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A framework for Coherent Decision-Making in Environmental Impact Assessments in the Energy Sector of South Africa

by

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ABSTRACT

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The current decision-making processes involved in Environmental Impact Assessments (EIAs) in South Africa suffer from a lack of coherence and do not include evaluation of trade-offs between qualitative and quantitative impacts, as well as environmental, economic, and social dimensions. In addition, insufficient capacity and knowledge among authorities, a lack of objectivity among Environmental Assessment Practitioners (EAPs), and mediocre reports add to the problems associated with effective decision-making. This work presents a framework aimed at improving the effectiveness and objectivity of the decision-making process applied in South Africa's EIAs in the energy sector[1].

A number of decision-making models and tools are available to researchers and practitioners throughout the world that could potentially be applied in EIAs. Among these are Cost-Benefit Analysis (CBA), Rapid Impact Assessment Matrix (RIAM), and Multi Criteria Analysis (MCA). Each of the tools has its own advantages and disadvantages. With respect to the CBA, its biggest disadvantage is the fact that it requires conversion into monetary terms of all impacts, which is sometimes difficult to achieve. The RIAM, on the other hand, fails to provide a systematic approach to the ranking of alternatives. Both of these issues are addressed by the MCA tools. The MCA framework, furthermore, is universal, transparent, easy to replicate, and does not require a particularly large amount of labour and financial resources to complete. It is, however, subjective, but this shortcoming can be overcome by making the decision process more transparent.

The framework proposed in this research paper is based on the Multi Criteria Analysis (MCA) technique that allows the identification of the proposed development's

[1] The review of the EIA process in South Africa presented in this research document presents the situation observed up to 2008. It does not include the NEMA EIA 2010 regulation gazetted by government on 18 June 2010. It therefore does not take into account improvements in the EIA process that are expected to transpire in the future as a result of the introduction of this new regulation. The new regulation, however, does not have an effect on the proposed framework.

cumulative impact versus the current status of the environment. It then compares possible alternatives, where available, in order to identify the most optimal solution. The proposed solution takes into account the trade-offs between the different impact metrics.

The research methodology followed in this paper comprised four steps, namely:

- Selection of case studies,
- Information collection,
- Framework application and testing and
- Feedback.

The development of the framework followed an eight-step approach that is generic for MCA and was tested on two case studies that have already gone through the Environmental Impact Assessment process, i.e. the Open Cycle Gas Turbine (OCGT) plant in the Western Cape and the Concentrating Solar Power (CSP) plant in the Northern Cape. The former was evaluated against the "no-go option", but included a decision tree comprised of impact areas, categories of impacts and dimensions (environmental, social, and economic). The latter included alternatives for four components of the project, but the decision tree comprised only of categories and dimensions.

The effectiveness of the framework was verified by testing the results of the case studies against the recommendations proposed in the respective Environmental Impact Reports. In all cases, but one, the results of the framework correlated with the recommendations made by the Environmental Assessment Practitioners in the respective studies. In addition, a workshop with the decision-makers was held to obtain their viewpoints regarding the usefulness of the framework in their decision-making environment. These decision-makers supported the use of the framework in their environment as it offered an integrated and transparent approach to the evaluation of projects and alternatives. They emphasised, however, that the decision-making process was complex and the application of the framework alone would not be able to address all the challenges.

The case studies demonstrated that the proposed framework could be successfully applied in the process of undertaking impact assessments in the energy sector. It can be used to determine the trade-offs between impacts and dimensions, while taking into consideration the opinions of specialists and decision-makers when assigning weights. The framework has the ability to clearly illustrate the benefit of introducing mitigation measures and it also indicates an alternative that produces the optimal cumulative impact.

In conclusion, the work presented contributes to the new body of knowledge in the field of Environmental Impact Assessment in the energy sector as it will assist authorities in making objective and informed decisions, while ensuring greater transparency in the process. It also opens opportunities for conducting follow-on investigations, such the application of the framework in other sectors of the economy, undertaking a sensitivity analysis to compare the range of scores used in the evaluation of impacts, and investigating the possibility of acquiring input from Interested and Affected Parties (I&APs) and integrating those into the framework.

Keywords: Environmental Impact Assessment, multi-criteria decision analysis, multi criteria analysis, multi criteria decision framework, pairwise comparison, direct weighting, energy sector, South Africa, decision-making processes.

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ACRONYMS

AHP	Analytical Hierarchy Process
BCR	Benefit/Cost Ratio
CBA	Cost-Benefit Analysis
CI	Consistency Index
CSIR	Council of Scientific and Industrial Research
CSP	Concentrating Solar Power
DEAT	Department of Environmental Affairs and Tourism
EAP	Environmental Assessment Practitioner
ECA	Environment Conservation Act
EIA	Environmental Impact Assessment
ES	Environmental Score
EWT	Endangered Wildlife Trust
FAO	Food and Agricultural Organisation
GGP	Gross Geographical Product
I&AP	Interested and Affected Parties
IA	Impact Assessment
IRR	Internal Rate of Return
ISEP	Integrated Strategic Electricity Planning
MCA	Multi Criteria Analysis
MCDA	Multi Criteria Decision Aid
MCDM	Multi Criteria Decision-Making
NEMA	National Environmental Management Act
NEPA	National Environmental Policy Act
NPV	Net Present Value
OCGT	Open Cycle Gas Turbine
OECC	Overseas Environmental Cooperation Centre
OECD	Organisation for Economic Cooperation and Development
RIAM	Rapid Impact Assessment Matrix
ROD	Records of Decision
RV	Range Value
TEV	Total Economic Value
TVI	Total Value Index
UNEP	United Nations Environment Programme
USA	Unites States of America
WPM	Weighted Product Model
WSM	Weighted Sum Modeloofrontthesis
WSM	Weighted Summation Method
WTA	Willingness to Accept
WTP	Willingness to Pay

CHAPTER 1: BACKGROUND

Forty years ago, Environmental Impact Assessment (EIA) did not exist as a formal discipline (Weaver and Sibisi, 2006). These days it is recognised as one of the most successful policy innovations and a legal requirement in most countries around the world (Weaver and Sibisi, 2006). Every EIA investigates trade-offs that lead to conflicts in decision-making (Stahl, Cimorelli and Chow, 2002). The more diverse the impacts are in nature (i.e. social, economic, political and environmental), the more difficult is their comparison due to the different nature of these impacts and measurements used in their assessment. Nevertheless, if the project is to be considered holistically, all these impacts need to be evaluated simultaneously, which means that trade-offs will have to be made. The current practice of presenting information for decision-making does not always allow the decision maker to see the trade-offs and compare them. Most often than not, specialists' inputs with respect to the proposed activity are analysed separately from each other without making any attempt to integrate them and compare against different alternatives or at least against a "no-go option". Furthermore, decision-makers rarely read entire EIA reports (Cashmore, Gwilliam, Morgan, Cobb and Bond, 2004) and, like any human, have a natural limited mental capacity and can only deal with a limited volume of information (Kornov and Thissen, 2000). Therefore, concise and focused documents and presentation of information in a way that would be understandable by stakeholders is good EIA practice that should be implemented through the board (Cashmore et al., 2004).

Given these purposes of EIA in South Africa and without diminishing the importance of further research needed to investigate EIA's substantive goals, it is argued that the focus on improvement of procedures involved in EIA decision-making in the country is still valid. It is thus argued that there is a need for the development of a framework that will clearly illustrate the trade-offs of the proposed activity and allow for the integration of decision-makers' views with respect to the importance of different factors. In addition, such a framework could assist with the measurement of the level of sustainability of the project under analysis, assuming the definition thereof provided in the National Environmental Management Act (NEMA). The objective of this dissertation was the investigation of frameworks that could potentially be used in integrating information supplied by different specialists in the EIA, and the testing of a chosen framework in terms of the context stated above. Case studies from the energy sector of South Africa were selected for the testing exercise. The rationale for this decision was that EIA's in the energy sector, and in particular with respect to electricity-generation activities, involve projects that are highly complex, that involve multi-billion Rand investments and that result in long-term effects. These EIA's also generally require a comprehensive set of specialists' inputs.

The following paragraphs briefly outline the history of the EIA process worldwide and in South Africa and describe the problems faced by decision-makers. This information provides the basis for formulating the research problem and subsequent research questions.

1.1 EIA process in South Africa

1.1.1 Historical development of EIAs worldwide and in South Africa[2]

Rapid population growth, development inequality, and unsustainable consumption patterns had a detrimental impact on natural environments and the lives of people. On one hand, the lack of development in some countries has led to a rise in poverty, which at the same time has contributed to environmental degradation of some areas (WCED, 1987). On the other hand, economic development has put pressure on the environment due to unsustainable consumption patterns employed by those countries (WCED, 1987). These problems highlighted the necessity to integrate the concepts of environmental protection and development, thereby resulting in the emergence of the sustainable development paradigm.

The concept of sustainable development was formally introduced and popularised at the United Nations Conference on Environment and Development at Rio de Janeiro, or The Rio Summit, in 1992 (OECC, 2000). Since then the tendency to incorporate sustainable development elements in new development activities has grown at a rapid pace. One of the outcomes of the Summit was The Rio Declaration. Principle 4 of this declaration stated that "in order to achieve sustainable development, environmental protection shall constitute an integral part of the development process and cannot be considered in isolation from it". In addition, Principle 17 calls for environmental impact assessments to be "undertaken for proposed activities that are likely to have a significant adverse impact on the environment and are subject to a decision of a competent national authority" (Rio Declaration on Environment and Development, 1992). In other words, a decision regarding any developmental project must take into account environmental considerations and an EIA should be used as a tool to achieve this goal (OECC, 2000). The Rio Summit was the major factor leading to the adoption of EIA processes throughout the world; even though some countries were already using equivalent processes.

The foundation for EIA processes was created by the enactment of the National Environmental Policy Act (NEPA) in 1969 in the Unites States of America (USA) (OECC,

[2] The review of the EIA process in South Africa presented in this research document presents the situation observed up to 2008. It does not include the NEMA EIA 2010 regulation gazetted by government on 18 June 2010.

2000). It was followed by the adoption of EIA procedures by industrialised countries such as Canada, Australia, the Netherlands, and Japan in 1973, 1974, 1981, and 1984 respectively (DEAT, 2002). In 1985, the European community adopted Directive 85/337EEC that made environmental assessments mandatory for certain projects, which was then amended in 1997 (DEAT, 2002). In the 1990s, the institutionalisation of the EIA became more common not only among countries, but also within the international organisations and agencies such as the World Bank, the Organisation for Economic Co-operation and Development (OECD), the Food and Agricultural Organisation (FAO), and the United Nations Environment Programme (UNEP) (DEAT, 2002).

In South Africa, the need for an approach towards sustainable development and environmental management has been highlighted in different national policies and strategies. Since the 19703, various approaches have been researched and discussed (DEAT, 2002). The first milestone in establishing an environmental policy to guide decision-making was the adoption of the Environment Conservation Act (ECA) No 73 of 1989 (Sowman et al., 1995). This Act specified the type of activities that would require an EIA (Section 21 of Act No 173 of 1989) and outlined the requirement for the content of EIA reports (Section 29 of Act no 173 of 1989).

The next breakthrough in facilitating and promoting the considerations of sustainable development in planning and implementation of various activities was the formulation of the NEMA (Act No 107 of 1998). The NEMA recognised sustainable development as "an integration of social, economic, and environmental factors into planning, implementation, and decision-making so as to ensure that development serves present and future generations" (South African Government, 1998). The NEMA emphasises the importance of the promotion of integrated environmental management activities through the application of the appropriate environmental management tools. Since then the EIA process has become an integral part of new developments in the country that prescribed considerations of impacts on environment, social lives, and economies.

In addition to the ECA and NEMA, sectoral legislation such as the National Water Act (Act No 36 of 1998) and the Mineral and Petroleum Resources Development Act (MPRDA) (Act No 28 of 2002) widen the range of activities for which the EIA process became a legal requirement (Du Pissani and Sandham, 2006).

On 21 April 2006, the Minister of Environmental Affairs and Tourism propagated the new EIA Regulations that replaced the ECA EIA Regulations (DEAT, 2006a). They were passed under Chapter Five of the NEMA and became effective from 1 July 2006.

1.1.2 Strengths and weaknesses of the EIA process in South Africa

EIA is one of the tools of Integrated Environmental Management (IEM). It is also generally acknowledged to be a fundamental tool for pursuing sustainable development principles and achieving sustainable development (Glasson, Therivel, and Chadwick, 2005).

Definitions of the EIA are numerous. Donnelly, Dalal-Clayton, and Hughes (1998) refer to impact assessment as a process that provides information on social, environmental and economic consequences of the proposed development and is seen as a 'mechanism by which information can be presented clearly and systematically to decision-makers'. Other definitions, although different, have one commonality, which is the prediction of impacts or effects of the proposed activity (for example in Jay, Joness, Slinn and Wood, 2007; Cashmore, 2004; Cashmore et al., 2004) The South African Department of Environmental Affairs and Tourism (2004a) defined EIA as a process that aims to predict both positive and negative impacts of proposed developments, propose measures to reduce adverse effects, shape projects to suit local environments, and present information to decision-makers regarding possible options and predictions.

As stated in the NEMA (South African Government, 1998), the focus of IEM, including the EIA process, is to identify, predict and evaluate the actual and potential impacts on the environment, socio-economic conditions, and cultural heritage of actions that require authorisation from government by law. The NEMA also specifies that integrated environmental management tools should evaluate the significance of the proposed actions, namely risks and impacts. The EIA process should incorporate evaluation of alternatives and options for the mitigation of activities (South African Government, 1998). Importantly, the assessment should include "investigation of mitigation measures to keep adverse impacts to a minimum, as well as the option of not implementing the activity" (South African Government, 1998). The latter is usually referred as a "no-go option". Importantly, one of the principles of the NEMA is to pursue the selection of the best practicable environmental option acknowledging that all elements in the environment are interlinked and taking into account the effects of the decision on all elements of the environment and people (South African Government, 1998).

Derived from the above, the EIA process provides **numerous advantages**, among which are:

- Facilitation of environmental protection or environmental improvement;
- Promotion of sustainable utilisation of resources;

- Facilitation of equitable access to environmental resources;
- Protection of vulnerable groups against unfair discrimination with regard to distribution of adverse environmental impacts;
- Facilitation of an informed decision regarding proposed activities; and
- Improvement of environmental knowledge and knowledge of local resources.

The practice of the EIA process, however, has many identified **drawbacks** that prevented the full realisation of its advantages. For many years researchers have evaluated the effectiveness of the EIA process and searched for ways to improve it. EIA effectiveness generally refers to the measurement of substantive and procedural criteria, where the former refers to an assessment of the level EIA achieves its purposes and the latter to the evaluation of how well procedures are followed (Cashmore et al., 2004). Most of the research so far has focused on the assessment of the procedural side of EIA's effectiveness (Cashmore et al., 2004). It has been shown that the quality of EIAs worldwide and decisions involved had improved over the years with the increasing practice of capacity building, use of mitigation measures, and improvement of procedures (Jay et al., 2007). Contribution to sustainability, or the substantive purpose of EIA, has been seen by many as an implicit aim of an EIA (Jay et al., 2007; Glasson, et al., 2005). However, this idea has not translated into the frameworks, principles and methodologies used by EIA (Jay et al., 2007). This was largely due to the lack of clear and agreed upon definition of EIA's aim with respect to sustainable development and the fact that the practice of EIA predated the formulation of its theory and concept (Jay et al., 2007; Cashmore, 2004; Cashmore et al., 2004,). As a result, the evaluation of EIAs effectiveness in terms of its substantive goals has not been as successful as in terms of procedural criteria, despite the fact that the former is a better measurement of effectiveness (Cashmore et al., 2004).

Despite the improvement of the quality of EIA and decision-making process observed in over the years, the EIA process in South Africa still suffers from certain shortfalls. The weaknesses of the process that have been identified by South African government itself throughout the internal revision processes include (DEAT, 2006b):

- Inconsistency in application of the regulations by authorities due to a wide interpretation of activities specified in the regulations;
- Numerous small and insignificant activities were made subject of the EIA regulations;
- The process encompassed several stop points and decision points that resulted in a lengthy process and overwhelmed government's capacity;
- Public consultations received insufficient attention;
- Weak enforcement measures; and
- Lack of linkage with strategic planning tools.

In addition to the above, the following flaws and constraints of the EIA process in the country could be highlighted (Sandham et al., 2010; Sandham and Pretorius, 2008):

- Poor overall report quality, with the provision of information regarding the impact identification, consideration of alternatives, mitigation measures, and monitoring being the areas of the poorest performance;
- Lack of political will and limited capacity of selected government departments;
- Acceptable practice of beefing-up scoping reports to be then presented as EIRs;
- Inadequate assessment methodologies employed and lack of details thereof in the reports.

1.1.3 Types of Environmental Assessments in South Africa

The Department of Environmental Affairs and Tourism (DEAT) and the provincial government departments have been reviewing the implementation of EIA regulations for years (Sandham and Pretorius, 2008; Sandham, Hoffman, and Retief, 2008). As a result, the revised EIA Regulations in terms of the NEMA were adopted in mid-2006 that largely tried to address the issues highlighted above. The new EIA Regulations narrow the spectrum of activities that are required to undergo an EIA, whilst including activities that were previously omitted (DEAT, 2006b). Furthermore, it split the process into the basic and environmental impact assessments (DEAT, 2006b).

The **Basic Assessment Process** is applicable to small-scale activities listed in Government Notice R. 386 of 21 April 2006 (DEAT, 2006a; EWT, 2006). Generally impacts for these activities would be known and are easily measured (DEAT, 2006b; EWT, 2006). The Environmental Impact Assessment Process, which involves **Scoping and EIA**, is applicable to the activities listed in Government Notice R. 387 of 21 April 2006. These activities are the higher-risk activities that would generally have a significant impact on the environment due to their nature or extent, and would be associated with high level of pollution, waste generation, or land degradation (DEAT, 2006b). The EIA process takes place in three main phases, namely submission of an application form, scoping, and an EIA (DEAT, 2006c). After submission of the application form and acceptance of the scoping report and a plan of study for the EIA, the Environmental Assessment Practitioner (EAP) must proceed with the study (DEAT, 2006c). The purpose of the EIA is then as follows (DEAT, 2006c):

- To address issues that have been raised during the scoping phase;
- To assess alternatives to the proposed activity in a comparative manner;
- To assess all identified impacts and determine the significance of each impact; and
- To formulate mitigation measures.

Since 1 July 2006, the EIA process prescribed the duration of each of the steps. This was done with an aim to increase the throughput of decision-making by regulating the timeframes, even though such an aspect might have put additional pressure onto authorities. Furthermore, the revised EIA process requires consideration of alternatives to a proposed activity. It also increased the amount of attention and importance given to the public participation process. The following section briefly reviews the quality of the EIA process in the country and the current decision-making process followed by the authorities in SA.

1.1.4 Quality of the EIA process and the decision-making process in South Africa

In South Africa, the purpose of EIA, as described in the previous section, is amongst others to predict the impacts and their significance suggests that the process largely follows a rationalist approach. This approach requires identification of goals and objectives, selection of alternatives, presentation of all information about the proposed activity's possible impacts, and selection of the best alternative given the goals (Kornov and Thissen, 2000). The introduction of EIAs into the planning system had, however, also a substantive aim through the promotion of integration of sustainable development concept into planning by the NEMA (South African Government, 1998). The NEMA provided a clear definition of sustainable development, which could be used to measure the effectiveness of EIAs in the country from the substantive criteria perspective. This exercise, however, goes beyond of this research, but could possibly be explored in the future.

Projects subjected to the EIA process, including those that are undertaken in the energy sector, are generally very complicated and require cognisance of various impacts that are sometimes very difficult to estimate and compare. Furthermore, risks, nature, and the extent of impacts involved in these types of projects are generally very high (DEAT, 2006b). The EIA decision-making process therefore has great value in determining whether a particular development will have a detrimental or beneficial impact on the environment, society and economy.

Given the importance of a transparent and coherent decision-making process, the quality of EIA processes in South Africa raised some concern (King and O'Beirne, 2007). Some of the issues observed by King and O'Beirne (2007) that **jeopardised the judicious decision-making process** were as follow:

- Inadequate IA scoping reports and Environmental Impact Reports have been accepted without requiring further investigation;
- Significant information presented had been ignored or discounted;

- The full legal requirements of the EIA process have not been implemented;
- The role and input of Interested and Affected Parties (I&APs) had been undermined and negated;
- Biased support for the proposed development had been apparent; and
- Independent Review had resulted in the overturning of RODs.

As indicated above, many of the issues were related to the ability of authorities to guide the EIA process and ensure its adherence to the EIA Regulations. At the same time, the decision-making process on average took much longer, which lead to a continuous backlog of EIA applications. The report compiled by Mosakong Management CC in 2008 and titled 'Review the Effectiveness and Efficiency of the Environmental Impact Assessment (EIA) System in South Africa' highlighted that on average authorities took 158 days (more than five months) to evaluate EIRs and make a decision, whilst the longest timeframe recorded for this process was 1 128 days. At the end of June 2006, 5 859 applications in terms of the 1997 EIA Regulations were still pending (National Assembly, 2007). This amount was considerably reduced within a year to 2 150 (National Assembly, 2007). Pending decisions with respect to EIAs submitted under the 2006 EIA Regulations were mostly within the timeframe and therefore had very small backlog at the time of the report (National Assembly, 2007). According to the DEAT (2006b), between 1997 and 2006 approximately 50% of applications were finalised within six months, 33% were finalised within one year, and about 9% of applications were finalised within two years. The latter statistics was one of the major concerns as it meant that there was a consistent backlog of applications (DEAT, 2006b).

Marthinus van Schalkwyk, the Minister of the Environmental Affairs and Tourism, in his speech at the opening of the conference '10 years of EIAs in South Africa' in Somerset West in 2008 stated that the major shortcomings of the EIA system from government perspective were inadequate capacity and skills at both provincial and national departments, staff turnover, and limited experience by the majority of staff (Schalkwyk, 2008). These statements were based on the findings of the detailed capacity audit and needs analysis survey conducted in 2006. In addition to this, the following reasons were noted to contribute to the backlog (Engineering News, 2006):

- Long period of inactivity on behalf of an applicant;
- Complexity of the application;
- Public objection and controversy;
- Poor quality of reports submitted; and
- Design changes during the duration of an EIA.

The issues of complexity and controversy that have been identified as some of the reasons contributing to the backlog are interlinked with the problem of poor quality of reports. It has been found that reports produced by EAPs in the country were generally of an acceptable standard, but suffered from insufficient scientific and technical information, consideration of alternatives, prediction of impact magnitude, and provision of appropriate mitigation measures (Sandham and Pretorius, 2008; Sandham et al., 2008; Sandham et al., 2010). Some of the reasons behind this included lack of training and inexperience of environmental practitioners involved in assessments, as well as time and financial constraints imposed on consultants (Sandham et al., 2010; Kruger and Chapman, 2005). It has also been observed that many EIRs do not consider socio-economic implications of proposed activities (Kruger and Chapman, 2005). The inclusion of these impacts into the assessment, however, creates other problems that EIAs have not been able to address effectively. Consideration of environmental impacts that are generally negative and socio-economic impacts that are usually positive creates a crucial dilemma for both EAPs and decision makers (Glasson et al., 2005). It could be argued that one of the reasons behind this situation is the fact that the consideration of trade-offs was not required by the legislation and therefore has not been practiced by EAPs. As a result, after the specialist studies were completed and impacts were assessed, most often than not, information contained in these study was simply put together to represent an integrated report (Weaver and Sibisi, 2006). The submitted report generally encompassed a summary of all impacts and recommendations of the environmental consultant, without the indication of the trade-offs between the impacts identified.

The other weakness of the EIA process in the country is the poor understanding of the needs of decision-makers and lack of integration thereof into the process (Cashmore, 2004, Cahsmore et al., 2004). EAPs think differently from the decision-makers (Mosser, 1999). If an EAP is focusing on capturing impacts and processes related to the analysed development, the decision-maker is looking for the information that would assist him or her in making the decision (Mosser, 1999). Kornov and Thissen (2000) argue that to be 'effective in a decision context', the focus of research should not be on the advancement of science of EIA, but on the application of known methods to improve the understanding of decision-makers and present them with information in line with their 'capabilities, interest and timetables'. The challenge therefore is to integrate these two different approaches, ensuring that all aspects of the development are assessed, that information provided is relevant and comprehensive, and that it is presented in a form that would assist the decision-maker in making the right choice.

Many EIA reports have considered a number of alternatives for comparison with the proposed project. Since 1 July 2006, the consideration of alternatives had become compulsory. However, the way the EIA reports were presented did not allow for an objective comparison of the proposed project with its alternatives taking into account qualitative and quantitative positive and negative impacts. As a result, when the authority was presented with the document it encompassed complex data matrices (Weaver and Sibisi, 2006) and a subjective opinion of the environmental consultant (Wilkins, 2003).

1.2 Research problem

The level of effectiveness of EIA is largely determined by its realisation of substantive goals. However, these goals are poorly defined and therefore their achievement cannot be properly measured. Until this issue has been resolved, the focus with regard to improving the effectiveness of EIA and decision-making involved in the process would need to remain on perfecting procedures and processes involved in EIAs to ensure that decision-makers are equipped with comprehensive information to decide on the future of the proposed development. This includes the improvement of quality of reports, as it is argued that poor EIRs would invariably results in ineffectiveness of the process since they contain the information that is used to make decisions (Sandham et al., 2008).

The analysis of EIAs and quality of reports in South Africa revealed that, amongst other issues, decision makers are not always supplied with the comprehensive assessment of potential impacts and integration thereof. In many cases trade-offs between different impacts are not properly assessed and presented, which complicated the issue of decision-making and made the process less transparent. Moreover, the needs of decision-makers have also not been incorporated in the process. This suggests that the current decision-making process, including the one applied in the energy sector's EIAs, is suffering from a lack of integration of decision-makers interests and does not always include a structured evaluation of trade-offs between qualitative and quantitative impacts. In this context, the problem to be investigated in this dissertation was a process for integrating the information presented in EIAs, whilst taking into account decision-makers' interests and making the decision process more transparent.

1.3 Rationale for research

An effective evaluation is the evaluation that allows decision-makers to compare the costs and benefits of the proposed activity, and make a decision that is 'socially optimal' (Kruger and Chapman, 2005). Information regarding the potential costs and benefits of the project, or positive and negative impacts is provided in EIRs, which makes it an important component of the whole process. While reviewing an EIR, the applicable authority needs to review the presented information, assess alternatives, and make the right decision using their own discretion. Therefore, it can be argued that the quality of EIRs could have a notable influence on the decision taken by the authorities.

It is clear from the previous sections that the intricacy of the presented information and difficulty involved in comparing qualitative and qualitative impacts, along with their trade-offs, pose a serious problem for decision-makers. Introduction of trade-offs does not form part of the requirement specified in the regulations. It has also been observed that the criterion regarding trade-off identification and interpretation does not form part of certain assessment packaged used by researchers to evaluate the quality and effectiveness of EIAs and EIRs. This includes the Lee and Colley Review Package and the North West University Review Package (adaptation of Lee and Colley) (Sandham and Pretorius, 2008; Sandham et al., 2008; Sandham et al., 2010). This is a significant shortcoming of the process, as an absence of a trade-off analysis limits the ability of a decision maker to make a structured and an informed decision. This suggests that there is a need for a framework that will:

- Illustrate the trade-offs by converting quantitative and qualitative information into relative scaling;
- Allow for an efficient integration of diverse issues affecting decisions;
- Convey the EIA information to the authorities more effectively; and
- Improve the transparency of decision-making.

Based on the requirements specified in the above list, it is clear that the decision-making framework would need to be applied from the beginning of the EIA process until its closure by the EAP and delivered as a summary to the authorities. This also implies that decision-making authorities would need to be engaged in the beginning of the process and their needs and interests would need to be identified before the EIR and the framework is to be submitted for their review. The development and application of such a framework would aid in an integrated decision-making process and improve its transparency. The associated research question is then defined as "What decision-making framework can be used to integrate information presented in EIRs and to what extent it can improve decision-making practices in the energy sector of South Africa?"

1.4 Research objectives

By answering the above research question, the objective of this study was to develop a framework for the integrated decision-making involved in the energy sector's EIAs, to investigate its application in two EIA case studies, and to verify its effectiveness through an evaluation by the stakeholders.

In order to address the research problem effectively it was proposed that:

- A decision-making framework could be formulated that would be used in the evaluation of alternatives in the energy sector's EIAs, that would be applied by an environmental consultant, that would reflect the interest of decision-makers, and that would assist the authorities in comprehending all trade-offs involved in the proposed activity.
- The use of the proposed framework in the energy sector's EIAs could be investigated by applying it on two case studies.

1.5 Importance of the research problem

The proposed decision-making framework could be applied by an EAP to evaluate and compare alternatives proposed for a development, even if only a 'no-go option' is considered in addition to the development. This framework would incorporate information necessary for decision-making as identified through a consultation process with the relevant authorities. Furthermore, the framework will take into account preferences with regard to indicators and criteria identified by the authorities. These features will increase the transparency of decision-making and assist the developers in altering the project's composition to improve its chances of receiving a positive decision.

Due to the fact that the framework will allow comparison of alternatives based on their relative scaling when qualitative data can be assessed on the same scale as quantitative data, the evaluation of alternatives would become easier. All of this will aid in identifying the preferred alternatives from the environmental, social, and economic considerations point of view or would highlight the major drawbacks of the selected options. In any event, it would assist in an improved decision-making process based on greater integration of information. The envisioned spill-over advantages of the framework were coherent and effective decision-making processes, less backlogs, and less controversy surrounding EIAs.

1.6 Limitations and assumptions of the study

The proposed decision-making framework is based on the following assumptions regarding the data and EIA process.

- The framework is developed for the South African EIA process.
- The framework is developed for EIAs in the energy sector.

- The framework assumes that its objective is to integrate the information provided by specialist studies to identify the most preferred alternative/s even if the proposed development is compared only to the “no-go option".
- The framework assumes that the EIA process is open and transparent.
- The framework assumes that the EIA process adheres to the NEMA regulations and thus follows its principles, including the precautionary principle of any development.
- The framework assumes that the precautionary principle of the NEMA regulation is interpreted by specialists through the introduction of mitigation measures for all specified impacts.
- The framework assumes that the data provided by specialists regarding impacts with and without mitigations is complete and reliable.
- The framework assumes that by modelling results based on specialists' information provided for impacts with and without mitigation, the results of the model satisfy the precautionary principle of the NEMA.
- The framework assumes that potential fatal flaws are examined after the modelling process.

1.7 Expected contribution of the research

The study will contribute to the body of knowledge in the field of Environmental Impact Assessments. However, it will have little contribution to the existing body of knowledge with regard to the decision-making models as it will focus on the application of existing theory. In this context, the main contribution of the study will be an attempt to improve decision-making in the EIA process by providing a coherent, effective, and integrated approach to impact analysis and presentation of its results.

The final product will consist of a set of steps, methods, and a framework that could be applied to the EIA process in the energy sector to determine the most preferred site for the development among the selected alternatives.

1.8 Research strategy

An overview of the research study is shown in the steps illustrated in Figure 1.1.

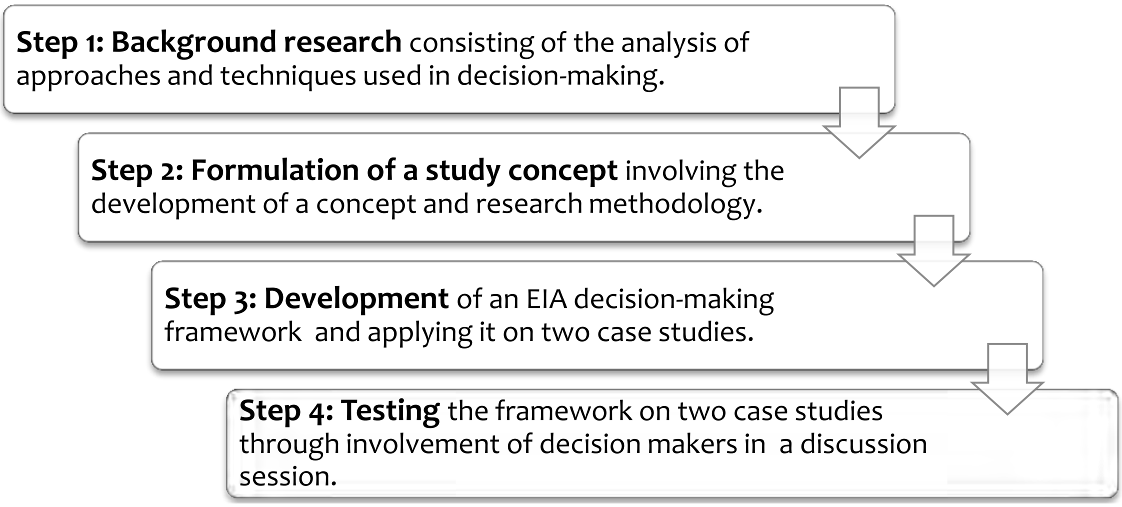

Figure 1-1: Research strategy

CHAPTER 2: LITERATURE REVIEW

The previous chapter highlighted the fact that decision-making in the EIA processes was not always transparent and based on a complete set of data regarding trade-offs. Sager (1995) suggests that the presentation of impact assessment results influences the ensuing communication among stakeholders. As a result, decision-makers are very often not capable of assessing trade-offs. This usually has a detrimental impact on decision-making resulting in a situation where judgment is made in a poorly informed environment.

Interpretation of trade-offs in environmental assessments

Johnson (2005) defines trade-off as the choices made by an individual or a group to accept having less of one thing in order to get more of something else.

Any human intervention has a wide-ranging impact. It can have both positive and negative effects and affect the environment, society, and an economy at the same time. In this context, the definition of trade-offs given by Johnson (2005) can be interpreted as the choice to accept a lower positive impact in one dimension and generate a lower negative effect in another or to accept a greater negative impact in one dimension but produce a larger positive effect in another dimension.

To address these issues of complexity, trade-offs, and presentation of results, a number of decision-making tools was developed that was aimed at assisting in organising, analysing, and presenting complex data in EIAs. Among these are the cost-benefit analysis (CBA), rapid impact assessment matrix (RIAM), and multi criteria analysis (MCA) frameworks.

This chapter aims at reviewing the decision-making tools mentioned above. It includes an analysis of their advantages and disadvantages and focuses on their potential for application in EIAs in the energy sector of South Africa.

2.1 Cost-Benefit Analysis

CBA is a decision-making tool designed to provide information about the proposed development that could assist in making a decision (Fuguitt and Wilcox, 1999). It is used either to rank projects or to choose the most appropriate option (DEAT, 2004b). CBA is used by the private sector, government, and international non-profit organisations to evaluate costs and benefits of social projects or policies. In the private sector, the CBA framework is used, for example, to justify equipment and technology investments, measure life-cycle costs, meet regulations cost-effectively, and quantify hidden costs (DEAT, 2004b). This framework is usually called financial CBA (DEAT, 2004b). Government or international non-profit organisations, such as the Organisation for Economic Co-operation and Development (OECD) and the World Bank, use the CBA framework to assess the social merits of projects and policies (DEAT, 2004a). This type of framework is called social CBA (DEAT, 2004a) and this is the tool that is normally used in EIAs (DEAT, 2004b).

In summary, social CBA could be used in the following instances (DEAT, 2004b):

- Evaluate or rank the feasibility of projects. The purpose of the social CBA in this case is to assess whether the proposed project should be undertaken.
- Analyse the effect of regulations. The objective of the social CBA in this situation is to identify the "optimal" level of intervention required to reduce or eliminate specified risks to environmental quality.
- Justify equipment and technology investment. Social CBA can assist in identifying whether the investment in new technology or equipment is an efficient use of taxpayers' money.
- Determine the most effective way to cut costs. The CBA can aid in identifying the most effective way to reduce costs of the project during the construction, operational, or phasing out phases.
- Determine the relative benefit of outsourcing and leasing. A traditional function of the state is to provide public goods. In some cases, however, government cannot deliver services as efficiently as private companies. In these circumstances, the social CBA could assist in making a decision regarding outsourcing of services on the bases of achieving improved quality and reduced costs.
- Quantify hidden costs and intangible assets. In the process of performing CBA, unanticipated costs and benefits could be uncovered. Furthermore, the CBA framework could assists in identifying the full spectrum of consequences, improving the decision environment, and aiding the EIA process.
- Ensure accountability of public sector decision-makers. CBA should provide the results in a clear format that is easy to interpret. Where it is part of an EIA, it provides the results for different stakeholders therefore improving the accountability of public decision-makers.

The areas of decision-making where CBA is applied vary significantly. It is used in valuation of life and injuries in insurance and litigation, disease control, environmental problems, water resources, information technology, social infrastructure problems, social regulations and safety, and many others (Dompere, 2004). Today, the CBA tool is also widely practiced by OECD in the fields of environmental policy, transport planning, and healthcare (OECD, 2006). The World Bank has used CBA in multiple disciplines, including the assessment of poverty projects, water resource projects, education, policy decisions, etc.

2.1.1 History of development

The CBA framework was initiated in the middle of the nineteenth century when economists started linking the theory of consumers' surplus with the net gain of communities from government projects (Mullins et al., 2007). The formal practice of CBA started in the United States and was introduced by the U.S. Army Corp of Engineers (Zebre, 2006). The advantage of the quantification of projects' costs and benefits and using this information in the decision-making process versus the ad-hoc approach to project evaluation then became noticeable. This practice resulted in the CBA tool being mandated with the adoption of the United States Flood Control Act of 1936 (Zebre, 2006). This Act recognised controlling flood waters to be "in the interest of general welfare" and stated that projects are to be economically justified "if the benefits of whomsoever they accrue are in excess of estimated costs" (Fuguitt and Wilcox, 1999).

After Wold War II, the increase in public expenditure and pressure to increase efficiency stimulated the interest and application of the CBA tool (Mullins et al., 2007). The earliest application outside the United States took place in the United Kingdom in 1960 for the M1 motorway project (Mullins et al., 2007) and then spread to the other Western countries (Fuguitt and Wilcox, 1999). A traditional technique therefore evolved within the more industrialised countries (Fuguitt and Wilcox, 1999). The adopted "modern" version of the CBA framework that would also be applicable to less developed countries was then developed in 1970s (Fuguitt and Wilcox, 1999). The principles underlying the CBA began to spread in other areas of decision-making, including the estimation of economic values of environmental qualities and natural resources (Fuguitt and Wilcox, 1999). Widespread use led to the development of the theory of environmental economics with the cost-benefit framework forming its theoretical foundation (Fuguitt and Wilcox, 1999).

As the application of the CBA tool in decision-making was spreading in the USA and other countries, the environmental movement began to challenge its application in Britain (Fuguitt and Wilcox, 1999). It particularly referred to the issues concerning assigning economical value to environmental attributes (Fuguitt and Wilcox, 1999). Despite the criticism towards the CBA framework, its application, including in the environmental field, continued to grow (Fuguitt and Wilcox, 1999). It was particularly evident in the USA. In the USA, the use of CBA and its application in different fields of decision-making was strengthened during the 1980's with the issuance of an Executive Order by Ronald Reagan declaring that Regulatory Impact Analyses be conducted for major projects (Zebre, 2006). It was then re-affirmed by Clinton's Executive Order of 1994.

In South Africa, large budget deficits, high inflation rates, and declining GDP growth in 1970s-1980s created the need for a framework that would prioritise government expenditure (Mullins et al., 2007). It was then when the concept and practice of the CBA tool was promoted by the then office of the Prime Minister's Economic Advisor and was backed by the Department of Finance (Mullins et al., 2007). The first CBA manual was released in 1989 and was restricted to public projects (Mullins, et al., 2007).

2.1.2 Theoretical foundation

The underlying theoretical foundation of CBA is as follows: Benefits are defined as increases in human wellbeing (utility) and costs are defined as reductions in human wellbeing (OECD, 2006). For a project or policy to qualify on cost-benefit grounds, its benefits should exceed its social costs (OECD, 2006). "Society" in this instance is defined as all individuals (OECD, 2006) that are directly or indirectly affected by the project or policy. The geographical boundary of CBA is usually limited to the nation, but could be extended to other countries if required (OECD, 2006).

The idea of measuring the net advantages of the capital investment in terms of society's net utility gain (welfare economics) originated with Dupuit's well-known publication "On the management of the utility of public works" published in 1844 (Mullins et al., 2007). Dupuit was the initiator of defining the consumer surplus as the measure of the net welfare gain of a project (Mullins et al., 2007). The aspect of consumer surplus is fundamental to the CBA tool. It is defined as the difference between the willingness or ability to pay for goods and services by individuals and the amount they actually do pay (Suranovic, 2004). Given the above, the net social benefit of all individuals could be defined as the sum of consumer surpluses.

CBA as a tool focuses on achieving efficiency of allocation of resources. The concept of efficiency was introduced by Pareto, which became known as Pareto optimisation or Pareto improvement. It states that the allocations of resources is Pareto efficient if no alternative allocation can make at least one individual better off without making another person worse off (Mullins et al., 2007). In welfare economics, a decision is said to promote efficiency if it increases social welfare (Fuguitt and Wilcox, 1999). Social welfare, in turn, refers to "social" value of effects of public or private decisions attempting to allow for all gains and losses from the societal point of view (Fuguitt and Wilcox, 1999).

The relationship between net benefits and Pareto efficiency is that if impacts are valued in terms of willingness to pay (WTP) or willingness to accept (WTA) and all inputs are valued in terms of opportunity costs, the positive or negative sign of the net benefit indicates whether the proposed project or policy will be able to compensate the affected parties sufficiently so that no one is left worse off than before this project or policy was implemented (Mullins, et al., 2007). The latter reflects Kaldor-Hicks criterion of weaker compensation.

2.1.3 Process and application in EIA

The following figure illustrates the process of CBA combined from steps proposed by DEAT (2004) and Kingston (2001).

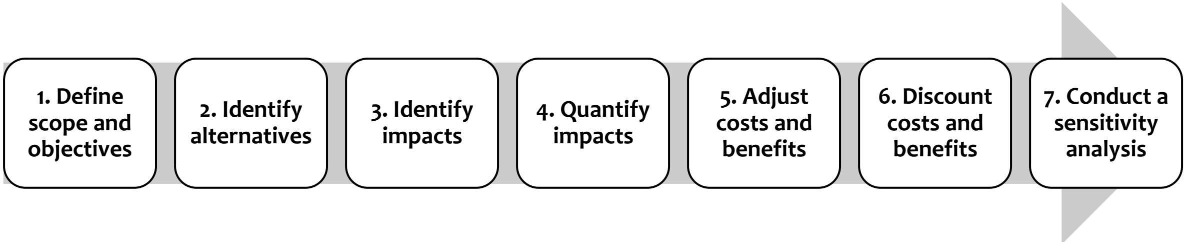

Figure 2-1: CBA process

As illustrated in Figure 2-1, the first step in conducting a CBA is to establish the **scope and objectives** of a project. During this step, boundaries of the project are defined and the goals are stated. In EIAs, this step coincides with the opening stages of the EIA process (DEAT, 2004b). During this step in the EIA process the project's definition is provided along with the identification of the important characteristics of the affected environment and significant issues that are to be examined (DEAT, 2002). The latter is guided by the nature of the proposed activity, as well as its legal, policy and planning context, which all form part of the definition (DEAT, 2002).

The second step in conducting a CBA entails the **identification of alternatives**. In CBA a leading alternative is usually the do nothing option (Kingston, 2001). This is applicable when only one project is considered and the net social benefit of the proposed project or policy is compared to the current state of social wellbeing. CBA can also consider a number of independent projects. Such a situation usually occurs when the evaluation requires ranking or prioritising alternatives based on their efficiency (Mullins et al., 2007). Lastly, CBA can also consider a number of mutually exclusive alternatives where there are different ways of achieving a stated goal (Mullins et al., 2007). Given the above, projects in an aggregate programme are assessed in a predetermined order. Firstly, mutually exclusive projects are evaluated based on their cost-efficiency criteria. Secondly, the chosen alternatives then evaluated amongst independent projects and ranked accordingly in terms of priority levels (Mullins et al., 2007). In EIAs, alternatives would be identified during the early stages of the process, such as during the scoping phase. The objective of identifying alternatives in the EIA process is to determine the most effective way of meeting the need and purpose of the proposed project, either through enhancing environmental benefits, or reducing potentially significant negative impacts (DEAT, 2004c). Alternatives would usually include mutually exclusive options, for example, such as different locations or design options. However, they could also encompass only the proposed project and a 'no go' option.

The third step of CBA is to **identify impacts or consequences** of the projects or polices under consideration. This step coincides with the step in EIA process during which the impacts of the proposed project are assessed (Mullins, et al., 2007). In EIAs impacts are usually identified for different stages of a project's life-cycle. This allows assessing direct and indirect impacts, as well as short and long-term impacts.

The next step is one of the most challenging in the CBA framework. It involves **quantifying the identified impacts** by converting them into costs and benefits (DEAT, 2004b). During this stage they are also put in time order, or discounted to represent the current values (DEAT, 2004b).

CBA views costs from a perspective of a forgone opportunity. Opportunity cost refers to what must be paid or given up in order for the activity to take place (William et al., 1998). In other words, they are values forgone when resources are used for one activity instead of another (William et al., 1998). Costs in CBA, and particularly in the version used in EIAs, refer not only to social and economic costs incurred during the implementation and running of a project or policy, but also to environmental costs, which are generally very challenging to estimate. The problem around evaluation of environmental assets relates to the fact that they are difficult to estimate in monetary terms because market prices cannot assess their full contribution to other economic activities and to human welfare (Costales, 1995). Complexity of monetising environmental costs also arises due to multiple functions that environmental assets serve (Costales, 1995).

To account for all environmental uses a Total Economic Value (TEV) could be calculated. TEV provides an all-encompassing measure of the economic value of any environmental asset, but it excludes values that are usually defined as those residing "in" the assets and unrelated to human preferences or even human observations (OECD, 2006). TEV can be broken down into the following uses:

- <u>Direct use values</u>. These values can refer to commercial and non-commercial uses of the asset (DEAT, 2004b). They are derived from the economic uses made of the natural system's resources and services (Costales, 1995).

- Indirect use values. These values are determined by the indirect support and protection provided to economic activities by the resource's system natural function and environmental service (Costales, 1995).
- Non-use values. These include an option value and existence value. The option value is the premium that people would be willing to pay to ensure the future supply of the resource that could be depleted (DEAT, 2004b). The existence value is the value confirmed by humans on ecosystem without considering its use (DEAT, 2004b). These values are utilities that people derive for just knowing that the asset exists and they are measured by the WTP or the contingent value assigned if the public good is to disappear (Costales, 1995).

The estimation of benefits can also be a challenge. Although some positive impacts, or benefits, could be easily quantified in monetary terms, in most cases they require assessment of people's preferences and WTP or WTA values.

Table 2-1 summarises techniques that could be used in estimating marketed impacts, i.e. those that have a clear financial value, and non-marketed impacts, i.e. those that do not have a clear financial value such as environmental assets.

Table 2-1: CBA evaluation techniques

Techniques using conventional markets	Techniques using non-conventional markets or implicit markets
Change in productivity	**Contingent Valuation Method**
This method is used in estimating direct use values. The change in the productivity could be valued by using standard economic prices (Costales, 1995).	This method involves conducting a survey among population to identify their WTP to preserve the recourse or WTA compensation for its destruction (DEAT, 2004b).
Loss of earnings	**Travel cost**
This method is also used in measuring direct use values of resources. Earnings lost upon death, illness or job absence is used as a measurement of the value of health impacts (Costales, 1995).	This method is used to measure the benefits produced by recreational sites (Costales, 1995). It assumes that the time and travel expenses people incur represents the WTP for access to the site (DEAT, 2004b). The advantage of this method is that is based on the actual observation of human behaviour rather than on hypothetical behaviour (DEAT, 2004b). The situation is complicated, however, by the fact that travel also have a value, trip to more than one site can have the same cost, and some costs could themselves be intangible (OECD, 2006).
Preventative expenditure	**Hedonic pricing**
Government and individuals invest in preventative measure to avoid certain impacts, including unwanted environmental effects	This method is used to evaluate the value of land (Costales, 1995). Hedonic pricing uses real estate prices. The logic is that since house prices capture

Techniques using conventional markets	Techniques using non-conventional markets or implicit markets
(Costales, 1995). Generally, environmental effects are difficult to estimate but historical information on the preventative measure could serve as an indicator of the minimal value of benefits created by prevention activities (Costales, 1995).	real amenities, such as proximity to shops and schools, it should also capture environmental amenities and disseminates, such as open space close by, view of how pristine the area is, traffic noise and pollution (DEAT, 2004b). It is necessary to be cautious when using this method as the market goods can have several intangible characteristics that can be collinear, and measuring these in a meaningful manner could be challenging (OECD, 2006).
Replacement cost	**Behaviour and defensive expenditure**
This technique refers to estimating the cost of replacement of the asset (Costales, 1995). It is important to note, however, that replacement costs are not estimates of benefits of avoiding damage (Costales, 1995).	This method is similar to hedonic pricing and cost of travel, but refers to the individual behaviour to avoid negative intangible impacts (OECD, 2006).

After **aggregated benefits and costs** are identified they need to be **adjusted** by assigning higher weights to benefits and costs accruing to low-income categories of people and disadvantages (OECD, 2006).

Following on the above is the **discounting of flows of costs and benefits** and application of the appropriate decision rule.

Discounting is the process by which costs and benefits occurring in different time periods could be compared (Costales, 1995). There is a consensus that in the private sector the discount rate is usually determined by the market rate of interests, i.e. opportunity cost of funds, although it is not always clear what it means as it could refer to the overdraft rate, long-term rate, and post-tax savings rate (DEAT, 2004b). In the public sector, there is no consensus on the rate that should be used for discounting (DEAT, 2004b). It could be the costs of long-term loans, or it could be the private sector's pre-tax marginal rate of return on capital (DEAT, 2004b).

Mulling et al. (2007) recommend that the real discount rate used in South Africa should range between 6% and 10%, with 8% considered to be a base real discount rate. This is on par with the discount rates recommended by major international organisations such as the World Bank (DEAT, 2004b). At the same time it is important to note that lower discount rates promote capital intensive production methods (DEAT, 2004b). Higher discount rates are viewed as discriminating against future generations due to the fact that they would prioritise projects with net social benefits occurring in the short term and social costs occurring in the long term (Costales, 1995).

Discounting in environmental projects is an on-going debate. Environmental projects generally involve long-term benefits but short-term costs, i.e. being biased towards the current generation (DEAT, 2004b). Costales (1995) recommends that accounting for long-term environmental costs a lower discount rate should be used, stating that it would allow large numbers of projects passing the CBA test and would create additional pressure on the environment. The DEAT (2004b), however, argues that lowering the discount rate is not the solution, as it would lower the costs of capital and promote resource intensive projects that would otherwise have a negative net present value. The DEAT (2004b) and Costales (1995) state that low discount rates could be useful in projects that have irreversible damage. In this case they propose to use the Krutilla-Fisher approach.

Krutilla and Fisher presumed that environmental benefits are likely to increase relative to other benefits in the economy (Neumayer, 2003). This means that environmental benefits are discounted at lower value than other benefits, or even not at all, and if the relative importance of these benefits increase over time, discounting them would take a negative sign (Neumayer, 2003). They suggest including preservation benefits forgone within the costs of the project, allowing them to increase over time with the annual economic growth rate. The DEAT (2004b) and Costales (1995) argue that although this approach is similar to discounting, it is applicable only to environmental benefits and costs and therefore avoids distorted resource allocations caused by arbitrary manipulation of discount rates .

After the discount rate is chosen and benefits and costs are adjusted accordingly, the **decision rule** is chosen and applied. The following decision rules could be used:

- Net Present Value (NPV). NPV is the most common decision rule. NPV is calculated by aggregating the net benefits discounted over time. If the project is compared to the "no-go option", it is accepted that if it results in a positive NPV. If two mutually exclusive projects are analysed, the project with higher NPV should be given the priority. Ranking of independent projects is done by assigning a higher priority to projects with higher NPV. It is important to note, however, that NPV does not provide an indication of the project's efficiency; in this case a Benefit/Cost Ratio should be applied (DEAT, 2004b).
- Benefit/Cost Ratio (BCR). BCR is calculated by calculating present values of benefits and costs separately and then calculating their ratio (DEAT, 2004b). The project is accepted if BCR is higher than one. It is important to note that this method is not applicable when ranking mutually exclusive projects.
- Internal Rate of Return (IRR). IRR is the discount rate that generates a zero NPV. If the calculated IRR is higher than the cost of capital the project is considered to be profitable, otherwise the project should be rejected. The

disadvantages of IRR are that it does not reflect different sizes of projects, assumes that cash flow is reinvested at a constant rate, and could imply multiple IRR (DEAT, 2004b). It is also recommended that IRR is not used in ranking and in selection of mutually exclusive projects (OECD, 2006).

The above notes demonstrate that all decision rules depend on the discount rate. The chosen discount rate therefore can have a significant impact on the final decision. In this context, it is important to conduct a **sensitivity analysis** to test the robustness of the CBA tool. The sensitivity analysis should include a key parameter that is believed to be subject to wide variations and is capable of significantly affecting the outcome of CBA (Mullins, et al., 2007). The general approach to the sensitivity analysis is to consider the chosen key parameters in terms of their outcomes. It could be viewed from the perspective of the likelihood of the parameter to take a specific form (worst, most likely and best scenarios) or from a viewpoint of the degree of its measure (high, medium, and low outcome). Examples of parameters that could be subjected to a sensitivity analysis are discount rates and income distributions that affect the discount rates (DEAT, 2004b).

2.1.4 Strengths and limitations

The CBA framework has a number of strengths and limitations, particularly with regard to its use in assessing environmental or social impacts, as in EIAs. The biggest strength of the CBA method is that it offers transparency and subsequently aids in accountability of decision-makers. The CBA framework is based on a number of assumptions, theories, methods, and procedures that allow tracing back any of the calculations and evaluating whether the decision is at variance with the analysis (Kopp et al., 1997). The application of the CBA framework also increases the effectiveness of joint decision-making as the CBA can be viewed as a simplified version of reality and forces the decision-makers to consider all consequences (Mullins et al., 2007).

As was mentioned earlier, CBA should include all impacts of analysed projects for which information need to be collected. Since these impacts and relevant data are structured in a user-friendly manner it is possible to assess the adequacy of information collected and, importantly, identify gaps in the data (Kopp et al., 1997). This characteristic provides a valuable insight into the level of ignorance regarding important attributes of the assessment (Kopp et al., 1997).

Another strong point of the CBA framework is its application in complex decision problems. CBA involves assessment of the proposed project on social wellbeing and therefore has to consider numerous impacts, which are sometimes very difficult to compare. The CBA framework attempts to capture the significance of all possible impacts in one index therefore providing a basis for comparison (Kopp et al., 1997).

Despite its many strong points, the CBA framework has a number of limitations that are sometimes difficult to overcome. These are as follow:

- Dodgson et al. (1999) state that one of the major limitations of the CBA framework is the fact that some of the non-marketed impacts are not practical to estimate in monetary terms. The reason for the latter could be unavailability of information or high costs related to its collection. Furthermore, Dodgson et al. (1999) and Kopp et al. (1997) argue that some impacts cannot be quantified in terms of monetary values. However, the importance of things could be revealed by what people would be willing to give up obtaining them (Kopp et al., 1997). Kopp et al. (1997) state that if the things given up are money, for example travel cost, then the value could be expressed in monetary terms; otherwise it could be expressed in the natural units of the resources.
- Omann (2000) states that specifications of welfare functions require complete knowledge regarding actions, their combination, trade-offs and constraints in decision-making. CBA involving environmental-social-economic decision-making, however, usually entails a certain level of uncertainty and far reaching consequences; therefore the requirement regarding complete knowledge cannot be fulfilled by CBA (Omann, 2000). In addition, Dodgson et al. (1999) highlight that CBA does not generally take into account interactions between impacts. This means that decision-making using CBA are unavoidably made in a situation of limited information and can lead to wrong decisions. This point is also supported by Laughland et al. (2007) who highlight that quantitative results are inevitably incomplete and could draw attention away from qualitative considerations not included in the monetary value.
- Laughland et al. (2007) and Kopp et al. (1997) identify the failure of CBA to include equity issues as another drawback of the framework. Incorporating equity, or distributional incidence of costs and benefits, implies initially identifying and then weighting the costs and benefits of individuals on the basis of difference of some characteristics (OECD, 2006). In this case, weights reflect the judgment of society's preferences towards income distribution (OECD, 2006). OECD (2006) states that in many cases CBA ignores distributional issues altogether; while Kopp et al. (1997) highlight that it generally takes the existing income distribution as given, thus failing short of including equity implications in the analysis. Attempts at assigning weights, on the other hand, are always subjective as they are based on an individual's, or group's preferences. Furthermore, the OECD (2006) emphasises that even small changes in

assumptions regarding weights could lead to drastically different results and therefore could have a detrimental impact on the final decision.

- Another limitation of the CBA framework relates to the assumption of satisfaction of individual preferences, which is crucial to the normative principles of CBA, i.e. satisfaction of individual preferences increase individual wellbeing and societal wellbeing is a function of an individual wellbeing (Kopp et al., 1997). The main concern is that these assumptions cannot be verified and they are ultimately subjective. Kopp et al. (1997) state that it is particularly relevant to the tangible and intangible assets that are not traded on organised markets, where it is possible to observe trade-offs and choices made by individuals.
- Although transparency of the CBA framework was identified as one of its strong points, Laughland et al. (2007) argue that CBA could be very difficult for "lay people" to understand and becomes resistant to public scrutiny.
- Discounting of costs and benefits is another area of criticism towards CBA's. Generally, CBA practitioners use the same discount rate throughout generations. Laughland et al. (2007) stress that this approach raises ethical questions as future generations have no voice in present decisions, and it is difficult to assign preferences to future generations in "a meaningful manner".
- Lastly, the other critical issue relating to the application of CBA is the assessment of risk. The latter is a fundamental principle of CBA but individuals perceive and react to risk differently depending on its type (Laughland et al., 2007). Risk assessment in CBA is based on the fact that society is risk-neutral and that risk-averse and risk-seeking individuals balance each other.

2.2 Rapid Impact Assessment Matrix

The Rapid Impact Assessment Matrix (RIAM) is a relatively new tool for carrying out an EIA. Literature describing the method and its application is limited and mostly comprises of articles released by the developer of the concept. RIAM provides a transparent and permanent record of the analysis process while at the same time organising the EIA procedure, which in turn considerably reduces the time taken in executing EIAs (Pastakia and Janssen, 1998). The method was originally developed for comparison of alternatives (Kuitenen et al., 2008). Its simplicity and generic criteria, though, provide an opportunity to applying this method in classifying different plans, projects, and programmes based on their different environmental and cost criteria (Kuitenen, et al., 2008).

Although this method is similar to the one applied by environmental practitioners in South Africa where impacts are evaluated against probability, extent, duration, intensity, confidence, and significance, it differs in the fact that it results in separate collective scores for projects' four components or a distribution of scores indicating collective value of impacts. It allows for a comparison of a project against other alternatives assessed through the similar method or ranking them in terms of priority, which aids in decision-making. It is because of this reason that it was chosen for a detailed review in the current study.

2.2.1 History of development

RIAM was developed by Christopher Pastakia, a Senior Environmental Advisor at VKI Institute for the Water Environment in Denmark, in the late 1990s. It was developed to improve on the existing EIA methods that had a number of shortcomings, including (Pastakia and Janssen, 1998):

- Subjective judgement, either in whole or in part, linked to either of the following:
  - Lack or inadequacy of baseline data;
  - Limited timeframe provided for acquisition of data and analysis;
  - Terms of reference for EIA; and
  - Capacity of assessors to cover a wide range of issues.
- Lack of transparency of subjective judgements and historic, written records thereof.

2.2.2 Theoretical foundation

Pastakia and Janssen (1998) stated that the problem of subjectivity and transparency related to the EIA could be addressed by clearly defining the process of judgement and specifying the criteria on which it is based. Today, criteria used in determining the impacts and for evaluating them are common. In South Africa, this includes considerations of the following (DEAT, 2002):

- Spatial extent
- Duration of the impact
- Intensity or severity of the impact
- Status of the impact (i.e. positive, negative, or neutral)
- Reversibility (i.e. reversible or permanent)
- Degree of certainty
- Mitigatory potential.

Pastakia and Janssen (1998) highlight that most of the specialists apply an "ad-hoc" judgement when determining a level of impact against each criterion used in EIA. If the scales for the criteria are available beforehand and used by all specialists, it becomes possible to record the process by which the conclusions are reached. This concept is at the heart of the RIAM method (Pastakia and Janssen, 1998).

2.2.3 Process and application in EIA

The RIAM method is based on a standard definition of impact assessment criteria and the means by which the semi-quantitative values for these criteria are collated (Pastakia and Janssen, 1998). Pastakia (1998) divides assessment criteria in two categories. The first category refers to criteria that are of importance to the condition and that can individually change the score obtained. The second category includes criteria that are of value to the situation, but that cannot change the score individually.

The value for the above criteria, either first or second category, is determined through the application of formulae that allow for determining the scores on a defined basis (Pastakia, 1998). Values for the first category criteria are multiplied by each other, while values for the second category criteria are added up. The final score is obtained by multiplying the results obtained for the first criteria and those obtained for the second criteria. The following formulae describe this process:

$$Fist\ category\ criteria\ (A): a1\ \times a2 = aT$$
$$Second\ category\ criteria\ (B): b1\ +\ b2\ +\ b3 = bT$$
$$Final\ assessment\ score: aT\ \times bT = ES$$

Positive and negative impacts for group A are determined by a scale of negative and positive scores passing through zero respectively. Therefore zero reflects a "no change" or "no importance" value. Zero, on the other hand, is avoided in the scoring of group B criteria; here instead of zero a value of one is applied for "no importance" scores.

The RIAM method so far comprises of five criteria, which Pastakia (1998) states represent the most important fundamental conditions for all EIAs and satisfy the following principles:

- The universality of the criterion that allows its usage in different EIAs; and
- The value of criteria determining whether it falls under the first or second categories.

Table 2-2 outlines the criteria and judgement scores comprising the RIAM method.

Table 2-2: Assessment criteria for the RIAM method (Pastakia, 1998)

Criteria	Score
Importance of condition (a1) - assessed against the spatial boundaries of human interest it will affect.	
Importance to national/international interest	4
Important to regional/national interests	3
Important to areas immediately outside the local condition	2
Important only to the local condition	1
No importance	0
Magnitude of change/effect (a2) – measure of scale of benefit/dis-benefit of an impact or condition if:	
Major positive benefit	+3
Significant improvement in status quo	+2
Improvement in status quo	+1
No change/status quo	0
Negative change to status quo	-1
Significant negative dis-benefit or change	-2
Major dis-benefit or change	-3
Permanence (b1) – defines whether the condition is permanent or temporary.	
No change/not applicable	1
Temporary	2
Permanent	3
Reversibility (b2) – defines whether the condition can be changed and is a measure of the control over the condition.	
No change/not applicable	1
Temporary	2
Permanent	3
Cumulative (b3) – reflects whether the effect will be a single direct impact or will include cumulative impacts over time, or synergistic effect with other conditions. It is a means of judging the sustainability of the condition and should not be confused with the permanence criterion.	
No change/not applicable	1
Temporary	2
Permanent	3

Assessment starts with identification of specific environmental components during the scoping phase. These components are grouped in terms of the following categories (Pastakia, 1998):

- **Physical/chemical**: This group covers all physical and chemical aspects of the environment, including non-renewable (non-biological) natural resources and degradation of the physical environment through pollution.
- **Biological/ecological**: This group includes all biological aspects of the environment, including renewable natural resources, conservation of biodiversity, species interactions, and pollution of the biosphere.
- **Sociological/cultural**: This group encompasses human aspects of the environment, including social issues affecting individuals and communities; together with cultural aspects, including conservation of heritage, and human development.
- **Economic/operational**: This group is used to qualitatively identify the economic consequences of environmental change, both temporary and permanent, as

well as the complexities of project management within the context of the project activities.

After the components are identified, the assessment is carried out by completing a matrix. At the same time the components can be sub-divided into detailed components allowing for better demonstration of impacts. The matrix consists of each component for which values for the first and second categories are provided (Pastakia, 1998). This matrix provides a clear record of how ES values, representing a score for each component, are calculated. To provide a clearer system of assessment the ES scores are banded together in Range Values (RV) that provide the means for comparison of alternatives or projects (Table 2-3).

Table 2-3: RIAM range bands (Pastakia, 1998)

Environmental Score (ES)	Range Value (RV) - Alphabetic	Range Value (RV) - Numeric	Description
108 to 72	E	5	Major positive change/impact
71 to 36	D	4	Significant positive change/impact
35 to 19	C	3	Moderate positive change/impact
10 to 18	B	2	Positive change/impact
1 to 9	A	1	Slight positive change/impact
0	N	0	No change/ status quo
-1 to -9	-A	-1	Slight negative change/impact
-10 to -18	-B	-2	Negative change/impact
-19 to -35	-C	-3	Moderate negative change/impact
-36 to -71	-D	-4	Significant negative change/impact
-72 to -108	-E	-5	Major negative change/impact

After the ES scores are entered into Range Values for each of the components, they are either added together within each component or analysed separately. Such analysis could be interpreted graphically or numerically, depending on the requirements. Table 2-4 and Figure 2-2 illustrate the possible interpretation of the results.

Table 2-4: Interpretation of RIAM results through a table (EL-Naqa, 2005)

Range	-108 to -72	-71 to -36	-35 to -19	-18 to -10	-9 to -1	0 to 0	1 to9	10 to18	19 to 35	36 to 71	72 to 108
Class	-E	-D	-C	-B	-A	N	A	B	C	D	E
PC	**4**	**0**	**1**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**
BE	**0**	**0**	**0**	**1**	**3**	**0**	**0**	**0**	**0**	**0**	**0**
SC	**1**	**2**	**0**	**2**	**0**	**0**	**0**	**1**	**0**	**0**	**0**
EO	**0**	**0**	**1**	**2**	**0**	**1**	**0**	**0**	**0**	**1**	**0**
Total	5	2	2	5	3	2	0	1	0	1	0

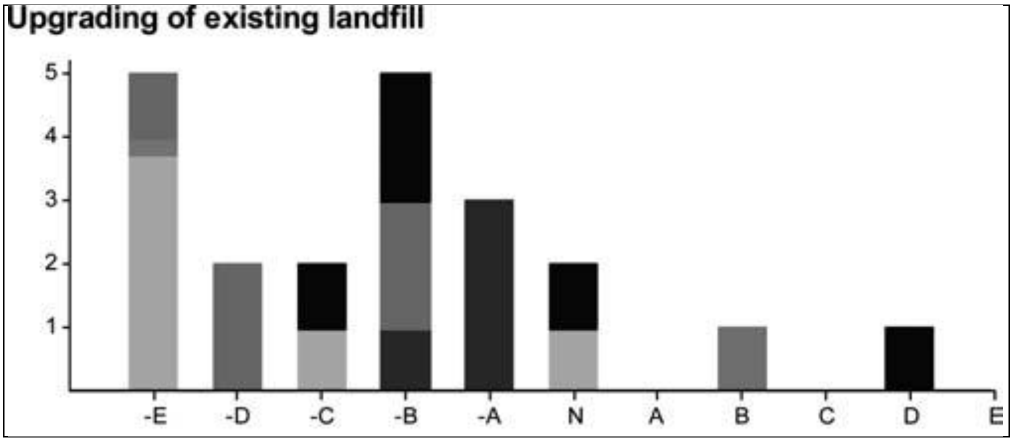

Figure 2-2: Interpretation of RIAM results through a diagram (EL-Naqa, 2005)

2.2.4 Strengths and limitations

The RIAM method has a number of advantages over the conventional methods used in EIAs. Firstly, the RIAM is a rapid and simple tool. It addresses the problem of subjective judgements by defining the criteria and scale, thus improving the transparency of decision-making. The RIAM method also provides a clear comparison against the "no-go option", which represents the status quo. In the RIAM method, the "no-go option" would usually represent a zero against all components, therefore when results of the project's assessment are illustrated graphically; it is very easy to compare the benefits and dis-benefits provided by the proposed project against the status quo.

A similar comparison could be provided when a number of alternatives are considered for the project, which allows for the selection of the most beneficial scenario given the ES scores for the components. In this case, a number of matrices equal to the number of alternatives are constructed. The use of multiple matrices provides an opportunity not only to compare alternative strategies, but also to isolate the major positive/negative impacts, define the temporary and permanent impacts, and show where mitigation can be effective in reducing negative impacts (Pastakia and Madsen, 1995).

The other benefits of the RIAM method could be summarised as follows (Pastakia and Janssen, 1998):

- Cost effectiveness compared to some of the other methods used in EIAs (Pastakia and Janssen, 1998).
- Allows for comparison of projects with and without mitigations options (Pastakia, 1998).
- Can be used in assessment where data is poor, given the assumptions are stated beforehand (Pastakia, 1998).

- Able to use qualitative data, and therefore can be used at different stages of the development providing continuous feedback with regard to impacts (Pastakia and Janssen, 1998).
- Interpretation of results through a diagram reflects a true representation of judgements by assessors (Pastakia and Janssen, 1998).
- Subjective judgements are understood by a reader through a defined scale of evaluation, which does not only indicate "high", "moderate", and "low" as many other methods do. The scale also provides an opportunity for reviewing the scores and quickly adjusting the Matrix, if necessary (Pastakia and Janssen, 1998).

The following drawbacks of the method could be identified:

- The method fails to acknowledge the relative importance of each environmental factor, meaning that all identified environmental impacts are treated equally, which is usually unrealistic (Wang,et al., 2006).
- Wang et al. (2006) state that the key environmental factors should receive a greater weight in decision-making compared to the other factors, which the RIAM method fails to reflect.
- Another drawback of the framework is the fact that it allows assignment of only one of the assessment values to each factor and cannot include a distribution of different values, which is usually observed when different stakeholders or numerous people are involved in decision-making or assessment (Wang et al., 2006).
- Wang et al. (2006) further highlighted that the RIAM method can only handle evaluations with certainty and cannot handle projects with incomplete information.
- The RIAM method implies a simple additive model for synthesising the assessment values, which creates another disadvantage of the framework as this implies that all environmental factors are additively independent, which is not always acceptable (Wang et al., 2006).
- Although the method has been used for comparison of different options, Wing et al. (2006) criticised it for not offering a systematic and effective method to rank and compare different alternatives.
- Although the method provides an opportunity to analyse the data from different sectors against a common criteria, it does not reflect possible trade-offs between different impacts.
- Lastly, the method has yet to prove that it can be applied universally in EIAs, although according to Pastakia and Janssen (1998) the present method is acceptable for projects related to water, tourism, sewage, forestry, and other resource exploitation situations.

2.3 Multi Criteria Analysis (MCA) Methods

MCA encompasses a large family of techniques of which forty or more are distinguishable in the literature and that span everything from highly sophisticated frameworks to simple rating systems (Wilson et al., 2001). At the heart of any MCA method is the recognition that there are complex problems that cannot be solved by a single structure analysis (Eliasson et al., 2003).

MCA methods have the ability to combine complex and conflicting objectives, thus providing decision-makers with integrated information that can assist in making an informed decision. Different MCA methods aim at supporting such complex planning and decision processes by providing a framework for collecting, scoring, and processing all relevant information (Lahdelma et al., 2000). They also allow identifying the preferences of stakeholders or decision-makers and incorporating these into the analysis (Abaza et al., 2004).

A variety of MCA methods are used in environmental planning and decision-making processes in order to clarify the planning process, to avoid various distortions, and to manage all the information, criteria, uncertainties, and importance of the criteria (Lahdelma et al., 2000). They can identify a single most preferred option, rank options, short-list a number of options for subsequent detailed appraisal, or simply distinguish between acceptable and non-acceptable alternatives (Dodgson et al., 1999).

2.3.1 History of development

Multi Criteria Analysis methods were developed within the last thirty years as a response to the increasing number of problems faced by decision-makers when dealing with complex issues (Omann, 2000). After World War II, the most prominent decision aid tool was CBA. With the integration of environmental and social issues into decision-making, the latter method failed to capture complete information about actions, their combinations and trade-offs, as well as constraints in decision-making (Omann, 2000). It became apparent that new techniques were required that would address the limitations of CBA and enable strategic evaluation of projects encompassing assessment of various issues and conflicting objectives.

The first development of MCA occurred in the field of multi criteria decision-making (MCDM), which methods required an exact formulation of mathematical models with an aim of finding a solution (Eliasson et al., 2003). The other group that forms part of MCA comprises multi criteria decision aid (MCDA) methods that encompass less discreet frameworks, which instead of looking for the solution aim at assisting decision-makers to advance to it (Eliasson et al., 2003). However, it has been observed that in most cases MCA, MCDA, and MCDM methods refer to the same group of decision-making tools that aid in assessment of situations with conflicting objectives and multiple criteria.

2.3.2 Theoretical foundation

MCA methods belong to the family of non-monetary evaluation methods (Omann, 2000). They take into account a set of objectives and criteria that can be conflicting, multidimensional, incomparable, and incommensurable (Omann, 2000). The information contained in the criteria can be uncertain and qualitative (Omann, 2000).

MCA methods provide an opportunity to use different measuring units and scales for the criteria, which makes it adaptable to almost any problem. Some criteria can be transformed into quantitative indicators (e.g.: monetary terms), others use qualitative parameters (e.g.: bad, moderate, or good) (Omann, 2000). At the same time, qualitative parameters can be used directly as linguistic variables, or can be transferred into cardinal ones and used as quantitative variables (Omann, 2000).

MCA methods applied in the EIA usually accounts for environment, social, and economic aspects of the project. These three dimensions constitute the sustainability concept, which was initially defined by the Brundtland Report (WECD, 1987) and which led to the development of three types of sustainability, i.e. weak, strong, or reasonable.

Sustainable development definition

The Brundtland Report (WECD, 1987), defined sustainability as the "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*". It clearly stated that social equity, economic growth, and environmental maintenance are simultaneously possible. However, the question regarding whether sustainability also means substitutability was not clearly defined, which lead to the development of "weak sustainability", "strong sustainability", and "reasonable sustainability" concepts.

Weak sustainability was developed by Pearce/Turner in 1991 and implied that resources can be substituted, while strong sustainability defined by Dali in 1991 denied substitutability of resources (Omann, 2000). A concept of reasonable sustainability was developed as a middle viewpoint between weak and strong sustainability concepts, which represent extreme viewpoints (Omann, 2000). It implied that certain forms of capital can be substituted, while some natural capitals cannot be replaced at all (Omann, 2000).

The choice between the different concepts of sustainability usually lies with the selection of the aggregation procedure that collates all information and produces rankings of the options. The aggregation procedure determines the compensability of resources. Omann (2000) defines compensability as *"the possibility of offsetting a disadvantage on some attribute by a sufficiently large advantage on another attribute; if no trade-offs occur, a preference relation is non-compensatory"*. At the same time, the aggregation procedure is defined by the MCA method that is being employed in the decision-making. Therefore the operationalisation of weak or strong sustainability depends on the type of the MCA method used in the analysis (Omann, 2000). Some of these methods will be described further in section 2.3.4.

2.3.3 Process and application in the EIA

The process of MCA is generic to any problem. The process followed by MCA consists of three phases and eight steps, and is illustrated in Figure 2-3.

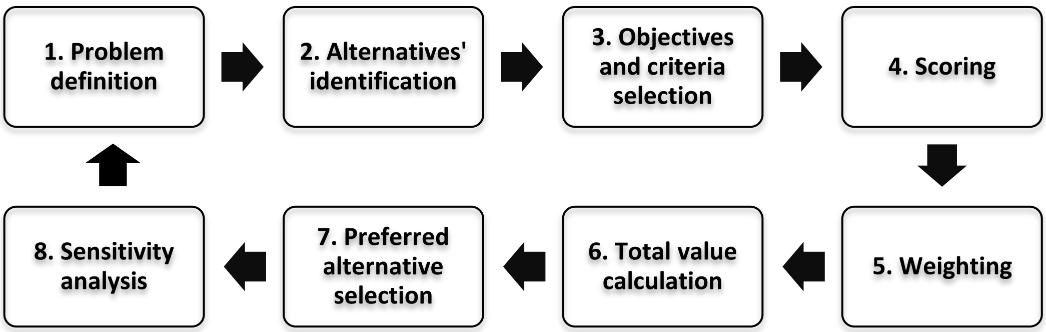

Figure 2-3: Decision-making cycle (adopted from NERA, 2000)

The first phase, namely problem structuring, encompasses identification of stakeholders and alternatives, definition of the decision context, and specification of objectives and criteria. It consists of the following steps:

- Step 1. Define the problem: The purpose of this step is to describe the problem and specify aims of the MCA and its decision context. The goals define tasks for the subsequent stages and keep the analysis on track.
- Step 2. Identify and describe options to be evaluated: The objective of this step is to formulate options that are to be compared and assessed.
- Step 3. Identify objectives, criteria and sub-criteria: The purpose of this step is, firstly, to identify the major objectives of the model. For example, it may assess economic impacts, environmental impacts or both. Secondly, this step aims at identifying a set of criteria, or impacts, with respect to each of the objectives. These criteria are then used to appraise the alternatives. An example of criteria for an objective "Assess economic impacts on local and regional levels" is

"Impact on Economic Development". Finally, for each criterion a set of representative sub criteria, or indicators, is identified. For the criteria "Impact on Economic Development" one of the indicators could be "Change in the local Gross Geographical Product (GGP)".

The process of identifying objectives and criteria is one of the critical steps in the MCA. A large portion of the "value-added" offered by MCA comes from establishing a soundly based set of criteria against which the options are jugged (Dodgson et al., 1999).

The list of objectives can be developed through a "top-down" or "bottom-up" approach. The former involves dividing the overall goal into the subsidiary objectives and these into criteria (Wilson et al., 2001). The latter refers to firstly identification of criteria and then grouping them into objectives (Wilson et al., 2001). Both of the approaches result in the development of a hierarchy that shows the relationship between criteria and objectives and the selection of a preferred strategy (Wilson et al., 2001).
Criteria could also be grouped into categories, thus providing the following benefits (Dodgson et al., 1999):

- Checking whether the selected criteria are appropriate to the problem.
- Easing the process of calculating the criteria weights, when first the weights within the categories are calculated and then categories themselves are assigned weights.
- Facilitating the understanding of trade-offs between key objectives.

The second phase, problem analysis, comprise the development of the performance matrix, relative scaling, weighting, calculation of the overall scores, examination of the results, and recommendation with respect to the decision context. The steps to be performed follow on those of the first phase:

Step 4, Scoring: The objective of this step is to develop a performance matrix that includes scores for different alternatives according to the identified criteria and indicators. This requires setting up consistent numerical scales for the assessment of criteria (Dodgson et al., 1999). The performance matrix is a standard feature of a multi criteria analysis in which each row describes an attribute and each column indicates an alternative. The individual performance assessments are generally numerical measures, but could also be expressed in bullet points or colour coding (Dodgson et al., 1999). Table 2-5 illustrates examples of different types of performance evaluation.

The performance matrix can be a powerful tool in supporting the evaluation of alternatives (Wilson et al., 2001). It can reveal where each option scored high and where there are shortcomings in respect to other alternatives (Wilson et al., 2001). Even in the simple performance matrix, it is still highly unlikely that one alternative will outperform other alternatives on the basis of all criteria (Wilson et al., 2001). In this case the evaluation will need to be done in some kind of relative scaling, where scores are "normalised".

Table 2-5: Examples of performance evaluation

Criteria	1st	2nd	3rd
Numerical values			
Sustainable job creation	100	0	250
Bullet points			
Contribution to welfare of the community	**	*	*****
Colour coding			
Impact on biodiversity	Medium	High	Low

Conversion into relative scaling is done by assigning zero (0) to the lowest score of each criterion among the alternatives, and hundred (100) to the highest measure of each attribute. Relative scores of all other alternatives for a particular criterion are calculated in proportion to these inputs. Table 2-6 illustrates the use of relative scaling for presented data.

Table 2-6: Example of relative scaling

Criteria	1st	2nd	3rd
Numerical values			
Sustainable job creation	40	0	100
Bullet points			
Contribution to welfare of the community	40	0	100
Colour coding			
Impact on biodiversity	50	100	0

The result of this step is a matrix that represents performance of all alternatives with regard to each criterion that can be compared.

- Step 5. Weighting: The objective of this step is to assess weights for each criterion and indicator. This is done to identify the level of importance of each criteria relatively to the others and to establish a composite measure of performance of alternatives across all criteria (Wilson et al., 2001). The allocation of weights for criteria uses a range from 0 (lowest preference) to 100 (highest preference). The weights add up to 100 and the weighting can be done through ratio weighting, pairwise comparison, or swing weighting techniques.

Ratio weighting provides direct and precise weights for criteria (Sijtsma, 2006). Ratio weighting starts with assigning 10 points to the lowest attribute and then sizing up other attributes relative to this by indicating, for example, whether it is four times or two and a half times more important than the lowest attribute (Sijtsma, 2006). Sijtsma (2006) recommends checking the consistency of weightings assigned to attributes so that the next lowest value attribute is used as the basis for weight elicitation.

The pairwise comparison method of assigning weights is based on comparing a pair of attributes and asking the stakeholder to express whether one is deemed to be much more important than the other, somewhat more important, equally important, less important, or much less important (Sijtsma, 2006). When all pairwise comparisons have been made, the weights are calculated and checked for consistency (Sijtsma, 2006).

Depending on which of the MCA methods is used in the decision-making, Step 5 could be excluded from the process. For example, the MCDA method NAIADE does not require elicitation of weights (Eliasson et al., 2003). The decision process will therefore be adapted to the type of MCDM or MCDA method chosen for the MCA.

In the situation where weighting of criteria is required, it could be beneficial for the analysis that stakeholders are involved in the elicitation of weights. When this is done, it offers the opportunity to engage decision-makers in structuring and resolving the problem, as well as exploring the consequences of their decisions (Wilson et al., 2001). Weights will be different depending on the decision-makers' views, which will require corresponding changes with regard to the preferred alternatives (Wilson et al., 2001). In order to explore the potential changes in weights and their impact on the decision, different weighting sets could be derived within different groups of stakeholders (Wilson et al., 2001).

- Step 6. Overall value calculation: This step entails calculation of the overall value of each alternative. The equation or a method that is used in calculating the overall value of each alternative is defined by the MCDM or MCDA framework employed in the decision process.

- Step 7. Preferred alternative selection: The overall values calculated in the previous steps give an indication of preference of one alternative over another. The purpose of this step is to examine the results and make recommendations with regard to the most beneficial alternative/alternatives based on the results of the model. Examination of results can be achieved in a variety of ways such as graphically, in tabular form, etc.

The third phase, namely the sensitivity analysis, involves assessing sensitivity of the model with regard to weighting of criteria and indicators. It highlights data that needs to be investigated and acquired to decrease uncertainty in the model, and points to the advantages and disadvantages of different options that can form the basis for developing a new alternative and that could be preserved as the best option.

2.3.4 Comparison of multi criteria analysis methods

Since MCA comprises of MCDM and MCDA methods, the following paragraphs provide a brief review of the most frequently used frameworks within each of these groups. It can be observed that all approaches make considered options and their evaluations in terms of different criteria explicit, and all require an exercise of judgment (Dodgson et al., 1999). They also differ in how they aggregate the data, which would define whether a project implies a weak or strong sustainability in the EIA.

a. Multi Criteria Decision-Making (MCDM) methods

The MCDM methods are frameworks that encompass a mathematical model aimed at providing one score or index for the option under analysis. The comparison of indices or scores for different options provide an opportunity to select the most preferred alternative or the best option given the data and relative importance of different impacts as identified by stakeholders or decision-makers.

This section reviews three of the most widely used MCDM methods, namely the Weighted Sum Model (WSM), Weighted Product Model (WPM) and Analytical Hierarchy Process (AHP). Implementation of these methods follow a similar process as described in Section 2.3.3.

Table 2-7: Selected MCDM methods

1. Weighted Sum Model (WSM)
This framework is considered by many researchers as the most widely used method, particularly in single dimensional problems (Triantaphyllou and Mann, 1989). The supposition that governs the model is the additive utility assumptions (Trintaphyllou and Sanchez, 1997). The method assumes that if there are M alternatives and N criteria, the score would be calculated as follows (Triantaphyllou and Mann, 1989): $A_{WSM} = \sum_1^N a_j w_j$, where A_{WSM} - the score of the alternative N – the number of criteria

a_j – the actual value of the alternative in terms of j-th criterion

w_j - the weight of importance of j-th criterion.

After calculating the total scores for each alternative, the best option will represent the alternative with the highest score. The assumption that governs the model is the additive utility assumption that assumes that the total value of each alternative equals the sum of products given as 1 (Triantaphyllou and Mann, 1989). Being a linear additive model, the WSM assumes that low scores on one criterion could be compensated by high scores on the other criterion (Kain and Soderberg, 2007). This means that the WSM model implies weak sustainability.

This method could be used easily if all criteria are expressed in one single unit. However, if alternatives are evaluated on the basis of multiple criteria that are expressed in different units, the values for each criterion will first require a conversion into normalised values. This technique is also only applicable if the criteria are mutually preference independent (Dodgson et al., 1999). On the other hand, WSM have a very well established record of providing robust and effective support to decision-makers (Dodgson et al., 1999).

2. Weighted Product Model (WPM)

This framework is based on the multiplication rather than on summation as the WSM. Firstly, each alternative is compared with another alternative with regard to each of the criteria by dividing the value of the criteria for the reviewed alternative by the value of the same criteria for another alternative. These ratios are then weighted and multiplied by each other to find a single score representing the alternative. The calculations are provided in the following equation (Triantaphyllou and Mann, 1989).

$$R(A_K/A_L) = \prod_{j=1}^{N}(\frac{a_{Kj}}{a_{Lj}})^{w_j}, \text{ where}$$

$R(A_K/A_L)$ – ratio of alternatives K to L

N – the number of criteria

a_{ij} – the actual value of the i-th alternative in terms of j-th criterion

w_j - the weight of importance of j-th criterion.

If the final score is greater than one, it means that the first alternative is better than the other alternative. An alternative that is better than other alternatives will score greater or equal with respect to all other alternatives (Triantaphyllou and Mann, 1989).

An advantage of this model is the fact that it excludes any units of measure, thereby making it dimensionless and applicable to single- as well as multi-dimensional problems (Triantaphyllou and Mann, 1989).

3. Analytical Hierarchy Process (AHP)

The AHP, originally introduced by Saaty (1980), is also based on a Linear Additive Model as the WSM model. The AHP involves the development of an MxN matrix, where M represents the number of alternatives, while N represents the number of criteria (Triantaphyllou and Sanchez, 1997).

The matrix is constructed by using the relative importance of the alternatives in terms of each criterion (Triantaphyllou and Sanchez, 1997). It uses a pairwise comparison for both criteria and alternatives, therefore reducing each choice to a relative judgement of two criteria or alternatives at a time (Kain and Soderberg, 2007). Afterwards, the AHP aggregates the pairwise judgments into a single value for each alternative (Kain and Soderberg, 2007), which allows for the comparison of

alternatives and selection of the preferred option. In the maximisation case, the best alternative is the one that corresponds with the highest preference value calculated following the same method as the WSM (Triantaphyllou and Sanchez, 1997): $$A_{WSM} = \sum_1^N a_j w_j \text{, where}$$ A_{WSM} - the score of the alternative N – the number of criteria a_j – the actual value of the alternative in terms of j-th criterion w_j - the weight of importance of j-th criterion. Due to the possibility of an unacceptable rank reversal occurring in the original version of the AHP when the new alternative is added into the evaluation, a revised AHP was proposed by Belton and Gear (Triantaphyllou and Sanchez, 1997). This version proposed to divide relative values by the maximum quantity of the relative values in each column of the MxN matrix, instead of allowing the relative value to sum up to one (Triantaphyllou and Sanchez, 1997). One of the strengths of the AHP is that users find the pairwise comparison form of data input straightforward and convenient. Given the definition of weak and strong sustainability concepts given earlier in this chapter, it could be concluded that the AHP also implies a concept of weak sustainability. One of the most common uses of AHP is elicitation of weights for decision models.

b. Multi Criteria Decision Aid (MCDA) methods

The MCDA is a family of discrete methods (Eliasson et al., 2003). The principal goal of the MCDA is not to discover a solution as in the case of the MCDM frameworks, but to assist the decision maker to analyse the information and advance to a compromise solution (Eliasson et al., 2003).

The MCDA includes the family of outranking methods. The principal outranking methods require similar data availability as the MCDM methods, including alternatives, criteria, and performances (Dodgson et al., 1999). The concept of outranking was originally devised by Roy and can be defined as follows (Dodgson et al., 1999):

"Option A outranks Options B if, given what is understood of the decision-makers' preferences, the quality of evaluation of the options and the context of the problem, there are enough arguments to decide that A is at least as good as B, while there is no overwhelming reason to reduce that statement."

Table 2-8 presents some of the MCDA frameworks used in environmental problems.

Table 2-8: Selected MCDA methods

ELECTRE
ELECTRE forms part of the family of the outranking methods. It involves identifying dominance relations seeking to locate a subset of options such that any option not in this subset is outranked by

at least one member of the subset (Dodgson et al., 1999). The aim is to make the subset as small as possible thus creating a shortlist of possible options from which a compromise alternative is chosen (Dodgson et al., 1999).

In ELECTRE, the preference matrix is developed by using a pairwise comparison, which assesses the criteria using concordance and discordance measures (Jeffreys, 2004). The concordance index is derived from the differences between all criteria for the two options, while the discordance index represents the maximum value between any individual criterion in the two options (Jeffreys, 2004). Therefore the concordance index measures the relative overall performance of the options, while the discordance index measures poor performance in individual criteria (Jeffreys, 2004).

The next step is the calculation of the concordance and discordance thresholds (Dodgson et al., 1999). For example, option 1 is said to outperform option 2 if the following statement applies: *The difference between the criterion's values for option 1 compared to that for option 2 is greater than the concordance threshold and smaller than the discordance threshold (Jeffreys, 2004).* The set of all options that outrank at least one other option and do not outrank each other is then assumed to contain the compromising solution for the problem (Dodgson et al., 1999).

NAIADE

NAIADE is an acronym for the Novel Approach to Imprecise Assessment and Decision Environments. It allows the assessment to be based on both qualitative and quantitative data and introduction of uncertainties (Eliasson et al., 2003). The method also does not use weights that can be contested, while at the same time it integrates conflict analysis in the calculation (Eliasson et al., 2003).

According to the NAIADE, the comparison of criterion scores of each pair of alternatives is carried out by means of the semantic distance (Eliasson et al., 2003). According to Eliasson et al. (2003), semantic distance measures the distance between two functions taking into account the position and shape thereof. If the scores in the impact matrix are presented in a stochastic of fuzzy evaluation, the semantic distance is applied. However, if the scores are presented in quantitative form, the distance is simply defined as the difference between the two values (Eliasson et al., 2003).

The comparison is based on preference relations for each criterion starting from the distance between alternatives for the selected criterion (Eliasson et al., 2003). Elliasson et al. (2003) state that preference relations are six functions that allow expression of an index of credibility of the statement that a particular alternative is much better, better, approximately equal, equal to, worse, or much worse than another alternative. The index of credibility is measured between 0 (definitely non-credible) and 1 (definitely credible) with monotone functions (Eliasson et al., 2003). NAIADE calculates a credibility index for each pair of alternatives and for each criterion (Eliasson et al., 2003). Afterwards, using the credibility indices, NAIADE calculates a preference intensity index of one alternative with regard to the other, which is then used to rank the options (Eliasson et al., 2003).

One of the limitations of the NAIADE is that it cannot determine the best alternatives amongst the analysed options and can only assist the decision-makers by providing information and suggestions concerning the alternatives (Eliasson et al., 2003). Furthermore, the method does not allow for weighting of different criteria and therefore assumes that all aspects and impacts of the alternatives are equally important, which is not always true in real-life problems. In addition, Elliasson et al. (2003) point out that the other disadvantage of the method is the difficulty in comprehension of the procedure's underlying preference elicitation. On the other hand, the method allows for incorporation of different kinds of knowledge and stakeholders' concerns into the assessment (Eliasson et al., 2003).

c. Comparison of MCDM and MCDA

Table 2-9 provides a comparison of MCDM and MCDA as outlined by Sijtsma (2006).

Table 2-9: Comparison of MCDM and MCDA methods (Sijtsma, 2006)

MCDM methods	MCDA methods
Alternatives	
The set of alternatives is well defined	The set of alternatives is not always final and can be changed throughout the decision process.
Preferences	
Preferences are structured from selected attributes, which do not change in the decision process.	Criteria reflect preferences of one or several actors. There is a consensus regarding definition and measurement of criteria, although this does not apply for weight.
Mathematical formulation	
A well formulated mathematical problem aimed at finding the alternate with the highest utility value.	An ill-defined mathematical problem based on the family of criteria – deemed relevant somehow by stakeholders – and inter-criteria information.

Although there is a difference in the MCDM (value function approach) and MCDA (outranking approach), where the former aims at identifying the preferred alternative and the latter aims at assisting stakeholders in understanding the problem and refining the alternatives, Sijtsma (2006) claims that there is no fundamental difference between these methods. He states that the difference primarily lies in how the techniques are used and limitations are presented. It is recommended that no matter which MCA technique is applied in the decision process a decision aiding approach is adopted for the process, where the objective of the MCA is to aid in decision-making, rather than provide decisions (Sijtsma, 2006).

2.3.5 Strengths and limitations of MCA

MCA has a number of advantages over the conventional decision-making methods. They are as follow:

- Openness and explicitness of the analysis (Dodgson et al., 1999).
- Robustness as the choice of objectives and criteria are open to analysis and can be changed by the decision-making group at any time of the process if they are considered inappropriate (Dodgson et al., 1999).
- Transparency of decision-making as the process is recorded on paper which provides an audit trail.
- Provides important means of communication with stakeholders and the decision-making body (Dodgson et al., 1999).

- Allows interdisciplinary groups of experts to decipher their understanding of impacts of a project and formally identify the decision criteria and rank alternatives in terms of explicit decision rules (Bojorquez-Tapia et al., 2005).
- Facilitate discussion between stakeholders, leading to a more comprehensive understanding of the problem and considerations of different points of view (Lahdelma et al., 2000).

The following limitations and disadvantages of the MCA frameworks were identified:

- The selection of the MCA method plays a crucial role in the decision analysis, and application of different methods could result in different solutions. At the same time, comparison of all methods is not possible in many cases (Lahdelma et al., 2000).
- Real-life applications of the MCA in the EIAs are limited and therefore restrict the knowledge concerning advantages and disadvantages of using specific MCA methods in EIAs and how the results of using these methods differ (Lahdelma et al., 2000).
- The MCA methods can be complex and require a specialist to implement them (Abaza et al., 2004).
- Attempting to provide one score for each option tends to simplify the reality, although this issue is usually overcome by the sensitivity analysis (Abaza et al., 2004).
- Elicitation of weights can be a lengthy process (Sijtsma, 2006).

Lastly, the subjectivity associated with the selection of objectives, criteria for selection, estimating weightings and in assessing the contribution of options to each performance criterion can be a concern (The Environmental Agency, 2008). The process does, however, allow for debates around these issues and usually allows for transparency in decision-making (The Environment Agency, 2008).

2.3.6 Application to EIAs

MCA methods have been successfully used in dealing with the various details inherent in consensus building in the EIA process (Bojorquez-Tapia et al., 2005). Examples of application of MCA methods in EIA come from different countries (Janssen, 2001; Bojorquez-Tapia et al., 2005). One of the prominent examples is that of the Netherlands.

EIA is a well-established institution in the Netherlands (Janssen, 2001). Comparison of alternatives form an integral part of the Netherlands's EIA process. It either happens during the scoping phase when the potential alternatives are scaled down to a smaller number, or during the final evaluation, when the selected alternatives are evaluated in more detail (Janssen, 2001). Janssen (2001) stated that in ten out of sixty EIAs completed in the Netherlands, the selection of alternatives either during the scoping phase or the final evaluation was done by employing MCA methods.

Table 2-10 provides some examples of the use of MCA in the EIAs performed in Netherlands.

Table 2-10: Examples of the use of MCA in EIAs performed in the Netherlands (Janssen, 2001)

Prooject	Problem	MCA methods
Provincial waste processing plant	16 criteria 29 alternatives	Concordance method
Road, train and water transport in the Amsterdam-Utrecht transport corridor	12 groups 50 criteria 9 alternatives	Aggregation of ordinal scores
New residential areas in Zaanstad	6 categories 20 criteria 10 alternatives	Weighted summation
International business park	6 categories 21 criteria 4 alternatives	Weighted summation
Cleaning polluted sediments in the provinces of Groningen, Friesland, and Drenther	7 categories 35 criteria 6 alternatives	Weighted summation
Reconstruction ring roads: A10 west	5 categories 28 criteria 4 alternatives	Weighted summation

Janssen (2001) indicated that many of the EIAs where MCA was applied were related to transportation and that some of the projects had low political profiles while others had a high political profile. Janssen (2001) further highlighted that the main purpose of the MCA was to bring out the differences between the alternatives.

As indicated in Table 2-10, MCA frameworks in the Netherlands would usually include not only criteria but would also be grouped in terms of categories. Janssen (2001) explained that this was done to assist the decision-maker to better understand the impacts. Weights were assigned to both criteria and categories. The weights assigned to categories were devised by decision-makers and reflect the trade-offs between policy objectives and/or stakeholders, while the weights of criteria were decided upon by experts on the basis of scientific knowledge (Janssen, 2001).

Another interesting fact that came out of Janssen's (2001) investigation into the use of MCA in the Netherlands's EIAs was that the weighted summation method was the most frequently used method. This method was also recommended by the Dutch Commission for EIA, because it is methodologically sound, easy to explain, and transparent (Janssen, 2001). Janssen (2001) also highlighted that in some cases, decision-makers and stakeholders showed a certain level of mistrust towards MCA. Their attitudes changed, however, during the process once they started appreciating the structured approach and efficient way of communication that MCA provided (Janssen, 2001).

In South Africa, the application of MCA is currently limited to the scoping phase. A small number of Environmental Assessment Practitioners in the country use this technique to scale down the number of alternatives to the most feasible ones. This leads to cost savings when the EIA is conducted and, most importantly, it allows the consideration of the most feasible alternatives.

2.4 Summary

This chapter reviewed three different methods that could potentially be employed in evaluation of alternatives as part of an EIA and therefore used in decision-making. The methods reviewed in the study included Cost-Benefit Analysis, the Rapid Impact Assessment Matrix, and Multi Criteria Analysis methods. Table 2-11 provides a comparison of the methods reviewed in this chapter. The comparison is based on the criteria adopted from Pastakia and Janssen (1998).

Table 2-11: Comparison of decision-making frameworks

Criterion	CBA	RIAM	MCA
Cost of method	Medium to High	Low to Medium	Low to Medium
Time required	Long	Short	Short to Medium
Accuracy of results	Non-subjective	Subjective	Subjective
Transparency of results	Good	Very good	Very good
Permanence of record	Permanent	Permanent	Permanent
Clarity of results	Poor	Good	Excellent
Replication of method	Difficult	Easy	Easy
Universality of use	Limited	Limited	Universal

In terms of methodology, it could be useful if a framework employed in the EIA allowed aggregation of results from an integrated assessment of one option into a single numerical score or index that could be compared with those derived following the same approach for other alternatives (Abaza et al., 2004). However, not all impacts for alternatives can be easily quantified and/or converted into monetary terms, which means that some of the methods become invalid. This applies to the CBA method and its limitations when employed in EIAs. The RIAM method reviewed in the chapter fails to provide a systemic approach to ranking of alternatives that could lead to one aggregated index. The MCA frameworks, on the other hand, address both of the issues of an aggregate index and qualitative data evaluation, which other methods under the analysis failed to do.

One of the drawbacks of the MCA frameworks and in particular the MCDM methods, however, is the fact that it relies on the subjective evaluation of scores and weights. Qualitative data evaluation, which is common to EIAs, will always be subjective and can only be assessed on the basis of human judgement. The challenge is to ensure that such a judgement is made transparent so that the decision process can be clearly outlined and traced back to the assumptions and assessments.

Based on the analysis of the literature it was decided to employ a set of MCA methods in creating a coherent framework for decision-making in EIAs in the energy sector of South Africa. The following chapter outlines the conceptual framework and associated methods that were developed.

CHAPTER 3: CONCEPTUAL FRAMEWORK AND METHODS

The previous chapter described three major frameworks that are used to interpret information with the purpose of assisting in decision-making. The strengths and limitations of applying Cost-Benefit Analysis, Rapid Impact Assessment Matrix, and Multi Criteria Analysis methods frameworks in decision-making processes, including EIAs, were analysed. Based on that analysis, it was concluded that a combination of the MCA methods could form a coherent framework for decision-making in EIAs in South Africa, including those conducted in the energy sector.

The review of the application of the MCA methodology highlighted that it was not widely used in the EIA process in South Africa and the rest of the world. Some use of MCA in EIAs takes place in the European countries, such as the Netherlands. MCA is used during the scoping phase and the final evaluation in the Netherland, but in South Africa the application of MCA is mostly limited to the scoping phase when a number of alternatives need to be investigated and scaled down.

Given the advantages that the MCA framework brings to the decision-making process, such as transparency, facilitation of communication between stakeholders, and the provision of a structured approach in complex decision-making, there is a definite gap in South Africa in applying it throughout the whole EIA process and not limiting its application to the scoping phase. In this context, it was proposed that a framework be developed that would assist in decision-making during the final evaluation of alternatives in two examples of EIAs in the energy sector of South Africa. The following sections outline the conceptual framework and MCA methodology that were used in the study.

3.1 Problem definition

Chapter 1 highlighted that the current decision-making process, including that used in the energy sector's EIAs, is suffering from a lack of integration, and does not always include evaluation of trade-offs between qualitative and quantitative impacts, as well as environmental, social and economic dimensions. In this context, the problem that was investigated in this dissertation was a methodology of integrating the information presented in EIAs so that it creates a structured approach to decision-making. The focus of this exercise was in particular on a comparison of different alternatives of proposed energy projects in terms of their trade-offs and integration of decision-makers values in the decision context.

3.2 Research proposition

The research study will focus on verifying the following research proposition:

The application of the proposed MCA framework in the EIAs in the energy sector in South Africa can facilitate the decision processes by, firstly, integrating opinions of decision-makers in the evaluation and, secondly, by providing them with an integrated, transparent, and coherent approach to the evaluation of alternatives that clearly shows trade-offs between different criteria.

3.3 Aims and objectives of the framework

The aim of the coherent decision-making process proposed in this research is to assist the decision-makers in making an informed decision with regard to the most beneficial alternative in terms of various economic, social, and environmental factors. In this context, the objectives of the framework are as follows:

- Provide a structured and transparent approach to evaluation of different alternatives considered in the energy sector's EIAs in South Africa;
- Provide a means of integrating various qualitative and quantitative criteria that are used in evaluation of alternatives; and
- Integrate stakeholders' and decision-makers' values in the decision context that would also assist in developing their trust towards the framework.

3.4 Approach

The approach to creating the decision framework is adopted from NERA (2000) and includes the following steps:

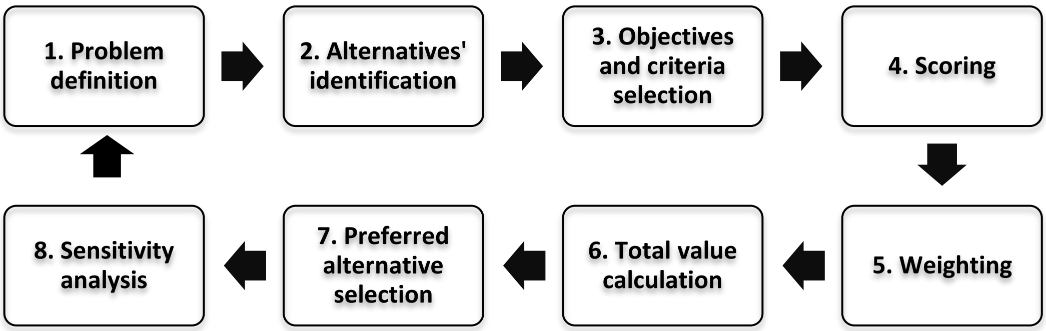

Figure 3-1: Approach to framework development

The paragraphs below describe a detailed step-by-step approach to the development of the framework and methods that will be used in its application.

Step 1: Problem definition. The problem definition is done by reviewing the background to the case studies' EIAs using either the Scoping Report or the Environmental Impact Report (EIR) compiled for the specific EIAs. The focus is on creating a brief project description with the goal of understanding the scope of the project and its affected environment. In particular, the definition includes a description of the project, location of the proposed development, and an outline of the affected environment.

Step 2: Alternatives identification. This step involves listing all the alternatives considered under the EIAs. A brief description for each alternative is provided focusing on the main points of difference.

Step 3: Dimensions and categories selection. During this step impacts that were assessed in the EIAs by different specialists are listed and grouped into a hierarchy. Firstly, a comprehensive list of all impacts considered in the EIAs is compiled. This list is developed after reviewing EIRs for the case studies. Impacts identified by each specialist are extracted from impact ranking tables that provide amongst other information on the type of impacts and their significance before and after mitigations. It is this information that is then used to develop performance matrices for each EIA. After all impacts are listed and before they are grouped into different categories, they are assessed against a number of qualities that ensures that the set is manageable, excludes double counting, and is complete. The detailed list of qualities against which the impacts are assessed is adopted from Dodgson et al. (1999) and includes:

- **Completeness.** This quality relates to analysing whether all important criteria have been included, i.e. whether a set of criteria is representative enough to compare performance of alternatives.
- **Redundancy**. This quality relates to screening of the identified criteria according to their necessity. Criteria that are unimportant or score the same with regard to all options can be eliminated.
- **Operationality**. It is important that each of the alternatives can be evaluated according to each of the identified criteria. Any of the criteria that do not satisfy that quality should be eliminated from the list.
- **Mutual independence of preference**. The MCDM requires that preferences associated with each criterion are independent from each other. In other words, if an alternative is preferred over a particular criterion, it should not indicate that it would also be preferable over another. The best way to identify mutual preferential independence between criteria is by asking whether the preference scores of an option on one criterion can be assigned independent of knowledge of the preference scores on another criterion.

- **Double counting**. If the set of criteria contains two or more attributes that describe the same effect from different points of view, some of the attributes should be eliminated so that only one criterion describes the same effect.
- **Size of a set**. It is advisable that the number of criteria is kept as low as possible. An extensive number of attributes lead to extra analytical efforts and slows down the process. However, the set should provide comprehensive information with regard to the major differences between alternatives.
- **Impacts occurring over time**. In many cases decisions concerning expenditure lead to impacts occurring over several subsequent years. In certain projects long-term impacts are given lower importance, while in the other cases they are given greater weights. Importantly, when assessment included evaluation of impacts with different life spans this had to be reflected in the scores that are given to the alternatives on the relevant criteria.

Secondly, the listed impacts are grouped into different categories. A bottom-up approach is adopted for creating a hierarchy of impacts and categories. The hierarchies are developed following a cluster analysis that results in the value trees.

The cluster analysis is a combination of techniques and methods for grouping objects of similar kind into respective categories (StatSoft, 2008). This tool divides information into groups that are meaningful, useful, or both (Tan et al., 2005). The goal that is pursued by the cluster analysis is that objects (further referred to as impacts) within the group be similar or related to one another and different or unrelated to the ones in other groups (Tan et al., 2005).

The results of the cluster analysis will be the value tree. The value tree will include three dimensions – social, economic, and environmental. It is at this level where the most important trade-offs will take place. Dimensions, the top level in the hierarchy, will encompass categories, which, in turn will include impacts. Impacts will stand at the lowest level of the hierarchy. The following principles will be applied when developing the value tree (adopted from Helsinki University of Tehnology 2002):

- The lower level items in the value tree are mutually exclusive and provide an exhaustive characterisation of the higher level items.
- Every higher level of hierarchy has at least two lower level items.

Step 4: Scoring. After impacts are identified and classified, a performance matrix is developed for each case study for two situations – before mitigations and after mitigations. Each performance matrix will include:

- List of impacts
- Unit of measurement

- Type of impacts (positive or negative)
- Score for the impact, which is calculated based on the impact ratings provided by specialists in their reports.

Generally, the evaluation of impacts is done using the following categories:

- Duration that represents the expected number of years during which the impact will take place
- Intensity that reflects the severity of the negative impact or the level of benefit derived if it is a positive impact
- Extent that measures the spread of the impact from a spatial perspective
- Probability that assesses the likelihood of the impact to take place
- Significance that represents the integrated assessment of the impact taking into account its duration, intensity, extent, and probability
- Degree of confidence that reflects the degree of certainty with which the assessment of a particular impact was made.

As indicated above, the significance rating is the product of duration, intensity, extent and probability. Therefore for the development of the performance matrix, only significance and the degree of confidence ratings are used.

The rating of impacts is usually done using a qualitative assessment, i.e. low, medium, or high. If an environmental specialist has already assigned specific quantitative values to the qualitative evaluation, these values are used to calculate the performance matrix scores. In other cases, i.e. where ratings are not associated with specific scores defined by the environmental practitioner, a score between 0 and 100 is assigned to the impact following the assumptions indicated below:

Significance:

- Neutral - 0
- Very low - 5
- Low - 15
- Low to moderate/Low to medium - 30
- Moderate/medium - 50
- Moderate to high/Medium to high - 80
- High - 100
- Very high - 150

Degree of confidence (probability):

- Unsure/don't know/unlikely – 15
- Possible/improbable –25
- Probable – 50
- Highly probable – 80
- Definite - 100

Review of various Environmental Impact Reports has identified that rating tables do not always include the degree of confidence, but always include the assessment of the significance of the impact. In the case where the degree of confidence is not provided by specialists, the performance matrix reflects values representing only the significance level. Otherwise, the score is calculated as the product of the significance and the degree of confidence:

$$\text{Score} = \text{Significance} \times \text{Confidence}/100$$

Step 5: Weighting. During this step weights are assigned to every level and impact in the hierarchy developed during Step 3. The following approach is employed for the assignment of weights:

- Weights for impacts, i.e. lowest level of the value tree, are determined by specialists themselves. These weights are used to calculate values of categories that include these impacts and which also constitute social, economic, or environmental dimensions. Every specialist involved in the assessment is requested to assign weights to the impacts that are identified by him or her in the study. It is believed that the involvement of stakeholders and decision-makers is not necessary at this point, as specialists are able to provide a more accurate assessment of the importance of impacts in their respective fields of expertise as they have a comprehensive understanding of the affected environment, potential consequences, their probabilities, extent, and significance.
- Weights for categories, or the middle level of the value trees, are assigned by the decision-makers. This approach ensures that these parties' values with respect to different categories of impacts are included in the evaluation and it will facilitate the acceptance of the framework by decision-makers.
- Weights for dimensions, i.e. the highest level of the value trees, are also assigned by the decision-makers.

Assignment of weights, whether for impacts, categories, or dimensions, follows the pairwise comparison and direct weighting techniques. The rational for choosing two methods for weight elicitation was the desire to, firstly, compare these two techniques, and, secondly, ensure that at least one set of weights received from specialists and EAPs was consistent and reliable. In the case where the set of weights received through the pairwise comparison shows a good consistency ratio, it is chosen over the set of weights elicited through direct weighting; otherwise, priority is given to the set of weights chosen through the direct weighting method.

The pairwise comparison method is a widely used method for determining the relative importance of impacts with respect to each other. In this approach, a decision-maker or a specialist involved in elicitation of weights has to express his or her opinion about the value of one single pairwise comparison at a time (Triantaphyllou et al., 1997).

Different scales exist for the expression of the relative importance in the pairwise comparison. The set of discreet choices that is used in this study was adopted from Triantaphyllou et al. (1997) and is provided in Table 3-1.

Table 3-1: Scale of relative importance (adopted from Triantaphyllou et al.. (1997))

Importance	Definition	Explanation
1	Equal importance	Two activities contribute *equally* to objectives
3	Weak importance of one over another	Experience and judgment slightly favours one activity over another
5	Essential or strong importance	Experience and judgment strongly favours one activity over another
7	Demonstrated importance	An activity is strongly favoured and importance is demonstrated in practice
9	Absolute importance	The favouring of one activity over another is of the highest possible order of affirmation
2,4,6,8	Intermediate values between two adjacent judgments	When compromise is needed
Reciprocal of non-zero (1/3, 1/5, 1/7, 1/9, etc)	If activity *i* has received one of the above non-zero values over activity *j*, then *j* has the reciprocal value when compared to *i*.	

Following the scale of relative importance presented in the above table, a judgment matrix is created for dimensions, categories, and every set of impacts comprising the categories. To calculate the weights for each set of impact, category, and dimension, the following approach is adopted, as described by Triantaphyllou et al. (1997):

- Firstly, a geometrical mean is found for each row, i.e. impact, following the formula provided below:

$$GM = \sqrt[n]{a1, a2, a3 \dots an}, \text{ where}$$

$$a1, a2, a3, \dots an - data\ set\ in\ a\ row$$
$$n\ -\ number\ of\ columns$$

- After the geometrical mean is found, the numbers are normalised by dividing them with their sum, which results in a vector of weights and sums up to 1.

The assignment of relative importance values can sometimes be inconsistent (Triantaphyllou et al., 1997). They are, however, considered to be relatively consistent if the corresponding consistency ratio (CR) is below 10% (Triantaphyllou et al., 1997). To calculate the CR coefficient the following approach is used by Triantaphyllou et al. (1997):

- Calculate the consistency index (CI).

- Sum up the values of the columns of the judgement matrix and multiply this vector by the vector of priorities calculated earlier. This yields an approximation of the maximum eigenvalue a_{max}.
- Calculate the consistency index using the formula:

$$CI = \frac{(a_{max} - n)}{(n-1)}$$

- Find the random consistency index (RCI) using the following table:

Table 3-2: Random consistency values for different *n* (adopted from Triantaphyllou et al.. **(1997))**

n	1	2	3	4	5	6	7	8	9
RCI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45

- Calculate the Consistency Ratio (CR) by dividing the CI value by the corresponding RCI value. If the CR value is greater than 0.10 (10%), then a re-evaluation of the judgement matrix is recommended.

The direct weighting method refers to the method where the weights are directly assigned. The total weights assigned should equal to 100 points, otherwise a normalisation needs to be performed to ensure that the sum of weights adds up to 100. This method provides a view of the trade-offs between various categories evaluated in a simple and straightforward manner.

Step 6: Overall value calculation. This step is aimed at calculating the overall value of each alternative given the normalised performance matrix and weights that were determined in the previous step. The calculation of the overall value for each alternative, which is called a Total Value Index, follows the weighted summation method (WSM) described in the previous chapter. The WSM method is chosen for a number of reasons, including:

- It is a straightforward method that could easily be understood by decision-makers, stakeholders, and specialists.
- The method brings transparency to the decision-making process, thus addressing the fears of decision-makers of a "black box" approach.
- The method is easily recordable and can be used for any case study.

Employment of the WSM in the calculation of the overall values of alternatives assumes a weak sustainability and a complete trade-off between social, economic, and environmental impacts. However, it is important that before the overall value calculation is performed, impacts are analysed and fatal flaws are identified.

Fatal flaws of an option cannot be traded-off against a very significant positive impact; thus, they cannot be included in the overall value as it can result in a faulty assessment and subsequently a mistaken decision. Ideally, fatal flaws in the EIA should be identified during the scoping phase and alternatives adjusted accordingly. It is still, however, recommended that before overall values are calculated impacts are reviewed and checked for fatal flaws.

Step 7: Alternative selection. After the values are calculated, the next step interprets them in order to identify the preferred alternative**.** The decision context involves the identification of an option that offers the largest benefits to the community, environment, and economy and creates minimal adverse effects to these dimensions. In this case, the preferred alternative will be the one that has the highest TVI.

Step 8: Sensitivity analysis. This is the last step in the decision framework. It involves the identification of the most critical decision impacts, the ranking of impacts in terms of sensitivity, and the assessment of how changes in the impacts may affect the decision.

Triantaphyllou et al. (1997) state that the most critical criterion is not necessarily the one that has the highest score. The most critical criterion, which in this study is represented by an impact, is the one for which the smallest change in its current weight will lead to alterations to the existing rankings of alternatives and therefore impact the decision (Triantaphyllou et al., 1997).

According to the logic presented by Smith et al. (2006), the dimension weights are the most important parameters, followed by the category weights, and finally the weights assigned for each impact. At the same time, the most important category weight would usually be more vital than the least important dimension weight.

The identification of the most important criteria is done through a one-dimensional approach whereby every weight is increased by 5% while keeping the rest of the weights at the same level of the hierarchy constant. After the weight is changed, the percentage variation between the original TVI and the TVI with the new weight is determined and recorded in a table, an example of which is presented in Table 3-3.

Tables similar to Table 3-3 are developed for dimensions, categories, and impacts. Those weights for which a 5% change would lead to the largest percentage variation of the TVI will be considered as the most important weights of the value tree.

Table 3-3: Example of the sensitivity analysis records

Criteria	Original weight	Original Overall Value	New weight	New overall value	Percentage change
Social	X	X	X	X	X
Environmental	X	X	X	X	X
Economic	X	X	X	X	X

3.5 Summary

This chapter briefly outlined the problem that is addressed by this research together with the proposed solution that was tested in the study. The focus of the chapter was on the conceptual framework and methods relevant to the study and that were used in testing the proposition. The next chapter is aimed at outlining the research strategy that will be followed to investigate the research hypothesis.

CHAPTER 4: RESEARCH METHODOLOGY

This chapter outlines the research methodology that was used to verify and validate the conceptual framework and methods formulated in the previous chapter. It briefly outlines the case studies that were used in the research and instruments that were applied in the collection of primary data.

4.1 Research methodology

Figure 4-1 illustrates the steps that were taken in conducting the case study research.

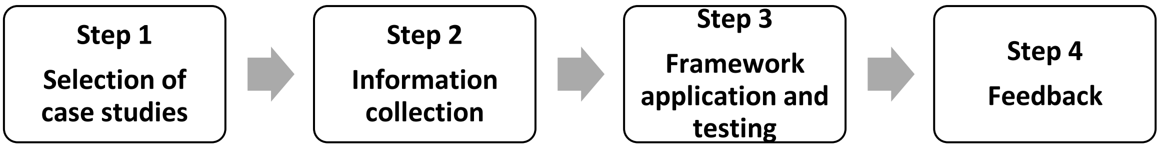

Figure 4-1: Research strategy

The **first step** of the research encompassed the selection of two completed EIAs in the energy sector. Their details are provided in Section 4.3. These case studies were selected based on the following criteria:

- The proposed development takes place in South Africa;
- The development has an environmental authorisation;
- The development is relevant to the energy sector of South Africa;
- The development documentation and information is publicly available; and
- The stakeholders, including authorities involved in decision-making and specialists engaged in the preparation of the Environmental Impact Report (EIR), must be accessible and willing to participate.

After the case studies were identified, the next step was to collect all the necessary information to evaluate the framework. This represents the **second step** of the case study research method. Details of data collected are presented in Section 4.3

Step three encompassed the application of the customised MCA framework to the case studies. The framework, proposed in CHAPTER 3:, was populated with the information contained in the EIAs.

Lastly, **step four** included:

- Consultations with two groups of stakeholders (environmental specialists and decision-makers) regarding the process applied in testing the framework through focus group discussions, interviews, or e-mail communiqué;

- Identification of weights for criteria and impacts using two different weighting techniques (direct weighting and pairwise comparison);
- Analysis and discussion of data; and
- Collection of feedback regarding applicability of the proposed framework and its potential to improve decision-making processes.

More details on how these activities were conducted are provided in Section 4.5.

4.2 Strengths and limitations of the chosen research methodology

4.2.1 Case Studies

The proposed research methodology is based on a case study method. Case studies can include a single case or multiple cases, and in terms of the purpose be exploratory, explanatory, or descriptive. As any research methodology, the approach has various weaknesses and strengths, which are highlighted below. Nevertheless, as long as the researcher is aware of the limitations and potential of the case study method, research based on it can provide robust, rigorous, and reliable results.

Strengths of the case study method include:

1. When performed well, the method can have a high degree of completeness, depth of analysis and readability (Duff, 2007).
2. The case study method can result in generation of new hypothesis, models and understanding of the subject under analysis (Duff, 2007).
3. Since the case study data are drawn from experiences and practices, the method has a very strong connection to reality (Blaxter, Hughs, & Tight, 2006) and the case study results can therefore be more persuasive and accessible.
4. Linked to the fact that the method is based on experiences and practices, is the applicability of this method to predict how a person/group of people will behave in the future. This ability of the case study method allows for long-term forecasting. It provides for an opportunity to apply the results of the case study to a future case.
5. The case study method allows for a combination of various analytical techniques, i.e. quantitative and qualitative (Duff, 2007).
6. Case studies can provide a data source from which further analysis can be performed (Blaxter et al., 2006).

The case study method has the following major weaknesses:

1. A case used in the analysis can be complex, which could complicate the analysis (Blaxter et al., 2006)

2. The method is data-driven rather than theory-driven.
3. Inherits constraints on quantitative assessment of small-sample data.
4. The case study method is sometimes criticised for its lack of objectivity (Duff, 2007). This is related to the fact that the researcher could be biased towards a particular point of view when undertaking the research, as well as the fact that if the case study involves participants, they can only provide subjective opinions or perceptions (Duff, 2007). Duff (2007), however, further argues that the matter of subjectivity is inherent to any research method because the researcher needs to use personal judgement and draw conclusions despite of the method used in the research. She (2007) further states that the difference only lies in the extent of the subjectivity, as some methods provide for an opportunity to check the reliability of the results.
5. Attrition of participants in the case study research is another criticism of the method. Duff (2007) argues that the issue of attrition, or the drop out of one or more participants, is of particular concern for case studies where the number of participants is small.

In addition to the aforementioned strengths and weaknesses of the case study method, there is also an issue of generalisation. Generalisability is a concept that aims at establishing the relevance, significance, and external validity of findings for situations or population beyond the research project under analysis (Duff, 2007). The issue of generalisation in case studies is controversial. On one hand, researchers argue that a single case study represents a unique situation, i.e. it is not a sample of one, but rather a population of one; therefore generalisation of results collected from the study is unwise or altogether impossible (Duff, 2007). The other camp of researchers, however, insists that the relative size of a sample used in the case study research does not transform it into a macroscopic study (Tellis, 1997). They argue that the goal of any case study is to establish parameters and then apply them in other research; therefore any case study results should be considered acceptable as long as they meet the established objectives (Tellis, 1997). Tellis (1997) further highlighted that according to Yin (1989), general applicability stems from the set of methodological qualities of the case, as well as the rigor with which the case is constructed.

Due to the difference in opinions within the research community with respect to the issue of generalisation, some researchers argue that case studies allow for generalisation from a specific instance to a more general use and therefore generalisations is seen by them as a strength of the method. Other researchers, who opt to believe that generalisation from a case study is flawed, view this issues to be the method’s weakness.

The other issue that is worth mentioning is the use of case studies in theory development and, in particular, the number of observations that should be chosen for the analysis. Eisenhardt (1989) stressed that selection of cases was an important aspect of building theory from case study analyses. She suggested choosing between four and ten, whilst acknowledging that there was 'no ideal number of cases'. Yin (2003), at the same time, suggested that the selection of the number of case studies should be guided by the replication logic, where the first case is used as a study on its own whilst subsequent examples are used to confirm or reject the findings of the first study. Importantly, subsequent cases do not have to replicate the exact conditions of the original case and that it is rather advisable as it would confirm the robustness of the original findings (Yin, 2003).

4.2.2 Triangulation

In order to ensure the validity of the results obtained during the research, a triangulation methodology is employed. Triangulation includes the combination of different data sources and makes use of various techniques and methods applied in investigating the same phenomenon. The advantage of the triangulation method is that it provides for in-depth and richer data sets by integrating multiple data from various sources through collection, examination, comparison, and interpretation (Insitute for Global Health, 2009). As a result, the methods triangulation assists in improving the validity of the results by reducing the risk of false interpretation of the collected information (Insitute for Global Health, 2009). The proposed research methodology will employ two types of triangulation – methodological triangulation and data triangulation.

Methodological triangulation refers to the use of multiple qualitative and/or quantitative techniques to study the case. The validity is established by comparing the results obtained from the application of all techniques, and if the results are similar, it could then be argued that they are valid (Guion 2002). Methodological triangulation in the current research is reflected through the application of two different weighting techniques, i.e. pairwise comparison and direct weighting.

Data triangulation involves the use of different data sets. In the current research, this in turn refers to the collection of opinions from various stakeholders with respect to the usefulness of the proposed framework in making an informed decision related to a particular alternative. In this context, feedback from two different groups of stakeholders was collected, namely decision-makers and environmental specialists.

4.3 Case studies

Following the selection criteria, two examples of EIAs in the energy sector of South Africa were selected for the research – one being used to identify the initial set of findings and the other to confirm or deny them.

- Proposed open cycle gas turbine (OCGT) power station, fuel supply pipeline, substation and transmission lines at Mossel Bay in the Western Cape Province; and
- Proposed establishment of a concentrating solar power (CSP) plant and related infrastructure in the Northern Cape Province.

4.3.1 Proposed CSP power station in the Northern Cape Province

Eskom embarked on exploring a number of alternatives to generate electricity. One of them was the possibility of establishing a concentrating solar power (CSP) plant that would utilise solar energy. The proposed CSP plant in the Northern Cape Province entailed the following (Bohlweki Environmental, 2006):

- Approximately 6 000 heliostats for the generation of 100 MW of electricity for up to eight hours after sunset.
- Footprint of about 4 km^2.
- Each heliostat to have a surface area of 130 m^2.
- Receiver to be approximately 210 m in height.

The EIA for the proposed project included the following specialist studies (Bohlweki Environmental, 2006):

- Impact on surface and groundwater
- Impact on ecology and flora
- Impact on terrestrial fauna
- Impact on soils and agricultural potential
- Avifaunal impacts
- Heritage resource impact
- Noise impact
- Impact on tourism
- Social impact assessment and land use, and
- Visual impact.

The project considered three site alternatives, which were reviewed during the scoping phase. The preferred option identified was then reviewed during the EIA phase.

Given the fact that alternatives for the preferred site were considered during the scoping phase and the EIA phase concentrated on identifying the impacts of the proposed project on the social and biophysical environments of the area that would be affected by the CSP plant, the testing of the decision-making framework involved the comparison of the integrated impacts of the proposed project with the status quo situation, or a 'no go option'.

4.3.2 Proposed OCGT power station near Mossel Bay

OCGT plants were identified by the Integrated Strategic Electricity Planning (ISEP) as a potential solution to providing electricity during peak times and in the short-term (Ninham Shand, 2005a). In this context, two OCGT plants were proposed, one of which was near Mossel Bay. The proposed project comprised of the following components (Ninham Shand, 2005a):

a) The proposed plant comprised three or four gas turbines with a capacity of between 150 and 250 MW each, i.e. between 450 and 1 000 MW in total.
b) The proposed plant was to be adjacent to the existing PetroSA facility.
c) The footprint of the proposed plant and substation was to be about approximately 9 ha.
d) The supply of kerosene was to be provided through a pipeline from the PetroSA facility adjacent to it.
e) The adjacent substation was to transmit the power generated through two 400 kV transmission lines to the Proteus substation from where the electricity was to be introduced to the national grid.

The EIA for the proposed project included the following specialist studies (Ninham Shand, 2005b):

- Visual impact
- Noise impact
- Botanical impact
- Air quality study
- Avifaunal impact
- Heritage resource impact
- Air pollution
- Risks related to the pipeline

- Socio-economic impact, and
- Traffic impact.

The project also considered a number of alternatives, including (Ninham Shand, 2005b):

- The location of the OCGT plant and substation
- Three options for the alignment of the transmission lines
- Three alternatives for the road access route, and
- Two alternatives for the fuel supply pipeline alignment.

Given the availability of information on the impacts that were considered for the alternatives applicable to the alignment of the transmission lines, road access route, and fuel supply pipeline alignment, the proposed decision-making framework was tested in terms of these three aspects of the project.

4.4 Collected information

Information required to complete the case studies was collected only from publicly available sources, and in particular from Eskom's website (http://www.eskom.co.za). The following list of documents was sourced from the website:

- OCGT plant EIA
    - Background Information Document, April 2005
    - Plan of study for scoping, April 2005
    - Final Environmental Impact Assessment Report, October 2005 including the following annexes
        - DEA&DP's approval for the study for EIR, August 2005
        - Botanical study completed by Nick Helme botanical surveys, August 2005
        - Avifaunal study completed by Ninham Shand, October 2005
        - Heritage study completed by Archaeology Contracts Office, July 2005
        - Visual study completed by CNdV Africa, August 2005
        - Noise study completed by Jongens Keet Associates, September 2005
        - Socio-economic study completed by Urban-Econ, July 2005
        - Traffic study completed by Ninham Shand, August 2005
        - Hazards of transportation of flammable liquids via overland pipeline from the PetroSA refinery, August 2005
        - Air pollution impact assessment, August 2005

        - Summary of Eskom's macroeconomic study completed by Eskom, October 2005
        - Letter to I&APs notifying them of changes to the proposed project, September 2005
        - Issues trail and comments from I&APs, September 2005
        - Review of Draft EMP and consultant team's response
        - List of registered I&APs
    - Record of Decision, December 2005
- CSP plant EIA
    - Environmental Impact Assessment Process. Proposed establishment of a concentrating solar power (CSP) plant and related infrastructure in the Northern Cape Province. Briefing paper, March 2006
    - Plan for study for the Environmental Scoping Study for the proposed establishment of a concentrating solar power (CSP) plant and related infrastructure in the Northern Cape Province, February 2006.

The final EIR for the CSP was not available on Eskom's website and was therefore sourced directly from the environmental consulting company involved in the EIA, i.e. Bohlweki Environmental. The following list of documents for the CSP plant EIA was sourced from the consultant in addition to the Final EIR of 10 May 2007:

- Acceptance of Environmental Scoping Report and Plan of Study for EIA
- Issues Trail, comments and I&AP Database
- Legal Discussions
- Visual maps
- Glossary of terms
- Details of the noise measurements survey and existing noise climate condition assessment
- Assessment of noise impact
- Minutes of the provincial authorities meetings
- Minutes of focus group meetings
- Minutes of the public meeting
- Minutes of the key stakeholders workshop
- Letter from Eskom regarding water supply.

4.5 Feedback

The viability of the proposed framework in its application of alternatives or options in EIAs in the energy sector was investigated by applying triangulation methods, and specifically:

- Data triangulation used to identify similarities in opinions among two different groups of stakeholders – environmental specialists and decision-makers, and
- Methodological triangulation expressed through the application of two different types of weighting techniques, i.e. pairwise comparison and direct weighting.

This approach is envisaged to provide valuable information regarding the applicability of the framework and its potential to improve decision-making practiced by people who are directly involved in the EIA process, and who could become potential users of the framework.

The purpose of the consultation process was to:

- Identify the main decision factors used in the original decision-making process;
- Identify weights for each criterion in the developed multi criteria decision-making framework;
- Compare the results of the original decision-making process with the results generated through application of the framework;
- Ask participants about weaknesses and strengths of the proposed framework; and
- Enquire about recommendations to improve the framework.

4.5.1 List of participants

Annexure A provides the list of people who were invited to participate and provide feedback through interviews or questionnaires sent by e-mail depending on their suitability for the respective participants. Annexure A also provides the reason for the selection of the particular individual and its relation to the respective EIA.

The criteria for choosing the participants were as follows:

- Involvement in decision-making or preparation of the EIA;
- Interested in improving the process of decision-making; and
- Current occupation is related to EIAs.

Where a participant did not express his/her willingness to participate in the research, an independent environmental consultant from the Council of Scientific and Industrial Research (CSIR) who has extensive experience in EIAs, but who did not participate in the completion of either case studies' EIRs, was asked to complete outstanding ratings of impacts and/or categories. This was necessary to ensure all necessary information for the development of the framework was obtained, while maintaining the integrity of the research.

4.5.2 Cover e-mail

Participants were contacted via e-mail. A cover e-mail was forwarded to each of the participants inviting them to participate in the study and enquire about their preferred method of participation. The template for a cover e-mail is provided in Annexure B.

As indicated in Annexure B, the following was addressed in the cover e-mail:

- Participants were asked to indicate their preferred method of participation.
- A short background to the research was provided and the reason for their assistance in the research was outlined.
- Dates and locations of the interviews were requested.

4.5.3 Participation through e-mail

Initial collection of feedbacks from participants was done by e-mail. Each participant was asked to complete a questionnaire, an example of which is presented in Annexure C. The focus of the e-mail participation was on completing the pairwise comparison matrices and direct weighting tables used for identifying weights for the framework.

After the framework was developed, participants were requested to comment on its ability to "provide the decision-makers with an integrated, transparent, and coherent approach to the evaluation of alternatives that clearly shows trade-offs between different criteria". In this context, they were asked to comment on their perception of advantages and drawbacks of the proposed framework in comparison with the current process used in EIA decision-making in the energy sector in South Africa. An example of the questionnaire used to collect feedback from the participants is included in Annexure D.

4.5.4 Interviews

Certain feedback from participants was also received through interviews. Interviews were of a structured nature where specific items set by the research context were asked of the participant or participants, and the responses were restricted to the range imposed by the researcher (Carole and Meyer, 2006). Interviews with decision-makers were scheduled during the course of the research. The focus of the interviews was on the following:

- Introduction and expression of appreciation for participation in the discussion session.
- Brief explanation of the purpose of the study and the framework.
- Process to be followed in identifying weights for each criterion: pairwise comparison and direct weighting.
- Weights identification (for interviews with decision-makers).
- Discussion of the proposed approach versus the current decision-making process.
- The way forward.

4.6 Results analysis

Following on the interviews and e-mail communiqué, each process and the analysis of the received comments regarding the framework were documented. The details are presented in Chapter 5. Finally, each participant received an e-mail thanking him/her for the participation and for providing feedback to the research process.

CHAPTER 5: RESULTS - DATA GATHERING AND ANALYSIS

The purpose of this chapter is to test the hypothesis stated earlier in the document. This will be done by, firstly, applying the proposed framework on the two chosen case studies; secondly, analysing the results; and thirdly, obtaining the decision-makers' opinions concerning the proposed framework. In this context, for each case study the chapter outlines the following:

- Development of a value tree representing a hierarchy of impacts, categories, and dimensions;
- Compilation of performance matrices before and after mitigation, based on the impact ratings assigned by specialists during the original assessment;
- Presentation of weights for each level of hierarchy that were derived through interviews, workshops and e-mail communication; and
- Presentation of scores for each level of hierarchy and for cases before and after mitigation.

5.1 Case study 1: CSP

The following sections present a step-by-step account of the proposed framework's application to the first case study, namely the CSP facility in the Northern Cape Province.

5.1.1 Value tree

Figure 5-1 and Table 5-1 outline the value tree developed for the first case study. As described in the methodology section, firstly, impacts were listed and were then grouped into categories. The result of this exercise is presented in Table 5-1, which shows all impacts that were identified by specialists and that were chosen to form part of the decision framework based on the selection criteria discussed earlier in the thesis.

In total, the framework comprises of 62 impacts grouped under 13 categories. Some of the impacts were disaggregated in terms of the life-cycle stage at which they occur, i.e. constriction phase or operational phase. Such a disaggregation was necessary to ensure that temporary impacts that usually take place during the construction phase are considered separately from similar types of impacts that take place during the operational phase, but which can have a far greater duration and sustainability levels.

Table 5-1: CSP impacts used in the decision tree (Bohlweki Environmental, 2006)

Criterion	Impact
Avifauna – power lines	Collision of birds
	Habitat destruction
	Disturbance
Avifauna – access roads	Disturbance
	Habitat destruction
Avifauna - power plant	Collision with heliostats
	Collision with central receiver tower
	Roosting on central receiver tower
	Burning in vicinity of central receiver tower
	Burning in focal points
	Habitat loss
	Disturbance
	Nesting
Groundwater	Migration of contaminants from Orange River water used in the plant
	Migration of hydrocarbon fuel spillage at the plant
	Leaching of herbicides used in ground sterilisation beneath the mirrors
	Leaching of Na/K-NO3 salts (used as coolant)
Ecology	Impact on vegetation
	Impact on fauna
Visual	Major tourism routes
	Residential areas: Upington
	Residential areas: Louisvale, Louisvel Road, Kanon Eiland
	Residential areas: Oranje Valley, Ses Brugge, Klippunt
	Protected areas: Spitkop NR
	Protected areas: Augrabies Falls NP
	Orange River
	Ancillary infrastructure: salt tanks
	Ancillary infrastructure: auxiliary house
	Ancillary infrastructure: transmission line
	Ancillary infrastructure: pipe line
	Lighting: glare- floodlights
	Lighting: glare-aircraft warning lights
	Lighting: spill light
	Lighting: sky glow
Noise	Construction phase
	Operational phase
Demographic changes	Introduction of people dissimilar in demographic profile - construction
	Introduction of people dissimilar in demographic profile - operation
	Inflow of temporary workers - construction
	Introduction of new social classes
Quality of life	Impact on daily living and movement patterns - construction
	Impact on daily living and movement patterns - operation
	Disruption of social networks and alteration of family structures - construction
	Social impact derived from industrial diversification - construction

Criterion	Impact
	Social impact derived from industrial diversification - operation
	Social impact derived from the environmental and economic benefits of solar power
	Air and dust pollution - construction
	Light intrusion - construction
	Noise intrusion - construction
	Air and dust pollution - operation
	Light intrusion - operation
	Noise intrusion - operation
Employment	Employment equity and occupation opportunities - construction
	Creation of employment opportunities - construction
	Employment equity and occupation opportunities - operation
	Creation of employment opportunities - operation
Tourism	Change in tourism and leisure opportunities - construction
	Change in tourism and leisure opportunities - operation
Service delivery	Impact on municipal services requirements - construction
	Impact on municipal services requirements - operation
Infrastructure	Change in community infrastructure - construction
	Change in community infrastructure - operation

Once categories had been defined, they were grouped under respective dimensions that were set beforehand, namely economic, environmental and social. The result of this exercise is presented in Figure 5-1.

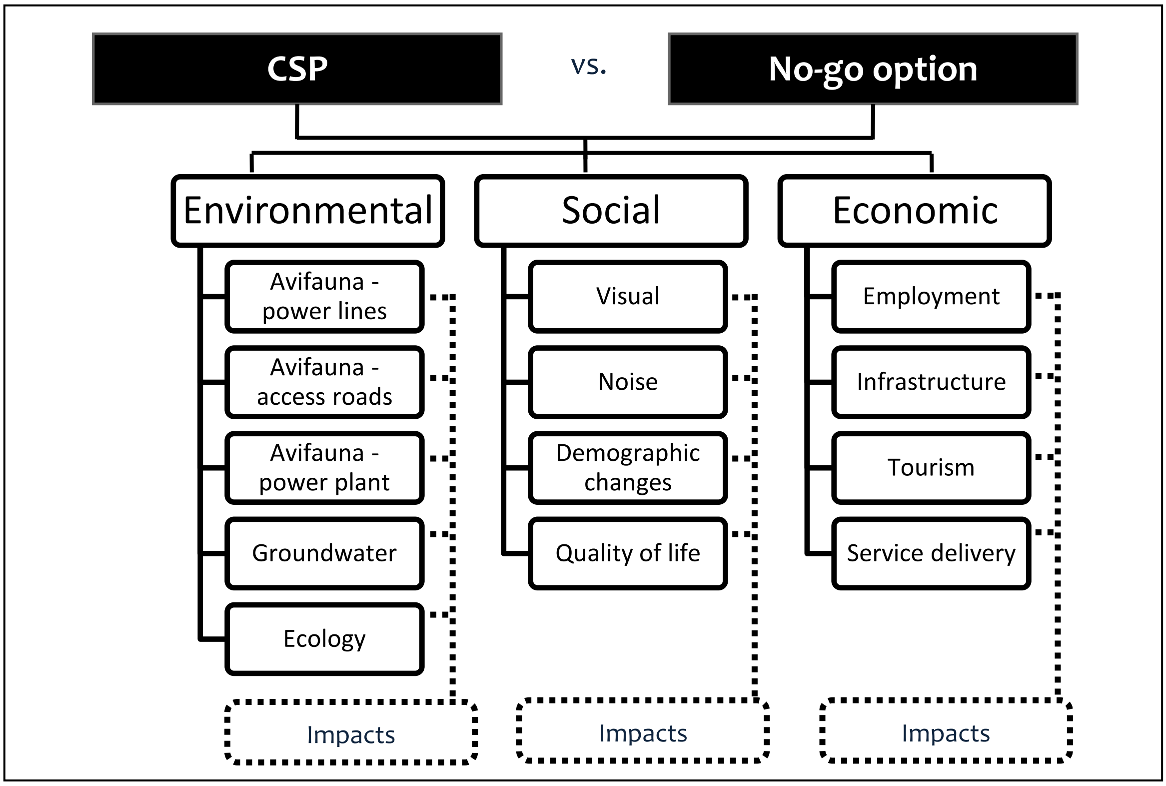

Figure 5-1: CSP case study value tree (Bohlweki Environmental, 2006)

As shown in this figure, the environmental dimension encompasses five categories, social comprises of four categories, and economic - also four categories.

5.1.2 Performance matrix

After all the impacts had been identified and grouped accordingly, impact rating tables, completed by each specialist during the Environmental Impact Assessment study, were used to extract information regarding their ratings. The result of this exercise is presented in Annexure F: CSP Impact Rating Tables. The tables indicate ratings that were assigned by specialists for the respective impacts in terms of their significance before and after mitigation and the probability of these impacts to take place, as judged by the specialist.

Afterwards, a performance matrix was developed following the approach described in the methodology section. This involved converting the significance ratings and the degree of confidence ratings into an index. Since the rating of each impact can change once mitigation is introduced, the performance matrix includes values for the situation before mitigation and after mitigation. The performance matrix is provided in Annexure G: CSP performance matrix. Importantly, the following assumptions were followed in developing the performance matrix, in addition to the one described on the methodology section:

- Where no indication of risk or the degree of confidence was given, it was assumed that it received the highest score, namely Definite.
- Where no indication of the significance of the impact after mitigation was given in the rating tables, it was assumed that it would receive the same significance ratings as in the case before mitigations.

5.1.3 First round of weights elicitation: impacts

All specialists involved in the Environmental Impact Assessment of the CSP and associated infrastructure were contacted by e-mail requesting them to complete pairwise comparisons and direct weightings of impacts identified by them in the respective studies. Unfortunately, only four out of ten specialists agreed to participate in the research, which represents 40% of the specialist population involved in the original assessment. In order to ensure that the rest of the impacts were weighted objectively and by a person or persons knowledgeable of the field, an independent environmental specialist from the Council of Scientific and Industrial Research (CSIR), Henri Fortuin, was requested to assist in completing the outstanding rankings. Copies of the EIR and specialists' reports were provided to the assessor to inform him of the project and the context of specialist studies to be used as background for the evaluation.

The following paragraphs and tables present the outcomes of the first round of weight elicitation, presenting weights for impacts that were derived through the pairwise comparison and direct weighting techniques.

a. Weights for groundwater impacts

Table 5-2 provides the weights that were assigned to groundwater impacts. It appears that among the four impacts considered under this category, the impact that is expected to have the greatest effect on the decision-making include "migration of hydrocarbon fuel spillage at the plant". The weighting score assigned to this impact through pairwise comparison and direct weighting techniques was 63.8% and 75%, respectively. The next most significant impact among the groundwater impacts was "leaching of herbicides used in ground sterilisation beneath the mirrors", if judging by the weights assigned through the pairwise comparison technique, and "leaching of Na/K-NO3 salts (used as coolant)" -if judging by the direct weighting technique.

Table 5-2: Weights for groundwater impacts

Impact	Pairwise comparison	Direct weighting
Migration of contaminants from Orange River water used in the plant	4.6%	2%
Migration of hydrocarbon fuel spillage at the plant	63.8%	75%
Leaching of herbicides used in ground sterilisation beneath the mirrors	20.4%	2%
Leaching of Na/K-NO3 salts (used as coolant)	11.2%	21%

The above results clearly indicate that the use of pairwise comparison and direct weighting techniques to identify the weights for the groundwater impacts produced mixed results. While in both cases, the most significant impact from the decision perspective appears to be the same, the second most significant impact differs.

b. Weights for ecology impacts

Table 5-3 indicates the weights assigned to the two ecology impacts identified for the project under discussion. As can be seen, the use of pairwise comparison and direct weighting techniques produced exactly the same results – the two ecology impacts were considered to be equally important for decision-making.

Table 5-3: Weights for ecology impacts

Impact	Pairwise comparison	Direct weighting
Impact on vegetation	50%	50%
Impact on fauna	50%	50%

c. Weights for avifaunal impacts

The avifaunal specialist disaggregated avifaunal impacts in terms of their drivers, i.e. impacts that are created as a result of commissioning of the plant, power lines, and access roads. The sets of impacts associated with each component of the project were treated separately and the results of the weighting process are presented in Table 5-4.

Table 5-4: Weights for avifaunal impacts

Impacts	Pairwise comparison	Direct weighting
Plant		
Collision with heliostats	21.7%	5%
Collision with central receiver tower	4.6%	10%
Roosting on central receiver tower	4.0%	5%
Burning in vicinity of central receiver tower	5.3%	10%
Burning in focal points	36.9%	30%
Habitat loss	13.5%	20%
Disturbance	9.8%	15%
Nesting	4.2%	5%
Power lines		
Collision of birds	76.6%	80%
Habitat destruction	15.8%	10%
Disturbance	7.6%	10%
Access roads		
Disturbance	50.0%	60%
Habitat destruction	50.0%	40%

The following can be deducted from the information presented in the above table:

- With respect to the impacts that are expected to occur due to the commissioning of the plant, the most significant impact identified through the pairwise comparison technique includes burning in focal points, collision with heliostats, and habitat loss. At the same time, the weights assigned through the direct weighting technique suggest that the most important impacts associated with the commissioning of the plant include burning in focal points, habitat loss, and disturbance. The above results suggest that the application of the two weighting techniques results in the identification of the same most significant impact. However, when the second and the third most important impacts for decision-making have to be identified, the techniques under discussion produce different results.
- With respect to the three impacts associated with the power lines, both weighting techniques identified the "collision of birds" impact to be the most

important for decision-making. In terms of the other two impacts, the pairwise comparison results suggest that "habitat destruction" should have a slightly greater decision weight than "disturbance", while direct weighting results considered these two impacts to be equally important for decision-making.

- In terms of the access road impact, of which the specialist identified only two, the results of the weighting process using the pairwise comparison technique suggest that they are equally important for decision-making, while direct weighting results give a slight preference to the "disturbance" impact over "habitat destruction".

d. Weights for noise impacts

Table 5-5 outlines the weights derived through the pairwise comparison and direct weighting techniques for the noise impacts that were disaggregated between the noise during construction and noise during the operational phase.

Table 5-5: Weights for noise impacts

Impacts	Pairwise comparison	Direct weighting
Noise - construction phase	83.3%	60%
Noise - operational phase	16.7%	40%

As indicated in the table, the "noise during construction" impact received greater weights through both weighting techniques, although it is important to note that the "noise during the operational phase" impact is considered less significant for decision-making when weighting is done through the pairwise comparison technique than through the direct weighting technique.

e. Weights for quality of life impacts

Table 5-6 provides the weights for the quality of life category of impacts derived through the direct weighting technique. Since this category had 12 impacts identified by the specialist and the pairwise comparison technique's reliability is highly dependent on the number of pairs compared (preferably no more than seven), weights for impacts of this category were identified only though the direct weighting technique.

Table 5-6: Weights for quality of life impacts

Impacts	Direct weighting
Impact on daily living and movement patterns - construction	15%
Impact on daily living and movement patterns - operation	15%
Disruption of social networks and alteration of family structures - construction	12%

Impacts	Direct weighting
Social impact derived from industrial diversification - construction	8%
Social impact derived from industrial diversification - operation	8%
Social impact derived from the environmental and economic benefits of solar power	20%
Air and dust pollution - construction	3%
Light intrusion - construction	3%
Noise intrusion - construction	5%
Air and dust pollution - operation	3%
Light intrusion - operation	3%
Noise intrusion - operation	5%

As indicated in the above table, the most significant impact for decision-making among the quality of life category is "social impact derived from the environmental and economic benefits of solar power". This impact received a weight of 20%. The second and third most significant impacts were the "impacts on daily living and movement patterns" during construction and operational phases, respectively. Impacts associated with air and dust pollution, light intrusion, and noise intrusions, both during construction and operation, were considered to be the least significant for decision-making.

f. Weights for tourism impacts

Table 5-7 indicates the weighs for the two tourism impacts that were differentiated in terms of those that would take place during the construction phase and those that would be observed during the operational phase. As outlined in the table below, both the results of the pairwise comparison and direct weighting techniques suggest that the impact on tourism during the operational phase should be given greater consideration during the decision-making process than the same impact during construction. Through the direct weighting technique the impact on tourism during construction also received a slightly greater decision importance than through the pairwise comparison technique.

Table 5-7: Weights for tourism impacts

Impacts	Pairwise comparison	Direct weighting
Change in tourism and leisure opportunities - construction	20%	40%
Change in tourism and leisure opportunities - operation	80%	60%

g. Weights for demographic impacts

Table 5-8 provides the results of the application of pairwise and direct weighting techniques for determining the weighting of demographic impacts.

Table 5-8: Weights for demographic impacts

Impacts	Pairwise comparison	Direct weighting
Introduction of people dissimilar in demographic profile - construction	30.4%	35%
Introduction of people dissimilar in demographic profile - operation	7.8%	15%
Inflow of temporary workers - construction	15.4%	30%
Introduction of new social classes	46.3%	20%

As can be seen, according to the pairwise comparison technique the most important impacts for decision-making in this category were introduction of new social classes and introduction of people dissimilar in demographic profile during the construction period. These two impacts alone score more than three quarters of the total weight assigned for the category. The second most important impact chosen through pairwise comparison was the most important impact chosen through the direct weighting technique. However, the second most important impact in the latter case was inflow of temporary workers during construction, which was only the third most important impact chosen by pairwise comparison. Thus, it can be concluded that the two weighting techniques used differed noticeably for this category.

h. Weights for employment impacts

Table 5-9 lists the weights assigned for employment impacts. It is clear that the most important impacts for decision-making in terms of this category differ depending on the technique used to identify it. In the case of the pairwise technique, the most important impact, which received 47.5%, is the employment equity and occupation opportunities during the operational phase. At the same time, the creation of employment opportunities during construction was the most important impact if identified through the direct weighting technique. Interestingly, the most important impact identified through pairwise comparison was the least important impact through direct weighting, and vice versa.

Table 5-9: Weights for employment impacts

Impacts	Pairwise comparison	Direct weighting
Employment equity and occupation opportunities - construction	27.5%	35%
Creation of employment opportunities - construction	9.2%	40%
Employment equity and occupation opportunities - operation	47.5%	10%
Creation of employment opportunities - operation	15.8%	15%

i. Weights for visual impacts

The visual specialist had identified 15 visual impacts. Due to the limitations of the pairwise comparison technique – the reliability of the weighting processes drastically reduces if more than seven pairs need to be compared – the specialist was requested to assign weights for visual impacts only through the direct weighting technique. The results of this exercise are presented in the following table.

Table 5-10: Weights for visual impacts

Impacts	Direct weighting
Major tourism routes	20%
Residential areas: Upington	20%
Residential areas: Louisvale, Louisvel Road, Kanon Eiland	9%
Residential areas: Oranje Valley, Ses Brugge, Klippunt	9%
Protected areas: Spitkop NR	13%
Protected areas: Augrabiesd Falls NP	2%
Orange River	8%
Ancillary infrastructure: salt tanks	2%
Ancillary infrastructure: auxiliary house	2%
Ancillary infrastructure: transmission line	2%
Ancillary infrastructure: pipe line	2%
Lighting: glare- floodlights	5%
Lighting: glare-aircraft warning lights	5%
Lighting: spill light	3%
Lighting: sky glow	3%

It appears that the most important impacts in this category in terms of decision-making are the impact of the project on the major tourism routes in the area and the impact on the Upington residential area. Together these impacts received 20% each. The third most significant impact chosen by the specialist is the impact of the project on the Spitkop NR protected area. Interestingly, all visual impacts related to ancillary infrastructure and lighting were given the lowest weights. Altogether the weights to these eight impacts do not exceed 25%.

j. Weights for service delivery impacts

Table 5-11 outlines the weights derived through pairwise comparison and direct weighting techniques for the two service delivery impacts. It appears that in both cases, the impact on municipal services requirements during construction is given a higher decision value than the same impact during the operational phase.

Table 5-11: Weights for service delivery impacts

Impacts	Pairwise comparison	Direct weighting
Impact on municipal services requirements - construction	83.3%	60%
Impact on municipal services requirements - operation	16.7%	40%

k. Weights for infrastructural impacts

Table 5-12 provides the results of pairwise comparison and direct weighting exercises for infrastructural impacts. It indicates that the results differ significantly. In the case of the pairwise comparison technique, the most important impact from the decision perspective is the change in community infrastructure during operations. Through direct weighting, however, the change in community infrastructure during construction received a higher decision value.

Table 5-12: Weights for infrastructural impacts

Impacts	Pairwise comparison	Direct weighting
Change in community infrastructure - construction	16.7%	60%
Change in community infrastructure - operation	83.3%	40%

5.1.4 Second round of weights elicitation: categories

Table 5-13 provides the results of the weighting exercises applied to categories.

Table 5-13: Categories' weights for the CSP project

Impact	Pairwise comparison	Direct weight
Category - Environmental		
Groundwater	39.4%	30%
Ecology	28.5%	25%
Avifauna - CSP plant	5.7%	10%
Avifauna - power lines	20.7%	25%
Avifauna - access roads	5.7%	10%
Category - Social		
Visual	11.9%	20%
Noise	20.7%	30%
Quality of life	53.6%	35%
Demographic changes	13.8%	15%
Category - Economic		
Employment	31.3%	30%
Tourism	13.7%	20%
Infrastructure	31.3%	25%
Service delivery	23.8%	25%

The following can be concluded from the above table:

- The environmental dimension included five categories that were assigned weights from 0 to 100% and when summed up equal 100%. It appears that the application of both of the weighting techniques resulted in the same categories being chosen as the most important categories among the environmental dimension. The highest decision value was assigned to the groundwater category, followed by the ecology category and avifauna-power lines. The last two categories – avifauna-plant and avifauna-access roads have the lowest weights in both cases and are treated equally important from the decision perspective.
- The social dimensions encompassed four categories under which related impacts were grouped. The most important category within this dimension identified through both the application of pairwise comparison and direct weighting, was quality of life. Importantly, though, weights assigned to this category through pairwise comparison were considerably higher than those through direct weighting. The category with the second highest weight was noise. The positioning of the other two categories differed between the two weighting exercises: through the pairwise comparison, demographic changes received a slightly higher weight than the visual category, while through direct weighting the situation was reversed.
- The economic dimensions included four categories. Among these categories, weights assigned through the pairwise comparison technique resulted in the selection of the employment and infrastructure categories receiving the highest, but equal, weights. The employment category was also chosen as the most important within this dimension through direct weighting. The infrastructure category received 5% less than employment through direct weighting and the same weight as the service delivery category. The latter was also the third most important category considering weights obtained through pairwise comparison. Tourism received the lowest weights in both pairwise comparison and direct weighting.

5.1.5 Third round of weights elicitation: dimensions

Table 5-15 provides weights assigned to the dimensions.

Table 5-14: Dimensions' weights for the CSP project

Impacts	Pairwise comparison	Direct weighting
Environmental	21.8%	17.2%
Social	30.2%	24.5%
Economic	48.0%	54.8%

The overall rating of dimensions as determined through pairwise comparison and direct weighting is the same:

- The economic dimensions received the highest weights in both cases, although the weight assigned through direct weighting (54.8%) is slightly higher than the weight assigned through pairwise comparison (48.0%).
- The second most important dimension from a decision point of view was social. It received 30.2% and 24.5% in the case of pairwise comparison and direct weighting, respectively.
- The environmental dimension is considered to be the least significant dimension in the decision process concerning the project under analysis.

5.1.6 Results

a. Results derived using weights obtained through pairwise comparison

The following table provides the results of the Total Value Index (TVI) calculation for the cases before and after mitigation, using the weights derived through the pairwise comparison technique. The actual values represent the total scores of each category calculated as the sum of impacts' scores multiplied by their respective weights. Figures presented in the weight adjusted column shows, firstly, the categories' scores multiplied by their respective weights, and secondly, dimensions' scores calculated as the sum of category scores multiplied by the respective dimension's weight. The table also shows the maximum and minimum amount that could be scored by each dimension and category, given the assigned weights, which are used to calculate the normalised values of the scores.

The information presented in Table 5-15 indicates that all environmental and social impacts for the CSP project are negative and that the maximum score that they can obtain, taking into account the weights, is zero. At the same time, the economic dimension has both positive and negative impacts. The total maximum score, given the respective weights for categories and dimensions, can be a positive 21.6.

Table 5-15: Results derived through the pairwise comparison

Impact	Actual values		Weight-adjusted		Range	
	Before mitigations	After mitigations	Before mitigations	After mitigations	Min	Max
Environmental	-	-	**-5.0**	**-4.1**	**-21.8**	**0**
Groundwater	-24.2	-24.2	-9.5	-9.5	-39.4	0
Ecology	-15.0	0.0	-4.3	0.0	-28.5	0
Avifauna - CSP plant	-51.3	-51.3	-2.9	-2.9	-5.7	0
Avifauna – power lines	-22.7	-22.7	-4.7	-4.7	-20.7	0

Impact	Actual values		Weight-adjusted		Range	
	Before mitigations	After mitigations	Before mitigations	After mitigations	Min	Max
Avifauna - access roads	-30.0	-30.0	-1.7	-1.7	-5.7	0
Subtotal	-	-	-23.1	-18.8	-	-
Social	**-**	**-**	**-4.0**	**-0.4**	**-30.2**	**0**
Visual	-45.9	-45.7	-5.5	-5.5	-11.9	0
Noise	-6.9	-6.9	-1.4	-1.4	-20.7	0
Quality of life	-7.9	12.2	-4.2	6.5	-53.6	0
Demographic changes	-15.5	-7.1	-2.1	-1.0	-13.8	0
Subtotal	-	-	-13.3	-1.3	-	-
Economic	**-**	**-**	**2.2**	**3.5**	**-26.4**	**21.6**
Employment	54.6	23.3	17.1	7.3	0.0	31.3
Tourism	7.5	23.0	1.0	3.2	0.0	13.7
Infrastructure	-10.4	-3.3	-3.3	-1.0	-31.3	0.0
Service delivery	-42.9	-8.8	-10.2	-2.1	-23.8	0.0
Subtotal	-	-	4.6	7.3	-	-
TOTAL VALUE INDEX	**-**	**-**	**-6.83**	**-0.99**	**-78.4**	**21.6**

The results of the TVI calculation for the CSP project following a pairwise comparison technique for weights derivation show a negative 6.83 for the case before mitigations. This score means that when compared to the "no-go option", the CSP project is not the preferred option as it would have an overall negative effect. The environmental dimension scored a negative 5.0, social scored a negative 4.0, and economic - a positive 2.2. Thus, it can be concluded that without mitigations the value of the project's positive impacts will not be sufficient to counterbalance the value of the project's negative impacts. At the same time, it appears that the projects impacts on the environment would have the largest negative impact.

The review of the actual values assigned to categories of the environmental dimension suggests that the worst set of environmental impacts of the project would be the impacts of the CSP plant on avifauna. However, taking into account the weights assigned to each category, which indicate their importance for decision-making, the groundwater category received a negative 9.5 score that translates into 41% of the subtotal for the dimension. This category therefore has the largest negative score, and subsequently represents the most significant category of impacts within the environmental dimension. Impacts on ecology and avifauna from power lines appear to be the next most significant environmental issues associated with the CSP project.

The analysis of the social dimension's scores suggests that the set of visual impacts bear the biggest negative effect within this dimension. Given its overall negative value and the weight assigned to it, the visual category also has the largest contribution towards the score of the social dimension. It is followed by the set of impacts categorised under the quality of life. It should be noted that the actual negative score for this category was relatively low, but given the significance of this category for decision-making it received an overall second highest negative score among categories within this dimension.

As far as the economic dimension is concerned, there are two sets of positive impacts and two sets of negative impacts. The overall score calculated for this dimension, namely positive 2.2, suggests that the value of positive impacts within the economic dimension was bigger than the value of negative impacts within the same dimension. The highest positive value of the CSP project is expected to be derived from the employment set of impacts. At the same time, the impact of the project on the service delivery in the affected areas is expected to be significant and counterbalance a significant portion of the positive impact derived from created employment.

The comparison of scores calculated for the case before and the case after mitigations suggests that the mitigation measures proposed by certain specialists will significantly reduce the overall negative impact of the project. Some of the impacts are difficult to mitigate or proposed mitigations would not have a noteworthy change on the probability of occurrence or significance of the respective impacts and therefore their scores would not change. Importantly, this was the case for those categories of impacts that received the largest negative scores within the environmental and social dimensions. There are, however, impacts that can be mitigated. Moreover, the extent of their mitigation would result in a noticeable reduction of these impacts' importance for decision-making. This reduction is particularly relevant to the sets of impacts grouped under the quality of life, ecology, and service delivery.

The question arises as to what the reason may be for the employment category scoring a lower positive value in the case after mitigations than the value obtained in the case before mitigations. Since mitigations of positive impacts are aimed at increasing their overall probability of occurrence, the positive score for the case after mitigations should either remain the same as for the case before mitigation or increase. Since in the CSP project it was reduced, it could be argued that the specialist who assigned new sets of probability and significance values for the employment impacts after mitigation made a mistake. If this was the case, it could also be expected that the value of the economic dimension after mitigations would have been greater. The result is that the TVI after mitigations could be reduced to neutral or even become positive, illustrating that positive impacts associated with the CSP project have the ability to counterbalance the negative impacts derived from it.

Figure 5-2 illustrates the dimensions' scores and the TVI for the cases before and after mitigations. It clearly shows the trade-offs between dimensions and benefits derived from mitigations measures. Assuming that the zero point represents the "no-go option", it is straightforward to compare the value of the CSP project with respect to each dimension and the TVI against this option.

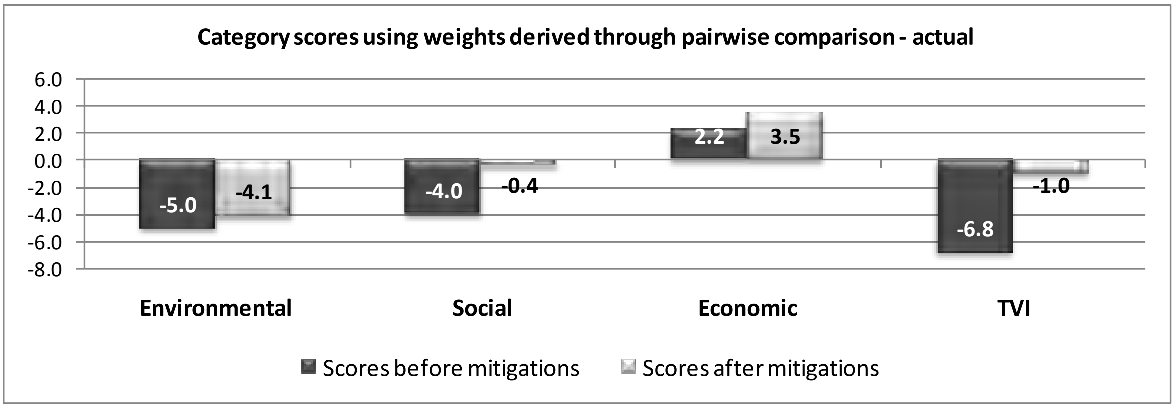

Figure 5-2: Illustration of weight-adjusted scores for the CSP project - pairwise comparison

The final scores calculated for the dimensions and the TVI can be normalised to indicate the extent to which the impacts under the respective dimensions trace behind the most beneficial situation. This assessment could be useful in exploring the areas that have the largest potential to be mitigated to reduce the negative score of the project or improve its benefits, as well as the extent by which the proposed mitigation measures are addressing the problems. Table 5-16 and Figure 5-3 illustrate the normalised scores and the TVIs before and after mitigations.

Table 5-16: Normalised scores of values derived through pairwise comparison

Dimension	Weight adjusted		Range		Normalised	
	Before mitigations	After mitigations	Min	Max	Before mitigations	After mitigations
Environmental	-5.0	-4.1	-21.8	0.0	76.9	81.2
Social	-4.0	-0.4	-30.2	0.0	86.7	98.7
Economic	2.2	3.5	-26.4	21.6	59.7	62.3
TVI	-6.8	-1.0	-78.4	21.6	71.6	77.4

As illustrated in Figure 5-3, given the normalised scores the negative impacts within the social dimension could be mitigated with the greatest success. Environmental and economic impacts mitigation measures, however, would not produce a similar result. At the same time, it appears that the greatest potential for mitigation and improvement of the performance of the CSP project lies in the economic dimension.

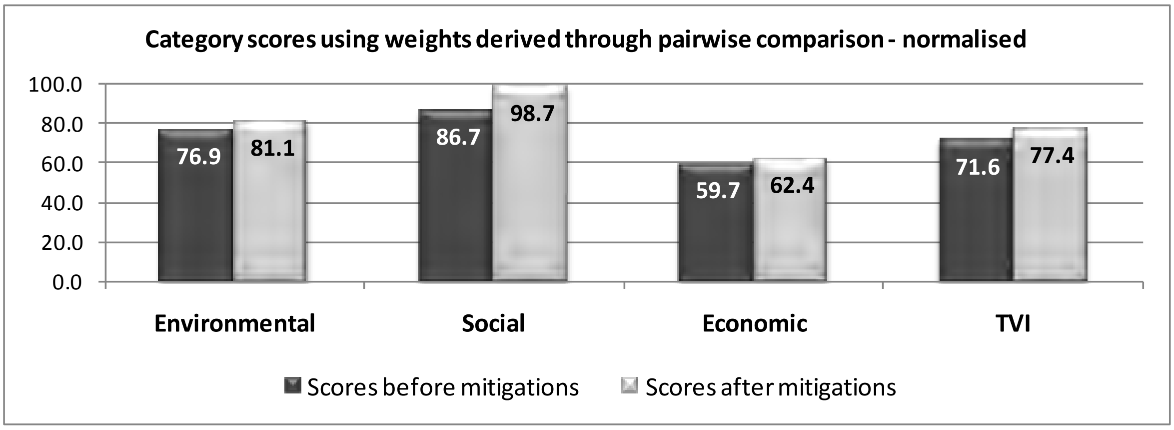

Figure 5-3: Illustration of normalised scored for the CSP project – pairwise comparison

b. Results derived using weights obtained through direct weighting

The following set of tables and figures provides the results of the TVI calculation for the CSP project using weights derived through the direct weighting technique. Table 5-17 illustrates the actual scores calculated for categories by multiplying the scores obtained for impacts with the respective weights and then summing up the totals. It also provides the scores of categories and dimensions taking into account the weights assigned to them by specialists. Lastly, it indicates the range – from minimum to maximum – within which the weight-adjusted scores can fall.

Table 5-17: Results derived through direct weighting

Impact	Actual values		Weight-adjusted		Range	
	Before mitigations	After mitigations	Before mitigations	After mitigations	Min	Max
Environmental	-	-	**-4.5**	**-3.8**	**-17.9**	**0.0**
Groundwater	-24.7	-24.7	-7.4	-7.4	-30.0	0.0
Ecology	-15.0	0.0	-3.8	0.0	-25.0	0.0
Avifauna - CSP plant	-51.2	-51.2	-5.1	-5.1	-10.0	0.0
Avifauna - power lines	-23.0	-23.0	-5.8	-5.8	-25.0	0.0
Avifauna - access roads	-30.0	-30.0	-3.0	-3.0	-10.0	0.0
Subtotal	-	-	-25.0	-21.3	-	-
Social	-	-	**-4.2**	**-1.9**	**-25.4**	**0.0**
Visual	-45.9	-45.7	-9.2	-9.1	-20.0	0.0
Noise	-6.0	-6.0	-1.8	-1.8	-30.0	0.0
Quality of life	-7.9	12.2	-2.8	4.3	-35.0	0.0
Demographic changes	-18.9	-6.8	-2.8	-1.0	-15.0	0.0
Subtotal	-	-	-16.6	-7.7	-	-
Economic	-	-	**5.5**	**6.0**	**-28.4**	**28.4**
Employment	70.0	34.8	21.0	10.4	0.0	30.0

Impact	Actual values		Weight-adjusted		Range	
	Before mitigations	After mitigations	Before mitigations	After mitigations	Min	Max
Tourism	7.5	21.0	1.5	4.2	0.0	20.0
Infrastructure	-18.0	-5.5	-4.5	-1.4	-25.0	0.0
Service delivery	-33.0	-10.5	-8.3	-2.6	-25.0	0.0
Subtotal	-	-	9.8	10.6	-	-
TOTAL VALUE INDEX	**-**	**-**	**-3.2**	**0.3**	**-71.6**	**28.4**

Given the weights derived through direct weighting, it can be concluded that the TVI for the CSP project before mitigations is a negative 3.2. At the same time, the environmental dimension had the biggest negative score, although the social dimension's negative score trailed slightly behind it. The economic dimension received a positive score of 5.5. These scores coincide with the trend observed with results calculated by using weights derived through pairwise comparison.

Within the environmental dimension, the CSP plant's impacts on avifauna have been identified as the category with the largest negative score. Given the weights assigned to the categories, however, it appears that the most significant category among the environmental dimension is groundwater. This is the same as was the case with the results observed with respect to scores derived using pairwise comparison weights. The environmental category with the second highest negative score, taking cognisance of the weights, is the category including impacts on avifauna from power lines. It is important to note that this is also the second rated most significant impact identified using the pairwise comparison technique.

Among the social dimension, the category of impacts that had the largest contribution to the final score of the same dimension was visual. It was also the most significant category before adjustment of the weights. The category with the second largest negative score was quality of life. Importantly, the top two contributors to the negative score of the social dimension derived through direct weighting were the same top contributors to the score of the same dimension derived using pairwise comparison weights. As far as the economic dimension is concerned, the employment category received the highest positive score while the service delivery category received the highest negative score.

The introduction of mitigation measures is expected to improve the TVI of the CSP project to such an extent that its trade-offs result in an overall positive impact. Thus, when compared to the "no-go option", the CSP project with mitigation measures appears to be a preferred option. Importantly, the lower positive score for the employment category for the case after mitigation did not prevent the CSP project from scoring a positive TVI, as was the case when scores were derived using pairwise comparison weights. The following figure illustrates the scores of dimensions and the TVI calculated using the weights derived through direct weighting.

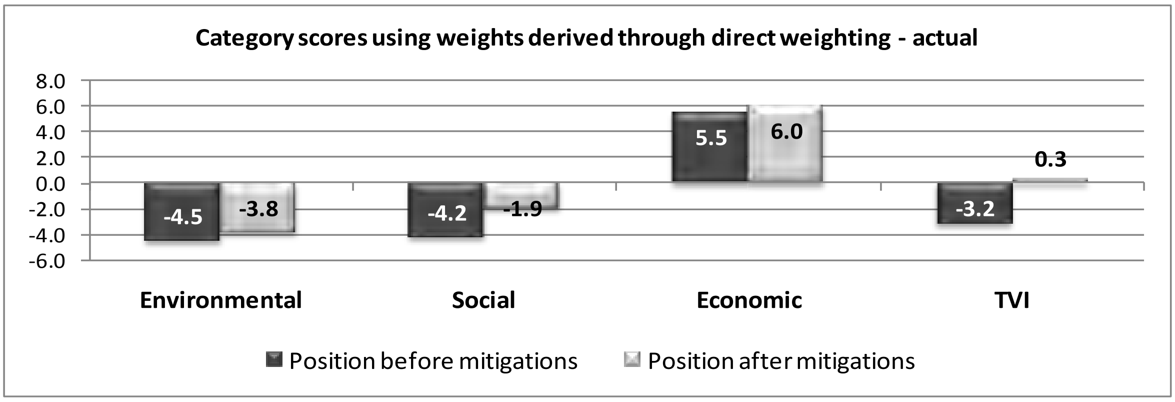

Figure 5-4: Illustration of weight-adjusted scores for the CSP project – direct weighting

The normalised values of scores obtained using the weights derived through direct weighting are shown in Table 5-19 and Figure 5-5. They show a similar dynamic as with the normalised scores calculated for the results obtained using pairwise comparison weights: The social dimension appears to have the value closest to its possible maximum scores, while the economic dimension, theoretically, has the largest scope for mitigation.

Table 5-18: Normalised scores of values derived through direct weighting

Dimension	Weight adjusted		Range		Normalised	
	Before mitigations	After mitigations	Min	Max	Before mitigations	After mitigations
Environmental	-4.5	-3.8	-17.9	0.0	75.0	78.7
Social	-4.2	-1.9	-25.4	0.0	83.4	92.3
Economic	5.5	6.0	-28.4	28.4	59.8	60.6
TVI	-3.2	0.3	-71.6	28.4	68.5	71.9

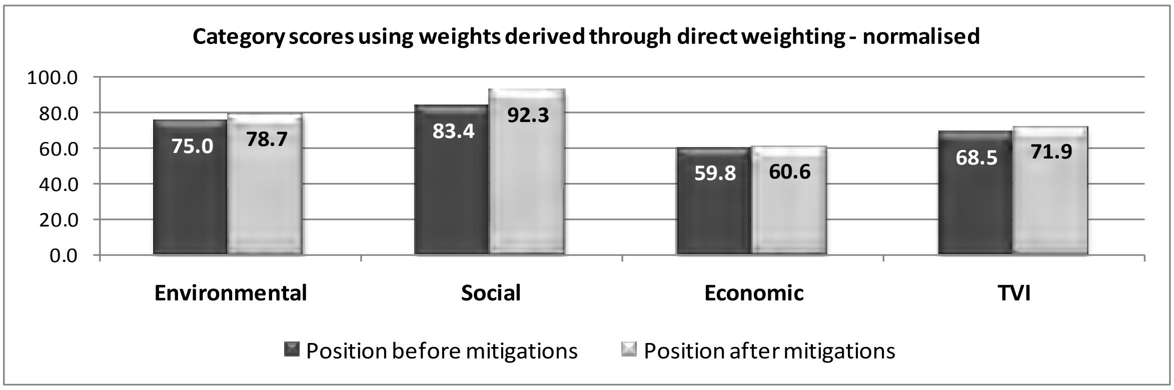

Figure 5-5: Illustration of normalised scored for the CSP project – direct weighting

c. Comparison of results derived through pairwise comparison and direct weighting

The following table compares the actual and normalised TVIs for CSP project between those obtained using pairwise comparison weights and those that applied the weights derived through direct weighting. The purpose of this exercise was to determine the extent by which the two different weight derivation techniques produced different results.

Table 5-19: Normalisation of TVIs for comparison purposes

Weighting method	Actual values		Normalised values (0-100)	
	Before	After	Before	After
TVI based on pairwise comparison	-6.8	-1.0	71.6	77.4
TVI based on direct weighting	-3.2	0.3	68.5	71.9

Figure 5-6 illustrates the information presented in Table 5-19.

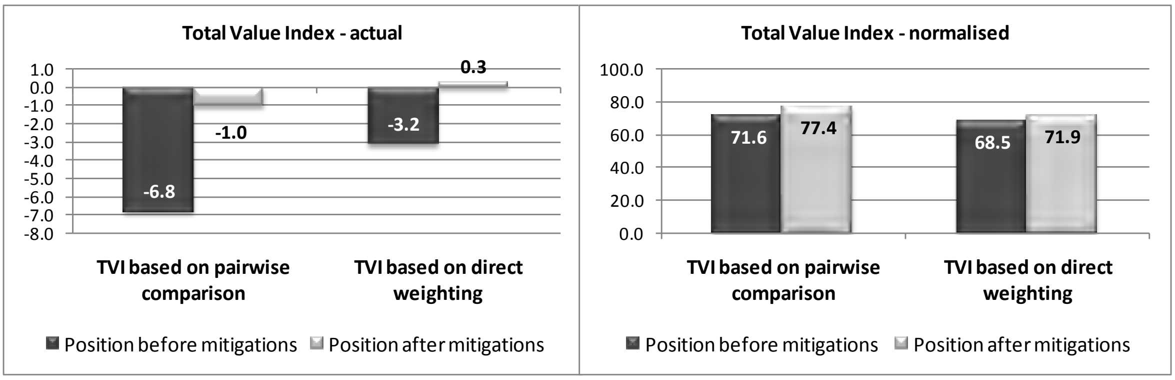

Figure 5-6: Comparison of TVIs for the CSP project

As indicated in Table 5-19 and illustrated further in Figure 5-6, the TVIs before mitigations for both cases differ. It appears that the TVI derived using weights obtained through direct weighting initially had a lower negative score before mitigations. It also had a better score for the case after mitigations. When normalised values are compared, however, the situation is reversed – scores calculated using pairwise comparison weights show a higher normalised value than scores obtained through application of the direct weighting technique. The differences between the scores in both cases are relatively small, though, and do not point to any fatal flaws or significant drawbacks of the project.

d. Comparison of results with recommendations made by the EAP in the EIA report

The result of the proposed framework application on the CSP project indicated that the project bears a greater negative impact than a positive impact before mitigations. If mitigation measures are introduced this negative impact will be significantly reduced and possibly be balanced out by the positive impact associated with the project. The results suggest that there are no significant issues that could prevent the project from being implemented, which corresponds to the recommendations made by the EAP in the assessment report:

"The findings of the specialist studies undertaken within this EIA provide an assessment of both the benefits and potential negative impacts anticipated as a result of the proposed project. The findings conclude that there are no environmental fatal flaws that should prevent the proposed project from proceeding, provided that the recommended mitigation and management measures are implemented." (Bohlweki Environmental, 2006)

5.1.7 Sensitivity analysis

The sensitivity analysis is an important component of any model development process as it provides a way to identify the parameters that have the greatest impact on the final decision. It is important to note that the most critical criteria or criterion that has the highest impact on the results of the model is not necessarily the one that has the highest weight. The most critical criterion is defined as the one that shows the largest degree of impact on the final score given the smallest change. Table 5-20 presents the results of the sensitivity analysis conducted for weights derived through pairwise comparison. They show the net TVI calculated as a result of increasing the weight by 5% of the respective category or dimension.

Table 5-20: Sensitivity analysis for weights derived through pairwise comparison

Impact	Before mitigation			After mitigations		
	New TVI	TVI % change	Rank	New TVI	TVI % change	Rank
Environmental	**-7.99**	**17%**	**2**	**-1.93**	**96%**	**1**
Groundwater	-7.09	4%	8	-1.25	27%	8
Ecology	-6.99	2%	14	-0.99	0%	16
Avifauna - CSP plant	-7.39	8%	6	-1.54	57%	4
Avifauna - power lines	-7.08	4%	10	-1.23	25%	9
Avifauna - access roads	-7.16	5%	7	-1.31	33%	7
Social	**-7.49**	**10%**	**5**	**-1.05**	**7%**	**15**
Visual	-7.52	10%	4	-1.68	70%	2
Noise	-6.93	2%	16	-1.09	11%	13
Quality of life	-6.95	2%	15	-0.80	-19%	11
Demographic changes	-7.06	3%	11	-1.09	11%	12
Economic	**-6.60**	**-3%**	**12**	**-0.62**	**-37%**	**6**
Employment	-5.52	-19%	1	-0.43	-57%	3
Tourism	-6.65	-3%	13	-0.43	-56%	5
Infrastructure	-7.08	4%	9	-1.07	8%	14
Service delivery	-7.86	15%	3	-1.20	21%	10

The first conclusion that can be made by analysing the information presented in the table is that the sensitivity of the model differs for the cases before and after mitigations. In the situation when mitigations had not yet been introduced, the results of the model based on the pairwise comparison weights are most sensitive to the changes of weights of such categories as employment and service delivery, as well as to the changes in weights of the environmental dimension. The social dimension and the visual category are also relatively sensitive to changes in weights: a 5% increase in their weights results in a 10% increase of the TVI (in a negative way).

For the case after mitigations, the sensitivity of all categories changes and in many cases they become much more sensitive. This is particularly relevant to the environmental dimension, which showed that a 5% increase of its weight results in the TVI for the project nearly doubling (in a negative way). Categories that are most sensitive to changes in weights – with the change results in 50% to 70% change in the score one way or the other – include visual, employment, tourism, and avifauna-CSP plant.

It has been observed that among the top five most sensitive categories and dimensions three appear in both cases – before and after mitigation. These are the environmental dimension, the visual category, and the employment category. Interestingly, the employment and visual categories are considered to be the greatest contributors to the scores of the respective dimension, while the environmental dimension has the greatest contribution to the TVI. The following table provides the results of the sensitivity analysis for the weights derived through the direct weighting technique.

Table 5-21: Sensitivity analysis for weights derived through direct weighting

Impact	Before mitigation			After mitigations		
	New TVI	TVI % change	Rank	New TVI	TVI % change	Rank
Environmental	**-4.41**	**40%**	**2**	**-0.80**	**-398%**	**1**
Groundwater	-3.38	7%	11	0.05	83%	10
Ecology	-3.30	4%	14	0.27	0%	16
Avifauna - CSP plant	-3.62	15%	8	-0.19	172%	6
Avifauna - power lines	-3.37	7%	13	0.06	77%	11
Avifauna - access roads	-3.43	9%	9	0.00	101%	9
Social	**-3.99**	**26%**	**4**	**-0.12**	**143%**	**7**
Visual	-3.75	18%	5	-0.31	217%	4
Noise	-3.24	2%	16	0.19	28%	15
Quality of life	-3.26	3%	15	0.42	-58%	13
Demographic changes	-3.40	8%	10	0.18	32%	14

Impact	Before mitigation			After mitigations		
	New TVI	TVI % change	Rank	New TVI	TVI % change	Rank
Economic	**-2.68**	**-15%**	**7**	**0.80**	**-199%**	**5**
Employment	-1.18	-63%	1	1.25	-369%	2
Tourism	-2.95	-7%	12	0.86	-223%	3
Infrastructure	-3.67	16%	6	0.11	58%	12
Service delivery	-4.10	30%	3	-0.03	111%	8

For weights identified through direct weighting, the most sensitive items to weight change in the case before mitigations include the employment category, the environmental dimension and the service delivery category. These are exactly the same as in the case of the weights calculated using the pairwise comparison technique. As for the case after mitigations, the most sensitive item include the environmental dimension, the employment category, and the tourism category. The first two are also in the top three most sensitive items for weights derived through pairwise comparison.

Finally, the TVI sensitivity to changes in weights for the case after mitigation increases considerably as shown in the table. In some cases, a 5% increase in the weight leads to a decline in the TVI by four times (e.g.: change of the environmental dimension weight) or increase of the TVI by more than three times (e.g.: change of weight of the employment category). As in the case with the weights derived through pairwise comparison, three out of five most sensitive items appear to be the same in cases before and after mitigation. These include the environmental dimension, the employment category, and the visual category.

5.2 Case study 2: OCGT

The following sections provide the results of the proposed framework application on the OCGT project. Unlike the first case study, this case study includes a number of alternatives for the components of the project aside from the "no-go option". These alternatives will allow the illustration of the framework's application specifically in the cases of multiple options.

5.2.1 Value tree

Figure 5-7 illustrates the value tree for the OCGT project. It shows that the project comprised four different components, for which numerous alternatives have been considered:

- The power plan only had the alternatives of a "no-go option";
- The transmission line had three alternative paths and a "no-go option";
- The access road had three alternatives paths and a "no-go option"; and lastly
- The fuel supply line had two alternative paths and a "no-go option".

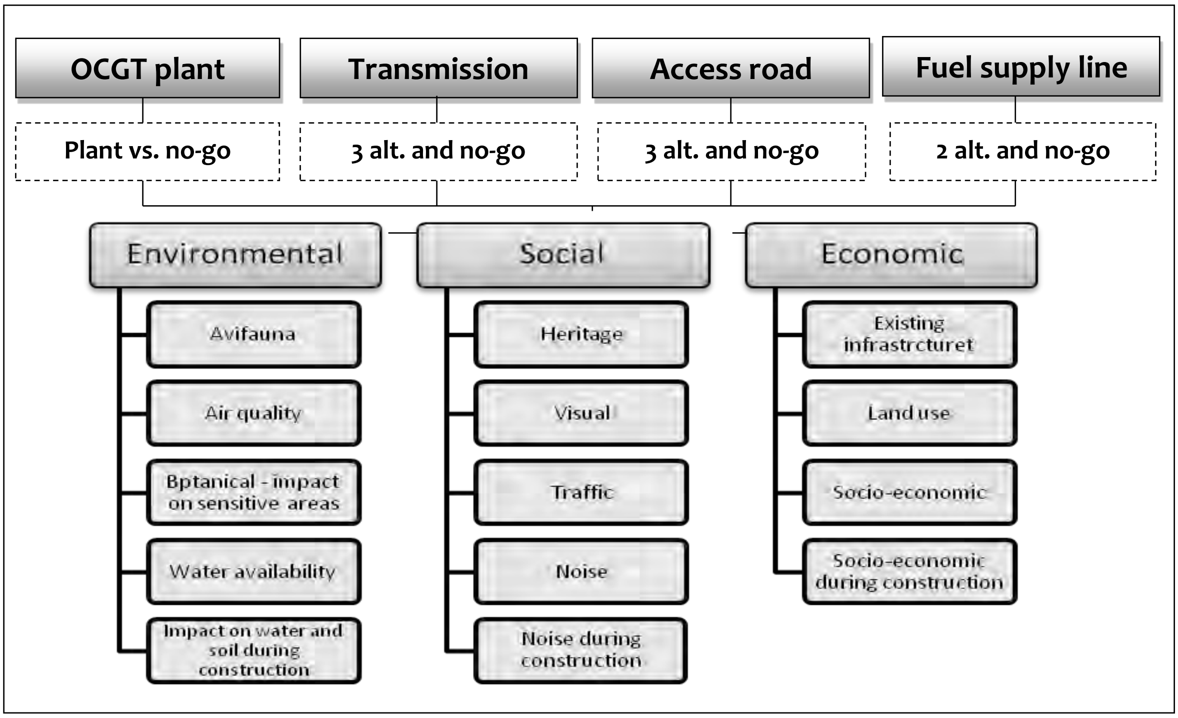

Figure 5-7: OCGT value tree

The OCGT project, unlike the CSP project, had two levels of evaluation – categories and dimensions. This means that no separate impacts were identified in the OCGT project and that the evaluation was done of the respective categories. The components and their alternatives were evaluated, where applicable, in terms of avifauna, air quality, botanical, water availability, impact on water and soil during construction, heritage, visual, traffic, noise, existing infrastructure, land use, and socio-economic aspects. As in the case of the CSP, all these categories have been grouped in terms of environmental, social, and economic dimensions. The environmental and social dimensions encompassed five categories each and the economic dimension included four categories.

5.2.2 Performance matrix

The OCGT project did not have specific impacts identified under each category and rather included evaluation of all alternatives in terms of their impact on the specified categories in general. Thus, to develop the performance matrix a complete list of ratings of categories was obtained including the specifications of the significance of impacts of the alternatives and probabilities of these impacts to occur. The table including the scores of significance and probabilities as specified by the specialists during the study is provided in Annexure I: OCGT Impact Rating. Both before and after mitigations tables are included in the Annexure. Using the provided rating information and the assumptions outlined in section 3.4 under Scoring, two performance matrices were developed: One showing the results before mitigations and one including the performance information after mitigations. These two matrices are provided in Annexure J: OCGT Performance Matrices.

5.2.3 Categories weights elicitation

Table 5-22 presents the results of weight elicitation following the pairwise comparison and direct weighting techniques. The weight elicitation of categories was undertaken by the Environmental Assessment Practitioner, who was involved in the compilation of the Environmental Impact Assessment Report for the OCGT project.

Table 5-22: Weights for OCGT categories

Impact	Pairwise comparison	Direct weight
Category - Environmental		
Botanical - impact on sensitive areas	7.0%	10.0%
Avifauna	3.0%	10.0%
Air quality	56.2%	30.0%
Water availability	26.9%	30.0%
Water and soil during construction	7.0%	20.0%
Category - Social		
Heritage	4.5%	10.0%
Visual	11.4%	20.0%
Traffic	3.3%	10.0%
Noise	40.4%	30.0%
Noise during construction	40.4%	30.0%
Category - Economic		
Existing infrastructure	6.7%	10.0%
Land use	6.7%	10.0%
Socio-Economic	25.7%	40.0%
Socio-Economic during construction	60.9%	40.0%

A review of the results of the pairwise comparison technique application suggests that the most important category of impacts within the environmental dimension was air quality, followed by water availability. Importantly, the EAP considered the air quality category to have a considerably bigger importance in the decision-making compared to the other categories of the dimension. Together, air quality and water availability accounted for more than three quarters of the total weight assigned for the environmental categories.

In terms of the social dimension, the most important categories for decision-making were noise and noise during construction. Together these two categories accounted for more than 80% of weights assigned to categories of this dimension. The least important category of impacts for decision-making was traffic. Within the economic dimension, the category of socio-economic impacts during construction category received the highest decision-making value, followed by social-economic impact in general. The other two categories of the economic dimension – existing infrastructure and land use – received 6.7% each.

The weight elicitation through direct weighting showed relatively the same trend, i.e. categories that received the largest decision-making significance as per direct weighting were the same categories that obtained the largest weights through pairwise comparison:

- Within the environmental dimension, air quality and water availability received the largest weights; although they were considered to be equally important as opposed to the pairwise comparison results that assigned higher importance to air quality;
- Within the social dimension, noise and noise during construction were assigned 30% each through direct weighting, while the visual category received 20%;
- Within the economic dimension, the most significant categories for decision-making were socio-economic and socio-economic during construction, which were also treated as equally important.

5.2.4 Dimensions' weights elicitation

Table 5-23 provides the results of the dimensions' weight elicitation exercise for the OCGT case study. Both the application of pairwise comparison and direct weighting techniques resulted in the economic dimension being assigned a higher decision importance among dimensions. At the same time, though, this dimension received a slightly higher weight through the direct weighting technique than through the pairwise comparison method. The second most important dimension for decision-making, as indicated by 30.2% and 24.5%, respectively, was the social dimension. The environmental dimension received the lowest weight in applications of both techniques.

Table 5-23: Weights for OCGT dimensions

Impacts	Pairwise comparison	Direct weighting
Environmental	21.8%	17.3%
Social	30.2%	24.5%
Economic	48.0%	54.8%

5.2.5 Plant: results and sensitivity analysis

The OCGT case study, as was mentioned in the previous chapter, involved an analysis of alternatives for different components of the project, including a plant, access road, transmission lines, and fuel pipelines. The analysis of the framework application results and sensitivity assessment is therefore broken down per component. This section, in particular, focuses on the review of the results for the plant component.

a. Results

Table 5-24 provides Total Value Indices for the plant components for cases before and after mitigations using both the pairwise comparison and direct weighting techniques.

Table 5-24: Results for the plant component

Impacts	Weight-adjusted – pairwise comparison		Weight adjusted – direct weighting	
	Before	After	Before	After
Environmental	**-4.35**	**-1.97**	**-3.68**	**-0.99**
Botanical - impact on sensitive areas	-6.97	-0.09	-10.00	-0.13
Avifauna	0.00	0.00	0.00	0.00
Air quality	-8.43	-8.43	-4.50	-4.50
Water availability	-4.03	-0.34	-4.50	-0.38
Water and soil during construction	-0.53	-0.18	-1.50	-0.50
Subtotal	-19.95	-9.03	-20.50	-5.50
Social	**-8.78**	**-3.19**	**-6.97**	**-2.36**
Heritage	-0.10	-0.03	-0.23	-0.08
Visual	-5.72	-1.43	-10.00	-2.50
Traffic	0.00	0.00	0.00	0.00
Noise	-20.20	-6.06	-15.00	-4.50
Noise during construction	-3.03	-3.03	-2.25	-2.25
Subtotal	-29.05	-10.55	-27.48	-9.33
Economic	**12.07**	**12.07**	**19.85**	**19.85**
Existing infrastructure	0.00	0.00	0.00	0.00
Land use	0.00	0.00	0.00	0.00
Socio-Economic	20.58	20.58	32.00	32.00
Socio-Economic during construction	4.57	4.57	3.00	3.00
Subtotal	25.15	25.15	35.00	35.00
TOTAL VALUE INDEX	**-1.05**	**6.92**	**9.20**	**16.50**

The results of the framework application using weights derived through pairwise comparison show that the plant component's TVI before mitigation is a negative 1.05 points. Both environmental and social dimensions received a negative rating, although the plant appears to have a greater negative impact on the social dimension than on the environmental dimension. Furthermore, the most significant negative impact of the plant component is noise. The TVI before mitigation, however, is expected to reduce significantly with the introduction of mitigation measures and even achieve a positive score. This means that positive impacts of the project's plant component associated with the economic dimension will supersede negative impacts that the plant is expected to produce.

The economic dimension scored 12.07 positive points before and after mitigations, which suggests that none of the mitigation measures for the economic dimension have the potential to increase the benefit of the project. This also means that the proposed mitigation measures for the environmental and social dimensions are expected to have a significant contribution towards reducing the negative impacts of the plant on social and environmental categories. To be more precise, impacts associated with water availability, noise, visual appearance, and sensitive areas could be significantly mitigated.

The TVIs received using weights derived through direct weighting are expected to be positive in both cases – before and after mitigations. This could be attributed to the fact that the economic dimension received a slightly greater weight through the direct weighting technique application than in the case of the pairwise comparison technique applications. Otherwise, scores obtained using weights acquired from direct weighting show a similar pattern to scores received using weights derived through pairwise comparison:

- Scores for the economic dimension before and after mitigation do not change;
- The social dimension has a greater negative score than the environmental dimension;
- Within the social dimension, the noise category followed by the visual category were associated with the greatest negative impact; while the greatest negative impact in the environmental dimension was associated with sensitive areas;
- Noise, visual and botanical categories can be mitigated with a noticeable drop in their negative scores.

The following table shows the TVI's before and after normalisation. Normalisation is useful when comparing the results of direct weighting and pairwise comparison weights application. It is clear that while the actual values received by the plant component using weights derived through both weighting techniques differ noticeably, their normalised scores vary only marginally.

Table 5-25: Plant's TVIs – actual and normalised

Weighting method	Actual values		Range		Normalised values (0-100)	
	Before	After	Min	Max	Before	After
TVI based on pairwise comparison	-1.05	6.92	-50.37	41.58	53.64	62.30
TVI based on direct weighting	9.20	16.50	-38.96	45.37	57.12	65.77

b. Comparison of results with recommendations made by the EAP in the EIA report

The results obtained using the framework suggest that if mitigation measures are introduced its negative effects will be minimised and the overall positive impact of the project increased. Thus, there would be no reasons preventing the project from being implemented. These results coincide with the recommendations proposed by the EAP in the Environmental Impact Assessment Report. The following was suggested by the EAP:

"As far as visual and botanical impacts are concerned, it is recommended that the site should be located as close to the PetroSA facility as possible, while remaining outside of the identified botanically sensitive areas. Although the impact of noise appears not to be significantly greater than the ambient, by situating the plant as distant as possible from the adjacent rural boundaries to the north and west, the noise regulations can be complied with. Accordingly, the site should be located as far to the south east as possible, without impinging on PetroSA's current and possible future options." (Ninham Shand, 2005b)

c. Sensitivity analysis

The following tables present the results of the sensitivity analysis for weights derived using both techniques.

Table 5-26: Sensitivity analysis for pairwise comparison weights – plant

Impact	Before mitigation			After mitigations		
	New TVI	TVI % change	Rank	New TVI	TVI % change	Rank
Environmental	-2.05	94.9%	5	6.47	-6.5%	4
Botanical - impact on sens. areas	-2.14	103.6%	4	6.90	-0.2%	11
Avifauna	-1.05	0.0%	12	6.92	0.0%	12
Air quality	-1.21	15.5%	8	6.75	-2.4%	8
Water availability	-1.21	15.5%	8	6.90	-0.2%	11
Water and soil during constr.	-1.13	7.8%	10	6.89	-0.4%	10
Social	-2.50	138.2%	2	6.39	-7.6%	3
Heritage	-1.09	3.2%	11	6.91	-0.2%	11
Visual	-1.81	71.9%	6	6.73	-2.7%	6

Impact	Before mitigation			After mitigations		
	New TVI	TVI % change	Rank	New TVI	TVI % change	Rank
Traffic	-1.05	0.0%	12	6.92	0.0%	12
Noise	-1.81	71.9%	6	6.69	-3.3%	5
Noise during construction	-1.16	10.8%	9	6.80	-1.6%	9
Economic	0.21	-119.6%	3	8.17	18.2%	2
Existing infrastructure	-1.05	0.0%	12	6.92	0.0%	12
Land use	-1.05	0.0%	12	6.92	0.0%	12
Socio-Economic	0.87	-182.6%	1	8.84	27.8%	1
Socio-Economic during constr.	-0.87	-17.1%	7	7.10	2.6%	7

Based on the information presented in Table 5-26, the categories most sensitive to weight adjustments include the botanical and socio-economic categories. It appears that all dimensions are highly sensitive to weight adjustments in both cases – before and after mitigations. The increase of weights for the social and economic dimensions could result in a significant increase of their negative scores and subsequently the worsening of the TVI. On the other hand, the allocation of a higher weight to the economic dimension would lead to an increase of the economic dimension score, and as a result, a better TVI.

Table 5-27 provides the sensitivity analysis results for weights derived using direct weighting. The most sensitive categories and dimensions in the case of weights derived through direct weighting are largely the same as in the case of the pairwise comparison weight derivation technique. The change is also expected to have the same effect as the change in the case of using pairwise comparison weights.

Table 5-27: Sensitivity analysis for direct weighting weights – plant

Impact	Before mitigation			After mitigations		
	New TVI	TVI % change	Rank	New TVI	TVI % change	Rank
Environmental	8.18	97.5%	4	16.22	-4.0%	4
Botanical - impact on sens. areas	8.31	85.3%	5	16.49	-0.2%	11
Avifauna	9.20	0.0%	12	16.50	0.0%	13
Air quality	9.07	12.8%	8	16.36	-1.9%	8
Water availability	9.07	12.8%	8	16.49	-0.2%	11
Water and soil during constr.	9.14	6.4%	10	16.47	-0.3%	19
Social	7.83	130.7%	3	16.03	-6.7%	3
Heritage	9.18	2.7%	11	16.49	-0.1%	12
Visual	8.57	60.3%	6	16.34	-2.3%	7
Traffic	9.20	0.0%	12	16.50	0.0%	13
Noise	8.57	60.3%	6	16.31	-2.7%	6

Impact	Before mitigation			After mitigations		
	New TVI	TVI % change	Rank	New TVI	TVI % change	Rank
Noise during constr.	9.11	9.0%	9	16.40	-1.4%	9
Economic	10.95	-166.5%	2	18.25	25.3%	2
Existing infrastructure	9.20	0.0%	12	16.50	0.0%	13
Land use	9.20	0.0%	12	16.50	0.0%	13
Socio-Economic	11.47	-215.8%	1	18.76	32.8%	1
Socio-Economic during constr.	9.42	-20.2%	7	16.71	3.1%	5

5.2.6 Transmission lines: results and sensitivity analysis

The following sections provide the results of the framework applied to the transmission lines components of the OCGT project.

a. Results

Table 5-28 lists the TVIs for the three alternatives proposed for the project's transmission lines using pairwise comparison weights.

Table 5-28: Results using pairwise comparison weights – transmission lines

Impacts	Before mitigations			After mitigations		
	Alt 1	Alt 2	Alt 3	Alt 1	Alt 2	Alt 3
Environmental	**-1.03**	**-0.50**	**-1.03**	**-0.28**	**-0.14**	**-0.28**
Botanical - impact on sens. aeas	-3.48	-1.39	-3.48	-0.87	-0.26	-0.87
Avifauna	-0.74	-0.36	-0.74	-0.22	-0.22	-0.22
Air quality	0.00	0.00	0.00	0.00	0.00	0.00
Water availability	0.00	0.00	0.00	0.00	0.00	0.00
Water and soil during constr.	-0.53	-0.53	-0.53	-0.18	-0.18	-0.18
Subtotal	-4.75	-2.28	-4.75	-1.27	-0.66	-1.27
Social	**-2.33**	**-1.81**	**-2.33**	**-1.70**	**-1.18**	**-1.70**
Heritage	-0.10	-0.10	-0.10	-0.03	-0.03	-0.03
Visual	-4.58	-2.86	-4.58	-4.58	-2.86	-4.58
Traffic	0.00	0.00	0.00	0.00	0.00	0.00
Noise	0.00	0.00	0.00	0.00	0.00	0.00
Noise during construction	-3.03	-3.03	-3.03	-1.01	-1.01	-1.01
Subtotal	-7.71	-5.99	-7.71	-5.62	-3.90	-5.62
Economic	**11.71**	**11.15**	**11.71**	**11.79**	**11.79**	**11.79**
Existing infrastructure	-0.25	-0.25	-0.25	-0.08	-0.08	-0.08
Land use	-0.50	-1.67	-0.50	-0.50	-0.50	-0.50
Socio-Economic	20.58	20.58	20.58	20.58	20.58	20.58
Socio-Economic during constr.	4.57	4.57	4.57	4.57	4.57	4.57
Subtotal	24.40	23.23	24.40	24.57	24.57	24.57

Impacts	Before mitigations			After mitigations		
	Alt 1	Alt 2	Alt 3	Alt 1	Alt 2	Alt 3
TOTAL VALUE INDEX	8.35	8.84	8.35	9.82	10.47	9.82
Ranking	2	1	2	2	1	2

Based on the information provided in the table above, it can be concluded that the transmission lines, regardless of the alternative chosen, would have an overall positive impact. The social and environmental dimensions both received negative scores for all alternatives. However, Alternatives 1 and 3 had a greater negative impact on the social dimension and environmental dimensions than Alternative 2. Although Alternative 3 had a slightly smaller positive impact on the economic dimension, the fact that its overall negative score was lower resulted in it being chosen as the preferred alternative. The introduction of mitigation measures is not expected to have an influence on the ranking of alternatives, but it will reduced negative impacts associated with the transmission lines, particularly with respect to such categories as botanical, avifauna, and noise during construction.

Table 5-29 shows the TVIs for the transmission lines using weights deriving through direct weighting. The results seem to coincide with the results of the pairwise comparison weights application. The second alternative comes up as the preferred option. Moreover, the scores of the same categories of impacts are expected to benefit from mitigation measures as in the case of the pairwise comparison weights application.

Table 5-29: Results using direct weighting weights – transmission lines

Impacts	Before mitigations			After mitigations		
	Alt 1	Alt 2	Alt 3	Alt 1	Alt 2	Alt 3
Environmental	**-1.61**	**-0.84**	**-1.61**	**-0.45**	**-0.29**	**-0.45**
Botanical - impact on sens. areas	-5.00	-2.00	-5.00	-1.25	-0.38	-1.25
Avifauna	-2.50	-1.20	-2.50	-0.75	-0.75	-0.75
Air quality	0.00	0.00	0.00	0.00	0.00	0.00
Water availability	0.00	0.00	0.00	0.00	0.00	0.00
Water and soil during constr.	-1.50	-1.50	-1.50	-0.50	-0.50	-0.50
Subtotal	-9.00	-4.70	-9.00	-2.50	-1.63	-2.50
Social	**-2.66**	**-1.90**	**-2.66**	**-2.24**	**-1.48**	**-2.24**
Heritage	-0.23	-0.23	-0.23	-0.08	-0.08	-0.08
Visual	-8.00	-5.00	-8.00	-8.00	-5.00	-8.00
Traffic	0.00	0.00	0.00	0.00	0.00	0.00
Noise	0.00	0.00	0.00	0.00	0.00	0.00
Noise during construction	-2.25	-2.25	-2.25	-0.75	-0.75	-0.75
Subtotal	-10.48	-7.48	-10.48	-8.83	-5.83	-8.83

Impacts	Before mitigations			After mitigations		
	Alt 1	Alt 2	Alt 3	Alt 1	Alt 2	Alt 3
Economic	**19.21**	**18.22**	**19.21**	**19.35**	**19.35**	**19.35**
Existing infrastructure	-0.38	-0.38	-0.38	-0.13	-0.13	-0.13
Land use	-0.75	-2.50	-0.75	-0.75	-0.75	-0.75
Socio-Economic	32.00	32.00	32.00	32.00	32.00	32.00
Socio-Economic during constr.	3.00	3.00	3.00	3.00	3.00	3.00
Subtotal	33.88	32.13	33.88	34.13	34.13	34.13
TOTAL VALUE INDEX	**14.94**	**15.48**	**14.94**	**16.67**	**17.58**	**16.67**
Ranking	**2**	**1**	**2**	**2**	**1**	**2**

The outcome of the normalisation exercise applied to the actual TVIs derived using both weighting techniques is provided in Table 5-30. The normalised scores show that the use of weights derived through direct weighting results in greater TVIs for alternatives and cases. Importantly, it does not have an impact on the ratings of alternatives amongst each other.

Table 5-30: Transmission lines' TVIs – actual and normalised

Item	Alt 1	Alt 2	Alt 3	Alt 1	Alt 2	Alt 3
Actual score	**Before mitigations**			**After mitigations**		
TVI based on PC	8.35	8.84	8.35	9.82	10.47	9.82
TVI based on DW	14.94	15.48	14.94	16.67	17.58	16.67
Min-max range	**Min**			**Max**		
TVI based on PC	-27.14	-27.14	-27.14	41.58	41.58	41.58
TVI based on DW	-33.73	-33.73	-33.73	45.37	45.37	45.37
Normalised score (0-100)	**Before mitigations**			**After mitigations**		
TVI based on PC	51.64	52.36	51.64	53.78	54.73	53.78
Ranking	2	1	2	2	1	2
TVI based on DW	61.53	62.21	61.53	63.71	64.87	63.71
Ranking	2	1	2	2	1	2

b. <u>Comparison of results with recommendations made by the EAP in the EIA report</u>

The results of the framework for the transmission lines component of the project suggest that there are neither fatal flaws nor major negative effects that could prevent this component from being implemented in the proposed area. Moreover, it is recommended that the 2nd alternative is given the preference. This recommendation coincides with the suggestions made by the EAP:

"In terms of floral, avifaunal and visual impacts, the central route option (Alternative 2) is likely to have the least environmental impact. While it may not be the preferred route from a landowner perspective and has implications for agricultural activity, adequate compensation and sensitive route alignment and tower placement would do much to alleviate landowner concerns." (Ninham Shand, 2005b)

c. Sensitivity analysis

Table 5-31 provides the results of the sensitivity analysis. However, unlike with the sensitivity analyses' results presented earlier in the thesis when the most sensitive categories were presented, this table shows the impact of changes made to weights on the ranking of alternatives. It is clear that changes to weights, regardless of the set, do not result in the change of rankings. Thus, it can be concluded that categories and dimensions are not sensitive enough to small (5% or less) weight derivations.

Table 5-31: Alternatives' rankings after the change of weights – transmission lines

Impacts	Before mitigations			After mitigations		
	Alt 1	Alt 2	Alt 3	Alt 1	Alt 2	Alt 3
Pairwise comparison weights						
Environmental	2	1	2	2	1	1
Botanical - impact on sens. areas	2	1	2	2	1	1
Avifauna	2	1	2	2	1	1
Air quality	2	1	2	2	1	1
Water availability	2	1	2	2	1	1
Water and soil during constr.	2	1	2	2	1	1
Social	2	1	2	2	1	1
Heritage	2	1	2	2	1	1
Visual	2	1	2	2	1	1
Traffic	2	1	2	2	1	1
Noise	2	1	2	2	1	1
Noise during construction	2	1	2	2	1	1
Economic	2	1	2	2	1	1
Existing infrastructure	2	1	2	2	1	1
Land use	2	1	2	2	1	1
Socio-Economic	2	1	2	2	1	1
Socio-Economic during constr.	2	1	2	2	1	1
Direct weighting weights						
Environmental	2	1	2	2	1	1
Botanical - impact on sens. areas	2	1	2	2	1	1
Avifauna	2	1	2	2	1	1
Air quality	2	1	2	2	1	1
Water availability	2	1	2	2	1	1
Water and soil during constr.	2	1	2	2	1	1
Subtotal	2	1	2	2	1	1
Social	2	1	2	2	1	1
Heritage	2	1	2	2	1	1
Visual	2	1	2	2	1	1
Traffic	2	1	2	2	1	1
Noise	2	1	2	2	1	1
Noise during construction	2	1	2	2	1	1
Subtotal	2	1	2	2	1	1

Impacts	Before mitigations			After mitigations		
	Alt 1	Alt 2	Alt 3	Alt 1	Alt 2	Alt 3
Economic	2	1	2	2	1	1
Existing infrastructure	2	1	2	2	1	1
Land use	2	1	2	2	1	1
Socio-Economic	2	1	2	2	1	1
Socio-Economic during constr.	2	1	2	2	1	1
Subtotal	2	1	2	2	1	1

5.2.7 Access road: results and sensitivity analysis

The following sections describe the results for the access road component of the OCGT project. They provide the TVIs and sensitivity analysis outcomes for the calculations using weights derived through pairwise comparison and direct weighting.

a. Results

The access road had three alternatives. Table 5-32 shows the results of the framework application using pairwise comparison weights for cases before and after mitigation.

Table 5-32: Results using pairwise comparison weights – access road

Impacts	Before mitigations			After mitigations		
	Alt 1	Alt 2	Alt 3	Alt 1	Alt 2	Alt 3
Environmental	**-0.17**	**-0.17**	**-0.49**	**-0.05**	**-0.05**	**-0.05**
Botanical - impact on sens. areas	-0.26	-0.26	-1.74	-0.05	-0.05	-0.05
Avifauna	0.00	0.00	0.00	0.00	0.00	0.00
Air quality	0.00	0.00	0.00	0.00	0.00	0.00
Water availability	0.00	0.00	0.00	0.00	0.00	0.00
Water and soil during constr.	-0.53	-0.53	-0.53	-0.18	-0.18	-0.18
Subtotal	-0.79	-0.79	-2.27	-0.23	-0.23	-0.23
Social	**-1.09**	**-1.11**	**-1.42**	**-0.46**	**-0.46**	**-0.78**
Heritage	-0.10	-0.10	-0.10	-0.03	-0.03	-0.03
Visual	-0.43	-0.43	-1.43	-0.43	-0.43	-1.43
Traffic	-0.04	-0.12	-0.12	-0.04	-0.04	-0.12
Noise	0.00	0.00	0.00	0.00	0.00	0.00
Noise during construction	-3.03	-3.03	-3.03	-1.01	-1.01	-1.01
Subtotal	-3.60	-3.68	-4.68	-1.51	-1.51	-2.60
Economic	**2.19**	**2.19**	**2.19**	**2.19**	**2.19**	**2.19**
Existing infrastructure	0.00	0.00	0.00	0.00	0.00	0.00
Land use	0.00	0.00	0.00	0.00	0.00	0.00
Socio-Economic	0.00	0.00	0.00	0.00	0.00	0.00
Socio-Economic during constr.	4.57	4.57	4.57	4.57	4.57	4.57
Subtotal	4.57	4.57	4.57	4.57	4.57	4.57

Impacts	Before mitigations			After mitigations		
	Alt 1	Alt 2	Alt 3	Alt 1	Alt 2	Alt 3
TOTAL VALUE INDEX	**0.93**	**0.91**	**0.28**	**1.69**	**1.69**	**1.36**
Ranking	**1**	**2**	**3**	**1**	**1**	**2**

Based on the results, it can be concluded that the access road components of the OCGT project is expected to have neither significant negative effects on the surrounding environment nor a considerable positive impact. Overall, the negative and positive impacts are expected to balance out with positive impacts slightly exceeding negative impacts. Positive impacts are expected to be the same regardless of the alternative chosen. The smallest negative impacts, however, are expected to be associated with the first alternative, thus, it is the preferred option with the Alternative 2 tracing slightly behind. The introduction of mitigation measures will have a noticeable impact on the rankings of the alternatives, as it appears that mitigation measures will make Alternative 1 and Alternative 2 equally preferred.

The same trends can be observed with respect to the TVIs calculated using weights derived through direct weighting, as is shown in Table 5-33. With respect to negative impacts, the most significant negative impacts associated with access roads are noise during construction, impact on water and soil during construction, and visual impact.

Table 5-33: Results using direct weighting weights – access road

Impacts	Before mitigations			After mitigations		
	Alt 1	Alt 2	Alt 3	Alt 1	Alt 2	Alt 3
Environmental	**-0.34**	**-0.34**	**-0.72**	**-0.10**	**-0.10**	**-0.10**
Botanical - impact on sens. areas	-0.38	-0.38	-2.50	-0.08	-0.08	-0.08
Avifauna	0.00	0.00	0.00	0.00	0.00	0.00
Air quality	0.00	0.00	0.00	0.00	0.00	0.00
Water availability	0.00	0.00	0.00	0.00	0.00	0.00
Water and soil during constr.	-1.50	-1.50	-1.50	-0.50	-0.50	-0.50
Subtotal	-1.88	-1.88	-4.00	-0.58	-0.58	-0.58
Social	**-0.85**	**-0.91**	**-1.36**	**-0.43**	**-0.43**	**-0.94**
Heritage	-0.23	-0.23	-0.23	-0.08	-0.08	-0.08
Visual	-0.75	-0.75	-2.50	-0.75	-0.75	-2.50
Traffic	-0.13	-0.38	-0.38	-0.13	-0.13	-0.38
Noise	0.00	0.00	0.00	0.00	0.00	0.00
Noise during construction	-2.25	-2.25	-2.25	-0.75	-0.75	-0.75
Subtotal	-3.35	-3.60	-5.35	-1.70	-1.70	-3.70
Economic	**1.70**	**1.70**	**1.70**	**1.70**	**1.70**	**1.70**
Existing infrastructure	0.00	0.00	0.00	0.00	0.00	0.00
Land use	0.00	0.00	0.00	0.00	0.00	0.00

Impacts	Before mitigations			After mitigations		
	Alt 1	Alt 2	Alt 3	Alt 1	Alt 2	Alt 3
Socio-Economic	0.00	0.00	0.00	0.00	0.00	0.00
Socio-Economic during constr.	3.00	3.00	3.00	3.00	3.00	3.00
Subtotal	3.00	3.00	3.00	3.00	3.00	3.00
TOTAL VALUE INDEX	**0.52**	**0.45**	**-0.37**	**1.17**	**1.17**	**0.66**
Ranking	**1**	**2**	**3**	**1**	**1**	**2**

Table 5-34 shows the actual and normalised TVIs calculated using two sets of weights. It is evident that when normalised, the TVIs calculated using weights derived through direct weighting are higher than normalised values calculated using the alternative weight elicitation technique employed in the study. Importantly, however, both cases produce the rankings of the considered alternatives.

Table 5-34: Actual and normalised TVIs – access road

Item	Alt 1	Alt 2	Alt 3	Alt 1	Alt 2	Alt 3
Actual score	**Before mitigations**			**After mitigations**		
TVI based on PC	0.93	0.91	0.28	1.69	1.69	1.36
TVI based on DW	0.52	0.45	-0.37	1.17	1.17	0.66
Min-max range	**Min**			**Max**		
TVI based on PC	-21.06	-21.06	-21.06	29.23	29.23	29.23
TVI based on DW	-23.13	-23.13	-23.13	22.68	22.68	22.68
Normalised score (0-100)	**Before mitigations**			**After mitigations**		
TVI based on PC	43.73	43.68	42.44	45.23	45.23	44.58
Ranking	1	2	3	1	1	2
TVI based on DW	51.62	51.48	49.68	53.04	53.04	51.93
Ranking	1	2	3	1	1	2

b. Comparison of results with recommendations made by the EAP in the EIA report

The results of the framework application suggest that Alternative 2 is the preferred option for the access road construction. This coincides with the recommendations made by the EAP in the report:

"In order to avoid an additional intersection on the N2 National Road, the traffic study suggests that either Alternatives 1 or 2 are preferable to Alternative 3. The visual impact study also refers to either Alternative 1 or 2 being preferred. From a botanical perspective there is a marginal preference for Alternative 2 as it avoids the sensitive area northeast of the proposed site. Accordingly, Alternative 2 would result in the least environmental impact." (Ninham Shand, 2005b)

c. Sensitivity analysis

Table 5-35 provides the rankings of alternatives after the respective categories and dimensions' weights were adjusted by 5%. As indicated, regardless of the set of weights used, categories and dimensions are not sensitive enough to small variations in weights to produce new rankings of alternatives.

Table 5-35: Alternatives' rankings after the change of weights – access road

Impacts	Before mitigations			After mitigations		
	Alt 1	Alt 2	Alt 3	Alt 1	Alt 2	Alt 3
Weights derived through pairwise comparison						
Environmental	1	2	3	1	1	2
Botanical - impact on sens. areas	1	2	3	1	1	2
Avifauna	1	2	3	1	1	2
Air quality	1	2	3	1	1	2
Water availability	1	2	3	1	1	2
Water and soil during constr.	1	2	3	1	1	2
Social	1	2	3	1	1	2
Heritage	1	2	3	1	1	2
Visual	1	2	3	1	1	2
Traffic	1	2	3	1	1	2
Noise	1	2	3	1	1	2
Noise during construction	1	2	3	1	1	2
Economic	1	2	3	1	1	2
Existing infrastructure	1	2	3	1	1	2
Land use	1	2	3	1	1	2
Socio-Economic	1	2	3	1	1	2
Socio-Economic during constr.	1	2	3	1	1	2
Weights derived through direct weighting						
Environmental	1	2	3	1	1	2
Botanical - impact on sens. areas	1	2	3	1	1	2
Avifauna	1	2	3	1	1	2
Air quality	1	2	3	1	1	2
Water availability	1	2	3	1	1	2
Water and soil during constr.	1	2	3	1	1	2
Social	1	2	3	1	1	2
Heritage	1	2	3	1	1	2
Visual	1	2	3	1	1	2
Traffic	1	2	3	1	1	2
Noise	1	2	3	1	1	2
Noise during construction	1	2	3	1	1	2
Economic	1	2	3	1	1	2
Existing infrastructure	1	2	3	1	1	2
Land use	1	2	3	1	1	2
Socio-Economic	1	2	3	1	1	2

Impacts	Before mitigations			After mitigations		
	Alt 1	Alt 2	Alt 3	Alt 1	Alt 2	Alt 3
Socio-Economic during constr.	1	2	3	1	1	2

5.2.8 Fuel pipeline: results and sensitivity analysis

The next two sections provide the results of the TVI calculation and sensitivity analysis for the fuel pipeline component of the OCGT project.

a. <u>Results</u>

Table 5-36 shows the TVIs for the fuel pipeline component of the OCGT project using weights derived through pairwise comparison.

Table 5-36: Results using pairwise comparison weights – fuel pipeline

Impacts	Before mitigations		After mitigations	
	Alt 1	Alt 2	Alt 1	Alt 2
Environmental	**-0.17**	**-0.17**	**-0.05**	**-0.05**
Botanical - impact on sensitive areas	-0.26	-0.26	-0.05	-0.05
Avifauna	0.00	0.00	0.00	0.00
Air quality	0.00	0.00	0.00	0.00
Water availability	0.00	0.00	0.00	0.00
Water and soil during construction	-0.53	-0.53	-0.18	-0.18
Subtotal	-0.79	-0.79	-0.23	-0.23
Social	**-0.99**	**-0.99**	**-0.36**	**-0.36**
Heritage	-0.10	-0.10	-0.03	-0.03
Visual	-0.14	-0.14	-0.14	-0.14
Traffic	0.00	0.00	0.00	0.00
Noise	0.00	0.00	0.00	0.00
Noise during construction	-3.03	-3.03	-1.01	-1.01
Subtotal	-3.27	-3.27	-1.19	-1.19
Economic	**2.19**	**2.19**	**2.19**	**2.19**
Existing infrastructure	0.00	0.00	0.00	0.00
Land use	0.00	0.00	0.00	0.00
Socio-Economic	0.00	0.00	0.00	0.00
Socio-Economic during construction	4.57	4.57	4.57	4.57
Subtotal	4.57	4.57	4.57	4.57
TOTAL VALUE INDEX	**1.03**	**1.03**	**1.78**	**1.78**
Ranking	**1**	**1**	**1**	**1**

From the above it can be concluded that the two alternatives proposed for the fuel pipeline have the same preference from a decision point of view. Overall, the fuel pipeline will not have a significant negative impact on the environmental and social dimensions. At the same time, its impact on the economic dimension, which is positive, is big enough to result in the TVI acquiring a positive score.

The proposed mitigations for the social and environmental categories are expected to reduce the overall negative impact of the component. This is particularly applicable to such categories as noise during construction and botanical. The introduction of mitigation measures will not have any implications on the rankings of the alternatives. A similar situation is observed when analysing the TVIs calculated using weights derived through direct weighting. This is indicated in Table 5-37.

Table 5-37: Results using direct weighting weights – fuel pipeline

Impacts	Before mitigations		After mitigations	
	Alt 1	Alt 2	Alt 1	Alt 2
Environmental	**-0.34**	**-0.34**	**-0.10**	**-0.10**
Botanical - impact on sensitive areas	-0.38	-0.38	-0.08	-0.08
Avifauna	0.00	0.00	0.00	0.00
Air quality	0.00	0.00	0.00	0.00
Water availability	0.00	0.00	0.00	0.00
Water and soil during construction	-1.50	-1.50	-0.50	-0.50
Subtotal	-1.88	-1.88	-0.58	-0.58
Social	**-0.69**	**-0.69**	**-0.27**	**-0.27**
Heritage	-0.23	-0.23	-0.08	-0.08
Visual	-0.25	-0.25	-0.25	-0.25
Traffic	0.00	0.00	0.00	0.00
Noise	0.00	0.00	0.00	0.00
Noise during construction	-2.25	-2.25	-0.75	-0.75
Subtotal	-2.73	-2.73	-1.08	-1.08
Economic	**1.70**	**1.70**	**1.70**	**1.70**
Existing infrastructure	0.00	0.00	0.00	0.00
Land use	0.00	0.00	0.00	0.00
Socio-Economic	0.00	0.00	0.00	0.00
Socio-Economic during construction	3.00	3.00	3.00	3.00
Subtotal	3.00	3.00	3.00	3.00
TOTAL VALUE INDEX	**0.67**	**0.67**	**1.33**	**1.33**
Ranking	**1**	**1**	**1**	**1**

Table 5-38 provides actual and normalised TVIs for the fuel pipeline component of the OCGT project. Based on the information presented in this table, it can be concluded that while the use of weights derived through direct weighting produce higher scores, the results with respect to rankings of alternatives and impact of mitigations measures are the same regardless of the set of weights used to calculate TVIs.

Table 5-38: Actual and normalised TVIs – fuel pipeline

Item	Alt 1	Alt 2	Alt 1	Alt 2
Actual score	**Before mitigations**		**After mitigations**	
TVI based on PC	1.03	-1.16	1.78	1.78
TVI based on DW	0.67	0.67	1.33	1.33
Min-max range	**Min**		**Max**	
TVI based on PC	-20.07	-20.07	29.23	29.23
TVI based on DW	-20.60	-20.60	22.68	22.68
Normalised score (0-100)	**Before mitigations**		**After mitigations**	
TVI based on PC	42.80	38.36	44.33	44.33
Ranking	1.0	2.0	1.0	1.0
TVI based on DW	49.15	49.15	50.65	50.65
Ranking	1	1	1	1

b. Comparison of results with recommendations made by the EAP in the EIA report

The result of the framework did not indicate a strong preference for a specific alternative route for the pipeline, either when using weights derived through pairwise comparison or when using direct weighting. The recommendations of the EAP in the Report, however, suggested a slight preference for Alternative 2:

"As far as risks to human health are concerned, neither of the two alternative routes offers significant constraints and there is no measurable difference between the two alternatives. However, the botanical study recommends that a 50 m buffer is maintained between the route and any sensitive botanical areas and this would suggest a marginal preference for Alternative 2 as it would avoid the sensitive botanical area northeast of the proposed site." (Ninham Shand, 2005b)

As indicated in the above recommendation, the EAP identified Alternative 2 as the preferred route based on its marginal difference compared to Alternative 1. The results of the framework, however, suggest that this difference was not illustrated in the ratings of categories' impacts. It can thus be concluded that subtle differences that do not have an impact on the rating of impacts, but that can still differentiate alternatives in a very subtle way cannot be recognised by the framework.

c. Sensitivity analysis

Table 5-39 lists the rankings of the alternatives after changing the weights of the respective categories and dimensions by 5% at a time. As in the case with the access road and transmission lines, the change of weights for derivation of the fuel pipeline's TVIs does not have any effect on the rankings of its alternatives. This is the case for both methods with which the TVIs are calculated.

Table 5-39: Alternatives' rankings after the change of weights – access road

Impacts	Before mitigations		After mitigations	
	Alt 1	Alt 2	Alt 1	Alt 2
Results for weights derived using pairwise comparison				
Environmental	1	1	1	1
Botanical - impact on sensitive areas	1	1	1	1
Avifauna	1	1	1	1
Air quality	1	1	1	1
Water availability	1	1	1	1
Water and soil during construction	1	1	1	1
Social	1	1	1	1
Heritage	1	1	1	1
Visual	1	1	1	1
Traffic	1	1	1	1
Noise	1	1	1	1
Noise during construction	1	1	1	1
Economic	1	1	1	1
Existing infrastructure	1	1	1	1
Land use	1	1	1	1
Socio-Economic	1	1	1	1
Socio-Economic during construction	1	1	1	1
Results for weights derived through direct weighting				
Environmental	1	1	1	1
Botanical - impact on sensitive areas	1	1	1	1
Avifauna	1	1	1	1
Air quality	1	1	1	1
Water availability	1	1	1	1
Water and soil during construction	1	1	1	1
Social	1	1	1	1
Heritage	1	1	1	1
Visual	1	1	1	1
Traffic	1	1	1	1
Noise	1	1	1	1
Noise during construction	1	1	1	1
Economic	1	1	1	1
Existing infrastructure	1	1	1	1
Land use	1	1	1	1
Socio-Economic	1	1	1	1
Socio-Economic during construction	1	1	1	1

5.3 Framework feedback

During the session with the decision-makers, the results of the OCGT project evaluation were shown to the attendees. The results of the CSP project were not shown to the decision-makers, as it was believed that showing the results of just one case study would be sufficient. They were afterwards requested to provide their opinion with respect to the usefulness and application of the proposed framework. The following paragraphs summarise the feedback received from the decision-makers with respect to each questions asked.

1. *Would you agree that the evaluation of impacts in qualitative and quantitative forms without clear indication of trade-offs between the impacts (particularly between economic, social and environmental impacts) makes their comparison difficult and complicates the decision process?*

   General answer: The decision-makers "partially agreed" with the statement. It was clear that they were of the opinion that without clear indication of importance and significance of impacts assessed, as well as their trade-offs, reaching a decision could be difficult. At the same time, though, the decision-makers interviewed thought that experience could noticeably ease the process of decision-making, as it gives "a bigger picture" and understanding of impacts that might not have been addressed in the report.

2. *Do you think the current decision-making process in the EIAs in the energy sector of South Africa would benefit from a framework that clearly shows trade-offs between the identified impacts and assist in making an informed decision regarding the most beneficial alternative?*

   General answer: The decision-makers partially agreed with the statement. They particularly emphasised the fact that if the Interested and Affected Parties and decision-makers participate in the selection of the criteria and their weights, it could certainly improve decision-making.

3. *Would you agree that the proposed framework clearly illustrates trade-offs between impacts?*

   General answer: The interviewed decision-makers agreed with the statement. They did, however, indicate that for the framework to add a significant benefit, the rating of impacts chosen by environmental practitioners should provide for sufficient disaggregation of various levels of significance. For example, instead of a three point rating (low, medium and high), there should be a five point rating.

4. *Do you think that the comparison of alternatives using the proposed framework offers greater knowledge of their differences and similarities?*

   General answer: This statement was supported by all decision-makers interviewed. The importance of using a wider range for rating of impacts was emphasised, though.

5. *Do you think that the proposed framework could facilitate/speed up the decision-making process in the EIAs in the energy sector?*

   General answer: The decision-makers partially agreed with the statement, as the complexity of the project that the proposed framework offers to address is not always the main reason behind the backlog. Workload and experience are other important factors that affect the duration of the decision-making process.

6. *Do you think that the proposed framework provides a structured and transparent approach to evaluation of different alternatives?*

   General answer: The decision-makers interviewed agreed with the statement. At the same time, though, they indicated that to ensure that the approach is structured and transparent, all stakeholders will need to be involved in the process.

7. *Do you think that the proposed framework provides a coherent, transparent, and integrated approach to decision-making?*

   General answer: The decision-makers totally agreed with the statement.

8. *In your opinion, could the proposed framework be implemented in EIAs in the energy sector in South Africa?*

   General answer: The decision-makers fully supported the use of the proposed framework in the EIAs in the energy sector in the country. They indicated that the greatest benefit of its application would be the achievement of a consistent approach to evaluation of energy-related projects. Knowledge of this approach would also aid the reviewers during the decision-making process. At the same time, the decision-makers interviewed posed their concerns regarding the possibility of achieving buy-in from I&APs and thus reaching an overall consensus.

9. *In your opinion, could the proposed framework be implemented in EIAs in other sectors in South Africa?*

General answer: The decision-makers agreed that the proposed framework could be used in EIAs in other sectors in the country. They raised a concern, though, about whether a consensus could be reached if the development considered a number of different options.

5.4 Summary

This chapter presented the results of the proposed framework application on the two case studies – the OCGT project that included assessment of four components of the project and contained alternatives for three of these components and the CSP project that included evaluation of impacts and comparison thereof with the "no-go option" only. The case studies also differed in the levels of impacts that were assessed. While the CSP project included evaluations of impacts, categories and dimensions; the OCGT project contained the assessment of only categories and dimensions. In addition, the chapter also presented the results of the discussion session held with the selected decision-makers that was aimed at obtaining their views on the proposed framework's potential.

The **CSP case study** involved the assessment of the proposed project against the "no-go option", as no other alternatives were considered during the impact assessment exercise. The project's impacts were grouped under 13 categories – five under the environmental dimension, and four under social and economic dimensions each.
The application of direct weighting and pairwise comparison weight elicitation techniques resulted in the economic dimension receiving a higher decision-making weight (48.0% in the case of pairwise comparison and 54.8% in the case of direct weighting) than the other two dimensions. This dimension was followed by the social dimension, meaning that decision-makers considered the environmental dimension to have the lowest decision value in this particular project.

The use of pairwise comparison weights resulted in the project scoring negative 6.83 points before mitigations and negative 0.99 points after mitigations. This suggested that given the project's expected effects on the environment, society and affected economies, its negative impact on the social and environmental dimensions would outweigh the positive impact that could be created in terms of the economic categories. It also means that the introduction of mitigation measures proposed by some of the specialists would considerably reduce the negative impact of the CSP project on the related categories. This was particularly true for impacts on groundwater, avifauna, and service delivery.

The results derived using weights obtained from direct weighting correspond with the results obtained using pairwise comparison weights in terms of the following:

- That the project in the case before mitigations would have a larger negative impact than a positive impact; and
- That the introduction of mitigation measures would improve the TVIs for the case before mitigations.

Importantly, the TVI for the case after mitigation using weights derived through direct weighting appears to be positive, which suggests that after mitigations, all negative effects of the project could be traded off for positive effects.

The sensitivity analysis revealed that regardless of the set of weights used in the calculation of the project's TVIs, the environmental and social dimensions were very sensitive to changes in weights, while such categories as employment, service delivery, and visual were the most sensitive among categories. Once mitigation measures were introduced, the sensitivity of the project to changes in weights increased drastically. At the same time, the most sensitive dimensions became environmental and economic. Employment and visual remained one of the most sensitive categories, with tourism completing the set.

The **OCGT project** was divided into a number of components, including the plant, transmission lines, access road, and fuel pipeline. For each of these components, except for the plant itself, two or three alternatives were proposed. The impacts associated with each component were grouped under 14 categories, which were then assigned to one of the dimensions. The application of different weighting techniques resulted in the economic dimension receiving a greater decision-making value, followed by social and then environmental. The use of these weights, as well as the weights assigned for categories produced the following results:

- **Plant.** The OCGT plant is expected to have a greater positive impact than negative, especially when the proposed mitigation measures are implemented. As far as weighting techniques are concerned, direct weighting appears to give a slightly greater score to the plant component, but overall they produce similar results.

  The sensitivity analysis revealed that changes to the weights of dimensions and such categories as noise, visual, botanical, and socio-economic result in the largest changes of the TVI. Changes to all dimensions also lead to noticeable changes in the TVI. Importantly, the increase of weights of the social and environmental dimensions decreased the TVI, while the increase of the weight of the economic dimension produced an opposite result. Importantly, the sensitivity of parameters drop considerably in the case after mitigations.

- **Transmission lines.** The alternatives were considered for the transmission lines. Overall, transmission lines are expected to have an insignificant negative impact on the environmental and social dimensions and considerable positive impacts with respect to the economic categories. Overall, the transmission lines component of the project, regardless of the alternative chosen, would have a positive rather than a negative effect.

  The results of the framework application indicated that Alternative 2 was the most preferred option, while Alternatives 1 and 3 have equal scores. In the cases before and after mitigations and using weights derived through pairwise comparison and direct weighting, Alternatives 1 and 3 received higher negative scores with respect to social and environmental dimensions, but also greater positive scores with respect to the economic dimension. The trade-off between the dimensions, however, was the most beneficial in the case of Alternative 2.

  Changes to the weights, irrespective of the technique used or cases involved, did not affect the rating of alternatives. This suggests that overall the transmission lines component of the project was not very sensitive to changes in weights.

- **Access road.** Three alternatives were considered for the access road. Before mitigations, the most preferred alternative was Alternative 1; however, the introduction of mitigation measures would equalise Alternative 1 and Alternative 2 making them both acceptable. Overall, the negative impacts associated with the access road were not expected to be high, although they would be greater in the case of Alternative 3 compared to the other two alternatives. Positive impact, however, would be equal regardless of the alternative chosen. The sensitivity analysis also revealed that none of the categories and dimensions was sensitive enough to change the rankings of alternatives.

- **Fuel pipeline.** The fuel pipeline had two proposed alternatives. The TVIs indicated that none of those alternatives was more preferred than the other. Overall they would not have a significant negative impact on the environmental and social categories, and its positive impact on the economic dimension would be the same as in the case of the access road. Lastly, neither the introduction of mitigations measures nor the change in weights would influence the rankings.

In conclusion, it appears that the introduction of mitigation measures clearly had a positive effect on the TVIs, but it did not impact the rankings. The use of weights derived through pairwise comparison and weights derived through direct weighting also produced the same results with respect to rankings, even though the TVIs derived using direct weighting weights generally have higher scores.

When comparing the outcomes of the framework application with recommendations made by the EAP it appeared that they coincided with each other. This suggests that the framework was able to capture not only the trade-offs of the options, but the differences between the alternatives too. The only weakness that had been identified in this respect was the fact that subtle differences between alternatives that do not affect the ratings of alternatives could not be captured by the framework. Therefore only knowledge of such minor variations in alternatives could assist in indenting the referred choice. This emphasised the fact that the proposed framework is only a tool for decision-making and not its panacea.

Lastly, the decision-makers interviewed during the feedback session were in favour of the proposed framework. They were of a firm belief that the framework could aid the decision-making process in EIAs in the energy sector in the country and could even be used in other sectors. They agreed that the framework provides for a consistent approach to the evaluation of projects, but questioned the transparency of the approach if I&A parties are not involved right from the start. They also indicated that the application of the framework would not speed up the decision-making process in all cases as there could be other reasons behind the slow reviewing process besides the complexity of the project. Lastly, they recommended that for the framework to serve its benefit, impact ratings for projects need to be diversified and include a wider range than a three point impact rating, i.e. low, medium and high.

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

The purpose of this chapter is to summarise the results of the study and to indicate the contribution of the proposed framework to the theory and practice, highlight its key strengths and weaknesses, objectively evaluate the research undertaken and provide recommendations and ideas for future research.

6.1 Research results

Both case studies and the feedback received from the decision-makers provided a valuable insight into the strengths and weaknesses of the proposed framework, and most importantly, tested the proposition. As was stated earlier, the proposition for the study was formulated as follows:

The application of the proposed MCA framework in the EIAs in the energy sector in South Africa can facilitate the decision processes by, firstly, integrating opinions of decision-makers in the evaluation and, secondly, by providing them with an integrated, transparent, and coherent approach to the evaluation of alternatives that clearly show trade-offs between different criteria.

The case studies' results revealed that the chosen MCA framework can be successfully applied to projects undergoing an impact assessment exercise in the energy sector in the country. It was shown that the proposed framework can be used to determine the trade-offs between environmental, social, and economic dimensions taking into account the opinion of specialists, Environmental Assessment Practitioners involved in the specific project, and importantly decision-makers. The testing of the proposed framework also indicated that the framework has the ability to clearly show the benefits of introduced mitigation measures, and particularly the extent by which negative impacts associated with the project could be reduced and positive impacts improved. The usefulness of the proposed framework in selecting the alternative that provides the most beneficial trade-off between negative and positive impacts was also evident. In all cases but one, the results of the framework correlated with the recommendations made by the EAPs for specific projects or components of the projects.

The comparison of the results of the framework application with recommendations made by the specialists in their respective studies provided important information with respect to its limitations. It became clear that the framework cannot capture subtle differences between the alternatives. If these variations are not significant enough to result in different ratings of impacts, they cannot be reflected by the framework either. However, they are important when two or more alternatives appear to have the same ratings and the preferred choice has to be selected.

The decision-makers interviewed during the study largely agreed with the hypothesis statement. They emphasised, though, that the proposed framework cannot be the only solution to increasing the process of decision-making as other factors also affect this process, but at the same time they agreed that it could without doubt assist when a decision has to be made. They also emphasised that the usefulness of the framework depends on the range of ratings used to assess the impacts, as the limited range could never provide for a clear indication of differences between different alternatives.
To conclude, the following should be acknowledged:

- The proposed framework is only a tool that can assist in the decision-making process. Other factors affect decision-making that the proposed framework cannot and is not meant to address or solve. These include, amongst others, the experience of the officials involved in the decision-making process.
- The results of the framework are only as good as its inputs.
- Transparency in the decision-making could only be achieved through the involvement of all Interested and Affected Parties throughout the project.

6.2 Contributions to the theory and practice

The study has contributed to the body of knowledge in the field of the Environmental Impact Assessment. It proposed an approach that could facilitate decision-making and assist in identification of solutions that optimise benefits derived from projects in the energy sector, whilst minimising their negative effects on the environment, society, and even economy.

It has been shown that the framework could be used to:

a) combine the qualitative and quantitative information presented in the reports compiled by the EAPs;
b) show the trade-offs between different impacts, categories and dimensions, and
c) allow the integration of opinions of specialists, environmental practitioners, and decision-makers.

All of the above stated benefits facilitate the discussion not only between the parties involved in the assessment, but also between the Interested and Affected Parties of the projects. This ultimately assists in making the whole process more transparent and integrative.

The following knowledge has been gained during the application of the proposed framework on two case studies and interviews with the decision-makers that could prove to be valuable in the future use of the framework:

- Application of the framework should be done by a person knowledgeable of both the Environmental Impact Assessment process and decision-making theories.
- Specialists should be introduced to the framework in the beginning of the study and provided with clear guidelines and requirements with respect to information that has to be provided.
- Strict control needs to be exercised by the environmental practitioner over the reporting format and context done by specialists to ensure that all necessary information for the framework is provided. Evaluation and ratings also have to be done in the same way to be consistent.
- A one day workshop should be organised with specialists to acquire weights for categories. Such an exercise will first provide a good platform for clear explanations of the approach that needs to be followed in performing pairwise or direct weighting and collecting their responses by the end of the workshop, thus saving overall time spent on developing the framework in general.
- The choice of using the direct weighting or pairwise comparison technique for weight elicitations should remain with the specialist in charge of the framework applications.
- Ranking of impacts should be done using a scale comprised of at least five different levels, namely none, low, low-medium, medium, medium-high, and high. A clear description of the method used to determine the scale should be provided in the report.
- The range of scores that are used to convert qualitative assessment to quantitative figures should also be derived through pairwise comparison.
- When undertaking the normalisation process, the context of the problem should be taken due cognisance of, i.e. whether the scores are derived from initially negative numbers or positive, or both. The disadvantage of normalisation is such that the derived scores no longer indicate positive or negative values. In a situation when two categories representing positive and negative scores are normalised at the same time resulting in a score between 0 and 100, the comparison of these scores could result in incorrect conclusions.
- When analysing the results, both actual scores and normalised values should be taken into account. The actual score provides an indication of the trade-offs between impacts, categories, and dimensions having negative or positive results. The actual value, however, should not be used to compare the scores horizontally (between categories and dimensions), as each category and dimension has different maximum and in some cases minimum values. This is

where the normalised scores become important as they allow the identification of those impacts that have the greatest contribution towards the overall score.

6.3 Self-assessment

The research has proven to be more challenging than was envisaged at the time of conception of the theme. This resulted in a greater time required to complete the study than was planned in the original proposal.

The major challenge was related to the collection of primary data (weights) from the specialists and environmental practitioners involved in the projects chosen for case studies, as well as obtaining feedback from decision-makers. The main reasons for the delays in primary information gathering were as follows:

- Specialists were too busy with their own work and were unwilling to contribute their time towards the research;
- Some specialists have moved to other companies;
- The delay in responding to the request to assist with the research also resulted in a delay in finding an alternative solution for gathering inputs in the cases when a specialist or environmental practitioner decided not to participate in the study;
- Even though some specialists and environmental practitioners agreed to provide inputs, it took months to gather that feedback from them due to them having busy schedules; and
- The delay in obtaining the feedback from specialists lead to a delay in the time taken when feedback from decision-makers could be gathered as these steps needed to be done sequentially.

Another problem that partially contributed to the delays in obtaining feedback was the spread of the specialists and decision-makers throughout the country and the location of the projects chosen for the case studies. Specialists and decision-makers involved in the case studies were not located in one province and were scattered mostly throughout the Western Cape Province, Gauteng, the Northern Cape, and the Free State. This made it logistically difficult to see each person and request to participate in the research, forcing the researcher to use e-mail and telephone means of communication that have proven to not always be successful. This challenge could be overcome in the future if the case studies selected are those that present projects in proximity to the researcher's province of residence.

It is believed that some of the delays in primary data gathering could also be attributed to the case studies chosen, and particularly the time when they were completed. A few years have elapsed since those studies had been finalised and the Record of Decision obtained. Thus, it is natural to assume that some specialists would move on and that most of them would not have a very good memory of what transpired during those studies and therefore be unwilling to participate. This challenge could be overcome in the future if the studies chosen were ones completed within the year preceding the research.

With respect to the results, the following limitations could be highlighted that need to be taken cognisance of:

- Due to the unavailability of some specialists and environmental practitioners for the research, a third party independent practitioner who was not involved in any of the chosen case studies had to be approached for the weight elicitation process. Although all the necessary background information was supplied to this practitioner, it could be argued that his assessment could have been less accurate than the assessment that could have been gathered from specialists involved in the project at the time.
- The weight elicitation provided by the Environmental Assessment Practitioner, who was requested to assist with bridging some gaps in the process, was requested to stand in as both a specialist and an EAP for the same project. This is not how the framework was designed originally, but due to limited options it had to suffice.
- The proposed framework was tested on two case studies - one containing comparison of the proposed project against a "no-go option" and the other containing comparisons of alternatives for different project's components. The chosen studies are representative of studies in the energy sector, but the fact that only one study actually included the assessment of numerous alternatives could be a drawback of the current research as it did not necessarily allow for checking the consistency in the framework's ability to disaggregate between the alternatives.
- Feedback with respect to the proposed framework and its potential application in the EIAs in the energy sector in the country was obtained from only two senior decision-makers at the Department of Environmental Affairs, despite an acknowledgement to attend the workshop set for a specific date received from at least seven people from the same unit. Although, as was mentioned earlier, the two participants were senior professionals with decades of experience in the field of EIAs, it should be noted that it was not sufficiently representative to obtain conclusive results.

6.4 Recommendations

The framework has definitely proven its potential for use in EIA studies and to assist in decision-making. The current research relied, however, on case studies that involved already completed projects. This fact, without doubt, limited the information that could be gathered on strengths and weaknesses of the framework, and subsequently, prevented the identification of possible solutions. It is therefore believed that great value could be obtained from the application of the proposed framework in the EIA of a selected project right from its inception as suggested in the thesis. Such an exercise could become part of a doctoral study.

Other improvements could be made to the research with the purpose of gaining a greater understanding of the proposed framework's limitations when applied to other cases and possibly providing solutions to overcome them. These include:

- Investigate the sensitivity of the framework with respect to the range of scores that are used to convert qualitative assessments into quantitative assessments.
- Research the application of the proposed framework in other sectors, not only in the energy sector.
- Research the possibility of acquiring input from the Interested and Affected Parties, particularly local communities, and integrating such input into the decision framework as opposed to the reliance on the inputs received only from specialists, environmental practitioners, and decision-makers.

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ANNEXURE A: LIST OF PARTICIPANTS

Table A-1: List of participants

Case study	Participant's name	Contact details		Reason for selection
		E-mail	Phone	
OCGT	Karen-Dawn Koen	enviropart@icon.co.za	(021) 422-0999	• Environmental Practitioner from The Environmental Partnership • Involved in completing EIR
OCGT	Carmen du Toit	enviropart@icon.co.za	(021) 422-0999	• Environmental Process Manager from The Environmental Partnership • Involved in completing EIR
OCGT	Bret Lawson	brett.lawson@shands.co.za	(021) 481-2505	• Project Manager from Ninham Shand • Involved in completing EIR • Involved in completing Avifaunal Impact Assessment study
OCGT	Kamal Govender	kamal.govender@shands.co.za	(021) 481-2510	• Environmental Practitioner from Ninham Shand • Involved in completing EIR
OCGT	Gillian Petzer	mail@airshed.co.za	(011) 805-1940 (011) 254-4929	• AirShed Planning Professionals • Involved in completing Air quality study
OCGT	Lucian Burger	mail@airshed.co.za	(011) 805-1940 (011) 254-4929	• AirShed Planning Professionals • Involved in completing Air quality study
OCGT	Adriaan Jongens	jongens@yebo.co.za	(021) 794-5643	• Jongens Keet Associates • Involved in completing the Noise study
OCGT	Tanya De Villiers	landscape@cndv.co.za	(021) 461-6302	• Specialists from CNdV Africa • Involved in completing Visual Impact Assessment study
OCGT	Nick Helme	botaneek@iafrica.com	(021) 780-1420	• Nick Helme Botanical Surveys • Involved in completing Botanical Assessment study
OCGT	Tim Hart	TJG@age.uct.ac.za	(021) 650-2357	• Specialist from Archaeology Contracts Office, UCT • Involved in completing Initial Heritage Statement study
OCGT	Ms Alex Kempthorne	alex@urban-econ.com		• Urban-Econ Development Economists

Case study	Participant's name	Contact details		Reason for selection
		E-mail	Phone	
				• Involved in completing Socio-Economic Impact Assessment study
OCGT	Brian Alexander	trans@shands.co.za	(021) 481-2400	• Ninham Shand: Transportation and roads • Involved in completing traffic study
OCGT	M. P. Oberholzer	jhbsales@ilitha.com	(012) 668-1075	• Ilitha Riscom • Involved in completing the study concerning risks of transporting flammable liquids
OCGT	Danie Swanepoel	Dswanepo@pgwc.gov.za	(044) 874-2160 (021) 483-4796	• Department of Environmental Affairs and Development Planning, Western Cape • Site visit • Representative of DEA&DP
OCGT	Chris Rabie	crabie@pgwc.gov.za	(044) 674-2160 (021) 483-4796	• Director of Integrated Environmental Management (Region A) at the Department of Environmental Affairs and Development Planning, Western Cape • ROD
OCGT CSP	Danie Smit	dsmit@deat.gov.za	(012) 310-3659	• Deputy director of Environmental Impact Evaluation at the Department of Environmental Affairs and Tourism, South Africa
CSP	Joggie van Staden	joggievs@bohlweki.co.za	(011) 466-3841	• Bohlweki Environmental • Project director for the EIA and public participation
CSP	Ashlea Strong	Astrong@gibb.co.za		• Project manager for the EIA and public participation
CSP	Johan Du Preez			• Specialist from MDA Consulting • Involved in flora and fauna assessment
CSP	Jon Smallie	jons@ewt.org.za	011 486 1102	• Programme Manager: Eskom-EWT Strategic Partnership from Endangered Wildlife Trust • Involved in compiling the Avifauna study
CSP	Lourens du Plessis	info@metrogis.co.za	(012) 349-2884/5	• Specialist from MetroGIS • Involved in Visual study
CSP	Jude Cobbing	jcobbing@csir.co.za	(012) 841-3857	• Specialist from CSIR

Case study	Participant's name	Contact details		Reason for selection
		E-mail	Phone	
				• Involved in assessment of surface and groundwater impacts
CSP	Arthur Chapman	achapman@csir.co.za	(021) 888-2443	• Specialist from CSIR • Involved in assessment of surface and groundwater impacts
CSP	Garry Patterson	garry@arc.agric.za	(012) 310-2601	• Specialist from the Agricultural Research Council • Involved in assessment of impacts on soils and agricultural potential
CSP	Cobus Dreyer	dreyerj@telkomsa.net	(051) 444-1187 (083) 357-7982	• Involved in Heritage study
CSP	Derek Cosijn	jongens@yebo.co.za	(021) 794-5643	• Jongens Keet Associates • Involved in completing the Noise study
CSP	Jan Perold	gera@afrosearch.co.za		• Specialist from Afrosearch • Involved in Social impact Assessment
CSP	Nicolene Venter	csp-eia@bohlweki.co.za	(011) 798-6001	• Imaginative Africa • Involved in Social Impact Assessment and public participation
CSP	Martin Jansen van Vuuren	mjvvuuren@gtct.co.za	(021) 481 9142	• Grant Thornton • Involved in Tourism study
CSP	Sengesiwe Masimang	mail@gtct.co.za	(021) 481 9142	• Grant Thornton • Involved in Tourism study
CSP	Coenraad Agenbach	cagenbach@deat.gov.za	(012) 310-3711	• DEAT
CSP	S.J. Mbanjwa	smbanjwa@half.ncape.gov.za	(053) 807 4800	• Northern Cape Department of Tourism, Environment and Conservation
CSP	Julius Koen	Jkoen@half.ncape.gov.za	(053) 807 4800	• Northern Cape Department of Tourism, Environment and Conservation
CSP	Basani Mkhombo	bmkhombo@half.ncape.gov.za	(053) 807 4800	• Assistant Director of Coastal and Impact Management at the Northern Cape Department of Tourism, Environment and Conservation

ANNEXURE B: COVER E-MAIL

Graduate School of Technology Management **Tel: +27 12 420 4606** **Fax: +27 12 362 5307**	100 1908 - 2008 UNIVERSITEIT VAN PRETORIA UNIVERSITY OF PRETORIA YUNIBESITHI YA PRETORIA Graduate School of Technology Management

Dear Sir/Madam

Research for Masters of Science in Technology Management: A framework for integrated decision making in Environmental Impact Assessments in the energy sector of South Africa

Mrs Elena Broughton is conducting research in the Graduate School of Technology Management of the University of Pretoria under the supervision of Drs Alan Brent (University of Pretoria) and Lorren Haywood (CSIR). Your participation in the research would be much appreciated.

The purpose of the research is to investigate the possibility of improving decision making processes in Environmental Impact Assessments based on case studies in the energy sector of South Africa. The research project encompasses the following:

a) Customisation of a multi criteria decision making (MCDM) framework to identify the most preferred option as part of the EIA process. The EIA process needs only consider two options that are included in the proposed project, i.e. the options of go/no-go in terms of the current state of affairs, or involve a trade-off analysis for a number of alternatives.
b) Application of the customised framework on case studies that received an environmental authorisation.
c) Consultation with stakeholders involved in the completion of EIRs and decision making including:
    - Identification of weights for each criterion in the developed multi criteria decision making framework;
    - Comparison of the results of the original decision making process with the results generated through application of the framework;
    - Discussion around weaknesses and strengths of the proposed framework;

- Enquiry about recommendations for the improvement of the framework.

The research involves applying the framework on two case studies and receiving feedback from stakeholders who were involved in the processes of decision making or completion of the EIRs used in the research. Two case studies have been chosen for the research:

a) Proposed open cycle gas turbine (OCGT) power station, fuel supply pipeline, substation and transmission lines at Mossel Bay; and
b) Proposed establishment of a concentrating solar power (CSP) plant and related infrastructure in the Northern Cape Province.

According to the information contained in documents prepared for the EIAs that were obtained from public sources, you have been involved in the ____________________ study for the ______________________________ project. Therefore the University would appreciate your assistance towards completing the study by participating in feedback sessions that will be scheduled in the near future.

The feedback session will include focus groups discussion sessions, interviews, or completing questionnaires distributed through e-mail.

The workshops are the preferred method of participation as they will allow for a comprehensive collection of feedback regarding the proposed framework. However, they also provide great benefits to the participants in terms of acquired knowledge of some of the MCDM techniques and their application potential, as well as an opportunity to discuss EIA decision making processes and ways of improving them. The workshops will be scheduled as close to your work location as possible to minimise any inconveniences. It is planned that they will take no longer than three hours.

The preliminary agenda for the workshop is as follows:

- Introduction and expression of appreciation for participation in the discussion session.
- Problems associated with the current decision making practices.
- Background to the multi criteria decision making process.
- Process followed in the development of the framework.
- Normative scores developed for the case studies through the population of the framework.
- Process to be followed in identifying weights for each criteria: Analytical Hierarchy Process (AHP).

- AHP application and weights identification.
- Results calculation and presentation.
- Discussion of results.
- Discussion of the proposed approach versus the current decision making.
- Way forward.

Could you please respond by completing the table attached to this e-mail , indicating whether you will be able to participate in the study and your most preferred method of participation? If you select the focus group discussion sessions or interview as your preferred method, please, provide the details of the most suitable dates and time during June, July and August, as well as the preferred location.

Please contact myself directly should you require more information.

Yours sincerely
Dr Alan Brent
Research Supervisor

Graduate School of Technology Management Tel: +27 12 420 4606 Fax: +27 12 362 5307	100 1908 - 2008 UNIVERSITEIT VAN PRETORIA UNIVERSITY OF PRETORIA YUNIBESITHI YA PRETORIA Graduate School of Technology Management

E-mail: alan.brent@up.ac.za

Response to participate in the research

Research for Masters of Science in Technology Management: A framework for integrated decision making in Environmental Impact Assessments in the energy sector of South Africa

Name						
Case study	Mossel Bay OCGT			CSP in the Northern Cape Province		
Participation	Yes			No		
Preferred method	Focus group		Interview		E-mail	
Preferred location for focus group	Stellenbosch					
	Kimberly					
	Pretoria					
	Other (please specify)					
Preferred dates and times of day for focus group/ interview	June	Day				
		Time				
	July	Day				
		Time				
	August	Day				
		Time				

ANNEXURE C: EXAMPLE OF A FORM USED TO RANK IMPACTS

The proposed Framework for Coherent Decision-Making in the Energy Sector in South Africa involves the application of the multi criteria decision model, and in particular the Weighted Summation Method technique for identification of indices and pairwise comparison and direct weighting techniques for identification of weights.

It will be much appreciated if you could assist us in elicitation of weights for impacts that you were directly involved in identifying and evaluating. ***Please complete the matrices below as directed in blue blocks.***

1. Weight elicitation: Pairwise comparison

Please, assign the importance of each impact relative to the other impact according to the scale provided in the following table by crossing the relevant cell and answering the next question:

For each pair of impacts under consideration, please indicate which impact has an equal importance/weak importance/strong importance/demonstrated importance/absolute importance over the other impact in the evaluation of the effect of the proposed development on a particular category (groundwater, avifauna, or other) indicated in the heading of the matrix. Please refer to the first spreadsheet for information on significance of impacts, if necessary.

Scales of relative importance for pairwise comparison		
Importance	**Definition**	**Explanation**
1	Equal importance	Two activities contribute *equally* to objectives
3	Weak importance of one over another	Experience and judgment *slightly favours* one activity over another
5	Essential or strong importance	Experience and judgment *strongly favours* one activity over another
7	Demonstrated importance	An activity is *strongly favoured and importance is demonstrated* in practice
9	Absolute importance	The favouring of one activity over another is of the *highest possible order of affirmation*
2,4,6,8	Intermediate values between two adjacent judgments	When compromise is needed

Category - Tourism																		
Impact	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Impact
A	Absolute importance		Demonstrated importance		Strong importance		Weak importance		Equally important	Weak importance		Strong importance		Demonstrated importance		Absolute importance		B
Change in tourism and leisure opportunities - construction																		Change in tourism and leisure opportunities - operation

2. Weight elicitation: Direct weighting

Please, assign a weight (from 0% to 100%) for each impact in the respective column by giving bigger weights to impacts that would have a bigger importance in evaluation of effects of the proposed development on the particular environment (groundwater, avifauna, or other), and lower weights to impacts with lower importance. Make sure that the total of the column equals 100%.

Category - Tourism	
Impact	Direct weight
Change in tourism and leisure opportunities - construction	
Change in tourism and leisure opportunities - operation	
	100%

ANNEXURE D: FEEDBACK QUESTIONNAIRE

Please answer the following questions and provide explanation to the selected answer.

1. Would you agree that the evaluation of impacts in qualitative and quantitative forms, without clear indication of trade-offs between the impacts (particularly between economic, social and environmental impacts) makes their comparison difficult and complicates the decision process?

Totally agree	Partially agree	Neither agree or disagree	Partially disagree	Totally disagree

Please explain why.

2. Do you think the current decision-making process in the EIAs in the energy sector of South Africa would benefit from a framework that clearly shows trade-offs between the identified impacts and assist in making an informed decision regarding the most beneficial alternative?

Totally agree	Partially agree	Neither agree or disagree	Partially disagree	Totally disagree

Please explain why.

3. Would you agree that the proposed framework clearly illustrates trade-offs between impacts?

Totally agree	Partially agree	Neither agree or disagree	Partially disagree	Totally disagree

Please explain why.

4. Do you think that the comparison of alternatives using the proposed framework offers greater knowledge of their differences and similarities?

Totally agree	Partially agree	Neither agree or disagree	Partially disagree	Totally disagree

Please explain why.

5. Do you think that integration of decision-makers' opinion in rating of dimensions that reflects developmental objectives develops trust towards the proposed framework?

Totally agree	Partially agree	Neither agree or disagree	Partially disagree	Totally disagree

Please explain why.

6. Do you think that the proposed framework could facilitate/speed up the decision-making process in the EIAs in the energy sector?

Totally agree	Partially agree	Neither agree or disagree	Partially disagree	Totally disagree

Please explain why.

7. Do you think that the proposed framework provides a structured and transparent approach to evaluation of different alternatives?

Totally agree	Partially agree	Neither agree or disagree	Partially disagree	Totally disagree

Please explain why.

8. Do you think that the proposed framework provides coherent, transparent, and integrated approach to decision-making?

Coherent				
Totally agree	Partially agree	Neither agree or disagree	Partially disagree	Totally disagree
Transparent				

Totally agree	Partially agree	Neither agree or disagree	Partially disagree	Totally disagree
Integrated				
Totally agree	Partially agree	Neither agree or disagree	Partially disagree	Totally disagree

Please explain why.

9. In your opinion, could the proposed framework be implemented in EIAs in the energy sector in South Africa?

Totally agree	Partially agree	Neither agree or disagree	Partially disagree	Totally disagree

Please explain why.

Strengths/Advantages/Pros of the framework and its application in EIAs:
Weaknesses/Disadvantages/Cons of the framework and its applications in EIAs:

10. In your opinion, could the proposed framework be implemented in EIAs in the energy sector in South Africa?

Totally agree	Partially agree	Neither agree or disagree	Partially disagree	Totally disagree

ANNEXURE E: CSP VALUE TREE - IMPACTS

Table E-1: CSP value tree - impacts

Category	Impacts
1. Groundwater	1.1 Migration of contaminants from Orange River water used in the plant 1.2 Migration of hydrocarbon fuel spillage at the plant 1.3 Leaching of herbicides used in ground sterilisation beneath the mirrors 1.4 Leaching of Na/K-NO3 salts (used as coolant)
2. Ecology	2.1 Impact on vegetation 2.2 Impact on fauna
3. Avifauna – power plant	3.1 Collision with heliostats 3.2 Collision with central receiver tower 3.3 Roosting on central receiver tower 3.4 Burning in vicinity of central receiver tower 3.5 Burning in focal points 3.6 Habitat loss 3.7 Disturbance 3.8 Nesting
4. Avifauna – power lines	4.1 Collision of birds 4.2 Habitat destruction 4.3 Disturbance
5. Avifauna – road access	5.1 Disturbance 5.2 Habitat destruction
6. Visual	6.1 Major tourism routes 6.2 Residential areas: Upington 6.3 Residential areas: Louisvale, Louisvel Road, Kanon Eiland 6.4 Residential areas: Oranje Valley, Ses Brugge, Klippunt 6.5 Protected areas: Spitkop NR 6.6 Protected areas: Augrabiesd Falls NP 6.7 Orange River 6.8 Ancillary infrastructure: salt tanks 6.9 Ancillary infrastructure: auxiliary house 6.10 Ancillary infrastructure: transmission line 6.11 Ancillary infrastructure: pipe line 6.12 Lighting: glare- floodlights 6.13 Lighting: glare-aircraft warning lights 6.14 Lighting: spill light 6.15 Lighting: sky glow
7. Noise	7.1 Construction phase 7.2 Operational phase
8. Quality of life	8.1 Impact on daily living and movement patterns - construction 8.2 Impact on daily living and movement patterns - operation 8.3 Disruption of social networks and alteration of family structures - construction 8.4 Social impact derived from industrial diversification - construction 8.5 Social impact derived from industrial diversification - operation 8.6 Social impact derived from the environmental and economic benefits of solar power 8.7 Air and dust pollution - construction 8.8 Light intrusion - construction 8.9 Noise intrusion - construction 8.10 Air and dust pollution - operation 8.11 Light intrusion - operation 8.12 Noise intrusion - operation
9. Demographic	9.1 Introduction of people dissimilar in demographic profile - construction

Category	Impacts
changes	9.2 Introduction of people dissimilar in demographic profile - operation 9.3 Inflow of temporary workers - construction 9.4 Introduction of new social classes
10. Employment	10.1 Employment equity and occupation opportunities - construction 10.2 Creation of employment opportunities - construction 10.3 Employment equity and occupation opportunities - operation 10.4 Creation of employment opportunities - operation
11. Tourism	11.1 Change in tourism and leisure opportunities - construction 11.2 Change in tourism and leisure opportunities - operation
12. Infrastructure	12.1 Change in community infrastructure - construction 12.2 Change in community infrastructure - operation
13. Service delivery	13.1 Impact on municipal services requirements - construction 13.2 Impact on municipal services requirements - operation

ANNEXURE F: CSP IMPACT RATING TABLE

Table F-1: CSP impact rating table

Category	Code	Impact	Type	Significance		Degree of confidence
				Before mitigations	After mitigations	
Environment						
1. Groundwater	1.1	Migration of contaminants from Orange River water used in the plant	Negative	Low	Low	Probable
	1.2	Migration of hydrocarbon fuel spillage at the plant	Negative	Moderate	Moderate	Probable
	1.3	Leaching of herbicides used in ground sterilisation beneath the mirrors	Negative	Moderate	Moderate	Probable
	1.3	Leaching of Na/K-NO3 salts (used as coolant)	Negative	Moderate	Moderate	Probable
2. Ecology	2.1	Impact on vegetation	Negative	Low to medium	N/A	Probable
	2.2	Impact on fauna	Negative	Low to medium	N/A	Probable
3. Avifauna - CSP plant	3.1	Collision with heliostats	Negative	Moderate	Moderate	Probable
	3.2	Collision with central receiver tower	Negative	Low	Low	Probable
	3.3	Roosting on central receiver tower	Negative	Low	Low	Don't know/unsure
	3.4	Burning in vicinity of central receiver tower	Negative	Low	Low	Don't know/unsure
	3.5	Burning in focal points	Negative	Moderate	Moderate	Probable
	3.6	Habitat loss	Negative	Moderate	Moderate	Probable
	3.7	Disturbance	Negative	Moderate	Moderate	Probable
	3.8	Nesting	Negative	Low	Low	Don't know/unsure
4. Avifauna – power lines	4.1	Collision of birds	Negative	Moderate	Moderate	Probable
	4.2	Habitat destruction	Negative	Low	Low	Definite
	4.3	Disturbance	Negative	Low	Low	Definite
5. Avifauna - access roads	5.1	Disturbance	Negative	Low to moderate	Low to moderate	Definite
	5.2	Habitat destruction	Negative	Low to moderate	Low to moderate	Definite
Social						
6. Visual	6.1	Major tourism routes	Negative	High	High	Highly probable

Category	Code	Impact	Type	Significance		Degree of confidence
				Before mitigations	After mitigations	
	6.2	Residential areas: Upington	Negative	High	High	Probable
	6.3	Residential areas: Louisvale, Louisvel Road, Kanon Eiland	Negative	Moderate to high	Moderate to high	Probable
	6.4	Residential areas: Oranje Valley, Ses Brugge, Klippunt	Negative	Medium	Medium	Probable
	6.5	Protected areas: Spitkop NR	Negative	High	High	Highly probable
	6.6	Protected areas: Augrabiesd Falls NP	Negative	Low	Low	Improbable
	6.7	Orange River	Negative	Low to moderate	Low to moderate	Probable
	6.8	Ancillary infrastructure: salt tanks	Negative	Low	N/A	Probable
	6.9	Ancillary infrastructure: auxiliary house	Negative	Low	Low	Improbable
	6.10	Ancillary infrastructure: transmission line	Negative	Low	Low	Probable
	6.11	Ancillary infrastructure: pipe line	Negative	Low	N/A	Probable
	6.12	Lighting: glare- floodlights	Negative	Moderate	Moderate	Probable
	6.13	Lighting: glare-aircraft warning lights	Negative	Moderate	Moderate	Probable
	6.14	Lighting: spill light	Negative	Low	Low	Improbable
	6.15	Lighting: sky glow		Low	Low	Probable
7. Noise	7.1	Construction phase	Negative	Low	Low	Probable
	7.2	Operational phase	Negative	Low	Low	Improbable
8. Quality of life	8.1	Impact on daily living and movement patterns - construction	Negative	Moderate	Low	Probable
	8.2	Impact on daily living and movement patterns - operation	Negative	Low	Very low	Probable
	8.3	Disruption of social networks and alteration of family structures - construction	Negative	High	Moderate	Probable
	8.4	Social impact derived from industrial diversification - construction	Positive	Low	Moderate	Probable
	8.5	Social impact derived from industrial diversification - operation	Positive	Moderate	High	Probable
	8.6	Social impact derived from the environmental and economic benefits of solar power	Positive	High	Very high	Probable
	8.7	Air and dust pollution - construction	Negative	Moderate to high	Low	Highly probable
	8.8	Light intrusion - construction	Negative	High	Moderate	Probable
	8.9	Noise intrusion - construction	Negative	Moderate	Very low	Probable

	Category	Code	Impact	Type	Significance		Degree of confidence
					Before mitigations	After mitigations	
		8.10	Air and dust pollution - operation	Negative	Low	Very low	Improbable
		8.11	Light intrusion - operation	Negative	Very high	High	Definite
		8.12	Noise intrusion - operation	Negative	Low	N/A	Probable
	9. Demographic changes	9.1	Introduction of people dissimilar in demographic profile - construction	Negative	Moderate	Low	Probable
		9.2	Introduction of people dissimilar in demographic profile - operation	Negative	Low	Very low	Probable
		9.3	Inflow of temporary workers - construction	Negative	Moderate	Low	Probable
		9.4	Introduction of new social classes	Negative	Low	Low	Probable
Economic							
	10. Employment	10.1	Employment equity and occupation opportunities - construction	Positive	High	Moderate	Probable
		10.2	Creation of employment opportunities - construction	Positive	High	Moderate	Definite
		10.3	Employment equity and occupation opportunities - operation	Positive	High	Low to moderate	Probable
		10.4	Creation of employment opportunities - operation	Positive	Moderate	Low to moderate	Definite
	11. Tourism	11.1	Change in tourism and leisure opportunities - construction	Positive	Low	Low to moderate	Definite
		11.2	Change in tourism and leisure opportunities - operation	Positive	Low	Moderate	Definite
	12. Infrastructure	12.1	Change in community infrastructure - construction	Positive	Moderate	Low	Probable
		12.2	Change in community infrastructure - operation	Positive	Low	Very low	Probable
	13. Service delivery	13.1	Impact on municipal services requirements - construction	Negative	High	Low	Probable
		13.2	Impact on municipal services requirements - operation	Negative	Low	Low to moderate	Probable

ANNEXURE G: CSP PERFORMANCE MATRIX

Table G-1: CSP performance matrix

Category	Code	Impact	Type	Before mitigations	After mitigations
Environment					
1. Groundwater	1.1	Migration of contaminants from Orange River water used in the plant	Negative	-7.5	-7.5
	1.2	Migration of hydrocarbon fuel spillage at the plant	Negative	-25.0	-25.0
	1.3	Leaching of herbicides used in ground sterilisation beneath the mirrors	Negative	-25.0	-25.0
	1.3	Leaching of Na/K-NO3 salts (used as coolant)	Negative	-25.0	-25.0
2. Ecology	2.1	Impact on vegetation	Negative	-15.0	0.0
	2.2	Impact on fauna	Negative	-15.0	0.0
3. Avifauna - CSP plant	3.1	Collision with heliostats	Negative	-25.0	-25.0
	3.2	Collision with central receiver tower	Negative	-7.5	-7.5
	3.3	Roosting on central receiver tower	Negative	-2.3	-2.3
	3.4	Burning in vicinity of central receiver tower	Negative	-2.3	-2.3
	3.5	Burning in focal points	Negative	-75.0	-75.0
	3.6	Habitat loss	Negative	-75.0	-75.0
	3.7	Disturbance	Negative	-75.0	-75.0
	3.8	Nesting	Negative	-2.3	-2.3
4. Avifauna – power lines	4.1	Collision of birds	Negative	-25.0	-25.0
	4.2	Habitat destruction	Negative	-15.0	-15.0
	4.3	Disturbance	Negative	-15.0	-15.0
5. Avifauna - access roads	5.1	Disturbance	Negative	-30.0	-30.0
	5.2	Habitat destruction	Negative	-30.0	-30.0
Social					
6. Visual	6.1	Major tourism routes	Negative	-80.0	-80.0
	6.2	Residential areas: Upington	Negative	-50.0	-50.0

Category	Code	Impact	Type	Before mitigations	After mitigations
	6.3	Residential areas: Louisvale, Louisvel Road, Kanon Eiland	Negative	-40.0	-40.0
	6.4	Residential areas: Oranje Valley, Ses Brugge, Klippunt	Negative	-25.0	-25.0
	6.5	Protected areas: Spitkop NR	Negative	-80.0	-80.0
	6.6	Protected areas: Augrabiesd Falls NP	Negative	-3.8	-3.8
	6.7	Orange River	Negative	-15.0	-15.0
	6.8	Ancillary infrastructure: salt tanks	Negative	-7.5	0.0
	6.9	Ancillary infrastructure: auxiliary house	Negative	-3.8	-3.8
	6.10	Ancillary infrastructure: transmission line	Negative	-7.5	-7.5
	6.11	Ancillary infrastructure: pipe line	Negative	-7.5	0.0
	6.12	Lighting: glare- floodlights	Negative	-25.0	-25.0
	6.13	Lighting: glare-aircraft warning lights	Negative	-25.0	-25.0
	6.14	Lighting: spill light	Negative	-3.8	-3.8
	6.15	Lighting: sky glow	Negative	-7.5	-7.5
7. Noise	7.1	Construction phase	Negative	-7.5	-7.5
	7.2	Operational phase	Negative	-3.8	-3.8
8. Quality of life	8.1	Impact on daily living and movement patterns - construction	Negative	-25.0	-7.5
	8.2	Impact on daily living and movement patterns - operation	Negative	-7.5	-2.5
	8.3	Disruption of social networks and alteration of family structures - construction	Negative	-50.0	-25.0
	8.4	Social impact derived from industrial diversification - construction	Positive	7.5	25.0
	8.5	Social impact derived from industrial diversification - operation	Positive	25.0	50.0
	8.6	Social impact derived from the environmental and economic benefits of solar power	Positive	50.0	75.0
	8.7	Air and dust pollution - construction	Negative	-64.0	-12.0
	8.8	Light intrusion - construction	Negative	-50.0	-25.0
	8.9	Noise intrusion - construction	Negative	-25.0	-2.5
	8.10	Air and dust pollution - operation	Negative	-3.8	-1.3
	8.11	Light intrusion - operation	Negative	-150.0	-100.0
	8.12	Noise intrusion - operation	Negative	-7.5	0.0

Category	Code	Impact	Type	Before mitigations	After mitigations
9. Demographic changes	9.1	Introduction of people dissimilar in demographic profile - construction	Negative	-25.0	-7.5
	9.2	Introduction of people dissimilar in demographic profile - operation	Negative	-7.5	-2.5
	9.3	Inflow of temporary workers - construction	Negative	-25.0	-7.5
	9.4	Introduction of new social classes	Negative	-7.5	-7.5
Economic					
10. Employment	10.1	Employment equity and occupation opportunities - construction	Positive	50.0	25.0
	10.2	Creation of employment opportunities - construction	Positive	100.0	50.0
	10.3	Employment equity and occupation opportunities - operation	Positive	50.0	15.0
	10.4	Creation of employment opportunities - operation	Positive	50.0	30.0
11. Tourism	11.1	Change in tourism and leisure opportunities - construction	Positive	7.5	15.0
	11.2	Change in tourism and leisure opportunities - operation	Positive	7.5	25.0
12. Infrastructure	12.1	Change in community infrastructure - construction	Negative	-25.0	-7.5
	12.2	Change in community infrastructure - operation	Negative	-7.5	-2.5
13. Service delivery	13.1	Impact on municipal services requirements - construction	Negative	-50.0	-7.5
	13.2	Impact on municipal services requirements - operation	Negative	-7.5	-30.0

ANNEXURE H: CSP SENSITIVITY ANALYSIS TABLES

Table H-1: Sensitivity analysis for pairwise comparison approach

Criteria and categories	Original weights	New weights															
Category - Environmental	21.8%	26.8%	21.8%	21.8%	21.8%	21.8%	21.8%	21.8%	21.8%	21.8%	21.8%	21.8%	21.8%	21.8%	21.8%	21.8%	21.8%
Groundwater	39.4%	39.4%	44.4%	39.4%	39.4%	39.4%	39.4%	39.4%	39.4%	39.4%	39.4%	39.4%	39.4%	39.4%	39.4%	39.4%	39.4%
Ecology	28.5%	28.5%	28.5%	33.5%	28.5%	28.5%	28.5%	28.5%	28.5%	28.5%	28.5%	28.5%	28.5%	28.5%	28.5%	28.5%	28.5%
Avifauna - CSP plant	5.7%	5.7%	5.7%	5.7%	10.7%	5.7%	5.7%	5.7%	5.7%	5.7%	5.7%	5.7%	5.7%	5.7%	5.7%	5.7%	5.7%
Avifauna – power lines	20.7%	20.7%	20.7%	20.7%	20.7%	25.7%	20.7%	20.7%	20.7%	20.7%	20.7%	20.7%	20.7%	20.7%	20.7%	20.7%	20.7%
Avifauna - access roads	5.7%	5.7%	5.7%	5.7%	5.7%	5.7%	10.7%	5.7%	5.7%	5.7%	5.7%	5.7%	5.7%	5.7%	5.7%	5.7%	5.7%
Category - Social	30.2%	30.2%	30.2%	30.2%	30.2%	30.2%	30.2%	35.2%	30.2%	30.2%	30.2%	30.2%	30.2%	30.2%	30.2%	30.2%	30.2%
Visual	11.9%	11.9%	11.9%	11.9%	11.9%	11.9%	11.9%	11.9%	16.9%	11.9%	11.9%	11.9%	11.9%	11.9%	11.9%	11.9%	11.9%
Noise	20.7%	20.7%	20.7%	20.7%	20.7%	20.7%	20.7%	20.7%	20.7%	25.7%	20.7%	20.7%	20.7%	20.7%	20.7%	20.7%	20.7%
Quality of life	53.6%	53.6%	53.6%	53.6%	53.6%	53.6%	53.6%	53.6%	53.6%	53.6%	58.6%	53.6%	53.6%	53.6%	53.6%	53.6%	53.6%
Demographic changes	13.8%	13.8%	13.8%	13.8%	13.8%	13.8%	13.8%	13.8%	13.8%	13.8%	13.8%	18.8%	13.8%	13.8%	13.8%	13.8%	13.8%
Category - Economic	48.0%	48.0%	48.0%	48.0%	48.0%	48.0%	48.0%	48.0%	48.0%	48.0%	48.0%	48.0%	53.0%	48.0%	48.0%	48.0%	48.0%
Employment	31.3%	31.3%	31.3%	31.3%	31.3%	31.3%	31.3%	31.3%	31.3%	31.3%	31.3%	31.3%	31.3%	36.3%	31.3%	31.3%	31.3%
Tourism	13.7%	13.7%	13.7%	13.7%	13.7%	13.7%	13.7%	13.7%	13.7%	13.7%	13.7%	13.7%	13.7%	13.7%	18.7%	13.7%	13.7%
Infrastructure	31.3%	31.3%	31.3%	31.3%	31.3%	31.3%	31.3%	31.3%	31.3%	31.3%	31.3%	31.3%	31.3%	31.3%	31.3%	36.3%	31.3%
Service delivery	23.8%	23.8%	23.8%	23.8%	23.8%	23.8%	23.8%	23.8%	23.8%	23.8%	23.8%	23.8%	23.8%	23.8%	23.8%	23.8%	28.8%
TVI before mitigation	-6.83	-7.99	-7.09	-6.99	-7.39	-7.08	-7.16	-7.49	-7.52	-6.93	-6.95	-7.06	-6.60	-5.52	-6.65	-7.08	-7.86
% change in TVI	-	-16.9%	-3.9%	-2.4%	-8.2%	-3.6%	-4.8%	-9.7%	-10.2%	-1.5%	-1.8%	-3.4%	3.4%	19.2%	2.6%	-3.7%	-15.1%
Rank (1 – highest change)	-	2	8	14	6	10	7	5	4	16	15	11	12	1	13	9	3
TVI after mitigation	-0.99	-1.93	-1.25	-0.99	-1.54	-1.23	-1.31	-1.05	-1.68	-1.09	-0.80	-1.09	-0.62	-0.43	-0.43	-1.07	-1.20
% change in TVI	-	-0.99	-0.99	-0.99	-0.99	-0.99	-0.99	-0.99	-0.99	-0.99	-0.99	-0.99	-0.99	-0.99	-0.99	-0.99	-0.99
Rank (1 – highest change)	-	1	8	16	4	9	7	15	2	13	11	12	6	3	5	14	10

Table H-2: Sensitivity analysis for direct weighting approach

Criteria and categories	Original weights	New weights															
Category - Environmental	17.9%	22.9%	17.9%	17.9%	17.9%	17.9%	17.9%	17.9%	17.9%	17.9%	17.9%	17.9%	17.9%	17.9%	17.9%	17.9%	17.9%
Groundwater	30.0%	30.0%	35.0%	30.0%	30.0%	30.0%	30.0%	30.0%	30.0%	30.0%	30.0%	30.0%	30.0%	30.0%	30.0%	30.0%	30.0%
Ecology	25.0%	25.0%	25.0%	30.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%
Avifauna - CSP plant	10.0%	10.0%	10.0%	10.0%	15.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%
Avifauna – power lines	25.0%	25.0%	25.0%	25.0%	25.0%	30.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%
Avifauna - access roads	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	15.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%
Category - Social	25.4%	25.4%	25.4%	25.4%	25.4%	25.4%	25.4%	30.4%	25.4%	25.4%	25.4%	25.4%	25.4%	25.4%	25.4%	25.4%	25.4%
Visual	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%	25.0%	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%
Noise	30.0%	30.0%	30.0%	30.0%	30.0%	30.0%	30.0%	30.0%	30.0%	35.0%	30.0%	30.0%	30.0%	30.0%	30.0%	30.0%	30.0%
Quality of life	35.0%	35.0%	35.0%	35.0%	35.0%	35.0%	35.0%	35.0%	35.0%	35.0%	40.0%	35.0%	35.0%	35.0%	35.0%	35.0%	35.0%
Demographic changes	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	20.0%	15.0%	15.0%	15.0%	15.0%	15.0%
Category - Economic	56.7%	56.7%	56.7%	56.7%	56.7%	56.7%	56.7%	56.7%	56.7%	56.7%	56.7%	56.7%	61.7%	56.7%	56.7%	56.7%	56.7%
Employment	30.0%	30.0%	30.0%	30.0%	30.0%	30.0%	30.0%	30.0%	30.0%	30.0%	30.0%	30.0%	30.0%	35.0%	30.0%	30.0%	30.0%
Tourism	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%	25.0%	20.0%	20.0%
Infrastructure	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	30.0%	25.0%
Service delivery	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	30.0%
TVI before mitigation	-3.16	-4.41	-3.38	-3.30	-3.62	-3.37	-3.43	-3.99	-3.75	-3.24	-3.26	-3.40	-2.68	-1.18	-2.95	-3.67	-4.10
% change in TVI	-	-39.5%	-7.0%	-4.3%	-14.5%	-6.5%	-8.5%	-26.2%	-18.4%	-2.4%	-3.2%	-7.6%	15.4%	62.7%	6.7%	-16.1%	-29.6%
Rank (1 – highest change)	-	2	11	14	8	13	9	4	5	16	15	10	7	1	12	6	3
TVI after mitigation	0.27	-0.80	0.05	0.27	-0.19	0.06	0.00	-0.12	-0.31	0.19	0.42	0.18	0.80	1.25	0.86	0.11	-0.03
% change in TVI	-	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27
Rank (1 – highest change)	-	1	10	16	6	11	9	7	4	15	13	14	5	2	3	12	8

ANNEXURE I: OCGT IMPACT RATINGS

Table I-1: Impact ratings before mitigations

Category	Code	Ranking	Type	OCGT plant	Transmission lines			Road access route			Fuel supply line	
					Alt 1	Alt 2	Alt 3	Alt 1	Alt 2	Alt 3	Alt 1	Alt 2
Environmental category												
Botanical - impact on sensitive areas	1	Significance	Negative	High	High	Med. to high	High	Low	Low	High	Low	Low
		Probability		Definite	Probable	Possible	Probable	Possible	Possible	Possible	Possible	Possible
Avifauna	2	Significance	Negative	Neutral	High	Medium to high	High	Neutral	Neutral	Neutral	Neutral	Neutral
		Probability		N/A	Possible	Unlikely	Possible	N/A	N/A	N/A	N/A	N/A
Air quality	3	Significance	Negative	Low	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral
		Probability		Definite	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Water availability	4	Significance	Negative	Low	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral
		Probability		Definite	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Water and soil during construction	13	Significance	Positive	Low	Low	Low	Low	Low	Low	Low	Low	Low
		Probability		Probable	Probable	Probable	Probable	Probable	Probable	Probable	Probable	Probable
Social category												
Heritage	5	Significance	Negative	Low	Low	Low	Low	Low	Low	Low	Low	Low
		Probability		Unlikely	Unlikely	Unlikely	Unlikely	Unlikely	Unlikely	Unlikely	Unlikely	Unlikely
Visual	6	Significance	Negative	High	Medium to high	Medium	Medium to high	Low	Low	Medium	Very low	Very low
		Probability		Probable	Probable	Probable	Probable	Possible	Possible	Possible	Possible	Possible
Traffic	7	Significance	Negative	Neutral	Neutral	Neutral	Neutral	Very low	Low	Low	Neutral	Neutral
		Probability		N/A	N/A	N/A	N/A	Possible	Possible	Possible	N/A	N/A
Noise	8	Significance	Negative	Medium	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral
		Probability		Definite	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Noise during	12	Significance	Negative	Low	Low	Low	Low	Low	Low	Low	Low	Low

Category	Code	Ranking	Type	OCGT plant	Transmission lines			Road access route			Fuel supply line	
					Alt 1	Alt 2	Alt 3	Alt 1	Alt 2	Alt 3	Alt 1	Alt 2
construction		Probability		Probable	Probable	Probable	Probable	Probable	Probable	Probable	Probable	Probable
Economic category												
Existing infrastructure	9	Significance	Negative	Neutral	Low	Low	Low	Neutral	Neutral	Neutral	Neutral	Neutral
		Probability		N/A	Possible	Possible	Possible	N/A	N/A	N/A	N/A	N/A
Land use	10	Significance	Negative	Neutral	Low	Medium	Low	Neutral	Neutral	Neutral	Neutral	Neutral
		Probability		N/A	Probable	Probable	Probable	N/A	N/A	N/A	N/A	N/A
Socio-Economic	11	Significance	Negative	Medium to high	Medium to high	Medium to high	Medium to high	Neutral	Neutral	Neutral	Neutral	Neutral
		Probability		Definite	Definite	Definite	Definite	N/A	N/A	N/A	N/A	N/A
Socio-Economic during construction	14	Significance	Positive	Low	Low	Low	Low	Low	Low	Low	Low	Low
		Probability		Probable	Probable	Probable	Probable	Probable	Probable	Probable	Probable	Probable

Table I-2: Impact ratings after mitigations

Category	Code	Ranking	Type	OCGT plant	Transmission lines			Road access route			Fuel supply line	
					Alt 1	Alt 2	Alt 3	Alt 1	Alt 2	Alt 3	Alt 1	Alt 2
Environmental category												
Botanical - impact on sensitive areas	1	Significance	Negative	Very low	Medium	Low	Medium	Very low	Very low	Very low	Very low	Very low
		Probability		Possible	Possible	Possible	Possible	Unlikely	Unlikely	Unlikely	Unlikely	Unlikely
Avifauna	2	Significance	Negative	Neutral	Medium	Medium	Medium	Neutral	Neutral	Neutral	Neutral	Neutral
		Probability		N/A	Unlikely	Unlikely	Unlikely	N/A	N/A	N/A	N/A	N/A
Air quality	3	Significance	Negative	Low	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral
		Probability		Definite	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Water availability	4	Significance	Negative	Very low	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral
		Probability		Possible	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Water and soil	13	Significance	Positive	Very low	Very low	Very low	Very low	Very low	Very low	Very low	Very low	Very low

Category	Code	Ranking	Type	OCGT plant	Transmission lines			Road access route			Fuel supply line	
					Alt 1	Alt 2	Alt 3	Alt 1	Alt 2	Alt 3	Alt 1	Alt 2
during construction		Probability		Probable	Probable	Probable	Probable	Probable	Probable	Probable	Probable	Probable
Social category												
Heritage	5	Significance	Negative	Very low	Very low	Very low	Very low	Very low	Very low	Very low	Very low	Very low
		Probability		Unlikely	Unlikely	Unlikely	Unlikely	Unlikely	Unlikely	Unlikely	Unlikely	Unlikely
Visual	6	Significance	Negative	Medium	Medium to high	Medium	Medium to high	Low	Low	Medium	Very low	Very low
		Probability		Possible	Probable	Probable	Probable	Possible	Possible	Possible	Possible	Possible
Traffic	7	Significance	Negative	Neutral	Neutral	Neutral	Neutral	Very low	Very low	Low	Neutral	Neutral
		Probability		N/A	N/A	N/A	N/A	Possible	Possible	Possible	N/A	N/A
Noise	8	Significance	Negative	Low	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral
		Probability		Definite	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Noise during construction	12	Significance	Negative	Low	Very low	Very low	Very low	Very low	Very low	Very low	Very low	Very low
		Probability		Probable	Probable	Probable	Probable	Probable	Probable	Probable	Probable	Probable
Economic category												
Existing infrastructure	9	Significance	Negative	Neutral	Very low	Very low	Very low	Neutral	Neutral	Neutral	Neutral	Neutral
		Probability		N/A	Possible	Possible	Possible	N/A	N/A	N/A	N/A	N/A
Land use	10	Significance	Negative	Neutral	Low	Low	Low	Neutral	Neutral	Neutral	Neutral	Neutral
		Probability		N/A	Probable	Probable	Probable	N/A	N/A	N/A	N/A	N/A
Socio-Economic	11	Significance	Negative	Medium to high	Medium to high	Medium to high	Medium to high	Neutral	Neutral	Neutral	Neutral	Neutral
		Probability		Definite	Definite	Definite	Definite	N/A	N/A	N/A	N/A	N/A
Socio-Economic during construction	14	Significance	Positive	Low	Low	Low	Low	Low	Low	Low	Low	Low
		Probability		Probable	Probable	Probable	Probable	Probable	Probable	Probable	Probable	Probable

ANNEXURE J: OCGT PERFORMANCE MATRICES

Table J-1: Performance matrix before mitigations

Category	Code	Ranking	Type	OCGT plant	Transmission lines			Road access route			Fuel supply line	
					Alt 1	Alt 2	Alt 3	Alt 1	Alt 2	Alt 3	Alt 1	Alt 2
Environmental category												
Botanical - impact on sensitive areas	1	Significance	Negative	-100.00	-50.00	-20.00	-50.00	-3.75	-3.75	-25.00	-3.75	-3.75
Avifauna	2	Significance	Negative	0.00	-25.00	-12.00	-25.00	0.00	0.00	0.00	0.00	0.00
Air quality	3	Significance	Negative	-15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Water availability	4	Significance	Negative	-15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Water and soil during construction	13	Significance	Positive	-7.50	-7.50	-7.50	-7.50	-7.50	-7.50	-7.50	-7.50	-7.50
Social category												
Heritage	5	Significance	Negative	-2.25	-2.25	-2.25	-2.25	-2.25	-2.25	-2.25	-2.25	-2.25
Visual	6	Significance	Negative	-50.00	-40.00	-25.00	-40.00	-3.75	-3.75	-12.50	-1.25	-1.25
Traffic	7	Significance	Negative	0.00	0.00	0.00	0.00	-1.25	-3.75	-3.75	0.00	0.00
Noise	8	Significance	Negative	-50.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Noise during construction	12	Significance	Negative	-7.50	-7.50	-7.50	-7.50	-7.50	-7.50	-7.50	-7.50	-7.50
Economic category												
Existing infrastructure	9	Significance	Negative	0.00	-3.75	-3.75	-3.75	0.00	0.00	0.00	0.00	0.00
Land use	10	Significance	Negative	0.00	-7.50	-25.00	-7.50	0.00	0.00	0.00	0.00	0.00
Socio-Economic	11	Significance	Negative	80.00	80.00	80.00	80.00	0.00	0.00	0.00	0.00	0.00
Socio-Economic during construction	14	Significance	Positive	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50

Table J-2: Performance matrix after mitigations

Category	Code	Ranking	Type	OCGT plant	Transmission lines			Road access route			Fuel supply line	
					Alt 1	Alt 2	Alt 3	Alt 1	Alt 2	Alt 3	Alt 1	Alt 2
Environmental category												
Botanical - impact on sensitive areas	1	Significance	Negative	-1.25	-12.50	-3.75	-12.50	-0.75	-0.75	-0.75	-0.75	-0.75
Avifauna	2	Significance	Negative	0.00	-7.50	-7.50	-7.50	0.00	0.00	0.00	0.00	0.00
Air quality	3	Significance	Negative	-15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Water availability	4	Significance	Negative	-1.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Water and soil during construction	13	Significance	Positive	-2.50	-2.50	-2.50	-2.50	-2.50	-2.50	-2.50	-2.50	-2.50
Social category												
Heritage	5	Significance	Negative	-0.75	-0.75	-0.75	-0.75	-0.75	-0.75	-0.75	-0.75	-0.75
Visual	6	Significance	Negative	-12.50	-40.00	-25.00	-40.00	-3.75	-3.75	-12.50	-1.25	-1.25
Traffic	7	Significance	Negative	0.00	0.00	0.00	0.00	-1.25	-1.25	-3.75	0.00	0.00
Noise	8	Significance	Negative	-15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Noise during construction	12	Significance	Negative	-7.50	-2.50	-2.50	-2.50	-2.50	-2.50	-2.50	-2.50	-2.50
Economic category												
Existing infrastructure	9	Significance	Negative	0.00	-1.25	-1.25	-1.25	0.00	0.00	0.00	0.00	0.00
Land use	10	Significance	Negative	0.00	-7.50	-7.50	-7.50	0.00	0.00	0.00	0.00	0.00
Socio-Economic	11	Significance	Negative	80.00	80.00	80.00	80.00	0.00	0.00	0.00	0.00	0.00
Socio-Economic during construction	14	Significance	Positive	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50