A SKILLS MEASUREMENT MODEL FOR THE SOUTH AFRICAN ENERGY SECTOR: APPLYING THE ANALYTIC HIERARCHY PROCESS TO THE SOUTH AFRICAN ELECTRIC POWER INDUSTRY

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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; and this can hamper the effective implementation of projects. In this study, a model was developed, based on the analytic hierarchy process (AHP), in which three different power generating projects were compared for their skills values at the feasibility stage. A hierarchy was developed, based on identified criteria and sub-criteria. This model was applied by various specialists in an industry-based scenario, where three different types of power generating projects (coal-fired power, nuclear power, and wind power) were compared for their skills values, with the goal of identifying the project that had the highest skills value. This process was conducted through individual guided survey questionnaires with each participant, together with tests, to determine the consensus of the participants. A sensitivity analysis determined that the validity and accuracy of the final result were acceptable. Coal-fired power generation projects were adjudicated as having the highest skills value, followed by nuclear, and then solar.

OPSOMMING

Die behoefte om die inherente waarde van vaardighede in 'n projek in die Suid-Afrikaanse elektrisiteitsektor te begryp het ontstaan uit die veelvuldige vaardigheid uitdagings binne hierdie sektor. Hierdie uitdagings kan die effektiewe uitvoer van die projekte beperk. 'n Model gebaseer op die analitiese hiërargie proses is ontwikkel. Die model vergelyk drie kragopwekkings-projekte op grond van hulle vaardigheidswaardes in die uitvoerbaarheidsfase. 'n Hiërargie is ontwikkel op grond van die geïdentifiseerde kriteria en subkriteria. Die model is toegepas deur verskeie spesialiste in 'n industrie gebaseerde scenario waar drie verskillende soorte kragopwekkingsprojekte (steenkool-, kern- en windgedrewe) oorweeg is met die doel om die projek met die hoogste vaardigheidswaarde te identifiseer. Die proses is aangevoer deur middel van begeleide meningspeilings wat elke deelnemer, saam met toetse, moes voltooi om die deelnemerskonsensus te bepaal. 'n Sensitiwiteitsanalise het bepaal dat die geldigheid en akkuraatheid van die finale resultaat aanvaarbaar was. Steenkool-gedrewe kragopwekkingsprojekte het aan die spits na vore getree, gevolg deur kern- en daarna windgedrewe kragopwekkingsprojekte.

1 INTRODUCTION

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 [1]. In 2015, the Minister of Energy, Tina Joemat-Pettersson, emphasised that the 5.5 percent economic growth envisaged by the National Development Plan would only be achievable with an adequate energy supply [1].

Gregory [2] 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, Staffell & Adamson [3] describe the current energy supply challenges as the result of many years of underinvestment in power infrastructure and skills development. Although there is an increased interest in South Africa's science, technology, and innovation (STI) capabilities [4], to a large extent the tertiary education sector has not yet met the demand for those associated skills among graduates.

A measure needs to be developed to assist decision-making when adjudicating the feasibility of a project. This measure must take 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. Organisations in the public sector have targets to meet in implementing official policy, including targets for skills development. A model can assist with getting feedback on targets and possible interventions. It can also be a deciding factor when two projects of a similar nature and financial return must be evaluated and prioritised.

This research sought to develop a model, based on the analytic hierarchy process (AHP) [5], to measure the set of skills that are most valuable in energy sector projects. The model was then used to evaluate three types of projects for the inherent value of the skills they required.

2 LITERATURE REVIEW

2.1 Skills

2.1.1 Skills background (energy and electricity sector) — international context

Skills shortages in general, and specifically in the energy and electricity sector, are not just a South African phenomenon. Hidayatullah, Stojcevski & Kalam [6] 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 bring to energy provision are often offset by the difficulty they have in implementation, due to the lack of critical skills [6]. Painuly [7] investigated the barriers that prevent more widespread implementation of renewable energy. Among many factors, one of the key challenges identified remains that of the skills shortage in the industry as a whole. Some of the reasons for the dearth of skills in this sector are the lack of experts available to train new graduates, too few training facilities, and inadequate efforts as a whole. Mihelcic *et al.* [8] 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 by the International Labour Office [9] sees the renewable energy sector still 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. Skills shortages occur in the renewable energy sector, with developing countries the most severely affected, while engineers and skilled technical staff are mostly sought globally.

2.1.2 Skills background (energy and electricity sector) — African context

In the African energy and electricity sector, Ozoemena [10] argues that some progress has been made towards dealing with energy shortfalls; but Ogano and Pretorius [11] highlight the frequent power outages that still occur in sub-Saharan Africa, pointing to a shortage of qualified engineers. Aliyu, Modu & Tan [12] state that sustainable energy projects in Africa are often hampered by the lack of skills and technology to implement them. This view is supported by Gabriel [13], who sees the lack of skilled labour as one of six key challenges in the implementation of energy projects in Africa.

Some success stories of skills transfer in the African electricity sector have been identified by Chaureya, Ranganathana & Mohanty [14]. Their study looked at electricity access for geographically disadvantaged rural communities. They found that certain technologies are easier to implement in these rural areas, with some successes in promoting photovoltaic (PV) electricity projects. Next to the easier-to-install technology, it was also found that the local youth had easily acquired the skills to understand this technology, and had used entrepreneurial skills to advance this technology in a low-technology format, independent of the national energy suppliers. It was also discovered that all the skills to install and maintain the PV systems were available locally, with only the manufacturing having to be insourced. Gabriel and Kirkwood [15] conducted a wide ranging study to determine whether entrepreneurship can aid the uptake of renewable energies in the African energy sector, and identified successes in various levels of business model.

2.1.3 Skills background (energy and electricity sector) — South African context

The South African energy market has grown significantly in the last decade, with a current nominal capacity of 44 175 megawatts (MW). Projections are that by 2025 an additional 40 000 MW will be required [16]. The South African energy sector, however, faces many challenges.

Gregory [2] investigated the current problems that are being experienced by the South African energy sector in delivering a reliable supply of energy, pointing to technical skills deficiencies in this sector as one of the main problems. Pollett *et al.* [3] 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, on all professional levels. McKechnie and Bridgens [17] 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 in this sector as being the historical education legacy of South Africa, the global demand for skills causing an exodus from the local sector, the deficiencies in the South African basic education sector that make it difficult for many learners to advance to tertiary education, the collapse of the traditional training of artisans, and insufficient work done by the Sector Education and Training Authorities [SETAs].

For the most part, government has accepted that this shortfall exists, and has launched various plans and initiatives such as the Skills Development Act, the Accelerated and Shared Growth Initiative for South Africa, and the Joint Initiative on Priority Skills Acquisition [18]. However, Awuzie and McDermott [19] point to the fact that government buy-in and support is necessary when implementing complex energy projects. Thus, in general, a need exists to understand the skills shortfalls, and to determine ways in which these can be supported to grow.

In a research report in 2016 funded by the Department of Higher Education and Training, Reddy *et al.* [20] looked 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 per cent between 2010 and 2014, with 83 per cent of this increase in the electricity supply and distribution sectors. That being said, there remains a lack of technical knowledge and skills among the employees in this sector. The growth in management and professional skills has been low. Engineering science professionals remain on the list for occupations in high demand [20].

Examining the energy sector in general, and the renewable energy sector specifically, Forsyth [1] discusses the impediments to 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 in South Africa, this shortage is even more detrimental due to the availability of so many natural resources. A study looking at the barriers that small and medium-sized enterprises (SME) experience in the electricity sector found that, next to access to capital and information, the lack of both internal and external skills in the organisations does not help to secure projects in the electricity sector [21].

Training and skills transfer does not take place regularly, particularly at management level. This becomes a problem at the latter levels of South Africa's Renewable Energy Independent Power Producers Procurement Programme (REIPPPP) process, where local sub-contractors need to act as sole contractors and not under the auspices of the large multi-nationals [1]. Very few degrees or diplomas are currently offered at South African tertiary institutions; there is a greater emphasis on short courses, which does not aid the transfer of skills. The REIPPPP was launched in South Africa in 2011, as a programme in which some sort of privatisation was to take place in the South African electricity supply sector. But there has long been a mistrust of renewable electricity in many sectors of government that 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 programme had already allocated 3 725 MW to five bidders, with many more programmes currently underway [22].

The result of this programme brings with it, among other things, substantial skills development. This is still largely a theoretical goal; in practice, 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. More semi-skilled and highly-skilled workers are required — something South Africa does not yet possess — so they are often imported [22].

2.2 The analytic hierarchy process (AHP)

2.2.1 Background and applications of the AHP

The theory behind the AHP was investigated to understand the parameters of the model to be developed. Saaty [23] offers a good primary source introduction to the AHP and the principle of pairwise comparison. 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 [24] 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 [24] states that deductive thinking is not natural; 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 to which are then combined into the solution to the main problem [24]. It is also stated that not all information is useful in improving our understanding and judgement [25]. 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 this creates some distance from 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 relationships between various components should aid in understanding the relationships between these variables. This reduces the complexity, and allows the user to engage more effectively with the problem at hand.

Applications of the AHP are varied. Of particular relevance to this study was an example described by Saaty [23] in which 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. The main criteria were further divided into sub-criteria to arrive eventually at the total hierarchy. The different options were then analysed with this hierarchy in pairwise comparisons. Vargas [26] suggests that the AHP can be applied in a wide variety of sectors, ranging from design to political, social, and technological problems. Similarly, Vaidya and Kumar [27] report on the application of the AHP in sectors ranging from social to personal, education, manufacturing, industrial, and government, while Weiss [28] shows its strength in a dynamic environment, and Wind [29] looks at the dynamic and marketing sectors. This offers insight into the versatility of the applications of the AHP.

The AHP was interrogated for its strengths and weaknesses, and compared with other multi-criteria decision-making methods, and was found to be suitable for this particular study. Its ability to break down a problem into easily analysable portions that are aggregated into a final conclusion responds to the natural human ability to make judgements on smaller problems, regardless of the decision-taker's background and level of education.

3 RESEARCH METHOD

3.1 The AHP process

The AHP is guided by three principles: "decomposition, comparative judgements and synthesis of priorities" [23]. The decomposition part deals with structuring the problem into 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 as being either functional or structural. The principle of comparative judgement deals with the pairwise comparison of the relative importance of the elements on a certain level with the shared or perceived elements of the level above, thereby creating the matrix that will be discussed in section 4.1 below. This matrix has its own corresponding principal eigenvector. The third principle is that of synthesising 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 [23].

3.2 Sampling

The first step in developing the model was to select the decision-makers or participants who would apply their judgement to the problem of determining the skills value for power generating projects. 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 [30]. For this study, the assessment was that four participants should be sufficient, given their varied backgrounds and levels of experience. The value of the results is a consequence of the aggregated judgements of all the participants, and not just certain individuals.

A combination of convenience sampling and snowball sampling was employed to compile the group of specialists selected to take part in a guided questionnaire process, with the focus on the level of appropriate experience. The guided questionnaire process was interactive, with feedback built into the process to test the consistency of the answers and the consensus among the respondents. The participants in this study are shown in Table 2.

Table 1: Sample that took part in guided survey questionnaire

ID	Job title	Experience	Gender	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 diverse in gender, which was as a result of the non-availability of some professionals identified at an earlier stage.

The data collected in the guided survey questionnaire process underwent a thematic analysis, identifying patterns among the responses of participants, both to look for consistencies and to find matrices that were not consistent. 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. A sensitivity analysis was also carried out to verify this.

3.3 Instrumentation

The information-gathering from the industry specialists consisted of a guided survey questionnaire that was conducted individually with each specialist. The questionnaire was sent to each individual with a verbal explanation of the background of the study, the AHP process, the components, and the relevant criteria.

3.4 Structuring the AHP hierarchy

3.4.1 Identifying the overall goal

The decision hierarchy was structured as a response to the critical research question:

> *"How can a model be developed to estimate the required skills at the feasibility stage of projects in the energy sector?"*

The overall goal of the study was determined to be:

> *"Which electricity generating project has the highest skills value?"*

The skills value is a measure of the inherent potential a project has to meet or improve skills in and through the project, based on the criteria developed specifically for that project.

3.4.2 Identifying the criteria and sub-criteria

The criteria identified to form part of this hierarchy were chosen from a list of skills attributes developed by reviewing the skills inherent in a project, based on the identified categories that were informed by the literature and by specialist opinion from the group of experts listed in Table 2. Not all of the identified categories formed part of this specific hierarchy. This was because, first, the hierarchy could not be so complex that it lost its interactive and reactive nature; and second, some of the categories were already contained in the goal formulation, whereas others would form part of the sub-categories. Only the criteria that contributed most to the solving of the problem were chosen. These criteria, which were identified from the list of skills to form part of the hierarchy, were:

- 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 to generate new fields of skills for the electrical industry

The process to determine the sub-criteria that constitute these criteria was 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?" [24]. 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 leads to the homogeneous matrix that will represent the hierarchy, composed of all qualitative and quantitative data that forms part of the goal. Also, here an item was introduced such that sub-criteria can also be a value judgement in the form of a numerical value, not only a specific criterion. 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 that the literature and specialists perceived to be part of the problem. Sub-criteria that fall under the main criteria are listed below, where each sub-criterion has an abbreviation that was used in the developed matrices (Figure 1).

- Potential for skills transfer inherent in a project
    - potential for this project to aid skill transfer for SMMEs (ST)
    - potential for portable skills that can be generated by this project then to be applied in different sectors (PS)
    - potential for this project to provide mentorship to younger engineers (MJ)
- Current availability of skills to implement a project
    - current availability of senior skills for this project in SA (SS)
    - current availability of junior skills for this project in SA (JS)
    - need 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 a project has to generate new fields of skills for the electrical industry
    - High likelihood (HL)
    - Low likelihood (LL)

For the purpose of this study, three typical energy project alternatives were selected that were based on the expertise of the specialists who formed part of this study:

- Coal-fired power
- Nuclear power
- Wind power

Graphically, the developed hierarchy can be presented as in Figure 1.

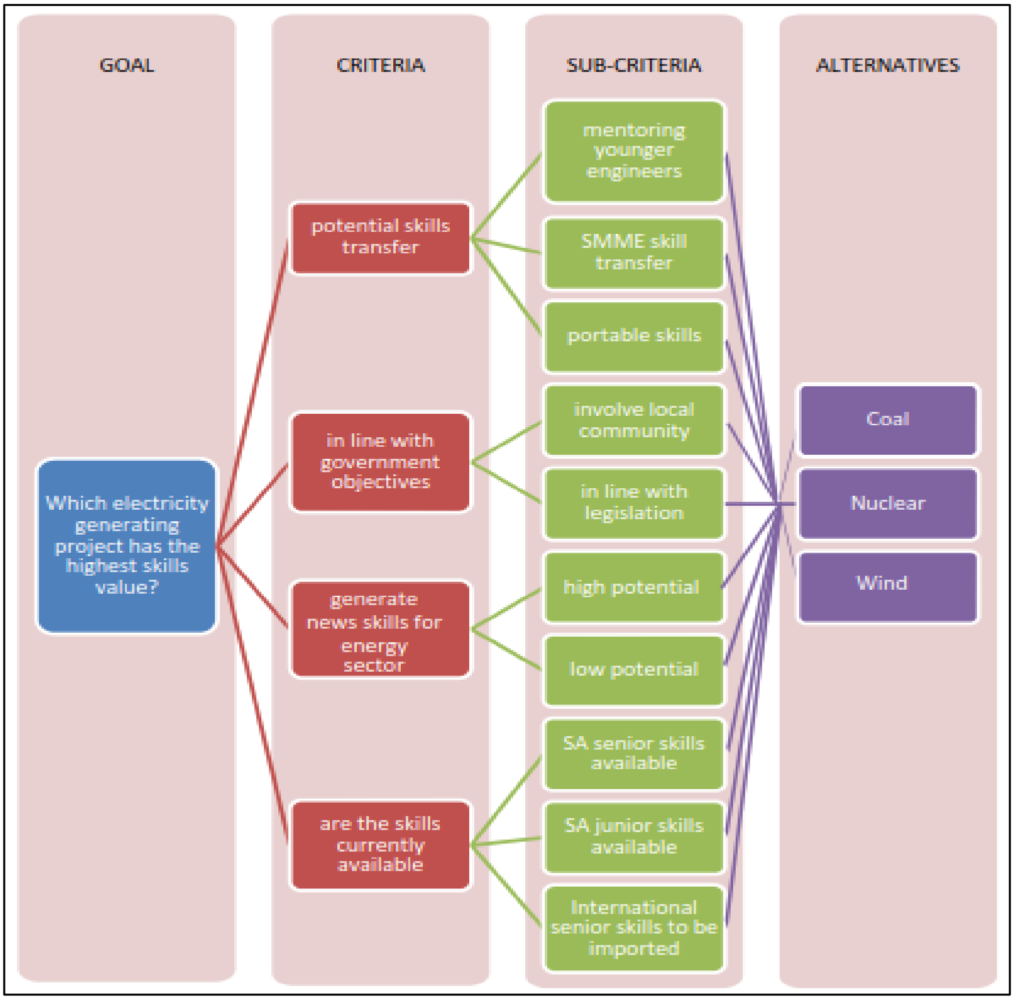

Figure 1: Final AHP hierarchy developed for the study

4 DATA ANALYSIS AND RESULTS

4.1 Pairwise comparison process and hierarchy matrices

A guided survey questionnaire was developed to directly reflect the hierarchy that was developed (Figure 1), taking into account the overall objective and the criteria and sub-criteria against which the three alternatives were being compared. It converts the process of pairwise comparisons into a set of questions, so that 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.

All the results were captured in spreadsheets, 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 specialists were approached to verify certain answers. In this study, three of the 15 matrices were outside the 0.10 threshold that was defined by Saaty as the maximum CR value within which accurate results were still possible [5], 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. Where these were identified, they were discussed with the relevant respondent, and the choice was left to that person whether or not to correct the answer.

4.2 Determine local and global priorities

As described in section 4.1, the 15 matrices that were interrogated and re-evaluated where necessary were inserted into a spreadsheet, indicating the hierarchy and the local priorities of each element in that hierarchy (Table 3). This was linked to another spreadsheet indicating the global priorities of all the sub-criteria (Table 4). These global priorities were derived by multiplying the local priorities of the sub-criteria by the priorities of the criteria directly above them in the hierarchy

Table 2: Local priorities of elements in the hierarchy

GOAL	PROJECT WITH HIGHEST SKILLS VALUE									
PRIORITY	1									
CRITERIA	POTENTIAL SKILLS TRANSFER			CURRENT SKILLS AVAILABLE			GOVT OBJECTIVES		NEW SKILLS	
PRIORITY	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 3: Global priorities of elements in the hierarchy

GOAL	PROJECT WITH HIGHEST SKILLS VALUE									
PRIORITY	1									
CRITERIA	POTENTIAL SKILLS TRANSFER			CURRENT SKILLS AVAILABLE			GOVT OBJECTIVES		NEW SKILLS	
PRIORITY (GLOBAL)	0,161			0,463			0,085		0,291	
SUB-CRITERIA	ST	PS	MJ	SS	JS	IS	LA	LC	HL	LL
PRIORITY	0,030	0,041	0,090	0,301	0,096	0,066	0,056	0,029	0,233	0,058

A set of tables indicating each alternative compared with all the sub-criteria was also developed. Again, each table indicated the local and global priorities, derived in the same fashion as previously explained. Table 5 is displayed below as an example.

Table 4: Local and global priorities of alternatives compared with 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

These tables were combined into a final spreadsheet that summarised all the preceding spreadsheets (Table 6) and tables. The final ranking of the three alternatives was achieved by aggregating all the derived global priorities for every alternative compared with the sub-criteria. 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 that ranked coal in first place was expected, based on the literature and specialist opinion, with the other two alternatives lying close to one another in the ranking.

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

Table 5: Summary of AHP model, indicating all results

AHP hierarchy, summary of model		GOAL	PROJECT WITH HIGHEST SKILLS VALUE										TOTAL	RANK
		CRITERIA	POTENTIAL SKILLS TRANSFER			CURRENT 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 that were derived from it, a sensitivity analysis was carried out. This was to test one of the criticisms levelled against the AHP, that rank reversal can happen, which would challenge the reliability of the data and the results. It must be remembered that the overall priorities were influenced to a large degree by the weights that were given by the specialists to the respective criteria. The consensus and consistency were tested as the weighting of the overall hierarchy was carried out; but the final results had still to be interrogated to ensure their overall reliability and validity. This process was also important in determining the robustness of the model and the trustworthiness of the final results. It also determined the stability of the inputs of the participants.

For the sensitivity analysis, Table 6 was duplicated, and the analysis was done through linking all the values. Two scenarios were tested in this analysis: one scenario in which all the sub-criteria were given equal priorities, and another in which one sub-criterion received a higher priority and all the other criteria were made equally small. The first scenario is indicated in Table 7, where all the sub-criteria were given the same global priority of 0.100. It must be noted that, when horizontally aggregated, all of these priorities must still amount to 1. The outcomes 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 6: Sensitivity analysis — all global priorities of sub-criteria equal

AHP hierarchy, summary of model		GOAL	PROJECT WITH HIGHEST SKILLS VALUE										TOTAL	RANK
		CRITERIA	POTENTIAL SKILLS TRANSFER			CURRENT 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 8), it was decided to increase the priority of the sub-criterion of ‘mentorship of junior engineers’ from the original values 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 the final priorities of the alternatives very similar to those in the previous sensitivity analysis (1 = 0,527; 2 = 0,254; 3 = 0,220).

Table 7: Sensitivity analysis — all global priorities of sub-criteria equal, except MJ = 0,30

AHP hierarchy, summary of model		GOAL	PROJECT WITH HIGHEST SKILLS VALUE										TOTAL	RANK
		CRITERIA	POTENTIAL SKILLS TRANSFER			CURRENT 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	
	GLOBAL		0,161			0,463			0,085		0,291		1,000	
	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 four 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 to address all the criteria and sub-criteria successfully that were developed as part of the study. These criteria were identified to form part of a way to determine 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, the consistency of the weightings and priorities, and the validity and reliability of the results; and it can deduced from this that these results are accurate and that the developed model can be trusted.

5 CONCLUSION

The goal of this study was to develop a model that can estimate a project’s required skills value (based on certain criteria) at the feasibility stage of a project, with the objective of applying this model in a real-world example by comparing three energy project options with each other. In order to fulfil this goal, each of the three energy options was compared by measuring their skills value at the 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 option 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 based on the criteria, the higher the rank. It must be noted that a different group of specialists might arrive at a different ranking, seeing that all the weightings respond to the collective skills and knowledge of the group. The strength of the AHP process is that it can absorb many different parameters and still arrive at an acceptable solution. The process owner remains in control to direct the process to find the solutions sought.

6 RECOMMENDATIONS

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 to 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 advancing skills on every level 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 its potential to meet or improve skills in 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 were chosen, with a strong focus 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 no reason why this model cannot be applied in other industries, seeing that most of the 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 help determine the skills value, and thereby offer strategic support to decision-making.

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