B	3
Nuclear Powered Power Station	Wind Power Station	A	3

15 **When comparing each energy generating project type, please compare the following alternatives with one another for their potential of a low likelihood in generating new types of skills for the electrical industry in this project**

Low likelihood in generating new types of skills for the electrical industry		Which Alternative has the higher potential? A or B	By what magnitude is the potential more than the other alternative? 1 to 9
A	B		
Coal-fired Power Station	Nuclear Powered Power Station	A	3
Coal-fired Power Station	Wind Power Station	A	3
Nuclear Powered Power Station	Wind Power Station	B	3

Name: WITHHELD

Date: 15/01/2019

Signature: WITHHELD

Appendix V – Filled-in Questionnaire Candidate 3

Survey Questionnaire for the study

A skills measurement model for the South African Energy Sector: applying the Analytic Hierarchy Process to the SA electric power industry

Thank you for agreeing to partake in this questionnaire. This study seeks to develop a model based on the Analytic Hierarchy Process (AHP), developed by Thomas Saaty, to measure skills in the energy sector in pairwise comparisons and thus being able to evaluate projects with regards to their inherent skill values.

The AHP process consist of a hierarchy of relationships between the goal of the study, the criteria the goal relies on, as well as 3 options that are compared to one another in their relative strengths of fulfilling the goals.

Below you will find a list of questions where 2 criteria will be compared to one another relating to a criteria on a higher level. For each question, please answer the following 2 points:

1. which of the 2 criteria is more important than the other
2. by how much more important is it than the other

The first answer will be a simple "A" or "B" answer, for the second part please refer to the following table and then assign a number between 1 and 9, indicating the magnitude of dominance of the one over the other.

Intensity of Importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
2	Weak or slight importance	
3	Moderate importance	Experience and judgement slightly favour one activity over another
4	Moderate plus importance	
5	Strong importance	Experience and judgement strongly favour one activity over another
6	Strong plus importance	
7	Very strong or demonstrated importance	An activity is favoured very strongly over another; its dominance is demonstrated in practise
8	Very, very strong importance	
9	Extremely strong importance	The evidence favouring one activity over another is of the highest possible order of affirmation

An example: in a study that is looking at buying a car the two criteria of safety and cost need to be compared to one another, the question is asked: Which of these 2 criteria is more important when considering to buy a car and by how much is the one more important than the other?

Objective of buying a car		Which Criteria is more important? A or B	By what magnitude is it more important? 1 to 9
A	B		
safety	cost	A	3

i.e. when considering to buy a car, the criteria of "safety" cost is moderately more important (value 3 from table) than the criteria of "cost".

With this in mind, please answer the following to the best of your ability and experience. Some topics might be less known to you than others, but a decision based on your experience will still be valid.

Questions:

1 **Comparing these criteria with each other, which of these criteria should be the more important to consider when evaluating a project based on the inherent value of skill it has:**

- potential for skills transfer inherent in this project
- current availability of skills to implement this project
- how much inherent potential there is for this project to comply with Government skills development objectives and legislation
- potential this project has in generating new types of skills for the electrical industry

Objective of determining the skill value in a project		Which Criteria is more important? A or B	By what magnitude is it more important? 1 to 9
A	B		
Potential for skills transfer in project	Current availability of skills	B	5
Potential for skills transfer in project	In line with government skills objectives	A	3
Potential for skills transfer in project	Potential to generate new skills for the energy sector	B	3
In line with government skills objectives	Potential to generate new skills for the energy sector	B	3
In line with government skills objectives	Current availability of skills	B	5
Potential to generate new skills for the energy sector	Current availability of skills	A	1

2 When analysing the potential for skills transfer inherent in this project, please compare the following criteria with one another for their importance

- potential for this project in aiding skill transfer for SMMEs (ST)
- potential for portable skills that can be generated by this project that can then be applied in different sectors (PS)
- potential for this project in providing mentorship to younger engineers (MJ)

Criteria to analyse the potential for skills transfer in a project		Which Criteria is more important? A or B	By what magnitude is it more important? 1 to 9
A	B		
Potential in aiding skills transfer for SMMEs	Potential for portable skills	B	3
Potential in aiding skills transfer for SMMEs	Potential to provide mentorship to junior engineers	B	3
Potential for portable skills	Potential to provide mentorship to junior engineers	A	1

3 When analysing the current availability of skills to implement this project, please compare the following criteria with one another for their importance

- current availability of senior skills for this project in SA (SS)
- current availability of junior skills for this project in SA (JS)
- necessity to import senior skills internationally (IS)

Criteria to analyse the potential for skills transfer in a project		Which Criteria is more important? A or B	By what magnitude is it more important? 1 to 9
A	B		
Current availability of senior skills in SA	Current availability of junior skills in SA	A	5
Current availability of senior skills in SA	Necessity to import senior skills internationally	A	3
Current availability of junior skills in SA	Necessity to import senior skills internationally	A	1

4 When analysing how much inherent potential there is for this project to comply with Government skills development objectives and legislation, please compare the following criteria with one another for their importance

- Skills Development Act, Accelerated and Shared Growth Initiative for South Africa and the Joint Initiative on Priority Skills Acquisition (LA)

- involvement of local community, focusing on skills transfer to take place, not financial benefit (LC)

Criteria to analyse the potential for skills transfer in a project		Which Criteria is more important? A or B	By what magnitude is it more important? 1 to 9
A	B		
In line with govt skills legislation	Involvement of local community	A	3

5 **When analysing how much potential this project has in generating new types of skills for the electrical industry, please compare the following criteria with one another for their importance**

- High likelihood (HL)
- Low likelihood (LL)

Criteria to analyse the potential for skills transfer in a project		Which Criteria is more important? A or B	By what magnitude is it more important? 1 to 9
A	B		
High likelihood	Low likelihood	A	9

Now, three possible energy generating projects will be compared to one another in how they compare with each other in importance against the criteria previously mentioned. The three types of projects are:

- Coal-fired Power Station
- Nuclear Powered Power Station
- Wind Powered Power Station

6 **When comparing each energy generating project type, please compare the following alternatives with one another for their potential in aiding skills transfer for SMMEs**

Potential in aiding skills transfer for SMMEs		Which Alternative has the higher potential? A or B	By what magnitude is the potential more than the other alternative? 1 to 9
A	B		
Coal-fired Power Station	Nuclear Powered Power Station	A	5
Coal-fired Power Station	Wind Power Station	A	5
Nuclear Powered Power Station	Wind Power Station	B	3

7 **When comparing each energy generating project type, please compare the following alternatives with one another for their potential in generating portable skills that can then be applied in different sectors**

Potential for portable skills		Which Alternative has the higher potential? A or B	By what magnitude is the potential more than the other alternative? 1 to 9
A	B		
Coal-fired Power Station	Nuclear Powered Power Station	A	3
Coal-fired Power Station	Wind Power Station	A	3
Nuclear Powered Power Station	Wind Power Station	A	3

8 **When comparing each energy generating project type, please compare the following alternatives with one another for their potential in providing mentorship to younger engineers**

Potential to provide mentorship to junior engineers		Which Alternative has the higher potential? A or B	By what magnitude is the potential more than the other alternative? 1 to 9
A	B		
Coal-fired Power Station	Nuclear Powered Power Station	A	1
Coal-fired Power Station	Wind Power Station	A	3
Nuclear Powered Power Station	Wind Power Station	A	3

9 **When comparing each energy generating project type, please compare the following alternatives with one another for their current availability of senior skills to implement this project**

Current availability of senior skills in SA		Which Alternative has the higher potential? A or B	By what magnitude is the potential more than the other alternative? 1 to 9
A	B		
Coal-fired Power Station	Nuclear Powered Power Station	A	7
Coal-fired Power	Wind Power Station	A	5

Station			
Nuclear Powered Power Station	Wind Power Station	B	3

10 When comparing each energy generating project type, please compare the following alternatives with one another for their current availability of junior skills to implement this project

Current availability of junior skills in SA		Which Alternative has the higher potential? A or B	By what magnitude is the potential more than the other alternative? 1 to 9
A	B		
Coal-fired Power Station	Nuclear Powered Power Station	A	7
Coal-fired Power Station	Wind Power Station	A	5
Nuclear Powered Power Station	Wind Power Station	B	3

11 When comparing each energy generating project type, please compare the following alternatives with one another for their current need to import skills to implement this project

Necessity to import senior skills internationally		Which Alternative has the higher potential? A or B	By what magnitude is the potential more than the other alternative? 1 to 9
A	B		
Coal-fired Power Station	Nuclear Powered Power Station	B	7
Coal-fired Power Station	Wind Power Station	B	5
Nuclear Powered Power Station	Wind Power Station	A	5

12 When comparing each energy generating project type, please compare the following alternatives with one another for their potential of skills transfer in line with government legislation for this project

Skills transfer in line with govt skills legislation		Which Alternative has the higher potential? A or B	By what magnitude is the potential more than the other alternative? 1 to 9
A	B		

Coal-fired Power Station	Nuclear Powered Power Station	A	3
Coal-fired Power Station	Wind Power Station	A	3
Nuclear Powered Power Station	Wind Power Station	A	3

13 **When comparing each energy generating project type, please compare the following alternatives with one another for their potential of involvement of local community, focusing on skills transfer to take place, not financial benefit, in this project**

Involvement of local community, focusing on skills transfer to take place, not financial benefit		Which Alternative has the higher potential? A or B	By what magnitude is the potential more than the other alternative? 1 to 9
A	B		
Coal-fired Power Station	Nuclear Powered Power Station	A	5
Coal-fired Power Station	Wind Power Station	A	5
Nuclear Powered Power Station	Wind Power Station	A	3

14 **When comparing each energy generating project type, please compare the following alternatives with one another for their potential of a high likelihood in generating new types of skills for the electrical industry in this project**

High likelihood in generating new types of skills for the electrical industry		Which Alternative has the higher potential? A or B	By what magnitude is the potential more than the other alternative? 1 to 9
A	B		
Coal-fired Power Station	Nuclear Powered Power Station	B	3
Coal-fired Power Station	Wind Power Station	B	3
Nuclear Powered Power Station	Wind Power Station	A	3

15 **When comparing each energy generating project type, please compare the following alternatives with one another for their potential of a low likelihood in generating new types of skills for the electrical industry in this project**

Low likelihood in generating new types of skills for the electrical industry		Which Alternative has the higher potential? A or B	By what magnitude is the potential more than the other alternative? 1 to 9
A	B		
Coal-fired Power Station	Nuclear Powered Power Station	A	3
Coal-fired Power Station	Wind Power Station	A	3
Nuclear Powered Power Station	Wind Power Station	B	3

Name: WITHHELD

Date: 15/01/2019

Signature: WITHHELD

Appendix W – Filled-in Questionnaire Candidate 4

Survey Questionnaire for the study

A skills measurement model for the South African Energy Sector: applying the Analytic Hierarchy Process to the SA electric power industry

Thank you for agreeing to partake in this questionnaire. This study seeks to develop a model based on the Analytic Hierarchy Process (AHP), developed by Thomas Saaty, to measure skills in the energy sector in pairwise comparisons and thus being able to evaluate projects with regards to their inherent skill values.

The AHP process consist of a hierarchy of relationships between the goal of the study, the criteria the goal relies on, as well as 3 options that are compared to one another in their relative strengths of fulfilling the goals.

Below you will find a list of questions where 2 criteria will be compared to one another relating to a criteria on a higher level. For each question, please answer the following 2 points:

1. which of the 2 criteria is more important than the other
2. by how much more important is it than the other

The first answer will be a simple "A" or "B" answer, for the second part please refer to the following table and then assign a number between 1 and 9, indicating the magnitude of dominance of the one over the other.

Intensity of Importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
2	Weak or slight importance	
3	Moderate importance	Experience and judgement slightly favour one activity over another
4	Moderate plus importance	
5	Strong importance	Experience and judgement strongly favour one activity over another
6	Strong plus importance	
7	Very strong or demonstrated importance	An activity is favoured very strongly over another; its dominance is demonstrated in practise
8	Very, very strong importance	
9	Extremely strong importance	The evidence favouring one activity over another is of the highest possible order of affirmation

An example: in a study that is looking at buying a car the two criteria of safety and cost need to be compared to one another, the question is asked: Which of these 2 criteria is more important when considering to buy a car and by how much is the one more important than the other?

Objective of buying a car		Which Criteria is more important? A or B	By what magnitude is it more important? 1 to 9
A	B		
safety	cost	A	3

i.e. when considering to buy a car, the criteria of "safety" cost is moderately more important (value 3 from table) than the criteria of "cost".

With this in mind, please answer the following to the best of your ability and experience. Some topics might be less known to you than others, but a decision based on your experience will still be valid.

Questions:

1 **Comparing these criteria with each other, which of these criteria should be the more important to consider when evaluating a project based on the inherent value of skill it has:**

- potential for skills transfer inherent in this project
- current availability of skills to implement this project
- how much inherent potential there is for this project to comply with Government skills development objectives and legislation
- potential this project has in generating new types of skills for the electrical industry

Objective of determining the skill value in a project		Which Criteria is more important? A or B	By what magnitude is it more important? 1 to 9
A	B		
Potential for skills transfer in project	Current availability of skills	B	5
Potential for skills transfer in project	In line with government skills objectives	A	5
Potential for skills transfer in project	Potential to generate new skills for the energy sector	A	3
In line with government skills objectives	Potential to generate new skills for the energy sector	B	5
In line with government skills objectives	Current availability of skills	B	5
Potential to generate new skills for the energy sector	Current availability of skills	A	3

2 **When analysing the potential for skills transfer inherent in this project, please compare the following criteria with one another for their importance**

- potential for this project in aiding skill transfer for SMMEs (ST)
- potential for portable skills that can be generated by this project that can then be applied in different sectors (PS)
- potential for this project in providing mentorship to younger engineers (MJ)

Criteria to analyse the potential for skills transfer in a project		Which Criteria is more important? A or B	By what magnitude is it more important? 1 to 9
A	B		
Potential in aiding skills transfer for SMMEs	Potential for portable skills	A	5
Potential in aiding skills transfer for SMMEs	Potential to provide mentorship to junior engineers	B	5
Potential for portable skills	Potential to provide mentorship to junior engineers	B	3

3 **When analysing the current availability of skills to implement this project, please compare the following criteria with one another for their importance**

- current availability of senior skills for this project in SA (SS)
- current availability of junior skills for this project in SA (JS)
- necessity to import senior skills internationally (IS)

Criteria to analyse the potential for skills transfer in a project		Which Criteria is more important? A or B	By what magnitude is it more important? 1 to 9
A	B		
Current availability of senior skills in SA	Current availability of junior skills in SA	A	9
Current availability of senior skills in SA	Necessity to import senior skills internationally	A	5
Current availability of junior skills in SA	Necessity to import senior skills internationally	A	5

4 **When analysing how much inherent potential there is for this project to comply with Government skills development objectives and legislation, please compare the following criteria with one another for their importance**

- Skills Development Act, Accelerated and Shared Growth Initiative for South Africa and the Joint Initiative on Priority Skills Acquisition (LA)

- involvement of local community, focusing on skills transfer to take place, not financial benefit (LC)

Criteria to analyse the potential for skills transfer in a project		Which Criteria is more important? A or B	By what magnitude is it more important? 1 to 9
A	B		
In line with govt skills legislation	Involvement of local community	B	3

5 **<u>When analysing how much potential this project has in generating new types of skills for the electrical industry, please compare the following criteria with one another for their importance</u>**

- High likelihood (HL)
- Low likelihood (LL)

Criteria to analyse the potential for skills transfer in a project		Which Criteria is more important? A or B	By what magnitude is it more important? 1 to 9
A	B		
High likelihood	Low likelihood	A	9

Now, three possible energy generating projects will be compared to one another in how they compare with each other in importance against the criteria previously mentioned. The three types of projects are:

- Coal-fired Power Station
- Nuclear Powered Power Station
- Wind Powered Power Station

6 **<u>When comparing each energy generating project type, please compare the following alternatives with one another for their potential in aiding skills transfer for SMMEs</u>**

Potential in aiding skills transfer for SMMEs		Which Alternative has the higher potential? A or B	By what magnitude is the potential more than the other alternative? 1 to 9
A	B		
Coal-fired Power Station	Nuclear Powered Power Station	A	7
Coal-fired Power Station	Wind Power Station	A	5
Nuclear Powered Power Station	Wind Power Station	B	5

7 **When comparing each energy generating project type, please compare the following alternatives with one another for their potential in generating portable skills that can then be applied in different sectors**

Potential for portable skills		Which Alternative has the higher potential? A or B	By what magnitude is the potential more than the other alternative? 1 to 9
A	B		
Coal-fired Power Station	Nuclear Powered Power Station	A	5
Coal-fired Power Station	Wind Power Station	A	2
Nuclear Powered Power Station	Wind Power Station	B	5

8 **When comparing each energy generating project type, please compare the following alternatives with one another for their potential in providing mentorship to younger engineers**

Potential to provide mentorship to junior engineers		Which Alternative has the higher potential? A or B	By what magnitude is the potential more than the other alternative? 1 to 9
A	B		
Coal-fired Power Station	Nuclear Powered Power Station	A	3
Coal-fired Power Station	Wind Power Station	A	3
Nuclear Powered Power Station	Wind Power Station	A	3

9 **When comparing each energy generating project type, please compare the following alternatives with one another for their current availability of senior skills to implement this project**

Current availability of senior skills in SA		Which Alternative has the higher potential? A or B	By what magnitude is the potential more than the other alternative? 1 to 9
A	B		
Coal-fired Power Station	Nuclear Powered Power Station	A	7
Coal-fired Power	Wind Power Station	A	5

Station			
Nuclear Powered Power Station	Wind Power Station	B	3

10 When comparing each energy generating project type, please compare the following alternatives with one another for their current availability of junior skills to implement this project

Current availability of junior skills in SA		Which Alternative has the higher potential? A or B	By what magnitude is the potential more than the other alternative? 1 to 9
A	B		
Coal-fired Power Station	Nuclear Powered Power Station	A	3
Coal-fired Power Station	Wind Power Station	A	3
Nuclear Powered Power Station	Wind Power Station	B	5

11 When comparing each energy generating project type, please compare the following alternatives with one another for their current need to import skills to implement this project

Necessity to import senior skills internationally		Which Alternative has the higher potential? A or B	By what magnitude is the potential more than the other alternative? 1 to 9
A	B		
Coal-fired Power Station	Nuclear Powered Power Station	B	7
Coal-fired Power Station	Wind Power Station	B	3
Nuclear Powered Power Station	Wind Power Station	A	5

12 When comparing each energy generating project type, please compare the following alternatives with one another for their potential of skills transfer in line with government legislation for this project

Skills transfer in line with govt skills legislation		Which Alternative has the higher potential? A or B	By what magnitude is the potential more than the other alternative? 1 to 9
A	B		

Coal-fired Power Station	Nuclear Powered Power Station	A	5
Coal-fired Power Station	Wind Power Station	A	5
Nuclear Powered Power Station	Wind Power Station	B	3

13 **<u>When comparing each energy generating project type, please compare the following alternatives with one another for their potential of involvement of local community, focusing on skills transfer to take place, not financial benefit, in this project</u>**

Involvement of local community, focusing on skills transfer to take place, not financial benefit		Which Alternative has the higher potential? A or B	By what magnitude is the potential more than the other alternative? 1 to 9
A	B		
Coal-fired Power Station	Nuclear Powered Power Station	A	5
Coal-fired Power Station	Wind Power Station	A	5
Nuclear Powered Power Station	Wind Power Station	B	~~8~~5

14 **<u>When comparing each energy generating project type, please compare the following alternatives with one another for their potential of a high likelihood in generating new types of skills for the electrical industry in this project</u>**

High likelihood in generating new types of skills for the electrical industry		Which Alternative has the higher potential? A or B	By what magnitude is the potential more than the other alternative? 1 to 9
A	B		
Coal-fired Power Station	Nuclear Powered Power Station	B	5
Coal-fired Power Station	Wind Power Station	B	3
Nuclear Powered Power Station	Wind Power Station	A	5

15 **<u>When comparing each energy generating project type, please compare the following alternatives with one another for their potential of a low likelihood in generating new types of skills for the electrical industry in this project</u>**

Low likelihood in generating new types of skills for the electrical industry		Which Alternative has the higher potential? A or B	By what magnitude is the potential more than the other alternative? 1 to 9
A	B		
Coal-fired Power Station	Nuclear Powered Power Station	B	5
Coal-fired Power Station	Wind Power Station	B	2
Nuclear Powered Power Station	Wind Power Station	A	5

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Date: 15/01/2019

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