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A Rapid Evaluation Method to Improve Project Decision-Making Associated with Natural Resources

A dissertation presented in partial fulfilment of the
requirements for the degree of

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Camila Rocío del Rosario Reyes Santolalla

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ABSTRACT

Today Multiple Criteria Analyses (MCAs) are widely used for project appraisals. In order to include the short and long term consequences that a project can have, most MCA models are built on a project specific basis. In addition, there is a proliferation of projects being put forward for consideration, thus the work of decision makers has become extremely time and resource consuming. The aim of this research is to develop and test an integrated method for project appraisal which can be used by decision makers to evaluate a diverse range of project proposals in a timely and resource efficient manner.

This led to the creation of a generic method that could be applied to all projects in the first instance. The research employed a modified Leopold matrix to create a checklist to be used as an initial tool to select key attributes for inclusion in the decision making analysis. This standardized approach allows decision makers to work with available data in the first instance to avoid excessive time and resource expenditure. MCA forms the basis of this rapid evaluation method (REM), as it can accommodate the integration of heterogeneous criteria that are measured by differing metrics. The explicit expression of preferences for certain decision attributes, a key element in the MCA process, is utilized here and a modified Delphi approach, using independent experts is employed to determine attribute weightings. From these, utility scores are calculated, sensitivity analyses conducted and recommendations made regarding the proposed project. At this point an 'accept' or 'reject' decision might be made or, alternatively there is a recommendation that a full independent MCA be executed. Taking this approach means that a unique and independent MCA will only be required for some projects. Therefore, this method accelerates the project decision-making process and reduces the overall resources needed for the appraisals.

Three diverse case studies are used to test and refine the REM. One is an energy project situated in New Zealand, another, a proposal for a privately owned abattoir in Chile and the third is a decision between two proposals relevant to the salmon farming industry in Chile. From this research it is clear that the application of the

REM can aggregate complex data into a pragmatic multi-criteria framework, improving the ability of agencies to estimate the trade-off between environmental, economic, and social impacts of a development project. The REM provides a benchmark for managers to determine whether a project should be accepted, rejected or requires more detailed analysis. This method has the potential to significantly reduce the time and cost involved in project evaluation.

Keywords: Multiple criteria analysis, analytical hierarchy process, project evaluation, integrated analysis, rapid evaluation method.

STATEMENT OF ORIGINALITY

Student name: Camila Rocío del Rosario Reyes Santolalla

Student I.D.: 07266340

I declare that:

- This is an original thesis and is entirely my own work.
- Where I have made use of ideas of others writers, I have acknowledged the source.
- Where I have used any diagrams or visuals I have acknowledged the source in every instance.
- This thesis will not be submitted as assessed work in any other academic course.

Student's signature:

Date:

For my family

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During the course of my study I travelled to Malaysia to participate in the International Symposium on Society and Resource Management (ISSRM), and to Chile to conduct two out of the three case studies. During those trips I was able to meet and discuss my activities with a large number of people associated in various ways with Natural Resources Management and project development evaluation. Also, for all three case studies, conducted within New Zealand and Chile, many experts were consulted, and they provided advice, information and ideas which were invaluable in undertaking this research. I am very grateful to all of them for the willingness with which they spared time to talk to me and the information they provided.

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LIST OF ACRONYMS

AHP	: Analytic Hierarchy Process
CBA	: Cost-Benefit Analysis
CDP	: Criterion Decision Plus
CV	: Coefficient of Variation
DSS	: Decision Support Systems
EIA	: Environmental Impact Assessment
EIAS	: Environmental Impact Assessment System
EPS	: Environmental Priority Strategies
ESE	: Economic, Social and Environmental
LDW	: Logical Decisions for Windows™
LM	: Leopold Matrix
MAUT	: Multi-Attribute Utility Theory
MCA	: Multiple Criteria Analysis
MUF	: Multi-measure Utility Function
NRM	: Natural Resource Management
REM	: Rapid Evaluation Method
SIA	: Social Impact Assessment
SMART	: Simple Multi-Attribute Rating Technique
SMARTER:	: Simple Multi-Attribute Rating Technique Exploiting Ranks
SUF:	: Single-measure Utility Function
UNCED	: United Nations Conference on Environment and Development
UNEP	: United Nations Environment Programme
WCED:	: World Commission for Environment and Development

DEFINITIONS OF TERMS USED

The following terms have precise meanings in this thesis and are drawn from Logical Decision for Window (LDW) (Logical Decision, 2010, p 12-1 to 12-10), the MCA software employed to run REM.

Alternative - Alternatives are the choices which will be ranked by the analysis. There is no limit on how many alternatives can be defined in Logical Decision software. Alternatives consist of a name and a level for each measure. Levels may be point estimates (single numbers), text labels or probabilistic.

Analytic Hierarchy Process - A process for computing the relative importance of a set of alternatives or goal members. The decision maker is asked to provide the ratios of the performances (or importance) of all the possible pairs of objects in the set. A method, based on linear algebra, is used to compute the relative utilities or weights for the objects in the set.

Attribute - Attributes are the criteria which quantify the achievement of the objectives. They describe the consequences of the alternatives and make value trade-offs. Attributes are expressed in measures and these may be qualitative or quantitative. The decision analysis literature uses many aliases for attributes, including 'criteria', 'measures', 'scales', 'components' and 'indicators' (Keeney & Gregory, 2005).

Goal - A set of measures (and possibly other sub-goals) treated as a unit for ranking purposes. The goals form a hierarchy ranging from most to least general. Each analysis is required to have at least one goal, called 'overall'. If no other sub-goals have been defined, all of the measures are members of the overall goal. A measure or sub-goal can be a member of only one goal.

Level - An alternative's level on a measure is the number on the measure's scale (having the proper units) that indicates how the alternative performs on that measure. Levels can also be probabilistic, so that the level is defined by a

probability distribution instead of a single number. Levels can be text labels, where each alternative is assigned one of a limited number of text descriptors. Levels can also be defined as the weighted sum of a group of measure categories. Levels should not have a value or preference content. Levels are just data. Preference information is added when the levels are converted to utility.

Measure - Evaluation measures are the variables that are used to rank the alternatives. A measure consists of a name, a three letter abbreviation, units and most and least preferred levels. Logical Decision software puts no restrictions on the most and least preferred levels. The most preferred level can be greater or less than the least preferred level. There is also no requirement that the ranges on different measures be comparable. The ranges are made comparable when levels on the measures are converted to utility.

Weight - Weights are a casual term for the scaling constants (small *ks*) associated with the members of a goal in the Multi-measure Utility Function (MUF) of a goal. Weights provide an indication of the relative importance of the measures given the ranges found for a set of alternatives. The weights in a MUF are determined by the trade-offs that define the MUF. The trade-offs define a unique set of weights that will allow all of the equally preferred alternatives in the trade-offs to get the same overall utility.

Trade-off - A trade-off is a pair of equally preferred hypothetical alternatives that differ on only two measures: Alternative B has a more preferred level on measure 1 and a less preferred level on measure 2, while alternative A has a less preferred level on measure 1 and a more preferred level for measure 2. The levels of the measures are set so that a change in measure 1 just compensates for a corresponding change in measure 2. Equally preferred alternatives should have equal overall utilities, and since alternatives A and B differ only in measures 1 and 2, these compensating changes can be used to compute the relative weights for measures 1 and 2.

Utility - Utility is a standardized measure of the relative desirability of a given level or set of levels for an alternative. Utilities are the output of a Multi-measure Utility

Function (MUF) or Single-measure Utility Function (SUF). They are used to convert the levels of measures, which are based on scales with potentially different units, into a comparable scale with a range defined to go from 0.0 to 1.0. Utility functions generally assign a utility of 0.0 to the least preferred level for a measure, and assign 1.0 to the most preferable level for a measure. Alternatives with utilities closer to 1.0 are preferred.

CHAPTER ONE – INTRODUCTION

Decision-making regarding the management of natural resources is multifaceted, merging a wide range of technical, environmental, financial, economic, social and institutional factors into an analytical evaluation (Kiker, Bridges, Varghese, Seager, & Linkov, 2005). The interdisciplinary nature of natural resource management (NRM) issues, which along with tangible goods and services, also deal with unpriced and intangible goods and services, making it difficult to value and incorporate them into empirical studies (Schmoltdt, Kangas, Mendoza, & Pesonen, 2001). Furthermore, the majority of resource-use decisions that address land, water and biodiversity objectives include numerous stakeholders with competing interests and priorities (Hajkovicz & Higgins, 2008; Kiker et al., 2005; Stahl, Cimorelli, & Chow, 2002). Therefore, the task of decision-making can be extremely complex because of the implications of what cannot be resolved through a single perspective.

Since the promulgation of Agenda 21 during the United Nations Conference on Environment and Development (UNCED) in 1992, the concept of sustainable development, which includes the integration of biophysical, social and economic criteria, has been cited as the current most important NRM challenge (Costanza, Jørgensen, Robert, & Sven Erik, 2002). An increasing number of integrated decision-making techniques have been developed worldwide (Argent, Grayson, & Ewing, 1999; Belton & Stewart, 2002; Cai, McKinney, & Lasdon, 2003; Margerum, 1995). However, merging information generated by these techniques into a simple project evaluation framework is difficult.

1.1 PROBLEM STATEMENT

Decision makers require timely identification of the economic, social and environmental strengths and weaknesses of proposed project investments. Most project proposals include a discussion on social, economic, financial,

environmental and institutional factors. Central, regional and local authorities as well as development agencies and others face the dilemma of dealing with a proliferation of complex project proposals using and integrating single discipline techniques such as Cost-Benefit Analysis (CBA), Social Impact Assessment (SIA) and Environmental Impact Assessment (EIA), to guide these evaluations. However, integrating these factors into the arithmetic of decision-making is resource intensive, time consuming and expensive as increasingly an independent and unique Multi-Criteria Analysis (MCA) is conducted in order to evaluate each individual project. What is needed is a method that can be used early in the project appraisal process to evaluate alternative courses of action; to help clarify trade-offs between economic, environmental and social concerns, that would enable decision makers to make a timely decision on whether a resource intensive, independent and project-specific MCA is required, or whether an early assessment can be made. What is sought is a method that balances the need to consider enough information to make a good and informed choice with the need to simplify the situation sufficiently to make it possible to come to a conclusion within an acceptable length of time.

1.2 AIM AND OBJECTIVES

The aim of this research is to develop and test an integrated method for project appraisal which can be used by decision makers to evaluate a diverse range of project proposals in a timely and resource efficient manner.

The objectives to achieve this aim are to:

1. Review the needs of the decision-making process addressing NRM and the current methods employed to evaluate project appraisal;
2. Develop a screening method for integrative and timely identification of the key economic, social and environmental strengths and weaknesses of a proposed project;
3. Identify case studies to test and refine the method; and,
4. Determine the usefulness of applying the method to these case study proposals and consider whether it can be more widely applied.

1.3 LIMITATIONS

Studies by other researchers suggest that there are a number of factors affecting the use of analytical decision-making models (Ascough, Maier, Ravalico, & Strudley, 2008; van Pelt, Kuyvenhoven, & Nijkamp, 1990). The main limitation of using decision-making models for NRM decisions is the potential difficulty of accessing appropriate data and information when dealing with proposals. In reality complexity characterises competing demands on natural resources and this has important implications for decision-making, as the representation of a complex system reflects only a subset of possible representations (Munda, 2003). Frequently, data is hard to quantify and even seemingly easily quantified attributes can be subjective. In practice, decisions are usually based on quantitative comparisons; therefore, all attributes considered vital to a decision must be quantified in some manner. If they are not, they will be subconsciously considered or completely excluded from the decision-making process (Allan, 2008).

Although imperfect data is an inherent part of decision-making, decisions must still be made. Given that there are no absolutes, all decisions must reflect the likelihood of different outcomes and the positive and negative implications of each. The objective of analytical techniques used in project appraisals is to improve the rationality of decision making processes when selecting an alternative option. A rational decision will be one that is consistent with the values of the decision-making body and the information available to make the decision.

1.4 IMPORTANCE OF THE RESEARCH

There is a growing interest in alternative, more integrated approaches to natural resource decision-making (Frame, 2002). The ascendancy of sustainable development as a new paradigm has led to a broadening of the scope of techniques used to aid decision making. This has occurred within individual fields, such as, the incorporation of environmental impacts into CBA and the vast array of techniques used to value non-market benefits from natural areas and ecosystem services. However, this has also led to interdisciplinary approaches that involve a systems perspective of the problem and the use of integrated assessment

techniques (i.e. Longworth, 2003; Nardini, 1997). This research will develop a method that integrates data from single discipline analyses (CBA, EIA, SIA) into a generic framework for the evaluation of proposed projects in a structured and robust, but time efficient manner. This goes beyond existing integrated assessment frameworks by explicitly including input from experts obtained from an attributes weighting exercise.

1.5 CONTRIBUTION TO KNOWLEDGE

The integrated method used in this research reflects a systems approach where trade-offs between economic, environmental and social impacts are considered. Such an approach is suitable for project appraisals characterised by the involvement of different institutional agencies, competing and conflicting objectives, interdependent socio-economic and environmental components, and a need for a timely and less resource intensive decision-making process.

The research employs a checklist developed from the Leopold matrix as an initial tool to select key attributes that should be included in the decision-making analysis. Also, an innovative weighting assessment approach, based on the Delphi method and a group of expert has been included to accelerate the project decision-making process. The rapid method is intended to act as a first step to determine whether a project appraisal requires a more detailed and independent analysis or whether a decision can be made at this first step as to whether the project can be accepted or rejected.

1.6 THESIS OUTLINE

Chapter One – Introduction. This chapter provides an introduction to the research accompanied by the problem statement, the research aim and objectives, and the limitations and importance of the research.

Chapter Two – Literature Review. This chapter is divided into six main sections. The first highlights the complex nature of NRM and provides a general overview of the complexities associated with the decision-making process. Section two

analyses the inclusion of economic, social and environmental principles in the evaluation of project proposals and their consequences for the management of natural resources. The institutional roles and challenges faced by decision makers are discussed in section three. Section four provides a review of decision support techniques that have presently received much attention to guide the evaluation of projects in NRM. Section five outlines why improved decision-making models for project appraisal are needed, highlighting the characteristics that a potential model should have and the chapter is concluded in section six.

Chapter Three – Decision Framework and Method Development. This chapter presents the methodological context used to develop the REM based on a MCA. In the first section, several different MCA software are reviewed in order to identify a suitable decision-making framework on which to build the method. In section two, the steps for developing the method are described and the structure of the resulting rapid evaluation method (REM) is presented. Also here the process of entering data into the LDW software is explained. Finally, section three reports on how the REM is implemented, describing case study selections and the preparation carried out prior to application of the method.

Chapter Four – Case Study 1. The first case study is the evaluation of a New Zealand based wind farm project with implications at the national level for the energy sector. This chapter demonstrates the step by step application of the REM to a ‘with’ and ‘without’ project appraisal to determine whether the wind farm project should be accepted, rejected or recommended for a full and detailed analysis before a decision can be made. The evaluation of the case study project is used to refine and test the method in order to determine the usefulness of the REM.

Chapter Five – Case Study 2. The structure of this chapter is similar to that of chapter four. This case study is an evaluation of the proposed Cisne Austral Ltda lamb export abattoir project situated in the Aysén Region of Chile.

Chapter Six – Case Study 3. Once again the structure of this chapter follows that of chapter four. The final case study involves the comparison and selection of one

of two proposed projects both of which are net-cage systems to be utilised by the salmon farming industry in southern Chile.

Chapter Seven – Discussion and Conclusion. In the final chapter of the thesis a discussion of the REM is presented and conclusions drawn. The discussion focuses on what makes the framework an REM, what makes the method novel, how the case studies are used to test and refine the method and what makes it useful. The first section will detail the nature of information required for applying the model. The final section concludes the thesis.

CHAPTER TWO - LITERATURE REVIEW

The use and allocation of natural resources has economic, socio-political and environmental implications and consequences. In the past, decision-making approaches to natural resource management (NRM) by way of project evaluation have emphasised the economic aspects of efficient resource use above other considerations. However, attitudes are changing and the bias towards economic outcomes at the expense of both the environment and social considerations has become less acceptable. This chapter provides an overview of a typical decision-making process that influences the use and allocation of natural resources, and the ensuing difficulties that occur when integrating environmental and social considerations into the analytical framework in both time and resource efficient ways.

This chapter is divided into five sections. The first section highlights the multifaceted nature of NRM and provides a general overview of the complexities associated with the decision-making process. In section two, particular focus is given to the term sustainability and to the institutionalisation of economic, social, and environmental principles in the evaluation of project proposals and their consequences for final decisions. The institutional roles and challenges faced by decision makers are discussed in section three. Section four provides a review of decision support techniques that have received much attention to guide the evaluation of projects in NRM; highlighting both, strengths that contribute to improve decision-making and limitations that lead to conflict. Discussion will also focus on identifying attributes that can move the project evaluation process from a single discipline perspective toward the integration of the three pillars of sustainable development: economic, environmental and social objectives. Section five introduces the field of integrated assessments and in particular Multiple Criteria Analysis (MCA). The key characteristics of MCA are reviewed, emphasizing the potential of this tool as an integrated method and the shortcomings of its implementation are also outlined. Finally, the need for

improved decision-making models is outlined along with the characteristics needed for a model to improve decision-making. Section six concludes the chapter.

2.1 THE NATURE OF NRM DECISION-MAKING

Human activities are driven by people's needs and wants (Schmoldt et al., 2001). All these activities are sustained by the natural environment, which provides humankind with the raw materials and input essential for the production of all goods and services (Field, 2001; Herath & Prato, 2006). As a result of increasing human population, the consumption of goods and services has increased significantly, generating a greater demand for natural resources (Nellemann & Corcoran, 2010). Since the satisfying of human needs is constantly changing and natural resources are limited, people are forced to make choices (Saaty & Vargas, 2006). Though there are a few resources that can be considered inexhaustible (for example, solar radiation, geothermal energy, and air), the majority of resources are non-renewable and can become rapidly depleted if poorly managed.

Natural resources most often have multiple possible uses, therefore, managing them requires an understanding of the most appropriate and effective way to use them. However, alternative productive uses of these environmental resources may produce incompatibilities which cannot coexist (Engel & Korf, 2006). For example, the choice to use a tract of land for conservation negates its use for agricultural production.

Ecosystems have limits to the modifications they can sustain to remain productive and the provision of ecosystem services is impaired when ecosystems become degraded (Herath & Prato, 2006). Nellemann & Corcoran (2010), in a report conducted for the United Nations Environment Programme (UNEP), stated that over 60% of ecosystem services and their biodiversity are degraded. They also affirmed that land degradation, erosion, overgrazing, deforestation and loss of soil fertility by poor management of activities on land, are compromising ecosystem sustainability, societal wellbeing and economic development. Further, depletion of soil fertility for productive purposes creates clear supply shortages. As a

consequence, management of land resources has become important due to rising demand and increasingly limited supply.

Economists define the condition of not having enough of something to provide for all that is wanted as 'scarcity', and they argue that scarcity makes choices unavoidable (Hackett, 2011). However, resource depletion, or even the total exhaustion of a resource can occur without necessarily being perceived as scarcity. As Rees (1990, p. 255) illustrated, "the extinction of wolves in Britain hardly seems a scarcity issue since, apart from some conservationists, few people would regard them as a valuable resource". Rees used this example intending to highlight the difference between scarcity and depletion, and demonstrated the way people's values affect the way in which NRM decisions are made.

In almost every case, resource allocation is influenced by conflicting interests and changing values. In the past few decades, debate has intensified regarding the values attributed to natural resources in terms of the 'non extractive' services that they can provide (for example, beautiful vistas, biodiversity conservation, support for recreational enjoyment) and this is reflected in the rising number of conflicts between extraction versus preservation objectives (Field, 2001). It is clear that environmental and resource issues have increased societal values attached to the natural environment (Munda, Nijkamp, & Rietveld, 1994). Today the evaluation processes that influence the use of natural resources have become a key issue, particularly since the decision-making processes are increasingly exposed to public scrutiny and expert review (Hajkowicz, Young, & MacDonald, 2000b).

Since decision-making in NRM is likely to be faced with conflicting perspectives and interests, the process should include multiple stakeholders and assess a wide range of disciplines. In addition, all decisions are based on the evaluation of future outcomes and as such, deal with considerable uncertainty (Gough & Ward, 1996). These key features characterising NRM decisions and their importance in the decision-making process are explored in the following sections.

2.1.1 MULTIPLE STAKEHOLDERS

People at all levels of society (citizens, government officials and business representatives) are faced with decisions that impact upon other individuals and groups, with either direct and or indirect consequences. As illustrated by Dale and English (1999):

A homeowner decides where to dump old house paint; a city government decides whether to issue a permit for a new subdivision; a state agency decides where to reroute a state highway; a business decides whether to expand its operations; the federal government decides how to revise an air quality standard. Each of these actions has effects that reach far beyond the person or group making the decision". (p. 1)

Effects comprise the mid- to long-term implications of a project, be they intended or unintended effects. A project or an action will always aim to have positive impacts that contribute to the achievement of the overall goal; however, there may ultimately be negative, unavoidable consequences (Nardini, 1997). Moreover, stakeholders may not be unanimous in their consideration of an impact to be positive or negative. Even in the case of a project characterized by a 'uniquely' positive economic impact (for example, an income increase), there is potential for conflict to arise if the income increase is deemed to be unevenly distributed (Burdge & Vanclay, 1995; Nardini, 1997). Therefore, a 'good decision' should be reached as a result of input from as many stakeholders as possible.

Stakeholder Analysis has been proposed to include the identification and prioritization of stakeholders, understanding and harmonizing their objectives and interests, as well as the integration of stakeholder judgment into the decision-making process (Grimble & Wellard, 1997; Kennedy & Koch, 2004). Although, a wide range of literature supports the idea that stakeholder participation can improve the process itself (Ananda & Herath, 2003; Grimble & Wellard, 1997; Irvin & Stansbury, 2004; Kennedy & Koch, 2004; Stahl et al., 2002), real case studies including public participation are seldom available. In practice, the inclusion of multiple stakeholders in the decision-making process can be a daunting task (Sarkissian & Walsh, 1994). Each group will ultimately have different levels of

expertise and knowledge that can lead to vastly different ways of understanding NRM problems, making negotiation a difficult process (Ascough et al., 2008).

Disagreements abound regarding the role of 'non experts', the timing and extent of their involvement as well as the techniques that should be employed (Harding, 1998; Jolley, 2007). Decision makers are often asked to engage the public without provision of adequate funds to work on multi-stakeholder projects that are both resource intensive and time consuming (Jolley, 2007). In such cases, Kahn (2005) suggested that representatives of different positions be selected to create a group of workable size. Harding (1998) emphasised that it was not a case of participation at all costs for every situation, but could vary according to the size and impact magnitude of the project and the level of public interest.

With or without a public hearing, the decision process should take into consideration, all types of impacts (both positive and negative), whether economic, bio-physical, aesthetic, cultural, health, political, etc. According to Nardini (1997, p. 176), in balancing benefits and cost, "decision-making becomes what it really is – a trade-off between conflicting criteria. In the end, this trade off should represent a social judgement both for public and private projects, because these (impacts) will affect people's quality of life to some extent".

2.1.2 *MULTIDISCIPLINARY MANAGEMENT*

The multiplicity of purposes and interest involved in natural resource allocation and environmental decision-making can create conflict between individuals from different disciplines (Adger et al., 2003). Each discipline has its own strengths and, with respect to NRM decision-making, these strengths may result in bias towards one or another in the three main areas; namely economic, social and environmental dimensions (Costanza et al., 2002).

Economic aspects relate to issues such as profits, investments, cost, efficiency of resource use, and security of supply. Social concerns refer to value and equity considerations, such as human interest, income distribution, and quality of life (Nijkamp & Ouwersloot, 1997). Environmental dimensions are concerned with

impacts in physical and chemical characteristics, biological conditions and ecological relationships of natural resources. Even though these three dimensions are strongly linked (Nijkamp & Rietveld, 1986), each uses different measurement values and scales. For example, environmental tools are based on physical parameters, whereas economic tools are normally based on monetary values. This difference represents a fundamental obstacle in promoting integration (Campbell & Sayer, 2003). The decision-making process requires an interactive and multidisciplinary approach to achieve a more comprehensive analysis and understanding of the links between traditionally separate disciplines (Bingham et al., 1995; Ekasingh & Letcher, 2008; Garcia, 2004).

2.1.3 MEASUREMENT UNCERTAINTY

Uncertainty takes place when system parameters are known but the probabilities of their occurrence are not (Gough, 1988). According to Baird (1989, p. 134), decisions made under uncertainty are defined as those in which “the decision maker is faced with more than one outcome for any particular alternative chosen but the probability of occurrence for each outcome is not known”.

Decision-making is invariably accompanied by some degree of *ex-ante* research or evaluation. In fact, the decision maker’s task is to select an action to maximize ‘expected’ utility (Hartwick & Olewiler, 1986). However, this is a challenging task because decision makers cannot easily anticipate the impacts associated with socio-economic-environmental risk and uncertainty, and cannot specify the probabilities of future outcomes (Prato, 2007). The outcome depends, to a large extent, on uncontrollable and uncertain variables (Nardini, 1997).

To provide reliable results, a robust decision analysis model must anticipate the “contingency, arbitrariness and ignorance in the way the problem is predicted and the process is implemented” (Gervásio & Simões da Silva, 2012, p. 7123). Therefore, in order to improve decision-making, the uncertainties associated with all stages of the evaluation process need to be explicitly considered and the rationale that underpins the decisions that are made should be readily defensible (Ascough et al., 2008; Joslin & Nicholas, 1999; Yoe, 2011). Uncertainty related to

NRM can be grouped into two categories: data uncertainty and decision uncertainty (Canter, 1996):

- Data uncertainty can be related to project definition, incomplete and/or irrelevant baseline information, problems in defining cause and effect relationship, model error, or inadequate collection of data.
- Decision uncertainty can occur due to failure to undertake an adequate scoping exercise, inadequate use of formalized scoring and weighting systems, data manipulation to meet different interests, pressure to use a 'worst-case' scenario, and influence of external contingent decisions, to name a few.

2.2 SUSTAINABLE MANAGEMENT OF NATURAL RESOURCES

“The 1992 Earth summit alerted the conscience of the world to the urgency of achieving environmentally sustainable development. We know enough to act today, but we must also find answers to the many tough conceptual and technical questions that remain” (Serageldin, Steer, & Cernea, 1994, p. 1).

The manner in which the natural environment is managed is linked to the general problem of allocating economic resources between competing ends (Ahmad, 1981; Munasinghe, 1993). In managing its economy, a society makes critical decisions about how much, when, and where to provide goods and services, and the means through which this will be accomplished and the goods and services distributed. From a strictly economic point of view, an optimum allocation of resources occurs when these decisions result from the interactions of producers and consumers through a free market (Field, 2001; Kahn, 2005). Market failure provides the justification for government intervention. Decision-making rules are needed to control the use and allocation of resources to achieve economic growth as well as environmental and social sustainability.

2.2.1 MARKET FAILURE AND GOVERNMENT INTERVENTION

Market failure occurs when one or more of the conditions required for a well-functioning competitive market are not met in a substantive way (Hackett, 2011). Markets operate according to conditions of demand and supply, that is, where the marginal willingness to pay for a good equates to the marginal cost of production of that good. The benefits and costs of goods (or services) should ultimately include all associated social benefits and costs (Field, 2001). However, in the case of natural resources, markets do not always reveal the full value of environmental goods and services, leading to them being under-priced or even without price (Asafu-Adjaye, 2000). Failure to properly account for the true value of environmental resources can be attributed to: a weak property rights regimen, open access to public goods, monopolization of markets, presence of significant externalities, and poorly informed buyers or sellers (Asafu-Adjaye, 2000; Munasinghe, 1993).

Market failure can sometimes be traced back to wrong decisions that lead to negative externalities such as, pollution, overexploitation and degradation, which in turn can induce government intervention to reverse or reduce the externalities. These interventions to regulate economic activities or regulate supply are undertaken to encourage trade in fair conditions (Duinker, 2001; Hackett, 2011). Government responses to market failure typically lead to a gradual process of institutionalisation of environmental matters into policies (Harding, Hendriks, & Faruqi, 2009).

Environmental policies typically take one of two main approaches. One approach is to use economic instruments based on inducement mechanisms, such as, taxes or charges, subsidies, deposit-refund systems and market creation to induce individuals, firms and territorial authorities to take into account protection of the environment in their decision-making. The other approach is the command and control approach, which utilises regulatory instruments to protect the environment. These include standards for permissible pollution, zoning for certain activities and also quotas (Kahn, 2005). These are the most common type of instrument used by governments to protect the environment. Regulations focus on limiting

environmental problems by specifying a maximum level of permissible pollution, which is then enforced by law (Hartwick & Olewiler, 1986).

The promulgation of these regulations enables governments to embed environment policy into all levels of decision-making. When standards are established, governments and institutions use them as a guideline to evaluate the effect of projects upon the environment. In doing so, environmental standards not only protect social well-being and the environment, they also ensure that a consistent approach to decision-making is practised. Ultimately, this approach creates a level playing field and enables decision makers to determine which projects should proceed (Further discussion is provided in section 2.2.3).

2.2.2 SUSTAINABILITY

Whilst sustainability has been one of the most used words in political and scientific discourse around the environment over the past 30 years (Pistocchi, 2011), a precise definition has not been accepted. According to Dovers (2005), sustainability refers to the ability of human society to persist in the long term in such a way that satisfies human demands but without negatively impacting the integrity of the natural world. The term has been linked to the idea of sustainable yield, used in relation to biological resources such as forests, fisheries or mining extraction, but this is a far more limited concept of sustainability (Harding et al., 2009).

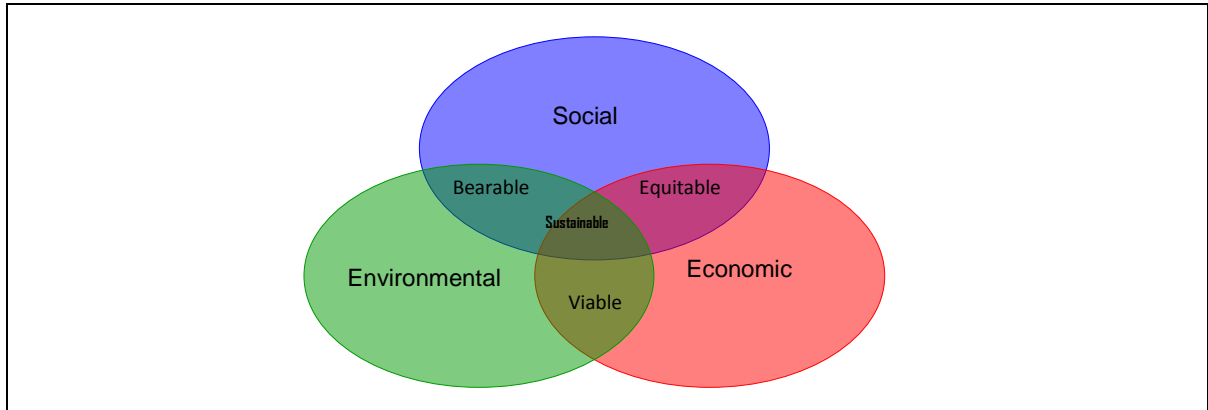
Sustainable capacity is used most often to refer to a renewable resource when its use must be allocated over time to provide equality of opportunity to future generations. The notions of sustainable yield have been applied to many different resources. However, according to Rees (1990), the maintenance of sustainable yield is not a costless strategy as it implies a reduction on current consumption which may affect the future development of the area where this resource is located, for example, maintaining water sources such as, lakes, dams or wells. The typical recommendation is that pumping rates should not exceed the average rate of replenishment. Such a recommendation may be acceptable in locations with relatively short recharge periods, but in extremely arid zones, a reduction of

water usage in order to preserve it for future generations may result in a decline in economic development (and even population) so that future generations may have plentiful water stocks but less goods and services as a consequence of economic growth.

The 'Bruntland Report' of the World Commission on Environment and Development in 1987, introduced the concept of sustainable development of the political arena (Fischer, Petersen, Feldkötter, & Huppert, 2007). Sustainable development became the catchphrase of the nineties, representing a further milestone in the long evolution of public and academic concerns with respect to natural resources and the environment (Camagni, Capello, & Nijkamp, 1998). The necessity to place environmental issues at the top of policy agenda culminated with the Earth Summit, at the United Nations Conference on Environment and Development (UNCED) in 1992, Rio de Janeiro, Brazil (Harris, 2007). This conference drew over 100 governments together to agree upon action and legal basis for future protection of the environment (Johnson, 1993). Worldwide recognition has driven international cooperation for a number of important agreements concerning the change from traditional free market approaches to sustainable development (Helming, Perez-Soba, & Tabbush, 2008). Today, the concept of sustainability and sustainable development are commonly interpreted as terms that are interchangeable (Pezzey, 1992). The most quoted definition of sustainable development remains that of the Bruntland Report: "paths of human progress which meet the needs and aspirations of the present generation without compromising the ability of future generations to meet their needs" (World Commission for Environment and Development (WCED), 1987, p. 43).

The concept of sustainable development seeks to integrate environmental, social and economic issues (Munasinghe, 1993), and underpins current challenges in land use and NRM (Johnson, 1993). Although, these three issues are closely interlinked, they are, to a certain extent also mutually conflicting. Nijkamp & Ouwersloot (1997, p. 2) observe that "putting more emphasis on a higher availability of the one category tends to reduce the availability or usability of either of the other ones".

Figure 2.1 The tripartite nature of sustainability



Source: Adapted from Harding et al. (2009) and Holmberg (1992)

The economic, environmental and socio-cultural aspects of sustainable development combine to exert a strong influence upon decision-making associated with the management of natural resources.

Economic Sustainability

A purely economic oriented approach to sustainability would focus on the maximum flow of income that could be produced while maintaining a minimum stock of assets that yields these benefits (Munasinghe, 1993). This approach applies the underlying ideas of optimality and economic efficiency to the use of resources. This concept has been extended to include the ideas of weak sustainability and strong sustainability (Beinat & Nijkamp, 1998; Lele & Norgaard, 1996; Marín & Delgado, 1997).

Weak sustainability does not specify the kinds of stock to be maintained. (Solow, 1991, p. 181) notes that: “If you don't eat one species of fish, you can eat another species of fish”. This suggests that we do not owe the survival of any one particular species to future generations. An economy is deemed to be sustainable if it ensures that the welfare of individuals does not decline generation after generation, but there is no specific object that the goal of sustainability requires to preserve (Pearce, Barbier, & Markandya, 1990). This criterion allows the over-exploitation of natural resources and environmental deterioration, as long as there exist compensation in similar capital (Anand & Sen, 2000; Lele, 1991).

The concept of strong sustainability requires limitations for the substitution of natural resource capital by other forms of capital. The concept acknowledges the threat of irreversible consequences associated with ecological processes and that natural resources and environmental quality should be preserved as a whole for future generations. However, it is also argued that strong sustainability can lead to an inefficient distribution and allocation of resources (Fischer et al., 2007; Lele & Norgaard, 1996; Prato & Hajkowicz, 1999).

Ecological Sustainability

The ecological view of sustainable development focuses on the stability of biological and physical systems. Of particular importance is the viability of the overall ecosystem (Common & Perrings, 1992). Preserving the integrity of ecological sub-systems is viewed as being critical for the overall stability of the global ecosystem (Serageldin et al., 1994). Protection of biological diversity is key and, rather than viewing environmental protection as a barrier to development, it is considered as a vital and fundamental element without which development could not take place (Adger et al., 2003). Furthermore, sustainable development must promote the conservation of natural resources such as, minerals, soil, water, and air, but also of man-made environments like cities and agricultural land (Rammel, Stagl, & Wilfing, 2007). Some argue for the preservation of all ecosystems, whilst less extreme views look towards preserving the resilience and dynamic adaptability of natural support systems. The emphasis here is on preserving the resilience and dynamic ability of such systems to adapt to change, rather than conservation of some 'ideal' static state (Meier & Munasinghe, 1994).

Social Sustainability

Sustainable development is associated with the concept of intra-generational equity and intergenerational sustainability. Both terms are a function of social goodness that describes social values and the transactions between the wellness of different groups or individuals (Kennedy & Koch, 2004). Moreover, the notion of 'future generation' implies uncertainty regarding future preference in technology

and environmental conditions (Dale & English, 1999; Krautkraemer & Future, 2005).

While economists, ecologists, and sociologists would all agree that each other's concerns matter, they view these concerns through differing lenses. The increasing use of the principles and practices of sustainability continue to highlight the need for agreement on what the term means when it comes to 'operationalizing' the concept so that it is practical, measurable and relevant for decision makers. "The standard definition of sustainable development from WCED is a meaningful starting point, but fails to offer manageable guidelines for sustainability strategies for (local, regional, national or international) decision-making bodies or other actors" (Nijkamp & Ouwersloot, 1997, p. 4).

2.3 ROLE OF INSTITUTIONS IN NRM

Most countries have embraced the notion of sustainability by adopting a set of objectives and principles of sustainable development to guide government policies and legislation. The roles and functions of institutions vary from multilateral agreements between countries to sub-regional or private institutions. Using data from Uphoff (1992), Table 2.1 lays out the levels of institutionalization of environmental principles, indicating the policy instruments used, the function of these and the authority or actor involved in ensuring the uptake of the environmental principle.

At the international level, many agreements embrace the principles of sustainability, and deal with a wide range of environmental concerns (Carraro & Siniscalco, 1992). One example is the International Treaty on Plant Genetic Resources for Food and Agriculture that aims at guaranteeing food security through conservation efforts. Another is the Kyoto Protocol for the United Nations Framework Convention on Climate Change whose aim is to combat global warming by international cooperation. In becoming party to an international environmental agreement, countries become responsible for institutionalizing their commitments in the law of their own country (Allan, 2008; Steiner, Kimball, & Scanlon, 2003).

Table 2.1 Levels of Institutionalization of Environmental Principles

Level	Principle	Policy Instrument Used	Function	Authority/Actor	Example
International	Sustainable development	-Policy statements -Agreements	International cooperation to achieve commitment to ensuring standards are met	- International leaderships - Commissions - NGOs	Agenda 21
National	Sustainable resource management	-Environmental legislation -General regulations	Set national requirements on processes or standards on resource use	- Ministry for the environment - Parliament	Resource Management Act (1991) New Zealand
Regional	Planning for sustainability	-Regulations -Designations (restrict use of an area to a specific activity; for example roads)	To set a policy framework and controls on the use of resources within an area and identify local and regional resource use issues	- Regional government	Water Management strategy
Local	Protect and sustain the natural environment	-Resource consents -Authorisation	Control the use of specified resources	- City council	Guidelines, frameworks
Community/ Private Sector/ Household	Maximise benefits	Project development	Maximise (resource capital) net benefits	- Person or group - Enterprise	Project Appraisal, such as, CBA (EIA, SIA, if they are mandatory)

Source: Uphoff (1992)

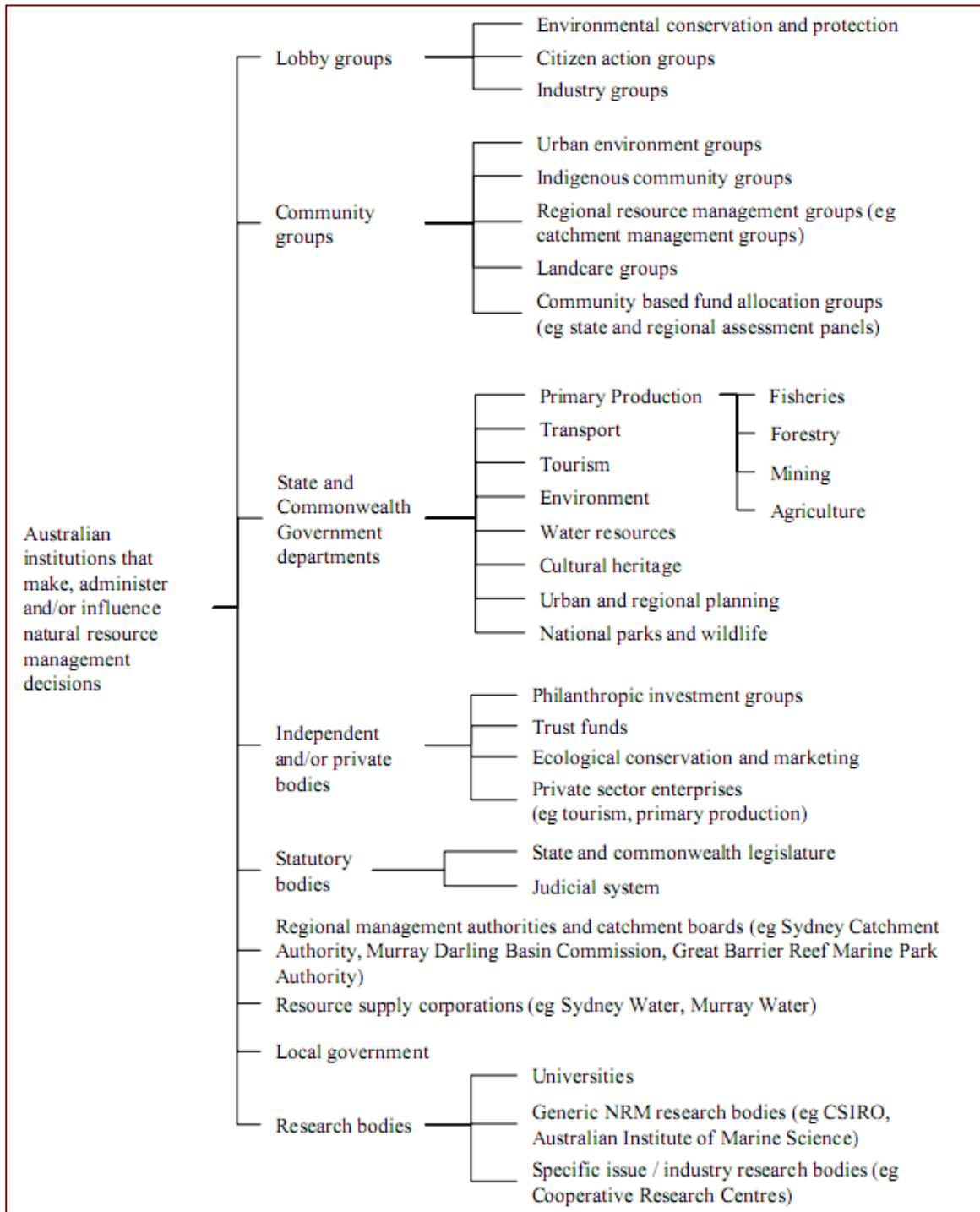
At the national level, the creation of environmental laws is carried out by the national Parliament through various Acts. It is generally held that such Acts should contain policies to guide development projects and programs (Harris, 2004). In the United States, for example, the U.S. Environmental Protection Agency (EPA) is the most well-known federal agency, with jurisdiction over many of the country's national air, water, waste and hazardous substance programs. Other federal agencies, such as, the U.S. Fish and Wildlife Service and National Park Service pursue primarily conservation missions, while still others, such as, the U.S. Forest

Service and the Bureau of Land Management, tend to focus more on the beneficial use of natural resources (Tang, 1991).

From the national to local level, the NRM decision process is highly influenced by a large number of institutions and their institutional frameworks. Each institution focuses on particular issues, such as, agriculture or mining and, to some extent, will limit the decision-making process by determining the nature of issues considered and the level of stakeholder involvement (Hajkowicz & Collins, 2007). Hajkowicz, et al. (2000b) proposed a classification of Australia's major institutions that, to some extent, influence, make or guide NRM. They identified nine major types of NRM institutions, which they further classified into sub-classes. This hierarchical concept is presented in Figure 2.2, and whilst the classes may differ at the detailed level, the administrative framework would be familiar to natural resource managers in most countries.

This rapid institutional development has resulted in the reallocation of responsibilities in some places. For example, the responsibility for the administration and enforcement of environmental laws has been relegated to agencies with varying, overlapping and, sometimes, conflicting missions. Over the past few decades many new NRM consulting firms and government departments have been established. The increased number of organizations involved exacerbates the problem of trying to find consensus in the complex, multiple criteria decision-making process.

Figure 2.2 Hierarchy of institutions



Source: Hajkowicz, et al. (2000b, p. 5)

2.3.1 PROJECT EVALUATION AND THE DECISION-MAKING PROCESS

Typically, the decision-making cycle for development or investment projects begins when a proposal is submitted for financial support or regulatory consent,

and is then scrutinised. This scrutiny relies upon technical, economic or financial (and political-strategic) evaluations that the proponent of the project has already carried out (Eggenberger & Partidário, 2000). It must then be determined whether the proposal would significantly affect the current socio-economic-environmental system and if so, an institutional judgement through the subsequent evaluation process, is required. Decision-making is primarily the responsibility of institutional agencies and government agencies both at the national and local levels (Tavana, 2003).

Project appraisal and assessment involves the analysis of a proposed project or program to determine its merit and acceptability in relation to established criteria. In doing so, it verifies the feasibility of the project against the current situation and that the objectives remain appropriate and the costs reasonable (European Commission, 2009). The main functions of project appraisal are to enable both the project developer/proponent and the decision maker to determine whether a project can be carried out with the available resources to achieve its planned objective (Squire, Hollis, & Srinivasan, 1989).

To the proponent of the project, the appraisal analysis is useful to determine the financial viability, and identifies and overcomes technical issues as well as legal matters (Squire et al., 1989). This is the final step before a project is approved for financing. In NRM, project appraisal is an *ex-ante* evaluation, which assists in the identification of potential environmental, social and economic impacts of a project's activities (Sexton, Easter, & Burkhardt, 1998). This information is relevant to the project developer as it helps evaluate the significance of these impacts and assists in building new alternatives or mitigation plans. However, at this stage, preliminary data can also be used by decision makers to determine if a project may lead to desirable or undesirable consequences and to help decide what action to take. "In decision-making, the *ex-ante* evaluation of possible future projects plays an increasingly important role at the national, regional and local levels. The quality of *ex-ante* evaluations is therefore becoming more and more important to the quality of decision-making" (Van Wee, 2007, p. 32).

A challenge for NRM researchers is to develop techniques and processes to help with the assessment of these complex decisions. The techniques currently available are too complicated or time consuming to be of practical value to most NRM decision makers (Hajkowicz et al., 2000b). Nevertheless, project consent applications are increasingly required to apply structured and transparent decision-making processes. In South Australia, for example, the Natural Heritage Trust (a major source of funding for community based projects) requires a cost benefit analysis (CBA) for any infrastructure projects which exceed \$150,000 in any year. The Murray-Darling¹ program specifically requires reporting of the CBA results, and in some cases, an independent review of the CBA (Hajkowicz et al., 2000b).

All projects submitted for approval should undergo an initial economic, environmental and social evaluation (Nardini, 1997). Recently, researchers working on project evaluation and selection have focused on multi-criteria decision models. These models have made definitive contributions to project evaluation but do not integrate the intuitive preferences of multiple decision makers into a structured and analytical framework.

2.3.2 FAILURE TO FULFIL SUSTAINABLE DEVELOPMENT OBJECTIVES

Although the idea of sustainable development has been well established, discussions on how to progress from concept to reality often become mired in the complexities of global politics and offer few concrete solutions. While achieving sustainable development will certainly require changes at the global level, patterns of sustainable development must be built from the bottom up (Holmberg, 1992). As Harding (1998, p. 32) has argued, there is a need for practitioners ...“to respond to the government’s guidelines for sustainability by making the environment a key consideration in every project undertaken”. He also reinforced that the principles of “sustainable development can be applied to virtually every area of professional practice”. Van Pelt, Kuyvenhoven, and Nijkamp (1990) declared that the notion of sustainability needs to be translated into concrete goals and criteria at the sector

¹ Murray-Darling basin is a geographical region located in the south-east of Australia, and its name comes from two major rivers in the area: the Murray and the Darling rivers.

level (meso level) and the project level (micro level). In contrast with these statements, the general idea that only mega projects should meet sustainability challenges has led to a mind-set that local or regional level projects/programs are not as important. However, the cumulative impact of many small projects can have the same impact as a large regional programme. Despite increasing emphasis being placed on environmental issues, the principles of sustainable development remain utopian (Costanza et al., 2002). For example, when considering the application of a new regulation standard, the Ministry for the Environment of New Zealand (MFE, 2007, p. vii), pointed out that “At present there is no explicit legislative requirement for council decision-making processes to consider the effects of activities on sources of human drinking-water... This is a gap that potentially leaves community water sources vulnerable to contamination”.

NRM decision-making often proves to be a difficult process, in both developed and developing countries (Slootweg, Vanclay, & van Schooten, 2001). The clear evidence of environmental degradation, public discontent, social conflicts, project delays, cost overruns, externalities and economic inefficiency, suggests that decision-making is often carried out in an unsatisfactory way (Nardini, 1998).

In many government agencies and non-government institutions, environmental values are obtained by employing monetary valuation techniques which are biased toward economic objectives. Historically, the failure to properly account for the value of some environmental resources in monetary terms has resulted in decisions that have had negative implications for the environment and for societal welfare (Asafu-Adjaye, 2000). This is a common contributor to sustainable development project failures, which often only become evident after substantial damage to natural and environmental resources, negative impacts on vulnerable social groups, and/or economic losses, have already occurred. Placing a value on the environment, whether through monetary-based methods or through other evaluation techniques, has been and will be a widely researched topic for years to come.

2.4 DECISION-MAKING TECHNIQUES FOR PROJECT APPRAISAL

In all decisions, information gathering and analytical tools offer the potential to improve input into the decision-making process and thus improve its outcome. Decision support may be defined as “any and all data, information, expertise and activities that contribute to option selection” (Andriole, 1989, p. 3). Further development has led to the formalization of the use of information in structured decision processes called decision support systems (DSS). Davis (1989) defined a DSS as a mechanism that facilitates complex decision-making. In doing so, these tools should be able to integrate the perspectives of various disciplines (e.g., economics and ecology) and various objectives (economic growth and environmental protection), and “their viewpoints should be as encompassing as possible, and feedbacks and linkages across disciplines should be fostered” (Dale & English, 1999).

Decision-making regarding the management of natural resources is multifaceted, merging a wide range of technical, environmental, financial, economic, social and institutional factors into an analytical evaluation (Kiker, Bridges, Varghese, Seager, & Linkov, 2005). The interdisciplinary nature of natural resource management (NRM) issues, which along with tangible goods and services, also deal with unpriced and intangible goods and services, making it difficult to value and incorporate them into empirical studies (Schmoldt, Kangas, Mendoza, & Pesonen, 2001). Furthermore, the majority of resource-use decisions that address land, water and biodiversity objectives include numerous stakeholders with competing interests and priorities (Hajkowicz & Higgins, 2008; Kiker et al., 2005; Stahl, Cimorelli, & Chow, 2002). Therefore, the task of decision-making can be extremely complex because of the implications of what cannot be resolved through a single perspective.

Central, regional and local authorities as well as development agencies and others face the dilemma of dealing with a proliferation of complex project proposals using and integrating single discipline techniques such as Cost-Benefit Analysis (CBA), Social Impact Assessment (SIA) and Environmental Impact Assessment (EIA), to

guide these evaluations. Some attempt at integrating these factors into the arithmetic of decision-making has been developed on the basis of Multiple Criteria Analysis (MCA) methods; however, these have their own limitations, which will be discussed in the next sections.

2.4.1 COST-BENEFIT ANALYSIS

Historically, cost benefit analysis (CBA) has been one of the most commonly applied project appraisal techniques (Dale & English, 1999). Many government bodies and organisations require a CBA as part of project evaluation and decision-making processes and it has been widely applied to NRM (Hanley, 2001).

As the name suggests, its analysis provides a means of comparing the benefits and costs of a NRM decision in monetary terms. The approach identifies a negative impact as a cost, and a positive impact as a benefit (Kondili & Kaldellis, 2012). A benefit is an outcome which results in an increase in the quantity or quality of goods that generates positive utility, or a reduction in the price at which they are supplied. A cost is an outcome which results in any decrease in the quality of such goods, or an increase in their price (Hanley, Spash, & Cullen, 1993). An economic cost benefit approach to project impact assessment has been considered logical because everyone has at least an intuitive appreciation for what constitutes a benefit or a cost (Erickson, 1994).

The identification of costs and benefits need to reflect the values to society as a whole, both in terms of the inputs and outputs of a project (Prest & Turvey, 1965). This concerns the likelihood that the project will contribute to the development of the economy and that its contribution justifies the use of the scarce resources it will need (Schaltegger & Burritt, 2000). In doing so, significant impacts on the physical environment (biophysical and ecological components) and social environment (personal, interpersonal and institutional components) should be included (Quah, 2011). In CBA, it is usual to compare the project scenario with a 'without' project scenario (Prest & Turvey, 1965) to establish whether investment in the proposed project will likely add value to the economy.

Cost and benefits are usually classified into two groups: Primary costs and benefits arising directly from the project, and secondary costs and benefits arising from activities or events that are triggered by the project (Erickson, 1994). For example, a large scale agricultural project would result in an increase in farm produce. In this case, the secondary benefits would include the increase in the profits of businesses that add value producing, agricultural products from the farm produce. As these costs and benefits are distributed over time in various arrangements, the first step in any analysis is to discount the stream of costs and benefits back to a single point in time, usually the beginning of the proposed project.

Bohm and Henry (1979) identified three important advantages of using the CBA approach: transparency, ignorance revelation and comparability. Nowadays, these characteristics are still considered by many to be the most important strengths of this technique (de Rus, 2011; Livermore & Revesz, 2013; Pearce, Atkinson, & Mourato, 2006). Transparency is improved as CBA documents all assumptions, theory and methods used in obtaining the results. A second benefit of CBA is that it documents explanations as to why any benefits or costs were not quantified. This allows the decision maker to identify missing gaps of knowledge and the overall scope of the economic analysis (Murphy & Simon, 2001). Thirdly CBA is clear in its requirement that any policy or project should be seen as one of a series of options. Hence setting out the alternatives for achieving the chosen goal is a fundamental prerequisite (Pearce, et al., 2006). In this way, CBA allows for a number of project decisions to be compared by way of a single index, and facilitates meaningful comparisons between different courses of action (de Rus, 2011).

Another characteristic which is considered to be an advantage of this technique is that it measures gain and loss independently of its use of money, and forces the decision-maker to look at who the beneficiaries and losers are in both spatial and temporal dimensions. It avoids what might be called 'lexical' thinking, whereby decisions are made on the basis of the impacts on a single goal or single group of people (Pearce et al., 2006).

The key criticisms of CBAs relate to valuing the environment by endeavouring to place monetary values on environmental resources. This can be complex as valuation techniques need to include irreversible changes in environmental quality and incorporate ecosystem complexity (Frank, 2000). In addition, environmental issues pose special problems in relation to choosing a discounted rate (Hanley et al., 1993; Jowsey, 2011).

As Adler and Posner (1999) have pointed out, CBA just emphasizes the inclusion of quantifiable environmental entities and processes. For example, when attention is given to the social environment, quantifiable attributes such as, the cost/benefit value of displaced households, generally receive primary attention. Typically, non-quantifiable attributes or those not easily addressed by numerical analysis, including many sociological, political, and psychological factors, are ignored (Erickson, 1994).

Another criticism of CBA has to do with equity and distribution issues. There are large equity concerns associated with CBAs, as income distribution is ignored (Quah, 2011). Decision makers need to be aware of exactly what information CBA provides and what it does not provide, in order for alternative social assessments to be made (Hanley, 1992).

2.4.2 ENVIRONMENTAL IMPACT ASSESSMENT

Environmental impact assessment (EIA) is perhaps the most widely recognised process for assessing the environmental consequences of NRM decisions. Shepherd & Ortolano (1996) suggested that the most common application of EIA is as a planning tool in which assessments are undertaken to forecast and evaluate the impacts of a development proposal and its alternatives. It is applied in most countries throughout the world in one form or another and is used by international organisations such as, the United Nations and World Bank (Meier & Munasinghe, 1994).

EIA is a systematic process for considering possible impacts prior to a decision being taken on whether or not a proposal should be given approval to proceed.

According to Jay, Jones, Slinn, and Wood (2007), EIA requires the publication of an EIA report describing likely significant impacts in detail. Consultation and public participation can be an integral part of this evaluation. EIA is thus an anticipatory and participatory environmental management tool.

Similar with CBA, the comparison of options is a vital part of the EIA study. It can involve a number of different tasks, depending on the nature of the EIA study being conducted. The comparison of options requires considerable skill and effort, and results must be presented in a way in which non-experts (politicians, administrators, industrialists and the public) as well as experts can understand them (Harvey, 2012). It plays an important role in providing useful information to decision makers who may have to select options and it focuses the results of the EIA.

The general format of most EIA procedures involves the following elements (Mesoamericano, 2002):

- Decide whether an EIA is required. A process needs to be developed to identify projects with potential environmental impacts that are sufficiently significant to warrant an EIA. This stage is referred to as screening.
- State the objectives, activities involved and intended outcomes of the proposed project.
- Identify alternative projects which could meet the same objectives and/or achieve the same outcomes.
- Decide what issues should be covered as part of the EIA. This requires an assessment of how the project and its alternatives will affect the quality of the environment. This is sometimes referred to as scoping.
- Prepare a preliminary survey. This should address all the issues identified in the scoping stage. It indicates the extent of impacts and how they can be mitigated.
- Review the EIA using environmental scientists, engineers, economists, social scientists and experts in other fields. Identify any technical inaccuracies or any inadequate coverage of issues.

- Make the public aware of the proposed development, obtain feedback and review its appropriateness (ideally public participation occurs throughout the entire EIA process).
- Make a decision as to whether the proposed project may proceed and with what conditions.
- Enable legal challenges to the proposed project on the grounds that the EIA was inadequate or improper procedures were applied.
- Monitor and evaluate the impacts of the project during and after its implementation.

If applied properly, EIA can be an extremely effective tool in enhancing the NRM decision-making process for the public and improving awareness for decision makers on potentially significant environmental impacts. Some of the major benefits of applying EIA include:

- Modification of proposed projects to minimise adverse environmental impacts.
- Improved public participation in NRM decision-making. The EIA process can provide a basis for proposed projects to be challenged by the public (Morris & Therivel, 2001).
- Development of formal and often legally enforceable guidelines to ensure a project meets environmental performance criteria.
- Increased awareness amongst project proponents of the importance of including environmental concerns into project design.
- Avoidance of projects which could lead to severe and irreversible environmental damage.
- Delivery of improved information to the public about projects which could impact on the environment and their quality of life.

Out of necessity, the EIA process is extremely flexible as it needs to accommodate a vast array of proposed projects, developments and actions. It must also function within the existing institutional, policy and legal frameworks of the society within which it is applied. This flexibility leaves EIA open to inappropriate application

(either inadvertently or intentionally). Some of the major problems which can result from misapplication of EIA are described as follows.

Firstly, EIA is sometimes used to justify projects regardless of their environmental merits (Harding, 1998). As the EIA is usually prepared by consultants contracted by the project proponents it can sometimes be significantly biased in favour of the proposal. Some project proponents view EIA merely as an obstacle or hurdle that must be cleared so that they 'can get on with doing what they originally wanted to'. These cases can often lead to unsatisfactory public participation and poor integration of EIA in the planning process.

Secondly, EIA can overlook alternatives to the proposed action (Wood, Dipper, & Jones, 2000). Explicit consideration of alternatives in EIA is only required in some countries. Where it is required, the EIA may identify and quickly dismiss several token alternatives in the first few pages. A failure to consider alternatives can lead to the assumption that the proposed action represents the most desirable choice (Jay et al., 2007). This can favour the development proposal by forfeit, i.e. a lack of better options.

Thirdly, the EIA process is often poorly integrated with the broader planning process (Harding, 1998). EIA is often seen as something that is done at the end of the planning process or as a final check prior to proceeding with development. This can lead to a failure to design appropriate alternatives and develop improved means of managing the environment. Ideally, environmental concerns are integrated at early stages of planning and influence all subsequent decision-making (Thomas & Elliott, 2005).

Fourthly, EIA does not always address cumulative impacts of development (Harding, 1998; Shepherd & Ortolano, 1996). EIA is typically undertaken for specific projects or actions. It does not give consideration to the cumulative impacts of multiple projects that occur over time or within a region. This creates a situation where EIA approves many individual projects each with minimal environmental impact. However, when each impact is added together the resulting net impact is unacceptable to society. This problem has led to the emergence of

cumulative impact assessment, which seeks to assess the impacts of many individual actions or projects together (Shoemaker, 1994).

Lastly, EIA often makes unrealistic assumptions about future administrative performance. If monitoring arrangements are not implemented then conclusions may be invalid. Like other techniques of decision support, EIA needs to handle multiple scenarios through sensitivity analysis. This will help assess whether a project has sound environmental performance under a range of possible outcomes (Thomas & Elliott, 2005).

EIA is a systematic process by which the effects of development actions can be identified and evaluated in advance (Glasson, Therivel, & Chadwick, 2005). The complexity and scope of EIA has meant that individual planners are unlikely to have the skills, time or resources to carry out all the different aspects of the assessment. This is not a criticism. As Carroll, Boyden, Carroll, and Thomas (2009) indicated, planners are not expected to be experts in their own particular subject and also have the time, resources or capabilities necessary to fully understand and predict the direct, indirect and cross-sectoral impacts of their planned projects. However, it is becoming increasingly desirable for development planners to be aware of the range of environmental impacts which may arise from projects (Harvey, 2012). It is also inherent in conducting an EIA that if potential environmental impacts are identified, then consideration should be given to altering the project's design and/or implementation in order to minimize its adverse environmental effects. Providing mitigating action such as this requires additional skills and expertise to those utilized in impact prediction and evaluation and serves to further complicate the EIA process (Howells, Edwards-Jones, & Morgan, 1998).

A common approach for the identification of impacts is by describing the ‘cause and effect’ relationships that may result from a planned intervention or activity associated with the project. This process is also known as screening, and is mostly used in social and environmental impact assessments. The process begins by identifying the source or origin of each impacts, which arise from the activities and actions associated with the project development (Harvey, 2012). Thereby, all activities must be identified, including the ones relating to the pre-construction, construction and post-construction phases (Erickson, 1994). The analysis should also take into account any mitigation or restoration practises, even if these activities are not directly related with the project objectives. An example of activities and actions encompassed in the various project phases are outlined in Table 2.2.

Table 2.2 Examples of Activities and Action Associated with Various Phases of Project Development

Pre-construction phases	Construction phase	Post-construction phase
<ul style="list-style-type: none"> • On ground preliminary recognition of site • Surveying of site • Collection of land-ownership records • Taking of test borings within proposed rights-of-way • Appraisal of real property • Negotiation with land owners • Relocation of displaced persons • Securing of physical access to site • Demolition and disposal of existing structures 	<ul style="list-style-type: none"> • Excavation • Dredging • Transport and placement of borrow • Clear cutting and disposal of vegetation • On-site transport and storage of material and supplies • Lighting • Structural fabrication and placement • Controlling runoff • Dust suppression 	<ul style="list-style-type: none"> • Selective cutting and disposal of vegetation • Application of preservatives • Application of pesticides • Disposal of runoff • Waste generation, storage and disposal • Resources utilization • Process chemistry and others risk management • Management of by-products • Landscape engineering and plantation

Source: Erickson (1994, p. 11)

Impacts can be classified as being either direct or indirect. Direct impacts are changes in environmental components and processes that result immediately from

a project related activity or action. Indirect impacts (also called secondary impacts) are changes in environmental components and dynamics that are consequences of direct impacts (Morris & Thérivel, 1995). For example, soil compaction is a direct impact of the use of heavy equipment, and may also lead to increased water runoff and thereby increase the risk for soil erosion. In this instance, increased water runoff and soil erosion are consequences secondary impacts.

At least four different techniques are used to perform the task of impact identification and summarisation. These are: checklists, overlays, matrices and networks (Mitchell, 1997). In order of increasing sophistication, these are:

- *Checklists* provide a list of specific considerations to be investigated. In this way, checklists serve as templates to alert the analyst to aspects that may be relevant. The items are based on general experience, and the investigator has to determine which items are pertinent. This tool then, consists of lists of environmental effects and impact indicators without assuming cause and effect links of the items on the checklist and the project activities.
- *Overlays* are a set of maps which describe environmental and social characteristics of a project area. The maps are superimposed to generate a composite picture. Then, judgement is made about which composites represent sensitive or valued attributes, and impacts are inferred.
- *Matrices* represent a more sophisticated version of a checklist, in that lists of actions or activities of a project are identified on one axis of the matrix and environmental and social conditions that could be affected by the project are identified on the other axis. The purpose is to use the matrix to identify first order cause and effect relationships between proposed activities and likely impacts.
- *Networks*. Their starting point is the identification of proposed activities, followed by the consideration of cause and effect networks at various levels (both direct and indirect). Networks explicitly recognise that there might be a series of impacts triggered by one action and that it is necessary to follow

through first, second and third order effects. Usually, it is executed utilising a flow diagram, which consists of boxes linked with arrows, indicating which are the stressors and which are the receptors.

Each of these methods has advantages and limitations. Networks are the most sophisticated but also the most complex and time consuming to create. Furthermore, the network approach is often difficult to use because there may not be sufficient information or understanding to trace the various levels of impacts. In contrast, checklists and overlays have often been used at the initial or preliminary stage of impact assessment. Checklists are simple and can be understood by everybody, and overlays produced quality spatial information. However, both are unable to show the cause-effect interactions (Smith, 1993), since they do not correlate particular types of impact with specific activities related to the various phases of project development (Cocklin, Parker, & Hay, 1992). Matrices contain a list of project activities, ranging from early planning through operational and maintenance phases of the project development. Although matrices can facilitate relating specific project activities with possible impacts, specific causal relationships are not addressed, nor do they distinguish between direct and indirect effects. However, the distinction between direct and indirect impacts has absolutely no meaning with respect to the actual environment, it is simply a useful heuristic device to organise the analysis in a manner that insures that possible effects are identified (Erickson, 1994).

Given that the development of a rapid assessment model is integral to this research, the matrix approach is utilised to identify likely impacts using the EIA method. An adaptation of the Leopold Matrix will be employed and therefore an overview of the matrix and its usefulness is presented.

Leopold Matrix

The Leopold matrix (LM) was developed by the US Geological Society in 1971 and originally comprised 100 columns along the horizontal axis that contained activities that might cause positive or negative environmental impacts, and 88 rows of environmental quality variables that may be susceptible to impact. This matrix

represents all the possible interdependences between a set of defined activities and a set of environmental components (Darbra, Ronza, Stojanovic, Wooldridge, & Casal, 2005).

The heart of the system is a matrix that is general enough to be used as a reference checklist or as a reminder of the full range of potential or actual actions and impacts on the environment that may relate to a project. The matrix can also serve as an abstract to enable the reviewers of the EIA report to quickly determine which impacts are considered significant, and their relative importance as evaluated by the reviewer of the impact report (Leopold, 1971). The main project activities and environmental elements included in the original Leopold Matrix are presented in Table 2.3 below. Further extension of the Leopold matrix can be made to include other potential activities or actions related to the project, such as mitigation or restoration.

As with other matrix methods, the LM employs multiplication techniques to determine the interactive effect of project activities on various environmental components, or to identify higher order effects. The matrix is completed by inserting two scores, one for magnitude and one for significance, in any cell where an activity is thought to interact with an environmental component. The magnitude is a quantifiable measure of the degree or scale of the impact; and can be defined as the degree of movement away from the baseline state of the specific environmental component under consideration. Magnitude is expressed on a scale ranging from highly detrimental (-5), through negligible (0), to highly beneficial (+5). Significance is a value judgement relating to the assessor's view of the level of how important the assessor feels importance of movement away from baseline conditions to be (Edwards-Jones et al., 2000). It can be expressed on a scale of high, medium and low significant. On the basis of these scores all activities can be ranked (Howells et al., 1998).

Table 2.3 Project Activities and Environmental Elements in the Leopold Matrix

Project Activities	
Modification of regime	Resource renewal
Land transformation & construction	Changes in traffic
Resource extraction	Waste emplacement & treatment
Processing	Chemical Treatment
Land alteration	Accidents
Environmental Elements	
A. Physical and chemical characteristics	<ol style="list-style-type: none"> 1. Earth 2. Water 3. Atmosphere 4. Processes
B. Biological conditions	<ol style="list-style-type: none"> 1. Flora 2. Fauna
C. Cultural factors	<ol style="list-style-type: none"> 1. Land use 2. Recreation 3. Aesthetics and Human Interest 4. Cultural Status 5. Man-made Facilities and Activities Parks and Reserves
D. Ecological Relationships	<ol style="list-style-type: none"> 1. Salinisation 2. Eutrophication 3. Disease-insect vectors 4. Food chains 5. Brush encroachment

This process serves to highlight the most threatening activities and concomitant impacts associated with a project through a system of scoring and ranking initiated by the user. However, recognition has been made that it should not be assumed as an evaluation method replacing the full EIA (Munier, 2004). The Leopold matrix is designed to make users think about the relative significance of actions and impacts, and hence it is the relative values of these scores to one another and not the absolute scores themselves that are important. The matrix, therefore, focuses attention on the interaction between development actions and the environment. Highlighting these interactions should ensure that a comprehensive assessment is undertaken.

Criticisms of the LM centre on its dependence upon subjective evaluation. It is argued that this subjective evaluation is converted into metrics that could provide a false sense of accuracy and objectivity (Edwards-Jones et al., 2000). This is a criticism levelled at most EIA methods, and at the preliminary assessment level, such subjective evaluation is difficult to avoid. The matrix provides a static view of impacts and cannot reflect impacts over time, secondary impacts, feedback events or irreversible impacts (*ibid*).

The original LM is seldom used in modern EIA, however variations of the matrix are used, particularly for rapid assessment. The LM provides adequate information for input into a MCA, and allows assessment to be kept at an indicative level. Attempting to provide a more comprehensive assessment is not always feasible given the nature of the alternatives, the level of information, and the time constraints. The Leopold matrix is simple, easily understood, appropriate for a wide range of projects and is able to reflect two dimensions of significance, namely magnitude and importance (Longworth, 2003).

2.4.3 SOCIAL IMPACT ASSESSMENT

Social impact assessment (SIA) is a process for identifying and assessing the social impacts of a proposed project, program, policy change or development prior to its commencement (Miller, Gale, & Brown, 1987). According to Burdge and Vanclay (1995), a social impact is any consequence of a policy or project which alters the ways in which people live, work, play, relate to one another, organise to meet their needs and generally cope as members of society. Vanclay (2003) mentions that SIA should not be understood simply as the task of predicting social impacts in an impact assessment process. SIA also includes the analysing, monitoring and managing of the intended and unintended social consequences, both positive and negative; of planned interventions; and of any social change processes invoked by those interventions. He also states that the primary purpose of SIA is to bring about a more sustainable and equitable biophysical environment for people.

The typical stages involved in the SIA are similar to those used in the EIA process (Burdge & Vanclay, 1995). Both are based on the rational model of planning and decision-making. One of the key concerns of SIA is that it needs to consider the equity implications of proposed development (Reynolds, 2002). This requires careful consideration of who will be impacted by the development, and to what extent there will be winners and losers.

Sloutweg et al. (2001) noted that EIA and SIA can become important project planning instruments when applied in the earliest stages of the decision-making process:

They [EIA and SIA] provide information on the consequences of specific development activities in a way that allows these consequences to be taken into account and used in the process leading to a final decision and in designing mitigation measures. Proper application of EIA and SIA can significantly improve the quality of project proposals and will eventually lead to important savings on project implementation because of reduced negative impacts and better acceptance of the project objectives. (p. 19)

According to Burdge and Vanclay (1996), while SIA is usually undertaken within the relevant national environmental policy framework, it is not limited to this, and SIA as a process and methodology has the potential to contribute greatly to the planning process. Accordingly, they also stated that the SIA process delivers guidance to the planning and project evaluation processes in several respects such as: (1) understanding, managing, and controlling change; (2) predicting possible impacts from change strategies or development projects that are to be implemented; (3) identifying, developing, and implementing mitigation strategies in order to minimize potential social impacts (that is, identified social impacts that would occur if no mitigation strategies were to be implemented); (4) developing and implementing monitoring programs to identify unanticipated social impacts that may develop as a result of the social change; (5) developing and implementing mitigation mechanisms to deal with unexpected impacts as they develop; and finally (6) evaluating social impacts caused by earlier developments, projects, technological change, specific technology, and government policy.

Explicit consideration of important social impacts in the appraisal of development or project proposals helps ensure they are given proper treatment by decision makers (Burdge & Vanclay, 1995; Dale, Taylor, & Lane, 2001; Gamboa & Munda, 2007). Assessment procedures which relegate the social impacts to consideration under EIA can lead to their effective exclusion from the decision-making process. By undertaking SIA, important social impacts can be brought to the forefront and can be given consideration by decision makers (Barrow, 1997).

Another significant benefit of SIA is that it leads to increased credibility of the assessment procedures from a community perspective. A project which has been subject to both SIA and EIA is often regarded as subject to more comprehensive, and thereby more credible assessment (Barrow, 1997). The SIA process, through its focus on human and cultural impacts of a project, engages the public more closely than EIA does (Dale et al., 2001). SIA is likely to involve social attitudinal surveys, public meetings and community focus groups. All these techniques allow the community to develop a sense of ownership over the decision-making process. This is likely to assist community empowerment and appropriate follow-through for the project (Reynolds, 2002). According to Vanclay (2003) the role of SIA goes beyond the *ex-ante* prediction of who wins and who loses. SIA also encompasses issues such as: the enhancement of the position of women, minority groups and other disadvantaged or marginalised members of society; the development of capacity building; the alleviation of all forms of dependency, an increase in equity, and a focus on poverty reduction.

According to critics of SIA, its main problem is a lack of theoretical underpinning and methodological rigour (Pearce, 1998). Such criticisms suggest that techniques used in SIA are poorly defined and unrepeatable. However, it is worth noting that many projects which have been declared environmentally and economically sound have proceeded to significantly damage the quality of people's lives. Whilst integrated impact assessment remains more of an idea than reality, SIA has a useful role to play in highlighting social concerns in NRM decision-making (Dale et al., 2001).

2.4.4 THE SINGLE NATURE OF CURRENT PROJECT APPRAISAL TECHNIQUES

Nowadays, the need for socio-politically, economically and scientifically sound natural resource management is more important than ever (Bellamy, Walker, McDonald, & Syme, 2001; Celik, Cebi, & Ucal, 2008; de Lange, Wise, Forsyth, & Nahman, 2010). As NRM merges biophysical, social and economic objectives together, management decision criteria becomes more extensive. NRM agencies need to establish decision models that provide some structure for how decision support information is organized and applied, so that decisions are made openly with justification transparent.

In many governmental agencies and non-governmental institutions, project evaluation is developed through separate and distinct single discipline analysis. The lack of an integrated framework for NRM has historically been compounded by poor management decisions, which fail to integrate social, economic and environmental issues at the project appraisal level (Costanza et al., 2002). Most project proposals include some discussion on social, economic, financial, environmental and institutional factors. However, government and non-government organizations face the dilemma of dealing with a vast number of complex project proposals, where data is mostly presented and analysed by way of separate CBAs, SIAs and EIAs to guide the evaluation (De Montis, De Toro, Droste-Franke, Omann, & Stagl, 2000).

Even when more than one approach is implemented to inform the decision making process, each tends to observe, collect and report socio-economic and biophysical data in different ways, making the separate results incompatible (Harding, 1998) and conclusions sometimes contradictory (Nardini, 1997). This is due to the fact that each is performing only a partial evaluation: "EIA 'forgets', in particular, the positive and economic impacts; CBA 'forgets' all that cannot be put in to monetary terms, and, more important, practically ignores the issues of equity and related interest conflict" (Nardini, 1997, p. 175).

Therefore, it does not make sense that these three approaches coexist with no integration. It could be argued that each is best suited for a particular type of problem. This is, however, false for EIA and CBA, since both these tools are often applied to the same projects. Thus, the way this information is actually perceived and assimilated by decision makers remains a difficult problem that is usually solved in an informal and highly subjective manner (Diakoulaki & Karangelis, 2007). The aim of EIA, CBA and SIA is to provide information to developers, the public and decision makers about the consequences of developing a project or programme. A comprehensive and accurate EIA, CBA and SIA are of little value unless the results of the assessment can be integrated into the decision-making process. It is therefore important to synthesise the results, so that they can be readily understood and easily incorporated into the decision-making process.

2.5 INTEGRATED ASSESSMENT

The long identified need to secure a balance between economic, environmental and social targets in the development process cannot be satisfied with conventional decision-making approaches. Therefore, more analytical methods and techniques have emerged in order to facilitate and improve the decision-making process.

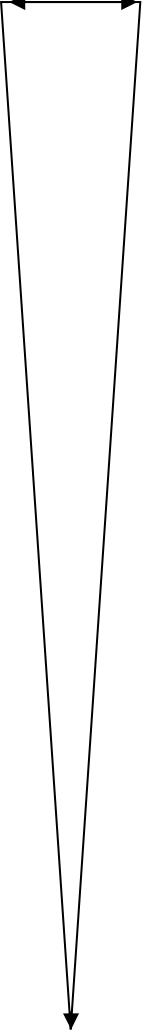
Integrated assessment was initially developed in the 1980s as a tool to assist scientists and policy-makers to synthesize and integrate disciplinary knowledge related to environmental problems in a way that could guide decision-making (Cimorelli & Stahl, 2005). Since then, the approach has been used most often in the context of sustainable development and integrating economic, social and environmental concerns. Rotmans and Dowlatabadi (as cited in Tol & Vellinga, 1998) offered the following definition of integrated assessment:

In general, integrated assessment can be defined as an interdisciplinary process of combining, interpreting and communicating knowledge from diverse scientific disciplines in such a way that the whole cause-effect chain of a problem can be evaluated from a synoptic perspective with two characteristics: added value compared to single disciplinary oriented assessment, and provide useful information to decision makers. (p. 181)

Table 2.4 shows the spectrum of what might be considered as integrated assessment. According to Morrison-Saunders and Therivel (2006), a better achievement of sustainability can be reached with a greater level of integration. In addition, they recognize that, in practice, assessments do not always fit precisely into these divisions, and one assessment may include components of various approaches. At the 'bottom end' of the spectrum is a conventional project-based EIA approach with the addition of economic and social impact calculations and mitigations.

The inherent complexity of the systems concerned, the uncertainty regarding the consequences of project approval affecting the use of natural resources, the conflict between contradictory values, and the multiplicity of institutional concern regarding decisions, advocate the use of powerful decision aid tools (Diakoulaki & Karangelis, 2007). An integrated assessment technique can help developers or authorities with decision-making responsibilities to analyse likely effects of a project at an early stage, and thus improve the quality of both project planning and decision-making (Slootweg et al., 2001).

Table 2.4 Spectrum of Approaches for Integrating Economic, Social and Environmental (ESE) Considerations

	Assessment Approach	Characteristics	Comments
<p>Most 'integrated'</p>  <p>Least 'integrated'</p>	Full integration	Sustainability considered as an integrated concept, not three separate pillars	Assessment is guided by clear integrated principles for sustainability and decision-making trade-off rules. Emphasis on justifying that sustainability has been achieved (or at least appropriate processes followed to best practicable extent)
	Maximise Objectives	Outcome should benefit each factor within each ESE pillar	Positive outcomes with respect to each individual factor are sought. Trade-offs between ESE factors can only be made in accordance with trade-off rules that protect bottom lines
	Win/win/win	In addition to minimizing impacts, also seeks to achieve positive outcomes in each ESE pillar overall	More actively seeks the positive in all pillars (e.g. ensure environment is not traded off). May promote mitigation beyond scope of normal IA practice (e.g. offsets)
	Net gains	Outcome should be net gains in ESE considerations overall	Does not demand gains in all pillars simultaneously (e.g. could have socio-economic gain at environmental cost)
	Threshold test	Impacts should be tested against a fixed bottom line of criteria for each factor	Implies pre-determined bottom lines that must not be breached. May still involve separate treatment of ESE pillars
	Minimise impacts + extra considerations	Also considers other sustainability issues (e.g. inter and intra generational equity, precautionary principle)	Considers other impacts beyond the scope of traditional EIA/SEA practice
	Minimise impacts	Expansion of traditional EIA/SEA to include economic and social impacts. Aim is to identify and mitigate adverse impacts	Tries to avoid adverse impacts. Offsets may be used to counter adverse impacts. Trade-offs between ESE pillars may occur

Source: Morrison-Saunders and Therivel (2006, p. 285)

2.5.1 THE RATIONALE FOR INTEGRATED ASSESSMENT IN PROJECT EVALUATION

The limitations of single assessment techniques (when used in isolation) and the recognition of the complexity of environmental and natural resource management problems have led to the development of more integrated techniques. Integrated

assessment provides a way to consider the full range of costs and impacts, short and long term, direct and indirect, that a project may have on the economy, environment and society (UNEP, 2005). Integrated assessment involves not only technical and scientific research, but also a process of synthesizing information that serves the fundamentally important purpose of qualifying or validating in real life terms, the expert conclusions reached, and of acquiring stakeholder perceptions on critical issues as well as insights on complex qualitative relations and interactions (Sánchez-Marrè et al., 2008). A multi-disciplinary approach is advocated for developing sustainability frameworks (UNEP, 2009).

Generally speaking, integrated assessment on project evaluation can serve at least three main purposes. These are:

- Exploring and clarifying the trade-off and links between the economy, society and the environment (UNEP, 2005). Sustainable development aims to balance at least the social, economic and environmental impacts of all our actions and activities, now and in the future. This task can be understood as the simultaneous optimization of biological, economic and social system goals. However, it is generally impossible to maximize all the different objectives at the same time and, therefore, the decision-maker has to find a compromise (Munda et al., 1994). The definition of sustainable development suggests a harmonization of different (often contradictory) goals (Gervásio & Simões da Silva, 2012). Over time, a better understanding of these relationships can encourage decision makers to develop 'least cost', sustainable development objectives, and build understanding and support among stakeholders for these measures (Hackett, 2011).
- Providing information to decision makers across government departments and agencies on the implications of proposed projects helps to enhance coordination between environmental monitoring, planning and sectorial use of natural resources, facilitating communication and building consensus and administrative capacity (Sexton et al., 1998).
- Increasing participation and transparency in decision-making. Integrated assessment takes as its starting point the preferences of a decision maker

or group of decision makers or sometimes a broader group of stakeholders in the project (Belton & Stewart, 2002). It can help to build consensus, provide more insights of divergent preferences and strengthen decision maker capacities, as well as ensuring that a broad range of views are considered in the assessment (UNEP, 2005). These assessments cannot resolve all conflicts, but they can help to provide systematic information, making a complex situation more transparent to decision makers and to the public.

Integrated assessment is best seen as an alternative to the traditional decision-making process, designed to enhance the contribution of NRM to sustainable development (UNEP, 2005).

2.5.2 MULTIPLE CRITERIA ANALYSIS

Multiple Criteria Analysis (MCA) is a structured framework for investigating, analysing and resolving decision problems constrained by multiple objectives and criteria (Nijkamp & Rietveld, 1986). MCA methods can be used to support decision-making where conflicting economic, environmental, societal, institutional and technical objectives may be involved (Eom & Lee, 1990; Garcia, 2004; Huang, Keisler, & Linkov, 2011). This multidimensionality is a characteristic of most questions concerning sustainable development (Hajkovicz, McDonald, & Smith, 2000a). MCA is suitable for supporting decision-making dealing with sustainability issues (Pietersen, 2006), and allows the use of heterogeneous criteria like project costs and benefits (valued in monetary terms), environmental quality (recorded in physical and qualitative terms) and social impacts (recorded in non-monetary terms) to be aggregated into a single measurement unit (Munda, 2005). It is valued as an alternative to CBA primarily because it does not require all impacts to be expressed in monetary units (Belton & Stewart, 2002; Carlo & Alessandra, 2008; Margerum, 1995). The potential of MCA for project appraisal and evaluation has been recognised in the literature (Haralambopoulos & Polatidis, 2003; Nardini, 1997; van Pelt et al., 1990).

Applications of MCA typically involve several key stages which are collectively referred to as the MCA process. The MCA process shares much in common with the rational model of decision-making. It follows the sequence of identifying objectives and alternatives, assessing the performance of alternatives against the objectives and making a final decision (Diakoulaki & Karangelis, 2007).

Over the last two decades many multiple criteria decision methods have been developed (i.e., Abrishamchi, Ebrahimian, Tajrishi, & Mariño, 2005; Ananda & Herath, 2008; Hajkowicz, 2009; Nas, Cay, Iscan, & Berktay, 2010; Romero & Rehman, 2003; Strassert & Prato, 2002; Turskis, Zavadskas, & Peldschus, 2009). Each method demonstrate its own properties with respect to the way of assessing criteria, the application and computation of weights, the mathematical algorithm utilized, the model used to describe the system of preferences of the manager facing the decision-making, the level of uncertainty embedded in the data set and the ability for stakeholders to participate in the process (De Montis et al., 2000). In a study reviewing the environmental applications of MCA between 2000 and 2009, (Huang et al., 2011) found a significant growth in the successful use of MCA across many areas of environmental application. For example, a model called Ecozone II was developed to aid operational decisions regarding proposed land management projects in agriculture, aquaculture and agro-industry. "Ecozone II does this by guiding users through the EIA procedure for a named project in a specific location. This process serves to highlight the most damaging activities and consequent impacts associated with a project through a system of scoring and ranking initiated by the user" (Howells, et al., 1998, p. 147).

Another example from the public sector is the European Union project SENSOR. This model develops *ex-ante* Sustainable Impact Assessment tools to support decision making on European land use and environmental policies. The project relates directly to the effort of the European Commission to integrate all single sector policy assessments into one impact assessment procedure. These models were developed for decision making within NRM utilising policy analysis instead of project evaluation.

MCA techniques are considered by some to be a natural tool to address environmental decision making problems and, specifically, natural resource management decisions (Huang et al., 2011; Mendoza & Martins, 2006; UNESCO, 1994). The main advantages of the MCA approach in environmental decision-making are:

- Its non-economic valuation characteristics.
- Its capacity to deal with multiple and conflicting issues.
- The help it can provide in structuring complex decision problems, thus increasing transparency.

MCA not only offers some advantages over traditional decision methods, but can also be integrated with other approaches to take advantage of the strengths inherent in each (Gamper & Turcanu, 2007; Schmoldt et al., 2001).

Experience in the use of MCA has shown that this method provides a flexible way of dealing with the qualitative and quantitative effects of decisions (Turskis et al., 2009). However, this does not mean that multi-criteria evaluation is a panacea that can be used in all circumstances without difficulties; it has its own problems (Munda et al., 1994).

Criticism of MCA has demonstrated that its theories, techniques and applications are often too complicated (Mendoza & Martins, 2006). Khorramshahgol and Steiner (1988) argued that the most serious limitation of these techniques is the rigid structure imposed by their algorithms. They also claimed that their implementation is resource demanding and time consuming. According to Campbell and Sayer (2003, p. 3), “these earlier attempts to conduct research at the level of complex systems are widely seen to have generated needs for excessive amounts of data, to have been costly to conduct, and to have yielded few results of immediate practical value”.

In addition, the time span and the cost of such a high level of analysis may be unsuitable to the timescales and budgets usually agreed for an evaluation. MCAs are often based on slow and iterative processes, which may include protracted

periods of negotiation. The analysis usually takes time, except for exceptionally simple situations, or when the goal is to collect opinions retrospectively. In ex-ante decision-making assistance, MCAs usually last several months (European Commission, 2005). In other case, to compensate for the time constraint of negotiation, some MCA models do not allow the managers' subjective value judgements to enter into the decision-making process (Steiner et al., 2003; Tavana, 2003). This limitation is probably one of the main reasons why MCA is still not widely used in practical applications (Kiker et al., 2005). This is reinforced by the fact that MCA is generally not included in administrative procedures (Beinat & Nijkamp, 1998). Practitioners are time-constrained and are looking for a decision-making methodology that has a sound theoretical base and overcomes the above limitations. In other words, they need a technique that is not rigid, is easy to use, is not time-consuming, and helps them think through their choices by allowing them not only to incorporate into the model the multiple objectives of the organization, but also to include some subjective value judgements in model evaluation and hence in the decision-making also.

Other criticisms of MCA relate to the lack of a consistent evaluation framework; the lack of support in the phases of problem definition and design (Janssen, 2001); the lack of methods for incorporating uncertainty; and susceptibility of the end result to the choice of methods and weightings (van Pelt, 1993). Nevertheless, these limitations are mainly related to models developed within the MCA framework, but are not a general constraint of the method itself. Instead these should be taken into consideration when developing an MCA model.

The next logical step is to respond to the information and analysis provided by an integrated assessment through developing and implementing a project evaluation model that can take advantage of the strengths that MCA offers. Such a model would be able to offer an explicit and structured approach, resulting in a more efficient and effective decision process as compared with the often intuitive and bias-driven decision processes that regulatory agencies are often accused of using in decision-making. The next section presents some attempts to develop a decision-making model based on MCA to help resolve NRM decision-making

issues. It will also present the desired characteristics that any future model will possess.

2.5.3 A RAPID INTEGRATED METHOD TO SUPPORT PROJECT EVALUATION

Decision makers and regulatory agencies need a pragmatic and robust process for assisting project evaluation. The integrative approach to sustainability analysis must be transparent and the monitoring auditable. MCA provides an integrated framework for developing a suitable methodology because it can handle a large range of incommensurate data and can express preferences in a robust manner. However, new analytical techniques based on MCA can be time consuming, resource intensive, and expensive to implement. Decision makers require cost-effective and timely identification of the economic, social and environmental strengths and weakness of proposed project investments. The challenge, then, is to design an approach particularly suited to problems that require rapid appraisal. This rapid method is intended to act as a benchmark for managers, providing them with a tool to inform the decision making process regarding project evaluation in NRM.

In order to minimise costs and time, while giving due consideration to sustainability and technical uncertainty, a rapid model that deals with economic, social and ecological factors simultaneously, is required. The essential characteristics that the REM should include are as follows:

(1) A clear presentation of the trade-off between economic, environmental and social components of sustainability.

Making decisions on project proposals can be complex, especially if the goal of sustainability is to be incorporated into the analysis. The integration of social, economic and environmental considerations is essential for the goal of sustainability and must be a central consideration in the design and implementation of the assessment (Gibson, 2006). Most often a project does not present favourable outcomes for all three considerations (economic,

environmental and social) so that some trade-off is required. For instance, a project where economic objectives are maximized can result in detrimental impacts on the environment. This could be a situation where loss in ecological values can be justified by the economic gain, however, this compensation should be clearly revealed in the evaluation process.

Morrison-Saunders and Hodgson (2009) recognized that, while in theory sustainability calls for integration, in practice it often means some level of trade-off between differing sustainability principles. Consequently, good decisions depend on the capacity to explore and clarify the trade-offs and links between the economy, society and the environment. The process of managing potential trade-offs then becomes specially important when developing a decision-making model (Morrison-Saunders & Hodgson, 2009), and a clear trade-off rule would need to be applied (Gibson, 2006). Several authors (Jenkins, Annandale, & Morrison-Saunders, 2003; Morrison-Saunders & Therivel, 2006) have argued that keeping the economic, social and ecological pillars in three separate folders, with integration (assumed to require a trade-off decision) reserved for the approval (or rejection) decision, can ensure that ecological as well as social and economic concerns will be treated with the same attention. To do so, REM will need to rely (for their final score) on the maximum net gains rule. According to Gibson and Hassan (2005), this rule means that any acceptable trade-off must favour achievement of the most positive feasible overall result, while avoiding significant adverse effects.

REM will be used to reveal the trade-offs between criteria. As a project or policy decision will have a variety of impacts, REM will measure these impacts as separate criteria. The criteria structure for an REM assessment has to meet a number of conflicting demands. On the basis of the scores of the different criteria, and their relative weights, the best choice can thereby be determined (Sijtsma, van der Heide, & van Hinsberg, 2013).

(2) Being general enough to tolerate different types of evaluations and be adaptable to a wide range of situations.

In the literature, many models have been developed to integrate the economic, environmental and social implications of project development. However, these models have been built on a project specific basis; therefore, they cannot be applied to another evaluation without major changes. Therefore, it would be advantageous to have a general framework that can be easily adapted to evaluate different projects. Recognition of this need has also been made by Nijkamp and Ouwersloot (1997), who have argued that:

In general, it would be desirable to construct a comprehensive impact model which would encapsulate the complex interacting patterns of a project development in relation to economic, social and environmental variables. Such a modelling activity could take the form of either an econometric model (validated by empirical data on solid statistical grounds) or a simulation model (calibrated at best by plausible information). In light of the near-impossibility to construct for each individual development plan or project a dedicated model, in practice one often resorts to an ad hoc impact assessment, based on simple cause-effect relationships. Such a more limited approach has obviously several shortcomings, but has the advantage that it is manageable, practical and based on local expertise. (p. 1096)

The cause-effect approach proposed by Nijkamp and Ouwersloot (1997) may constitute a starting point for a generic approach. The reason for this is that most project submitters are required to provide an in-depth project proposal, which usually includes CBA, EIA and SIA reports, with a clear discussion of the project's proposed activities (cause) and their possible impacts (effect). Following a cause-effect relationship, the project's impacts can be readily identified and summarized into a broader three folder approach.

The advantage of the three folder approach is related to the usefulness of its application. Gibson (2006) describes this type of model:

They [the three folder approach] fits well with the established capacities of assessment and review experts trained in the three constituent fields (social, economic and ecological), with the organisation of much of the relevant information (e.g. data sets collected separately under these categories), and with the usual division of social, economic and

environmental mandates among government bodies with relevant responsibilities in strategic as well as project assessments. (p. 263)

A three folder structure of REM will allow it to be general enough to tolerate different types of evaluation, such as, considering the acceptability of a single project or, investigating simultaneously several projects with the view to ranking them and then selecting one or more of those projects. In addition, it could be adapted to a wide range of project types, such as, infrastructure investments, conservation initiatives, policies, technology development, and funding allocations, etc.

(3) Focusing on key criteria.

Within each of the three main criteria (economic, environmental and social goals), there will always be a number of factors that need to be taken into account with respect to a particular decision. These factors are also known as attributes in decision-making terminology. There is general agreement that policies, plans, programmes and projects should be planned so as to take full account of economic, environmental, and social considerations (Morrison-Saunders & Therivel, 2006). At the same time, in the measurement stage of any MCA, an important step is to make a so-called impact matrix, which shows the measures of the impacts for each considered alternative. However, for many decision-making processes, the impact matrix becomes far too cumbersome (Sijtsma et al., 2013) and an overly large impact matrix provides little judgment (Belton & Stewart, 2002). Ascough (2008) describes the delicate balance of incorporating criteria into a model:

Importance of acknowledging that the 'best' model may not be the most complex or 'complete', in the sense that quantitatively incorporating every aspect of the system under study may result in more uncertainty than if only the salient processes (if known) are considered. A 'reductionist' approach, where every minute detail is represented in a model's structure, may be capable of reproducing the real system, while an understanding of dynamical mechanisms important to environmental decision-making may still be lacking. (p. 389)

In applying REM, attributes should be selected to indicate the degree to which each of the main objectives is met by the alternatives proffered. Thus, a wide choice of attributes clarifies each objective, provides a useful description of the impacts of each alternative, and facilitates an insightful evaluation of alternatives (Keeney & Gregory, 2005). Therefore, the focus of the analysis should be placed on the most relevant and significant economic, environmental and social consequences of the project implementation. Attributes/criteria selection involves the identification of key issues of concern, thereby ensuring that the assessment remains focussed and the analysis manageable and practical.

(4) Incorporating judgement weights to each goal

Weights, using value judgements, reflect the importance of the specific issues or attributes. As MCA applications usually involve a number of attributes, ranking of alternatives is often arrived at on the basis of explicit weights, assigned either in quantitative or qualitative terms, showing the relative importance of these criteria. Outcomes of the appraisal are highly sensitive to the weights used (van Pelt et al., 1990). This use of weights would go some way toward solving the problem as stated by Huang, Chu, and Chiang (2008):

As governments strive to become more efficient and reduce the costs of services in order to remain competitive, the choice of government-sponsored Technology Development Programs (TDP) projects has become increasingly important. Due to the funding scale and complexity of technology, the selection of TDP projects can be viewed as a multiple-attribute decision that is normally made by a review committee with experts from academia, industry, and the government. However, these experts, who have a diversity of knowledge, often enter the group with different assumptions, viewpoints, and interpretations of the issues involved and often select proposed TDP projects based on evaluation criteria that are not clearly defined. Therefore, review committees tend to select projects with consensus. An effective mechanism to resolve this kind of cognitive conflict is necessary. (p. 1039)

2.6 CONCLUSION

In earlier decades the allocation of natural resources was dominated by economic decisions to the detriment of environmental protection and social acceptability, but increasingly, the focus of NRM merges biophysical, social and economic objectives. To add to the complexity, the concept of sustainable development has been recognized worldwide as the major challenge for NRM (Slootweg et al., 2001). Concern regarding limits to growth and tension between economic development and environmental protection and social acceptability have “led to sustainability being emphasised as a concept concerned with integrating these goals” (Harding et al., 2009, p. 26). Since there are as many different views and interests as there are players involved in decision-making, there is likely to be conflict, significant uncertainty and irreversible outcomes, making the decision process extensive and unmanageable (Schmoldt et al., 2001).

It is also acknowledged that projects impacting the allocation of natural resources impose a diverse range of costs and benefits on recipient communities. These costs and benefits can be economic, environmental or social in nature, and most often a project will incorporate all three types of costs and benefits. Decision makers increasingly require cost-effective and timely identification of the economic, social and environmental strengths and weakness of proposed project investments. In isolation, these separate analyses provide only part of the picture. The next step is to incorporate them into an integrated approach.

MCA provides an integrated framework for developing a suitable methodology because it can incorporate a large range of diverse data and express preferences in a robust manner. However, analytical techniques based on MCAs are frequently time consuming, resource intensive, and expensive to implement. They require a systematic approach to sustainability analysis that is transparent and auditable, but which is also time and resource efficient.

A more rapid approach to project appraisal, while maintaining a level of comprehensiveness, is needed to integrate the economic, environmental and social strengths and weaknesses put forward by the proponents of the project.

Such an approach needs to be applicable to different types of evaluations, to focus on key criteria and to clearly include the trade-offs between economic development, environmental protection and social acceptability. The following chapter will outline the method used to obtain such a model.

CHAPTER THREE - DECISION FRAMEWORK AND METHOD DEVELOPMENT

The scope and scale of natural resource management is increasing each year as governments and institutions become more aware of the necessity of ensuring environmental protection, whilst also encouraging economic development and improving societal welfare. Therefore, government officials and other practitioners must regularly choose between alternative actions, with the aim of achieving a balance between the tensions created by conflicting economic, environmental and social needs.

The preceding chapter reviewed the need for an integrated framework that can help decision makers in their task of timely identification of the economic, social and environmental strengths and weaknesses of proposed project investments. This chapter presents the methodological context used to develop a suitable decision-making model based on the multiple criteria analysis (MCA) that can accelerate the decision-making process to determine whether a development project is viable or not, or warrants further investigation.

This chapter is divided into three main sections. In the first section (3.1), several MCA software are reviewed in order to identify a suitable decision-making framework on which to build the model. In section two (3.2), the steps taken to develop the model are described and the structure of the resulting Rapid Evaluation Method (REM) is presented. In this section, the process of entering data for each alternative into the Logical Decisions® for Windows™ (LDW) software is explained. Finally, section three (3.3) reports on how the REM is implemented, and also describes the case study selection and the preparation done before applying the model.

3.1 MULTIPLE CRITERIA ANALYSIS SOFTWARE

The processes that involve multiple criteria decision analysis take explicit account of multiple, sometimes conflicting, criteria in aiding decision-making. This helps to structure the problem, and also provides a focal point for further discussion (Belton & Stewart, 2002). These methods can help decision-makers understand the problem at hand, and their own values and judgements, as well as the values and judgements of others. Through this process of organization, the relevant information can be synthesised and presented properly in order to guide the courses of action identified through the resulting discussion (ibid.).

Decision-making software should be interactive to enable useful feedback in order to improve results. The most useful approaches should be conceptually simple and transparent to allow for easy elicitation of values and preferences entered and edited, and for the effects of any change to be better understood. Belton & Stewart (2002) state that software should support the decision-making process and not be the driving force behind it. The MCA process should serve to both complement and challenge, by acting as a sounding board against which ideas can be tested. It should not seek to substitute intuitive judgment or experience (ibid.). The process should lead to better-considered and explainable decisions by way of a transparent audit trail.

3.1.1 SOFTWARE SELECTION

Today a wide variety of software has been developed specifically to support MCA decision-making. Many general software tools, such as linear programming packages and electronic spreadsheets that do not implement specific MCA techniques, can also be used to analyse multiple criteria problems. MCA software covers various stages of the decision-making process, from problem exploration and structuring to discovering the decision maker's preferences and the most preferred compromise solution.

Many of the general commercially available decision aids have been included in the biennial decision support systems reviews in *OR/MS Today* (*OR/MS Today*,

2012). These surveys compile vendor-supplied information into matrices, to allow for quick comparison of features in terms of the operative system required, applications, software features, decision algorithms implemented, availability of graphical elicitation techniques, types of output displays and analysis charts, pricing information, availability of training classes, specific industries or market segments in which the software tool was more popular, and specific applications for which the software was most widely used (OR/MS Today, 2012).

According to the OR/MS Today survey, an increasing number of packages are available for interactive use via the Internet. However, software that use internet-based weighting methods, such as 1000 Minds, were considered unsuitable for the purposes of this work, as the process and mechanism used to obtain a result is unknown, and aggregated utility functions cannot be disaggregated to determine the contribution that each attribute contributes to the overall result. In addition, they rely on internet availability, limiting their use in the field or in places without appropriate connectivity.

To identify suitable MCA software that could be employed in this study, a number of options were considered and evaluated against set criteria. The options considered include Criterium DecisionPlus 3.0, EQUITY, HIVIEW, Hi Priority, and Logical Decisions® for Windows™. These software packages were designed specifically for discrete choice situations, warranting further testing.

The method used to determine which software was going to be used, was developed according to a list of considerations presented in Table 3.1, and each was scored accordingly. With future use of the model in mind, the software package chosen must be easy to use. Other necessary parameters identified include: the ability to incorporate multiple decision makers' preferences, the ability to import data and export graphics, the ability to view and print the model structure, the graphical representation of results, and the ability to make notes within the structure of the model. The five software packages identified by Maxwell (2002) are also surveyed and evaluated by him. The results of his evaluation are presented in Table 3.1 and revealed the two 'best' software packages were

Criterion DecisionPlus 3.0 (CDP 3.0) and Logical Decisions® for Windows™ (LDW).

Table 3.1 A comparative analysis of MCA software capability for this study

	Ease of use	Trade-off analyses between multiple objectives	Uncertainty representation	Probability representation	Scenario or multiple stakeholder capability	Import (database, spreadsheet)	Can model structure be displayed on screen?	Does the software support group weight elicitation?	Are graphical sensitivity analyses possible on weights?	Can analytical results be portrayed graphically?	Is the software Capable of both AHP & MAUT?	Total Score
CDP 3.0	+	+	+	-	+	+	+	+	+	+	+	10
EQUITY	+	+	+	-	+	+	+	-	-	+	-	7
HiView	-	+	+	-	+	+	+	-	+	+	-	7
Hi Priority	+	+	-	-	+	+	+	-	+	+	-	7
LDW	+	+	+	+	+	+	+	-	+	+	+	10

Source: Murray (2005, p. 39)

A further ‘ease of use’ assessment was undertaken by Murray (2005) based on evaluation criteria as presented in Table 3.2. Murray (2005) identified the advantages of LDW over CDP 3.0 in Table 3.2, even though there was no difference in the overall capability scores in Table 3.1. Advantages included the possibility of scenario analysis using the preference settings facility; the availability of two methods of Multi-Attribute Utility Theory (MAUT); six distribution types able to be used to model probability values; file size is limited by computer memory only; cut-off sorting can be undertaken where limits are placed on criteria levels; and the cost of the software was favourable.

Table 3.2 A MCA comparison between Criterion Decision Plus and Logical Decision for Window

	Criterion Decision Plus (CDP)	Logical Decisions for Windows (LDW)
Sensitivity analyses & result analyses	Spider chart – clear & readable; Sensitivity by weights against decision scores; Contribution by criteria; Alternatives scatter plot – contours, accumulated values; Trade-off analysis; Uncertainty contribution	Dynamic weight sensitivity – adjustable; Individual criteria spider graph; Many more available
Clear/transparent	yes	yes
Scenario Analysis	no	Yes, through preference settings
Uncertainty plotting	Based on probability – 5 distribution types available	Monte Carlo simulation capability with 6 distribution types available
Many alternatives	160 blocks	Unlimited as is based on PC memory
Methodology used	AHP or MAUT (SMART)	AHP or MAUT (SMART, SMARTER)
Problem structuring	Brainstorming chart to hierarchy	Matrix & simple hierarchy
Help files	Yes, clear, ordered and relevant – easy to use	Yes, but difficult to understand initially
Graph & figure quality	Good graphs but poorly drawn, poorly reproduced	High quality & clear to read & understand
Cut-off sorting	No	Yes
General comments	Easy to use; graphics easy to interpret; logical process; good tutorial; Limits to the real model are having only 200 alternatives and 300 goals or objectives	Hierarchy procedures and terminology difficult to understand; jargon used but no glossary; no overview; Decision Lab in Auckland are distributors.

AHP: Analytic Hierarchy Process

MAUT: Multi-Attribute Utility Theory

SMART: Simple Multi-Attribute Rating Technique

SMARTER: Simple Multi-Attribute Rating Technique Exploiting Ranks

Source: Adapted from Murray (2005, p. 39)

3.1.2 SOFTWARE PACKAGE

A thorough assessment of the ‘ease of use’ of these two packages was undertaken by Murray (2005), and Logical Decisions® for Windows™ (LDW) was found to be the most user-friendly. Some of the characteristics of LDW from

an ease of use perspective are presented in Table 3.3. The software offers simple problem structuring, good preference and analysis settings, and high quality figure generation. The key disadvantages of LDW are, help files that are hard to use and jargon that differs from that used in the majority of MCA literature. For example, criteria are described as ‘measures’, and data or measures of the criteria are described as ‘levels’ (Allan, 2008).

Table 3.3 Characteristics of Logical Decisions® for Windows™ Software

Characteristics	Logical Decisions® for Windows™ Software
Sensitivity analyses and results analysis	Dynamic weight sensitivity, individual criteria spider graphs; others
Scenario analysis	Thorough preference settings
Uncertainty plotting	Monte Carlo simulations capability with six distribution types available
Number of alternatives possible	Unlimited, based on computer memory
Weight assessment methodology	Both AHP and MAUT (SMART and SMARTER)
Problem structuring	Matrix and simple hierarchy
Help files	Difficult to understand initially but accompanying text book is helpful
Graph and figure quality	High quality, clear to read and understand
Cut-off sorting (where limits are placed on criteria levels)	Yes
Jargon	Attributes = ‘measures’ Data = ‘levels’

Source: Adapted from Allan (2008, p. 230) and Murray (2005, p. 39)

A further consideration was that the findings of a more recent survey concur with these results. This was the survey of more than 45 decision analysis software packages (OR/MS Today, 2012) considered features such as decision algorithms implemented, availability of graphical elicitation techniques, types of output displays and analysis charts, pricing information, availability of training classes, specific industries or market segments in which the software tool was more popular, and specific applications for which the software was most widely used. The survey concluded, among other things, that for decisions with many criteria and value judgments, LDW's offer many features and graphic displays making it the most powerful software in its class. Therefore, for all these reasons LDW was chosen for use in this research.

3.1.3 THE DECISION PROCESS IN LDW

LDW enables the researcher to evaluate alternatives. Alternatives may refer to jobs, factory locations, project designs or household decisions. Logical Decisions® allows the researcher to consider alternatives systematically by adhering to a series of pre-defined steps. These steps enable the researcher to describe or articulate alternatives. In doing so, they allow the researcher to think about preferences and value judgments that are required to identify the best alternative from those available. Once this step has been completed, the researcher will have a quantitative ranking of alternatives. The researcher will also be able to review the results in different display formats, which will increase the researcher's confidence, that the best choice has been made.

The underlying principle supporting decision analysis is to reduce complicated decisions down to smaller part-decisions that can be dealt with individually and then reassembled logically. An important aim of decision analysis is to clearly distinguish between the choices that can be made (the alternatives), the characteristics of the alternatives (the measures) and the comparative desirability of alternative sets of characteristics (preferences). These distinctions allow the researcher to clearly separate the objective and subjective elements of the decision-making process. The alternatives, and the way that measures are used to quantify them, make the process relatively objective. Even if the researcher has uncertainties about the levels of the measures, it is generally possible to reach a consensus about how to characterize those uncertainties (Logical Decisions, 2010).

On the other hand, the relative importance (weights) of the different measures, the connections between them and the outlook toward risk and uncertainty are innately subjective and this leads to disagreements amongst individuals. Whilst one cannot generally eliminate these subjective elements of a decision, the model offers a way to logically deal with both the objective as well as the subjective elements of a decision while keeping them separated (ibid.).

3.1.4 STRUCTURE THE PROBLEM

An often quoted statement is: 'a problem well-structured is a problem half solved' (Belton & Stewart, 2002; Clemen, 1996; Guitouni & Martel, 1998; Malczewski, 1999). A decision problem can be broadly defined as the perceived difference between the existing and desired states of a system (Belton & Stewart, 2002). Structuring the problem facilitates better understanding by determining and assessing the decision-maker's objectives, and by identifying the stakeholders, the alternative courses of action, the criteria against which to compare the alternatives, and the nature of the data required to compare them (Kiker, Bridges, Varghese, Seager, & Linkov, 2005). In this stage of free-thinking around the decision problem, values, beliefs, priorities, facts, points of view, constraints, consequences, and causes related to the issue are explored (Belton & Stewart, 2002). The Logical Decisions (2010) process can be summarised as:

- 1) Identify the alternatives to be ranked.
- 2) Clarify the goals and objectives that should be met by choosing the top-ranking alternative.
- 3) Identify measures to quantify how well the alternatives meet the goals and objectives.
- 4) Quantify the level for each measure for each alternative.
- 5) Quantify preferences of the different levels of the measures.
- 6) Rank the alternatives by combining information from steps (4) and (5).
- 7) Conduct 'sensitivity analyses' to see the effects on the results of changes in measure levels or preferences.

In the LDW system, the researcher defines the alternatives that are to be evaluated (alternatives of the choices to be ranked in the analysis). However, in addition to defining the alternatives the researcher must also describe the strengths and weaknesses of alternatives for particular decisions. In Logical Decisions® this is done with goals and evaluation measures. These measures are

the variables that are used to describe alternatives, for example, price. Generally, there are several measures to describe the alternatives.

Measures are organised according to goals that have been defined. For example, related measures such as, capital costs and operational costs, may be combined into a goal called Least Cost.

In LDW, the researcher organises the goals and measures into a decision-tree structure that is referred to as a 'goals hierarchy'. The hierarchy has broad goals to ensure optimum decisions at the top and specific goals below them. The evaluation measures the lowest goals of the goals hierarchy (Logical Decisions, 2010). The researcher describes how successful each alternative is under various evaluation measures and then employs the goals hierarchy as a framework to combine the performance of alternatives on individual measures into an overall score for each alternative.

3.2 METHOD DEVELOPMENT

Most projects meet technical and political requirements before being lodged for application to public authorities. As such then, decision makers do not usually consider in detail the technical, institutional or commercial aspects relating to a project. Instead, they assume that such preparations are already well in-hand and that specialists who are knowledgeable in these matters can easily be consulted in the course of the analytical process (Gittinger, 1985). Therefore, with a REM developed, a higher level evaluation can take place, focusing primarily on the trade-off between economic, environmental and social factors. The model (utilizing the multiple criteria analysis software Logical Decisions®) will comprise a three-fold framework (economic development, environmental protection, social acceptability) populated with relevant data to determine whether a development project is acceptable or not, or whether a more complete MCA is required using more detailed technical, commercial and institutional data.

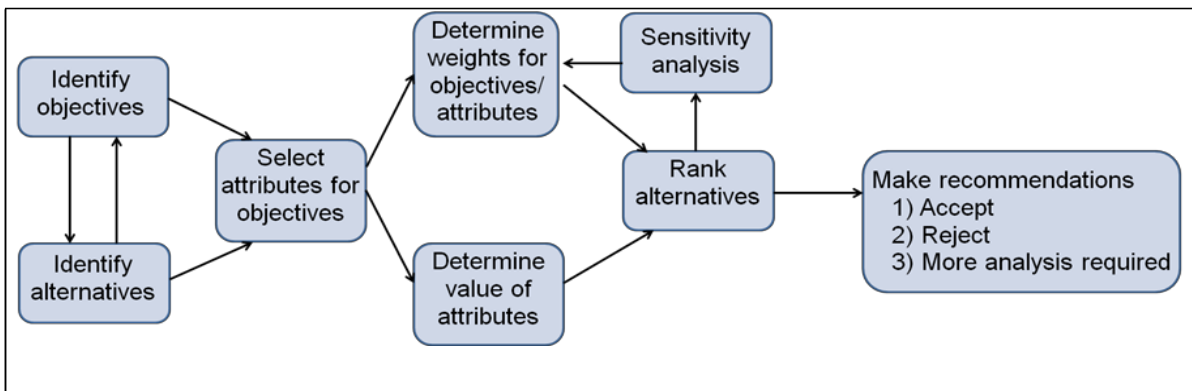
A panel of key decision makers and experts are employed to assign importance/value weightings to each data unit and then assign the unit to one of

three frameworks in the model. The analyst is then able to measure the relationship between each element and generate a single number to guide the investment decision.

The REM generates ‘with project’ and ‘without project’ scores that enable decision-makers to identify the net economic, environmental and social benefits of the project under consideration. In addition to the section scores, the model also calculates a single score of the integrated scores from each of the sections that decision-makers can use to assess the viability of the project.

Selecting the best framework to ensure the projects and programmes selection process are well executed can be a complex matter. In order for a decision to be made in an organised manner, there is a need to categorise the decision-making process into a series of sequential steps. The process for addressing any project proposal is reasonably standardized and is summarized as shown in Figure 3.1.

Figure 3.1 Flow chart of decisional process



The diagram illustrated in Figure 3.1 outlines the conceptual framework that underlies this research approach. This then leads to the application of LDW software to develop the REM. Subsequent sections expand upon the steps identified in Figure 3.1. First, the formal objectives of the model are agreed upon. Second, decision-making options (alternatives) to be evaluated with the model are described. Third, a general list of decision criteria on economic development, environmental protection and social acceptability objectives is identified, and a

summary table based upon the project attributes is presented. Fourth, ways to elicit preference are presented and a method to determine weights for attributes that integrate expert opinion is settled. Fifth, risk and uncertainty factors are addressed by way of sensitivity analyses. Sixth, the aggregation procedure to obtain the alternatives' rank and rationale for determining the decision support system is presented. Finally, the interpretation of outcomes and recommendations generated by the REM are discussed.

3.2.1 FORMAL OBJECTIVES OF THE METHOD

The first phase of developing a REM is to clearly articulate the aim and concomitant objectives of the development investment project to be evaluated by the model sub-goals, which may be specified by stakeholders or decision makers in central government, local government or institutions. As stated in Chapter Two, governments and institutions must consider how social and economic development can be achieved whilst protecting the environment and preserving natural resources. Even in private development projects, special attention to the 'triple bottom-line' is required. Companies need to expand their traditional focus on financial objectives to also take into account the (biophysical) environmental impact and social performance.

3.2.2 DECISION ALTERNATIVES

The purpose of this stage of model development is to identify the alternatives to be analysed and ranked by the decision-making model. Alternatives reflect all the possible options that may be undertaken in order to achieve the objectives that have been identified (Belton & Stewart, 2002). Depending upon the characteristics of the project, several kinds of decision alternatives can be recognised. An important separation concerns the distinction between continuous versus discrete evaluation problems. In the case of continuous problems, the precise alternatives are not known beforehand; hence the development of alternatives would become part of the analysis. In the case of discrete problems, the alternatives are known as 'a priori' and, often are ready to be subjected to evaluation (Munda, Nijkamp, & Rietveld, 1994). Since the REM is intended to be used when a decision needs to

be made about the approval or rejection of a project, alternatives will be discrete in nature.

At the project level in which this research is based, sometimes the project itself constitutes the only alternative with no other options to analyse. However, even in this case, at least two alternatives can be identified: 1) Do the project ('with' the project scenario) or 2) Do nothing ('without' the project or status quo scenario). In project analysis, the relevant comparison is the net benefit with the project compared with the net benefit without the project. This would be the case in a 'single option selection'. The rapid model will be able to tolerate more than one alternative in the without project scenario (the evaluation of two or more different projects at the same time) if these projects can be analysed with the same set of selected attributes. This type of analysis will represent 'project prioritisation'.

All projects make use of relatively scarce inputs to produce an output of goods and services valued by society. In general, without the project, the availability of these inputs and outputs to the rest of the society would be different. Comparing the situation both with and without the project constitutes the basic method of measuring the additional benefits that can be attributed to the project. In most cases, the situation without the project is not simply a continuation of the status quo, because some changes in input and output levels and prices are likely to take place anyway. In agricultural projects, for example, cropping patterns, yields, output levels, and commodity prices may be expected to change substantially from their base levels even without the project as a result of market conditions or other factors. Conceivably, situations could arise that are worse after a project is completed than before. The project may, nevertheless, be justified, if without it the deterioration would have been greater. Thus, an accurate comparison of the situations expected to prevail with and without the project may call for difficult judgments (Adhar, 1996).

It is essential to have a good inventory of the project elements before the commencement of the project in order to be able to make future comparisons between conditions after the changes and effects created by a project and the

original ones. This is called the baseline, and it applies not only to the environment but to the social and economic aspects as well. The baseline, or the without the project situation, will always be an alternative to consider under the Rapid Model, and when this alternative achieves the overall highest rank, this means that under the condition, the project should be rejected.

3.2.3 ATTRIBUTE SELECTION

When the objectives of the project under consideration are clarified and the alternatives are identified, the next phase of developing REM decision attributes can proceed. Attributes are defined to describe the consequences of the alternatives and make value trade-offs; therefore, it is necessary to identify appropriate attribute measures for each objective. In this sense, attributes are the yardsticks against which to quantify the achievement of the objectives. These may be qualitative or quantitative and provide a base upon which objectives can be normalised and compared with each other (Fernandes, Ridgley, & Van't Hof, 1999).

Attribute selection depends on many features, including types of alternatives, possible issues that may be affected for each alternative, importance of the project, data availability, etc. Munier (2004) gave some examples of attributes that can be used in different projects. These general attributes are summarised in Table 3.4.

Table 3.4 Summary of general attributes for project appraisal

Attribute	Associated with:	Examples of measures				
Environmental	Thresholds that are not to be exceeded	Water use	Fossil energy use	Number of trees to be cut	Water bodies crossing	Fauna migration
Safety	Thresholds that expressed in percentage	Social unrest	Energy security	Security risk	Geological risk	Risk of soil contamination
Social	Peoples' perception of different issues	People affected by the project	Persons to be resettled	Populated areas near the project site	Public health	Heritage conservation
Economic	Economic facts	Production unit cost	Direct economic benefits	Indirect economic benefits	Resource use efficiency	Market competitiveness
Construction	Technical facts	Terrain, slope	Geological faults	Difficulty for access	Type of soil	Logistics
Scales distribution	Special and temporal effects	Diffusion of pollution	Distance to a populated area	Trans-boundary effects	Persistence	Length of time

The set of attributes identified in a project appraisal should provide insight to decision makers regarding the full range of consequences of their decisions. In this sense, the selection of attributes deals with the identification of key parameters/indicators that can describe all negative and positive impacts related to the project. However, these indicators are not mutually exclusive since values cannot always be unequivocally assigned to an attribute (Fülöp, 2005). For example, water quality is usually a parameter associated with environmental problems, however, if a project has an impact on the quality of drinking water of nearby dwellings, water quality may represent an indicator of a social issue. In view of this and other difficulties, Baker et al. (2002, p. 4) and later Keeney and Gregory (2005, p. 3) have proposed a list with desirable properties that the selection of a set of attributes should meet. These properties are as follows:

- Comprehensive: Able to discriminate among the alternatives and to support the comparison of the performance of the alternatives.

Consequences and value trade-offs made using the attribute should readily be understood and clearly communicated.

- Direct: An attribute is direct when its attribute levels directly describe the consequences for the fundamental objective of interest.
- Complete (to include all goals): There should be no further attributes which can be used to judge between two alternatives.
- Operational: Attributes must be meaningful to the decision maker and measurable in some way. In practice, information to describe consequences should be available and a reasonable value of trade-offs be made.
- Unambiguous: A clear relationship exists between consequences and descriptions of consequences using the attribute.
- Decomposable: Two factors should not be in opposition in a single criterion.
- For example, if tree planting is beneficial in some areas but not in others, tree planting cannot be used as an attribute.
- Non-redundant: Any aspect of the problem should enter the criteria only once to avoid the consequences of double counting. Keeney and Gregory (2005) indicate two common ways that non-redundancies enter the set of attributes; through the inclusion of attributes related to both means and ends (objectives) or when some attributes represent inputs into a system and others represent outputs.
- Few in number: The set of attributes should be as small as possible to keep the problem dimensions manageable. No smaller set of attributes should be available that satisfy the above criteria.
- Interdependency: This situation arises when changes in the level of one attribute are perceived to be related to changes in another attributes. While interdependence is a common feature of environmental systems, every effort needs to be made to choose attributes that would be perceived by decision makers to be independent.

The development of attributes is a crucial stage in the MCA process. Two approaches can be used; either a top-down or a bottom-up approach (Edwards-

Jones et al., 2000; Lahdelma, Salminen, & Hokkanen, 2000). A top-down approach starts with an overall objective which is then broken down into sub-objectives, then further down until the 'impact level'² is reached (Keeney & Gregory, 2005). A bottom-up approach starts at the impact level and builds these into attributes. Both approaches are used in the literature. In developing the REM, a general checklist of attributes is proposed utilising a top-down approach. To begin, a general objective tree is developed to build up the model. In doing so, each of the general objectives identified in the previous section (in terms of economic development, environmental protection and social acceptability) is decomposed into sub-categories, until measurable indicators are obtained. This breakdown can help the process of checking whether the set of attributes selected is appropriate to the problem. In addition, it can simplify the process of calculating attribute weights, and can facilitate the emergence of higher level views of the issues. Further, the tree structure is frequently used to arrange decisions containing a relatively large number of measurable indicators (Department for Communities and Local Government, 2009).

One objective of this study is to offer a broad framework for decision-making on project evaluation that balances economic development against environmental protection and also against social impact, effectively trading one of against another without bias for one over another. This requires the selecting of attributes that are generic enough to cover a wide range of circumstances, and therefore suitable for the evaluation of most projects, but specific enough to be meaningful to decision makers and relevant for the decision-making process. The remainder of this subsection presents each of the attributes identified (in the three broad areas), and finally all are presented in summary in Table 3.5.

Economic Development Attributes

Economic attributes refer to the value of goods and services that a project would generate, impacting on the economic development of the area. Most projects are

² It refers to the ultimate level in which an attribute can be decomposed, so that a single measure can be reached. These attribute levels are also known as indicators.

intended to add value to the local or national economy; however, the effect of a particular economic attribute may be either positive or negative. These can be individual economic activities (agriculture, industries, fisheries, construction), household income (as an overall indicator of the financial condition of the population), or per capita gross regional product, as an indicator of the income of society as a whole (Munier, 2004; Slootweg, Vanclay, & van Schooten, 2001).

Financial Viability

A financial evaluation is an important subset of the economic evaluation, in that it estimates the financial impact of the project on the project initiators (whether it is a company, agency, or the government). The value of money is also related to time. The purpose (justification) of investments is to set aside a sum of money now in expectation of receiving a larger sum in the future. The financial justification statement reports the results of the financial viability of each project option. This financial evaluation can be made using the following measures:

- Net Income – is the residual income of a firm after adding total revenue and gains and subtracting all expenses and losses for the reporting period. The most common financial tools used to assess the net income of a project are its net present value (NPV) and/or its internal rate of return (IRR). These are differing expressions of the same approach. The NPV determines today's value of all expected future cash flows at a given discount rate. In the case of the IRR, one seeks to determine the discount rate (or interest rate) at which the cumulative net present value of the project is equal to zero. When comparing alternative investment opportunities the project with the highest NPV or IRR is the most attractive one (Quah, 2011).
- Payback Time – This measures the time needed for the cumulative project investment and other early project expenditure to be exactly balanced by the cumulative net income. "Prior to the breakeven point the project is still in overall debt; beyond the breakeven point is reached and so the shorter the payback time, the more attractive the project appears to be" (Allen, 1991, p.24)

Spillover Effects from Expenditure

Project expenditure can generate secondary or indirect effects in others areas of economic activity and people not directly involved in the project. For example, government spending can stimulate additional private spending (Cwik & Wieland, 2011). Therefore, even when the investment expenditure is an economic cost for the project initiators, it can have a positive effect on the local economy since it generates an injection of resources, enriches local infrastructure and boosts local income. The sum of all these other rounds of indirect expenditures rippling through the economy is known as the multiplier effect. In economics, a multiplier is a factor of proportionality that measures how much an endogenous variable changes in response to a change in some exogenous variable (ibid.).

Multiplier effects can be difficult to estimate, since, one variable can have indirect effects, and these effects can also generate further effects. However, project spending, which includes capital and operational expenditure, can help identify spillover effects.

- Capital expenditure – may help produce other goods in the future, as the result of investment creating benefits by the acquiring or upgrade of physical assets such as, equipment, property, or industrial buildings.
- Operational costs – in project evaluation the operational expenditure includes the ongoing costs for running a project, business, or system. Examples of operating expenses include wages for employees, research and development, and raw materials costs.

Productivity Growth

This concept refers to the ratio of a volume measure of output to a volume measure of input use. Productivity relates the quantity of output produced to one or more inputs used in its production, irrespective of the efficiency of their use. Productivity growth can result from innovative activity that results in an outward shift of the global production possibility frontier. Firms can also improve productivity by adopting production processes and products developed elsewhere (imitation). Productivity growth may also be due to reduced (technical) inefficiency.

An inefficient firm or industry uses more resources and factor inputs than are required by a particular technology, thus tying resources to low-productivity activities and reducing the overall allocative efficiency of an economy. Understanding the reasons behind productivity growth is therefore necessary before attributing such changes to specific sources (Schreyer, 2001).

Productivity growth means more value is added, thereby increasing the distributed income. From a national point of view, increases in real economic output are essential for growth in living standards. At a firm or industry level, the benefits of productivity growth can be distributed in a number of different ways. For example, to:

- the workforce through better wages and conditions;
- shareholders and superannuation funds through increased profits and dividend distributions;
- customers through lower prices;
- the environment through environmental protection initiatives; and
- Governments through increases in tax payments.

There are essentially two ways in which productivity is determined. First, the available technology for converting resources into outputs; and second, the way in which resources are organised in firms and industries to produce goods and services.

Efficiency of Resource Use

This is the degree to which a production process reflects 'best practice', either in an engineering sense ('technical efficiency') or in an economic sense ('allocative efficiency'). Full technical efficiency characterises a production process where the maximum possible output has been achieved, given a fixed set of inputs and given a certain technology. The full allocation of efficiency prevails when the input-output combination is cost-minimising and/or profit-maximising.

Resource efficiency can be achieved in a number of ways, namely:

- Reducing material requirements for goods and services – This principle aims to reduce the material that is consumed in the production of goods and services, thus, when less material is consumed, fewer resources are consumed.
- Reducing energy intensity requirements of goods and services – This principle aims to reduce the energy consumption of any process. An example of this is the Volvo Environmental Priority Strategies (EPS) system that assesses the environmental impacts of products and processes in terms of ecological and human health consequences. The results are built into a computerised system that derives a composite score of the environmental impacts of any given product design. On this basis, alternative materials and product configurations can be evaluated in an iterative process to establish an optimum design (Bare & Thomas, 2006).
- Enhancing material recyclability – Aimed at the reduction of energy and material consumption by focusing on recycling waste. Many eco-efficiency initiatives to date have been driven by legislated pollution controls, either actual or anticipated. However, a number of companies are going beyond legal requirements and are attempting to significantly reduce their raw material requirements and emissions through the development of 'closed-loop' processing cycles whereby wastes are either completely recycled or reused and never re-enter the environment. In some cases, as with office equipment, manufacturers are turning to reconditioning or rebuilding old equipment, rather than building every new machine from virgin materials.
- Use of renewable resources – This principle aims at increasing the use of renewable resources through sustainable use; forestation is a good example of this strategy, or the use of electric vehicles that are charge with electrical power derived from cleaner and/or renewable sources.
- Extending product durability – This is to increase the usable life of a product.

Effects Across Other Sectors

This refers to all direct economic effects that a project could have on any other economic sector in the area of impact. For example, suppose that a coastal restoration program resulted in increased commercial harvesting of fish, the change in economic activity levels of third parties would be the total economic impact of expanded fish harvesting, measured as the total spending created by the new economic activity. This process identifies the target populations or clients, and the anticipated impact to these groups. Common effects across other sector could include the displacement and/or creation of new economic activities opportunities (e.g. recreation and tourism).

Factors of Production

- Price reduction – e.g. Fuel cost savings reduction in delivery costs
- Economies of scale – This refers to the reduction in unit cost when the usage levels of other inputs increase.

Security of Supply

Security of supply is fundamentally about the management of risk. More secure systems are those with lower risks of system interruption. There are many ways in which systems can become increasingly insecure. It is risky in the long-term for a region to rely heavily on a single industry. Most businesses are influenced by the market, global economy, and political stability of the country. These variables are impossible to control and potentially have large impacts on the economy. It is best if a local economy attracts a diverse range of businesses so if a market in a particular country experiences a downturn, the risk is spread and the consequences are less severe (Page, Brunt, Busby, & Connell, 2001). Another, frequently debated issue concerns the risk related to security of supply of essential goods and services, as weather production capacity may be too limited for peak demands on the system.

- Food security – can be defined in terms of food supply, assuring the availability and price stability of basic foodstuffs at the national level (Pinstrup-Andersen, 2009). However, in economic terms it is also important

to ensure food access, leading to a definition based on the balance between the demand and supply side of the food security equation and the equity of their distribution. According to the World Food Summit definition, “Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life” (FAO, 2003, p. 29). Food security occurs when:

- farmers and fishers can earn a fair income for their efforts
- food is produced in a way that is safe for people and the environment
- local, regional, and community food production is supported
- social justice and inclusion are priorities
- all people are empowered to work together to create positive change in the food system and our communities

Food security is threatened whenever food is hard to get, such as when:

- there are no farms or grocery stores nearby
- food travels great distances to get to consumers
- there isn't enough money
- healthy and safe food is not available
- healthy foods cost more than unhealthy foods
- rivers are polluted so fish don't survive
- traditional foods are not available or accessible

Energy Security

Energy security refers to the association between national security and the availability of natural resources for energy consumption. Access to cheap energy has become essential to the functioning of modern economies.

It is risky in the long-term for a region to rely heavily on a single industry. International tourism is a fickle business that is influenced by fashions, the economy of the visitor's country, the economy, and political stability of the host country, the cost of travel, and perceptions about the pristine condition of a destination. These variables are impossible for a host destination to control and potentially have large impacts on a destination. It is best if a destination attracts a

diverse range of tourists so if a market in a particular country experiences a downturn, the risk is spread and the consequences are less severe (Page et al., 2001).

Land Tenure

Land tenure is the name given, particularly in common law systems, to the legal regime in which land is owned by an individual. The term 'tenure' is used to signify the relationship between tenant and lord, not the relationship between tenant and land.

- Property rights – refer to the undivided authority to shape how a resource is used, whether that resource is the property of a government or an individual (Alchain, 2008). Unencumbered property rights are a function of three characteristics, first they need to be specific (for example a title deed should exist for land); second, property rights need to be enforceable and; third, property rights need to be transferable (Holland, 2012 pers. comm.).

Inflation

Development for the purposes of some economic sectors, like tourism for example, can create inflationary effects on local economies, increasing the cost of land, property, and goods. Increased land prices benefit sellers, but can disadvantage local people who find it difficult to purchase property. In comparison, tourism development ventures are often able to pay higher prices (Page et al., 2001).

Employment

- Characteristics of employment: The numbers of direct or indirect new jobs generated from the project. This includes:
 - Skilled labour or permanent positions
 - Unskilled labour or temporary positions
- Labour supply and training
- Wage levels
- Local – non-local employment

Environmental Protection Attributes

Environmental attributes refer to the value that society derives from the maintenance of the earth's life support systems. These values may come in two forms, temporal ecological value and spatial ecological value. The first refers to potential future benefits that can be derived from biological diversity (genetic, species and ecosystem diversity) and key ecological processes that maintain the world's life systems for future generations. Spatial ecological value refers to the interactions that ecosystems have with other systems, and the functions which are performed to maintain those other systems (Slootweg et al., 2001). Both of these values are associated with the sustainability and protection of the environment.

As Slootweg et al. (2001) affirm, project interventions create changes to the characteristics of the natural resources in the biophysical setting under all circumstances, irrespective of the type of ecosystem or land-use type in which the intervention is carried out. To achieve the environmental protection objective, it is crucial that these biophysical changes are identified and quantified to determine their impact.

A common approach for the identification of impacts is to describe the 'cause and effect' relationships that may result from a planned intervention or activity associated with the project. This process is also known as screening, and is used mostly in social and environmental impact assessments. Most of the common methods were developed with the objective of facilitating environmental (and social) impact identification. Given that the development of a rapid assessment model is integral to this research, the Leopold Matrix (LM) approach has been selected to identify likely impacts using the EIA method.

The heart of the system is a matrix that is general enough to be used as a reference checklist or as a reminder of the full range of potential or actual actions and impacts as a result of the implementation of a project on the environment. These impacts, adopted from the LM are divided into the following three groups:

- 1) *Physical and chemical characteristics:*
 - Earth*
 - Water*
 - Atmosphere*
 - Processes*

- 2) *Biological conditions:*
 - Flora*
 - Fauna*

- 3) *Ecological Relationships:*
 - Salinisation of water resources*
 - Eutrophication*
 - Disease-insect vectors*
 - Food chains*
 - Salinisation of surface material*
 - Brush encroachment*

Social Acceptability Attributes

There is general agreement among SIA practitioners, that social impacts relate to “all social and cultural consequences to human populations of any public or private actions that alter the ways in which people live, work, play relate to one another, organise to meet their needs, and generally cope as members of society” (Interorganisational Committee, 1994, p. 107). SIA variables point to measurable change in human population, communities, and social relationships resulting from a development project or policy change (Burdge et al., 1994). These variables are closely related to quality of life in general and can be expressed in many different units, depending on the social context and cultural background of the situation.

In the previous section, a list of environmental attributes developed in the LM has been adopted to derive project impacts that result from biophysical interventions, affecting environmental protection objectives. In this section, social elements from the LM are further elaborated to address the ‘human’ impacts that result from planned interventions (changes in the social setting). The social elements of the LM have been rearranged using a list of social variables suggested by Burdge et al. (1994) under the general headings of:

Population Characteristics

Such characteristics describe both the present population and any expected change, ethnic and racial diversity, and influxes and outflows of temporary residents as well as the arrival of seasonal or leisure residents.

Community and Institutional Structures

Community and institutional structures cover the size, structure, and level of organization of local government including links to larger political systems. Also included are historical and present patterns of employment and industrial diversification, the size and level of activity of voluntary associations, religious organizations and interests groups, and finally, how these institutions relate to each other.

Political and Social Resources

This resourcing refers to the distribution of power authority, the interested and affected publics, and the leadership capability and capacity within the community or region.

Individual and Family Changes

Individual and family change attributes refer to factors which influence the daily life of the individuals and families, including attitudes, perceptions, family characteristics and friendship networks. These changes range from attitudes toward the policy, to an alteration in family and friendship networks, to perceptions of risk, health, and safety.

Community Resources

Community resources include the effect on man-made facilities, patterns of natural resource use and land use; the availability of housing and community services to include health, police and fire protection and sanitation facilities. A key to the continuity and survival of human communities are their historical and cultural resources. Under this collection of variables, we also consider possible changes for indigenous people and religious sub-cultures.

Change on Aesthetics and Human Interest

Aesthetics and human interest includes changes in recreational activities and the value placed on scenic views and vistas, wilderness and open space qualities by society, the landscape design and unique physical features, parks and reserves and rare and unique species or ecosystems.

Summary of Attribute Selection

By defining a planned intervention (a project, plan or programme) in terms of economic, environmental and social components, and by describing the way in which human activities affect these components, it is possible to assess the potential impacts of human activities overall. A conceptual framework can be used as a generic guideline for screening and scoping the impact assessment. Decision-makers can use these generic guidelines to further operationalize the framework within the existing local procedures for impact assessment.

In order to offer a widely applicable framework based upon a systematic scoping of impacts, a checklist is presented in Table 3.5. This checklist contains general attributes of economic development, environmental protection and social acceptability. Such a set of attributes is, however, not exhaustive; the ultimate choice of relevant attributes depends upon the specific project under evaluation and on the stated objectives of the project or programmes.

Table 3.5 Economic, environmental and social selection attributes

Goal	Attribute	Sub-Attribute	Impact on:	Effect	Data	Description of measure	
A. Economic development	Financial viability	Net income					
		Payback time					
	Spillover effects	Multiplier effects from capital expenditure					
		Multiplier effects from operational expenditure					
	Productivity growth	Technology for converting resources into outputs					
		Gross domestic product					
		Benefits of productivity growth on:	Workforce through better wages & conditions				
			Shareholders through increased profits & dividend distributions				
			Customers through lower prices				
	Governments through increases in tax payments						
	Efficiency of resource use	Reducing material requirements					
		Reducing energy intensity requirements					
		Enhancing material recyclability					
		Use of a renewable resource					
		Extending product durability					
		Synergies in joint operation					
	Effect across other sectors	Displacement and/or creation of economic activities					
		Impact at the local commercial sector					
		Effect on the primary sector, as:	Agricultural (livestock & horticulture)				
			Fisheries (river or sea)				
			Mining (mines & rocky supplements)				
			Forestry (forest)				
		Effect on the secondary sector, as:	Industry				
			Energy				
			Construction				
		Effect on the tertiary sector, as:	Transport				
			Communications				
			Commercial				
			Tourism				
			Health				
	Education						
	Financial & Administration						
	Entertainment (music, theatre, television, etc.)						
Effect on the quaternary sector, as:	Research						
	Development						
	Innovation						
	Information						
Cost reduction							

Goal	Attribute	Sub-Attribute	Impact on:	Effect	Data	Description of measure	
	Security of supply	Food security					
		Energy security					
	Land tenure	Property rights					
	Inflation	Increase on cost of land					
		Increase on cost of property					
		Increase on cost of goods					
	Employment	Characteristics of employment	Unskilled labour or temporary position				
			Skilled labour or permanent position				
		Labour supply & training					
		Wage levels					
	Local – non-local employment						
B. Environmental Protection	Effect in physical & chemical characteristics	Earth	Mineral resources				
			Construction material				
			Soils				
			Landform				
			Forcefields & background radiation				
			Unique physical features				
		Water	Surface				
			Ocean				
			Underground				
			Quality				
			Temperature				
			Recharge				
		Atmosphere	Snow, ice & permafrost				
			Quality (gases, particulates)				
			Climate (micro, macro)				
		Processes	Temperature				
			Floods				
			Erosion				
			Deposition (sedimentation, precipitation)				
			Solution				
			Sorption				
	Compaction & settling						
	Stability (slides, slumps)						
	Stress-Strain (earthquake)						
	Air movements						
	Effect in biological condition	Flora	Trees				
			Shrubs				
			Grass				
			Crops				
			Microflora				
			Aquatic plants				
			Endangered species				
			Barriers & Corridors				
Fauna		Birds					
		Land animals including reptiles					
		Fish & shellfish					
		Benthic organisms					

Goal	Attribute	Sub-Attribute	Impact on:	Effect	Data	Description of measure		
	Effect in ecological relationships		Insect					
			Microfauna					
			Endangered species					
			Barriers & Corridors					
			Salinisation of water resources	Eutrophication				
				Disease-insect vectors				
				Food chains				
				Salinisation of surface material				
				Brush encroachment				
				Other				
				C. Social Acceptability	Population Characteristics	Population change		
		Ethnic & racial distribution						
		Relocated populations						
Influx or outflows of temporary workers								
Seasonal residents								
Concerns about social well-being	Change on land use	Wilderness & open spaces						
		Wetlands						
		Forestry						
		Grazing						
		Agricultural						
		Residential						
		Commercial						
		Industrial						
	Change on recreation activities	Mining & quarrying						
		Hunting						
		Fishing						
		Boating						
		Swimming						
		Camping						
		Hiking						
	Change on human interest & community resources	Picnicking						
		Aviation activities						
		Facilities for outdoor activities						
		Scenic views & vistas						
		Wilderness qualities						
		Open space qualities						
		Landscape design						
		Unique physical features						
Individual & family changes	Parks & reserves							
	Monuments							
	Rare & unique species or ecosystems							
	Effect historical or archaeological sites							
	Displacement/relocation concerns							
	Trust in political & social institutions							
	Residential stability & effect on private property							
	Cultural patterns							
	Density of acquaintanceship							
	Attitudes toward policy/project							

Goal	Attribute	Sub-Attribute	Impact on:	Effect	Data	Description of measure	
		Family & friendship networks					
		Daily life activities disturbance					
		Perceptions of risk, health & safety	Presence of misfits				
			Risk of pest & diseases dissemination				
			Risk of health illness				
			Noise effects				
			Odours effects				
			Vibration Effects				
		Community & Institutional Structures	Voluntary associations				
			Interest group activity				
	Size & structure of local government						
	Historical experience with change						
	Employment equity of minority groups						
	Local/regional/national linkages						
	Presence of planning & zoning activity						
	Man-made facilities & activities		Structures				
			Transportation network				
			Utility networks				
		Waste disposal					
		Barriers					
	Corridors						
	Political & Social Resources	Distribution of power & authority					
		Identifications of stakeholders					
		Interested & affected publics					
		Leadership capability & characteristics					

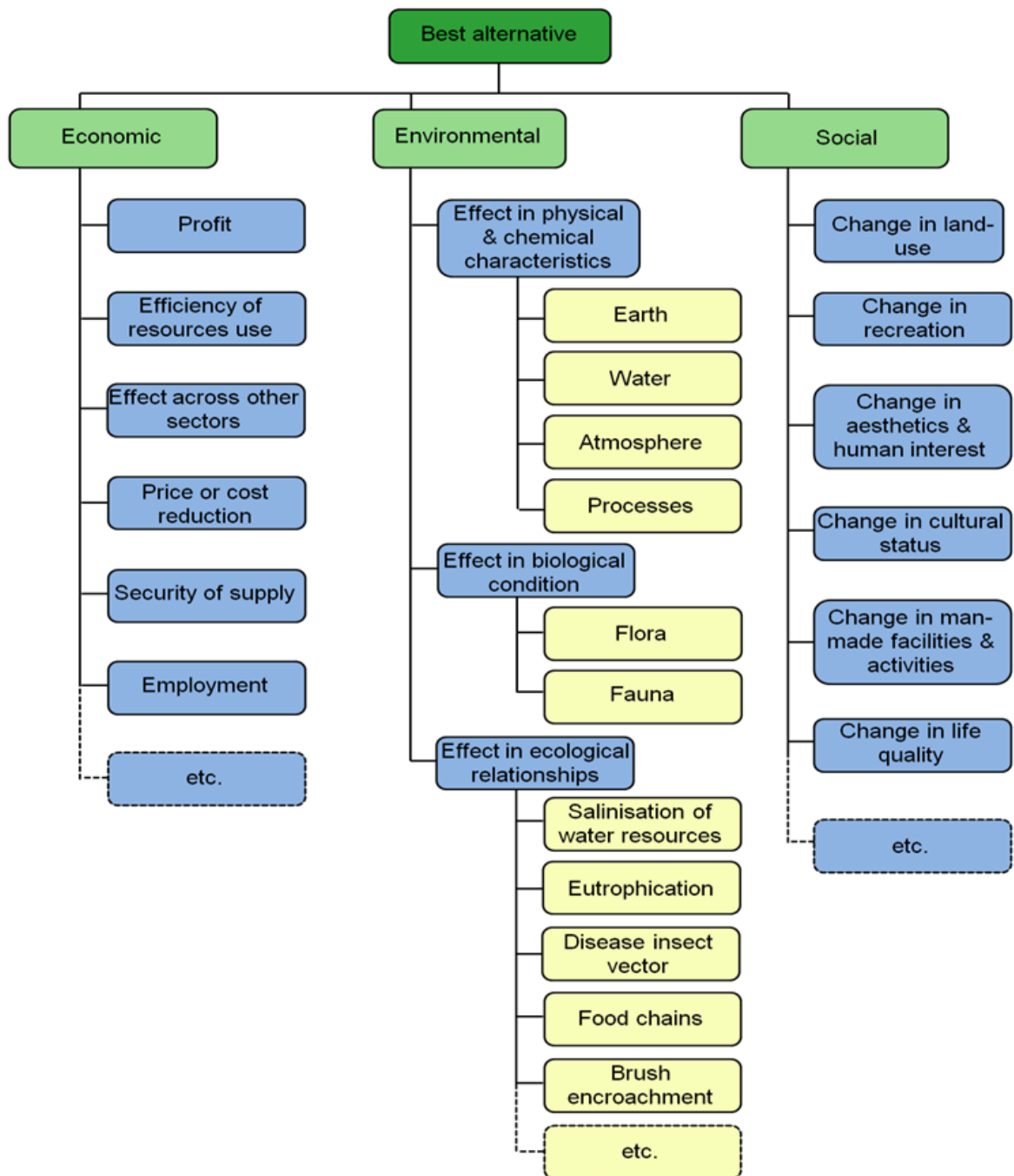
MAGNITUDE	
4	Significant positive effect
3	Moderate positive effect
2	Minor positive effect
1	Negligible positive effect
0	No effect
-1	Negligible negative effect
-2	Minor negative effect
-3	Moderate negative effect
-4	Significant negative effect

IMPORTANCE
Low Importance
Moderate Importance
High Importance

POTENTIAL MITIGATION OF IMPACT
Low Importance
Moderate Importance
High Importance

To simplify the original LM, this checklist focuses solely on impacts. The original columns along the horizontal axis containing activities from the LM have been replaced by three new columns called 'effect', 'data' and 'description of measure'. The first column, 'effect', refers to the type of impact, which can be positive or negative. This column is completed by inserting two scores utilized in the LM, one for magnitude and one for significance. The magnitude is a quantifiable measure of the degree or scale of the impact; and can be defined as the degree of movement away from the baseline state of the specific attribute under consideration. Magnitude is expressed on a scale ranging from highly detrimental (-5), through no effect (0), to highly beneficial (+5). Significance is a value judgement by the assessor as to the degree to which the attribute has caused movement away from the baseline condition (Edwards-Jones et al., 2000). It can be expressed on a scale of high, medium or low importance, coupled with potential low, moderate or high mitigation impact. Each importance's level is represented by a colour. The 'Data' column denotes the possibility of obtaining information from submitter to value the impact. Lastly, the description of measure column is used to describe how the attribute will be entered in the model for the specific project under evaluation. The checklist presented in Table 3.5 is reasonably comprehensive, though not exhaustive. The hierarchical three pillar structure of the model is presented in Figure 3.2.

Figure 3.2 Hierarchical structure of the model



3.2.4 DETERMINING THE VALUE OF ATTRIBUTES

The identification of key attributes associated with the perceived impact of a project does not itself imply that the attribute will have a significant impact upon the outcome of the project. This can only be determined once the attribute has a 'value' linked to it.

Assessment of these different values requires that information be derived from various sources and compared with one another. Dale & English (1999) highlight that the process of selecting this information is informed by both technical and philosophical determinants. Technical issues are generally associated with the availability of information and the availability of resources for data gathering. In the case of philosophical issues, these are related to questions concerning what is meant by terms like 'value' and the 'trustworthiness' of alternative information sources. Information required for obtaining the value or level of attributes should have already been provided in the project proposal submission. These will often include economic, environmental and social issues and potential impacts. If insufficient information or prior assessment is submitted at the time of the project proposal, then it is likely that analysis using the REM will produce an outcome requiring further investigation or that a full MCA be undertaken.

Depending upon the attribute, data input can have a quantitative scale, with respect to some commonly shared and understood unit (e.g. money) or a qualitative scale of measurement, reflecting the assessment of an evaluator. Both types of scale can be entered into LDW.

Entering Data Value/Levels in LDW

The levels for each attribute are entered into LDW in the matrix view. The best and worst levels for each measure are defined within LDW as the 'most preferred level' and the 'least preferred level' (from the goals hierarchy or matrix view). For numerical levels these maxims are a function of the characteristics of the particular project evaluation being analysed, rather than universal standards.

Common Units Conversions

Attribute levels are converted from their original units to standardized units of utility. This approach allows all attributes to be entered into the software with the same unit thus minimising problems associated with attempting to compare attributes with inherently different scales (e.g., water quality and air emissions). In the REM each attribute level is associated with a corresponding numeric score as

shown in Table 3.6. The highest, most preferable utility has a measure of one, and the lowest, least preferable is zero. The intermediate levels can be assigned in LDW using one of five methods: Single-measure Utility Functions (SUFs), the Analytic Hierarchy Process (AHP), AHP SUFs, Adjusted AHP, or direct assessment. All five methods are applicable to attributes with numerical scales, but attributes with labels can only be converted to common units through direct assessment, AHP, or adjusted AHP. For quantitative attributes the simplest conversion method is a graphical SUF. The most common SUF is a straight line SUF, which is the default in LDW. If a straight-line SUF is not suitable for an attribute, a negative straight-line SUF, or negative or positive exponential SUF can be specified. In this research quantitative attributes were converted to utility with the default linear SUF, while for qualitative attributes Table 3.6 was created so that qualitative attributes could be assessed with the descriptors presented (in Table 3.6) and then converted to the common units given and these are further explained in the paragraph following the table.

Table 3.6 Attribute scores associated with each attribute level for those attributes evaluated qualitatively

Attribute level	Utility
Significant positive effect	1.000
Moderate positive effect	0.875
Minor positive effect	0.750
Negligible positive effect	0.625
No effect	0.500
Negligible negative effect	0.375
Minor negative effect	0.250
Moderate negative effect	0.125
Significant negative effect	0.000

For this step in the attribute rating process, each attribute is rated on the nine-point qualitative scale without reference to other attributes. The nine points are then assigned a value equally distributed between, and including, both zero and one (as seen in Table 3.6). For example, the worst potential water quality impact is identified and assigned a score of 0.000 without reference to what the worst air emission impact might be. Some scores are not relevant to some attributes,

where, for example, there might realistically be only five likely types of outcome (e.g., No effect, Negligible negative effect, Minor negative effect, Moderate negative effect, and Significant negative effect). Applying this scale approach to qualitative attributes necessitates the assessor making some judgment as to what constitutes best, medium or worst. To make this process as transparent as possible, in the following case study chapters the meaning of each condition for each attribute is explicitly described.

3.2.5 DETERMINING WEIGHTS FOR OBJECTIVES/ATTRIBUTES

The weighting is a value parameter assigned to indicate the preferences of the decision maker regarding the importance of each attribute. Therefore, this is the phase in which decision makers' judgments are incorporated into the evaluation method. There are two parts to the weighting process that need to be specified for the REM, a weighting method and a method for the elicitation of preferences.

Weighting method

In MCA decisions preferences are expressed through either criteria weighting or holistic evaluation methods (Belton & Stewart, 2002; 1999; Holz, Kuczera, & Kalma, 2006). Assigning weights to criteria is the most common approach to expressing preferences. In so doing, the importance of each criterion relative to other criteria is shown (Belton & Stewart, 2002). It is vital that the weights and any resulting trade-offs are a true reflection of the participants' preferences (Proctor & Qureshi, 2005).

LDW offers six weight assessment alternatives, including two MAUT methods and the AHP method. The MAUT methods are 'simple multi-attribute rating technique using swings' (SMART) and 'simple multi-attribute rating technique exploiting ranks' (SMARTER). The SMART method uses the concept of relative importance to determine weights amongst criteria, while the SMARTER method computes criteria weights from a rank order using a 'centroid' formula (Edwards & Barron, 1994). The AHP method uses pairwise comparisons between sets of criteria to determine criteria weights (Edwards & Barron, 1994). Several MCA methods have

been developed, each involving different weighting assessment with particular mathematical processes to compare alternatives against different criteria or attributes. In this research the AHP was selected to structure the model. This method allows for the integration of the three main objectives identified earlier (economic, environmental and social) to be structured into a hierarchy (or value tree) with several branches (attributes) per objective.

The AHP Method

The AHP method requires the user to assess weight ratios for all possible pairs of attributes for each objective. This process involves entering more ratios than are strictly needed. An approach based on linear algebra is used to compute a best fit set of weights based on the ratios entered (Logical Decisions, 2010).

For each pair, LDW prompts the user to identify which attribute is more important. The user must select an 'importance strength' rating, indicating the ratio of importance of the better performing attribute to the other attribute. The importance strength is selected from a scale of one (equal strength) to nine (extreme), as shown in Figure 3.3. Explanations for the nine levels are given in Table 3.7.

Figure 3.3 Pairwise Comparison using the Analytical Hierarchy Process for Weight Assessment

The image shows a software dialog box titled "Importance for OVERALL Goal" with a close button (X) in the top right corner. The dialog is divided into two main sections: "Importance Ordering:" and "Importance Strength:".

Importance Ordering:

- Water Quality has more Importance than Air emissions
- Air emissions has more Importance than Water Quality

Importance Strength:

<input checked="" type="radio"/> 1 - Equal	<input type="radio"/> 6
<input type="radio"/> 2	<input type="radio"/> 7 - Demonstrated
<input type="radio"/> 3 - Moderate	<input type="radio"/> 8
<input type="radio"/> 4	<input type="radio"/> 9 - Extreme
<input type="radio"/> 5 - Essential/Strong	

On the right side of the dialog, there are three buttons: "OK", "Next", and "Cancel".

Table 3.7 The Scale of Relative Importance

Intensity of Importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Weak importance of one over another	Experience and judgment slightly favour one activity over another
5	Essential or strong importance	Experience and judgment strongly favour one activity over another
7	Demonstrated importance	An activity is strongly favoured and its dominance demonstrated in practice
9	Extreme importance	The evidence of favouring one activity over another is of the highest possible order of affirmation
2,4,6,8	Intermediate values between the two adjacent judgments	When compromise is needed

Source: Adapted from Logical Decisions (2010). In the assessment matrix, LDW provides information about the consistency of the ratios in the matrix. The 'consistency index' (C.I.) is an absolute measure of the consistency of the ratios. The 'consistency ratio' (C.R.) is a relative measure of consistency, and if this is above 0.10 the ratios should be adjusted to make them more consistent (Logical Decisions, 2010).

This ratio is then automatically added to the assessment matrix. The ratio of a member to itself must be one, so ratios are not shown on the diagonal of the matrix; in its place these cells show the current weight for each attribute. The default is for all attributes to have equal importance, with ratios of one. Every pair combination appears twice in the matrix, so ratios are only entered in the cells above the diagonal. Once a weight ratio has been entered, LDW uses the AHP computation process to derive a new set of weights for the attributes (Logical Decisions, 2010).

To elicit pairwise comparisons from a group of more than nine people, another version of LDW, Logical Decisions® for Groups, is used. This is an enhanced version of LDW that captures the judgments of an entire group. Results can then be computed and displayed for either the group consensus or for any individual (Allan, 2008; Murray, 2005)

Preference Elicitation Methods

It has been well documented that deriving preferences or weights for attributes from either an individual or a group is time-consuming (Bana e Costa, 2001; Keeney, von Winterfeldt, & Eppel, 1990). A number of conflicting factors must be taken into account each time when different groups of decision makers get involved in the process. Each group brings different experiences and points of view that must be resolved within a framework to reflect mutual compromise and understanding. A wide range of issues (e.g. employment, air quality, cultural value) are at stake in the development of project investment, and should therefore be addressed as part of a decision-making process. It is clear that a single decision maker, or a group of decision makers with similar interests, cannot suffice to produce and guarantee the selection of a viable project. In order for the model to be practical, the number of people involved should be minimised to reduce time and cost pressures. However, the model must also be robust so those involved should represent relevant fields of expertise.

When a decision situation involves multiple actors, each with different values and informational systems, the final decision will generally be the result of an interaction between all of them. As both Keeney (1992) and Roy (1996) attest, this interaction is not free of conflict, which may be due to any of a number of factors, e.g. different ethical or ideological beliefs, different specific objectives, or different roles within organization. A group decision is usually understood as the reduction of different individual preferences on a given set to a single collective preference (Jelassi et al., 1990). The main goal of this work is the prescription of a final group ranking from these individual preferences.

Expert Opinion

There are several methods that permit the elicitation of a set of preferences based on expert opinions. Such methods range from simple round table discussions to the structured Delphi technique (which is explained shortly). All these methods involve subjectivity in the determination of the attribute weightings which cannot be

replicated by another set of experts (Erickson, 1994). A comparison between three expert opinion methods is shown in Table 3.8.

Table 3.8 Comparison of three expert opinion methods

Characteristics	Meeting	Conference	Delphi
Effective group size	Small to medium	Small to large	Small to large
Interaction mode	Medium	Large	Large
Length of interaction	Medium to long	Long	Short to medium
Number of interactions	Varies	Single	Multiple
Format	Flexible. Could be open or controlled by chairman.	Directed. Presentations follow prearranged agenda.	Structured. All interactions go through the monitor.
Cost	Travel and individuals' time.	Travel, fees and individuals' time.	Clerical, secretarial, individuals' and monitor's time.
Other consideration	Equal flow of information to and from all. Psychological ill-effects maximized.	Efficient flow of information from few to many.	Equal flow of information to and from all. Psychological ill-effects minimized. Time demands minimized.

Source: Ahmad & Sammy (1985)

Meetings and conference/seminars are face-to-face discussions of an expert group, the former being more flexible than the latter. These methods are subject to several psychological ill-effects, 'noise', dominance and conformity. 'Noise' refers to the many distractions which affect an average committee discussion. For example, during the course of a discussion one opinion may be repeated many times by an individual who champions it. Care must be taken by the analyst because studies have shown that the statements which are accepted by committees are not necessarily the most relevant or important ones (Meijering, Kampen, & Tobi, 2013; UNEP, 2007; von der Gracht, 2012). Instead, they tend to be the ones which have been repeated most often or when a dominant individual imposes his/her views on others. Thus, the opinion of the most senior member, or even just the loudest member, becomes the consensus. Finally, studies have shown that most people tend to conform to peer pressure and avoid radical sounding positions (Saaty & Peniwati, 2008). On the other hand, open or face-to-face meetings have the advantage of letting people consider,

listening to other experts, about aspects that they have not considered (Smit & Spaling, 1995).

The Delphi technique is an improvement upon the traditional expert opinion approaches to obtaining a consensus of opinion. Like the committee, it draws upon the knowledge of a panel of experts on the subject being investigated. Unlike the committee, the Delphi technique utilizes individual assessment, statistical analysis and controlled feedback to arrive at the consensus (Okoli & Pawlowski, 2004). These changes in format reduce the effects of 'noise', dominance and conformity (Landeta, 2006).

When a Delphi study is performed, each panellist is asked to assess the situation independently. The results are then pooled and analysed. Each expert is then allowed to study his own response and the pooled group response and then asked to review his own answers in light of the group consensus. These new responses are again pooled and analysed. If necessary, the process is taken through third and fourth rounds (Linstone & Turoff, 1975). The advantages are many. Since the same Delphi instrument is circulated to all panellists, the chance of bias due to variations in the questionnaire is removed. The experts work independently, and are therefore not subjected to repetition of arguments or dominance by others. The anonymity resulting from the statistical analysis removes the pressure to conform. Also, the anonymity allows the individual to change his mind without embarrassment (Landeta, 2006).

However, the Delphi method also has its drawbacks. Related to preference analysis, one of the problems could be that experts based in different locations could not know much about the effects that a certain project would produce in a particular location. Another disadvantage of the Delphi method is that experts, because of their backgrounds, might not have the same level of knowledge for all types of attributes proffered (Okoli & Pawlowski, 2004).

Even when the Delphi method suggests using a certain level of consensus as a stopping criterion, the extensive literature review by von der Gracht (2012) found numerous situations where the number of rounds is determined *a priori*,

independently of the consensus level reached. The author identified that this condition was applied to studies with certain budget or time constraints that may not allow for a Delphi process to go beyond three rounds, or when another round would not significantly add to the results and, therefore, the process was terminated.

In the case studies for this research, panels of experts are employed to collectively determine the attribute weightings utilised in the models. The interactive phases for the weighting evaluation are intended to be carried out in three rounds, and the Delphi procedure will be modified to include a focus group meeting during the last interactive phase (third round). The idea is to give to the expert panel members the chance to listen and present their different point of view to the rest of the group.

Quantifying the development of agreement among experts

The three round elicitation method proposed in this research, further focuses on opinion building, usually consensus, among experts. Because experts may change their opinion based on the feedback that they receive from the analyst (or facilitator), it is expected that the level of agreement among experts increases in every subsequent round (Meijering, Kampen, & Tobi, 2013). In other words, there may be a certain level of conformity that causes the level of agreement among experts to increase across rounds. As von der Gracht (2012) has indicated, consensus measurement is a valuable component of data analysis and interpretation of results.

According to recent literature, the most common techniques used to measure the spread of distribution of the results are measures of central tendency (such as the standard deviation and coefficient of variation) and the coefficient of Kendall (when dealing with ordinal rank). In order to determine and quantify the evolving level of agreement among experts on each round, these two complementary methods will be adopted and reported in the case studies.

Parametric statistics for consensus measurement

Measures of central tendency are usually analysed in connection with one or more measures of dispersion (i.e. standard deviation and coefficient of variation) that indicate the spread of scores in a distribution. The standard deviation shows the variation of these scores from the mean score. It is usually examined in combination with the mean, and these variables represent the most common descriptive statistics. A low standard deviation indicates that the scores given are grouped closely around the mean, while a high standard deviation indicates that the scores are spread out over a larger range of values (Dodge, 2003). In contrast, the Coefficient of Variation measures the spread relative to the size of the mean. This makes it a standardized measure of dispersion and useful for the comparison of distributions. It is a dimensionless number and is calculated as the standard deviation divided by the mean. It is usually reported as a percentage. In Delphi research, various studies have used the coefficient of variation as a measure for consensus, since it allows for a direct comparison of statements from succeeding rounds. The ideal case would be that an item's coefficient of variation decreases from round to round. English and Keran (1976), cited by von der Gracht (2012), have published the following rules on how to interpret the coefficient of variation for the measurement of consensus and these are presented in Table 3.9.

Table 3.9 Coefficient of variation and degree of consensus

CV	Decision rule
$0 < CV \leq 0.5$	Good degree of consensus. No need for an additional round
$0.5 < CV \leq 0.8$	Less than satisfactory degree of consensus. Possible need for a n additional round
$CV > 0.8$	Poor degree of consensus. Definite need for an additional round

Source: English and Keran (1976), cited by von der Gracht (2012, p. 1531)

The coefficient of variation (CV) is defined as the ratio of the standard deviation σ to the mean μ :

$$CV = \frac{\sigma}{\mu}$$

Kendall's coefficient of concordance

Kendall's coefficient of concordance is also known as the coefficient of Kendall or the coefficient of concordance, W . It was developed by Kendall (1955) as a solution to the problem of testing for agreement among sets of ranking objects. Therefore, it is considered a measure of correlation or association (Schucany & Frawley, 1973). The coefficient of Kendall has various applications in psychology, social sciences, group decision-making and so on. It is used as a descriptive, non-parametric statistic measure which allows a researcher to evaluate the degree of agreement within a group of k observers, also known as 'inter-judge reliability' (Grzegorzewski, 2006). As it can be used for assessing agreement among raters, many researchers have used Kendall's W coefficient in Delphi studies, as an agreement measure for multiple experts (Meijering et al., 2013; Schmidt, 1997; von der Gracht, 2012).

Kendall's coefficient of concordance is calculated on an ordinal scale, considering the order rankings (Schucany & Frawley, 1973). For example, suppose that object i is given the rank r_{ij} by expert j , where there are in total n objects and m experts. Then the total rank given to object i is (Kendall, 1955):

$$R_i = \sum_{j=1}^m r_{ij}$$

The mean value of these total ranks is

$$\bar{R} = \frac{1}{2} m (n + 1)$$

The sum of squared deviations, S , is defined as

$$S = \sum_{i=1}^n (R_i - \bar{R})^2$$

Then Kendall's W is defined as

$$W = \frac{12 S}{m^2(n^3 - n)}$$

The values of W range from 0 to 1. A high Kendall's coefficient essentially means that the experts are using the same criteria to evaluate the samples (Picado, 2008). In simple words, the closer to one, the stronger the association, as shown in Table 3.10.

Table 3.10 Interpretation of Kendall's W

W	Interpretation	Confidence in ranks
0.1	Very weak agreement	None
0.3	Weak agreement	Low
0.5	Moderate agreement	Fair
0.7	Strong agreement	High
0.9	Unusually strong agreement	Very High

Source: Schmidt (1997, p. 767)

If the test statistic W is 1, then all the experts or survey respondents have been unanimous, and each expert or respondent has assigned the same order to the list of objects or concerns. If W is 0, then there is no overall trend of agreement among the respondents, and their responses may be regarded as essentially random. Intermediate values of W indicate a greater or lesser degree of unanimity among the various experts or respondents (Hervé, 2007; Meijering et al., 2013). "Using W , one can make a realistic determination of whether any consensus has been reached, whether the consensus is increasing, and the relative strength of consensus" (Schmidt, 1997, p. 765).

3.2.6 RANKING ALTERNATIVES

Integration calls for analysing and drawing together information on economic, environmental, and social impacts in order to make trade-offs. As a consequence it is desirable to have a tool with the analytical power to illustrate these trade-offs. In this phase, results are exploited in order to clarify why an alternative is ranked more favourably than another, which are the attributes of more or less importance, and the possibility of structuring an improved alternative from the better-ranked actions.

Algorithms are used to rank the alternatives against the attributes, using the data and attribute weights to determine an overall performance score for each alternative. The next step in the analysis is to combine levels to compute each overall utility score by describing preferences about the relative importance of attributes and objectives. This is computed by combining the utilities for each of an objective's members (attributes or sub-attributes) in a weighted average called a multi-measure utility function (MUF). The utilities of the attributes under each objective must all sum to one. This is repeated for each objective grouping in the analysis (i.e. economic development, environmental protection and social acceptability). Separate MUFs for each objective are beneficial because they simplify the assessment by requiring fewer members to be considered at once (Logical Decisions, 2010).

Preference information is stored in LDW as a preference set. The information in each preference set includes category multipliers, SUFs, and the weight assessment information LDW uses to compute the MUFs for each objective. It is at this point that environmental losses and gains will be combined with the economic costs and benefits and the social issues (positive and negative), to produce a full picture for each project alternative. The primary output from the evaluation is a ranking of alternatives showing trade-offs, displaying the results in a bar graph.

3.2.7 SENSITIVITY ANALYSES

Concerns regarding uncertainty and the relative objectivity and subjectivity of the data must be addressed. Sensitivity analyses are employed in this research to account for the uncertainty that prevails with forecasting the future, and indicates the sensitivity to changes in key parameters. It is used to assess the possible impact of uncertainty by posing 'what if' questions (Asafu-Adjaye,2000). These questions pertain to what would happen to the project's viability if some or all of the key parameter values differ from the assumed original values.

A sensitivity analysis highlights the critical factors affecting the project's viability. This allows the decision makers or the project manager to pay attention to these

factors during the implementation stage. A sensitivity analysis is normally carried out by recalculating the project's performance criteria, using a range of values for the uncertain parameter(s). A sensitivity analysis helps to identify critical variables and, in so doing, provides information that could be used to redesign a particular option. Sensitivity analyses may also point out the need to acquire additional information to ensure that the assumptions are as realistic as possible.

Uncertainty is also inherent to any MCA process because the decision-maker's preferences, expressed as weights, are subjective values. Consequently, MCA has been criticised for being an inexact procedure. Sensitivity analyses explore the robustness of the result(s) and their sensitivity to changes in aspects of the model (Belton & Stewart, 2002; Edwards-Jones, et al., 2000). They also allow greater exploration and understanding of the nature of the decision problem, the weightings, and the data.

Although a number of variables can be subject to sensitivity analyses, there is nothing to gain in examining all of them arbitrarily. Given the usual constraints in conducting such analyses, only the key critical variables should be analysed. It is important to identify issues that may have a disproportionate bearing on the overall impact of a project (The Treasury, 2005).

3.2.8 MAKE A DECISION OR RECOMMENDATION

The final step in the process is to make the decision or recommendation. The ultimate outcome of the REM is a decision whether or not to proceed with a project proposal. This outcome is an aid to the decision-making process, but it does not make the decision. Decision makers must also consider incommensurable factors that are not incorporated into the analysis before making a final decision. In some instances, the analysis may show that there is value to delaying the decision for the purpose of collecting additional data for analyses. Delaying and collecting more information is in itself a decision. The entire evaluation process may need to be repeated if new data, considerations, or views come to light.

If the sensitivity analyses show the results to be robust they can be accepted. Recommendations typically take at least one of the three forms: a single optimal alternative, a feasible set of options, or specific trade-off relationships between options and objectives (Belton & Stewart, 2002). The best decision is the one that gives the best outcome (measured as utility). However, there is no single 'correct answer' resulting from an MCA; rather, MCA is an aid for decision-making and its principal benefit is to facilitate better understanding of the problem. Thus, REM will not relieve the decision-maker from the responsibility of making a decision.

In this last step, the score of the overall decision-making process is generated. There are selections of scores that can be generated. There can be a selection of the best alternative, a sorting of the alternatives into different categories or a ranking of the alternatives. It is especially important that the decision maker knows what kind of result s/he expects from an appraisal, so the most appropriate application is chosen.

3.3 CASE STUDY SELECTION

In the previous section, the steps in the REM were described, as well as the theoretical framework upon which this model is developed. The purpose of this section is to describe the case study selection in this research and the preparation executed before applying the model.

3.3.1 PURPOSE OF THE CASE STUDIES

- Case studies are widely used in different types of research for a variety of reasons, such as, “to provide description of phenomena, develop theory, and test theory” (Darke, Shanks, & Broadbent, 1998, p. 275). In this research, three case studies are used to apply and test the usefulness of the REM. More specifically, case studies will help to determine:
- the effectiveness of the model to identify the impacts associated with a project;
- the extent to which the model can be applied and its limitations;
- the reliability of the outcomes; and

- what can be done to avoid difficulties and to improve the model.

3.3.2 DATA AND INFORMATION SOUGHT TO INFORM CASE STUDIES

Criteria to guide the choice of case studies include: (a) a project that has being planned but not yet submitted to an institutional decision-making process; (b) a project where the decision-making process is in progress; or (c) projects where the decision-making process has already been completed.

The success of selected case studies will depend upon access to data and the potential to gain the collaboration of experts. In the case of a new project that has yet to be submitted to a governmental institution for approval, the data related to the project is of private nature, making it difficult to gain full access to data. To facilitate and ensure a case study was selected that contained readily accessible data, a number of potential projects were considered using online open access to public projects.

3.3.3 CRITERIA DEVELOPMENT FOR CASE STUDY SELECTION

Given the diverse biophysical, socio-political and economic settings under which the rapid model can be applied, it is important that the selected case study sites reflect the complexity of the problems that decision-makers face. Ideally, the type of data and information that are collected through the case studies should provide enough detail to determine the extent to which the REM can be generalized. Careful selection of case studies ensures that the model is tested in diverse project scenarios, that reflect:

- Differing scope - case studies can range from project at the infrastructure services sector to the private industrial sector;
- Differing scale - projects having the potential to impact economic environmental and social settings at the national, regional or local level;
- Differing strength of economic, environmental or social components (for example, private v/s community based projects);
- Differing market economies (project carried out in a developed or a developing country); and

- differing community value components (i.e. high, medium and low community involvement).

The resource and time constraints associated with the research meant that the number of case studies was limited to three. A preliminary case study list was selected in New Zealand and Chile. These countries have been chosen to represent both developed and developing country settings which are within the language and financial constraints of the researcher.

For potential projects effort was made to compile and review available data and identify gaps needing to be addressed during initial site investigations. From the potential projects, the final three selected projects were:

- a New Zealand wind farm project
- a Chilean abattoir project
- a Chilean salmon cage project

The first study selected (as a pilot for testing the model) was in New Zealand and was a wind farm project to be constructed in a designated reserve. Under New Zealand legislation this project was classified as a matter of national importance. A benefit of first piloting the model with this project of national significance is that the project should reflect a higher complexity than one of regional or local significance only; and, therefore, should provide a major set of appropriate data, facilitating the development of the model.

3.3.4 CASE STUDY APPROACH

Desk-top study to:

- Identify key stakeholders
- Provide key information on attributes levels
- Identify missing data
- Design Questionnaire Survey instrument
- Selection of panel of experts
- Preparing the focus group meeting

The questionnaire development stage involves designing a survey instrument that is used to elicit expert preferences to obtain the weight attributes needed in the model. In general, the design principles used in the development of a survey are based on those used in analytical hierarchy process (Saaty, 1999).

Throughout the questionnaire design, particular attention is given to the overall structure of the survey and presentation. Bateman *et al.* (2002) suggested that the typical question order consists of an introductory section, a valuation section inclusive of choice sets, and a final section which elicits respondent characteristics. For presentation purposes, the survey instrument needs to be user-friendly and visually appealing. This can be achieved through the use of neutral colours, a large font and an uncluttered layout in order to give a professional appearance (*ibid*).

3.4 CONCLUSION

The MCA software Logical Decision for Windows® was determined to be the most suitable decision-making framework to build the REM. The methodological guidelines used to develop the REM include the following requirements:

- (1) Formal objectives of the model: The REM must be able to integrate the three pillars (economic, environmental and social) and should be incorporated into the decision-making process to identify the best alternative to maximise those pillars whilst, at the same time, evaluating the trade-offs between them.
- (2) Decision alternatives: The REM must have the potential to consider 'with project' and 'without project' scores to enable decision-makers to consider the net economic, environmental and social benefits of the project.
- (3) Decision criteria: In order to consider key project attributes associated with economic development, environmental protection and social acceptability, a checklist has been developed to facilitate the identification of criteria to be included in the analysis.

- (4) Determining attribute values: Project information and secondary data need to be collected to estimate the impact of each alternative.
- (5) Determining weights for objectives/attributes: The REM must elicit expert knowledge to assign importance/value weightings to each unit of data. This method must accommodate different points of view, whilst also keeping the analysis manageable.
- (6) Ranking alternatives: The analyst must be able to measure each element in order to generate a single number or factor weighting to guide the investment decision. In addition to the individual section scores, the model also generates a single score for each of the integrated units that decision-makers use to assess the overall viability of the project.
- (7) Sensitivity Analyses: The REM uses sensitivity analyses to account for the uncertainty associated with forecasting future outcomes or changes.
- (8) Final decision and recommendation: The outcome of the REM is a decision that the proposal is either accepted for uptake, rejected or, notification that additional data is required to enable decision-makers to consider the proposal with more detailed information before an accept or reject decision is made.

Three case studies were selected to calibrate and test the model. These case studies are: the Turitea Wind Farm project (in New Zealand); the Cisne Austral Abattoir project (Chile) and the selection of one of two net-cage salmon farm systems (in Chile). The calibration and adaption of the REM to the specific project under evaluation will generate the final model structure that is determined by data availability and project characteristics. The procedure followed to implement the model for each case study is presented in the three chapters which follow.

CHAPTER FOUR - CASE STUDY 1: WIND FARM

4.1 INTRODUCTION

This case study evaluated a proposal by the electricity company, Mighty River Power, to build a wind farm on city council owned land within a natural reserve, in Palmerston North, New Zealand. Within the Turitea Reserve, the land predominantly supports native vegetation and incorporates the catchment and dam infrastructure that provides most of the water supply for the city. Since the purpose of the reserve was limited to water supply and protection of indigenous flora and fauna under the Reserves Act 1977, the status of the reserve required a re-classification in order to add electricity generation as an additional purpose in the reserve's management plan. A large number of rural residential properties are located on the slopes below the proposed wind farm, with the residents of these properties having major concerns primarily over visual and noise effects. The proposed wind farm is well aligned with the New Zealand Energy Strategy to 2050 (Ministry of Economic Development, 2007), which promotes increasing the proportion of renewable electricity generation from the current 65% to 90% by 2025. This project has been classified as a proposal of national significance; in 2008 a resource consent application was called in under section 141B of the Resources Management Act 1991 by the Minister for the Environment of New Zealand. An independent Board of Inquiry was appointed to consider submissions on the proposed wind farm, hold public hearings and make a final decision (Ministry for the Environment, 2010).

The evaluation process and decision-making undertaken in this study did not form part of the actual decision process, but it is used as a case study only. In order to use the Turitea Wind Farm project proposal as a case study, the assessments presented to local authorities as part of the resource consent applications were employed to inform the model. More specifically, secondary data were obtained from these assessments to define the measures of the attributes considered in this

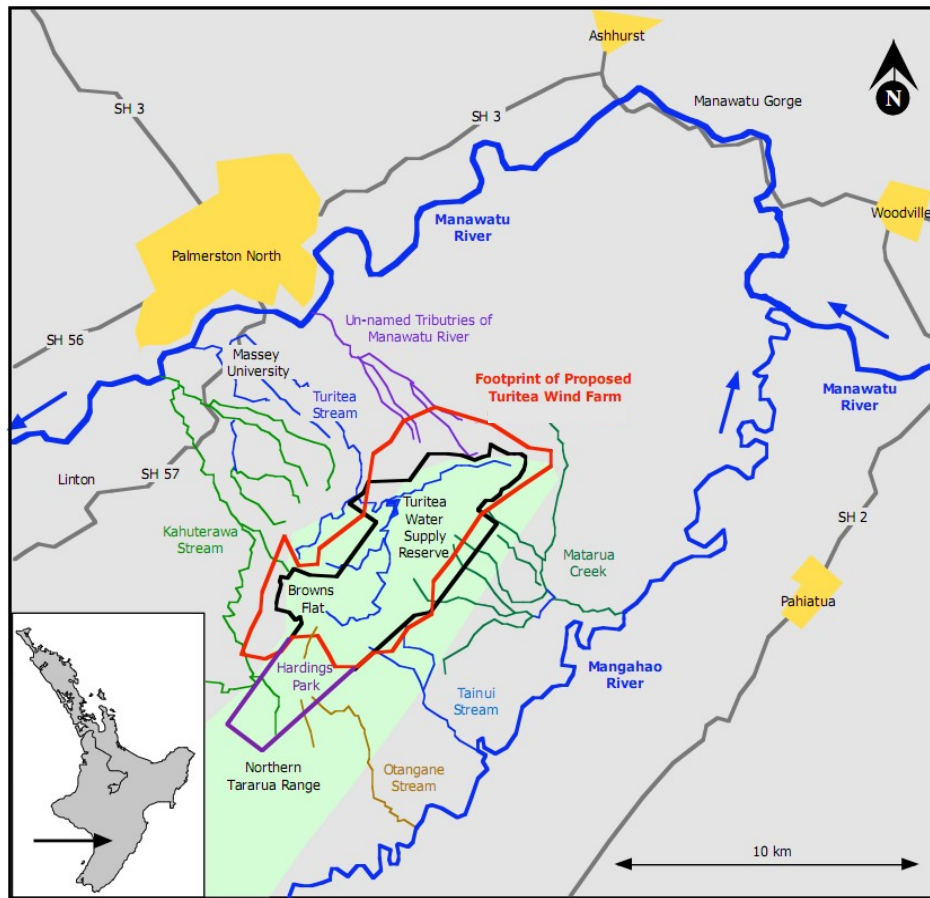
evaluation. These assessments were undertaken by an independent private consultancy tasked with the assessments by Mighty River Power Company, and were accessible to the public on the New Zealand Ministry for the Environment website (Ministry for the Environment, 2010). Information was accessed in January of 2010, and a second check for updated data occurred in July of 2012. These data were supplemented with personal interviews with experts, official documentation from the Palmerston North City Council (PNCC), which included The Turitea Reserve Management Plan (PNCC, 2004a, 2004b), and relevant literature, such as research conducted in the surrounded area, and other wind farm impact evaluation from New Zealand and overseas.

The information obtained on the relative weightings assigned to each attribute were primary data obtained from the input of a selected panel of experts. These data were gathered from both a survey that was undertaken as well as from focus group meeting conducted to elicit the collective experience of a knowledgeable group of people on economic, social and environmental disciplines.

4.2 PROJECT BACKGROUND

The site of the proposed wind farm is located approximately 10 kilometres south east of Palmerston North, primarily along a 14 kilometre ridge in the northern Tararua Ranges. The turbines of the wind farm are to be located mostly on the main ridge line that is exposed to the prevailing winds. The site is reported to be ideal for the development of a wind farm due to the exceptional wind resource conditions (Ashby, 2004; Energy Efficiency and Conservation Authority, 2010; Pretli, 2003; Turner, 2009). There are three existing wind farms just to the north, Te Apiti, Te Rere Hau and Tararua Wind Farms. A further wind farm to the south, Motorimu, has been approved but is yet to be built. The proposed Turitea Wind Farm is comprised of 104 turbines, 61 of which are to be constructed in the designated reserve and the remaining 43 turbines on adjoining farmland. The general location of the proposed Turitea Wind Farm site is shown in Figure 4.1.

Figure 4.1 General location of the Turitea Wind Farm proposal



Source: Coffey (2008, p. 3)

The Turitea Reserve was established in 1881, when Crown land that included most of the area of the Turitea catchment was reserved for the purpose of ‘growth and preservation of timber’ (PNCC, 2004b). Palmerston North became a borough with an elected council in 1877 and in 1885, PNCC initiated an enquiry into the Turitea Stream as a potential water supply for the town. The PNCC began to build the first four meter intake weir on the streambed on 1888, and the official opening of the water works, including a storage reservoir and pipes network, was held in August 1889 (PNCC, 2004c). In 1905 it was decided that the exclusive purpose of the Turitea Reserve would be its water supply function (PNCC, 2004a).

From the original land vested to the PNCC in 1905, further small areas of land were purchased, and today the Turitea Reserve is comprised of three sub-division

areas. Each area has a classification and public access scheme, and these are summarised in Table 4.1.

Table 4.1 Sub-division areas of the Turitea Reserve

Name	Area (ha)	Classification	Access
The Water Supply Catchment	2600	Local Purpose Reserve	Closed to public
The Water Structures Area	105	Local Purpose Reserve (Water Supply)	Closed to public
Harding's Park	869	Scenic Reserve	Some areas opened to public

The Turitea Reserve is the largest reserve owned and administered by PNCC, and is a strategic resource for the region. The water supply catchment is a fundamental part of the city's water infrastructure with the Turitea Stream supplying around 60% of the Palmerston North water demand. The water supply catchment contains two water reservoirs (the upper and lower dam) located on the Turitea Stream. The upper dam has a capacity of almost 1.7 million cubic meters, with the lower dam providing additional storage of around 0.3 million cubic meters (PNCC, 2004c). The Upper Turitea Stream Catchment supplies water to the reservoirs. Land within the water supply catchment is predominantly within the reserve; however, small areas of adjacent pastoral farmland also supply water to the catchment. In order to preserve the water quality of the water catchment, the general public has been prevented from entering the Turitea Reserve for a long time. However, Harding's Park, outside the water supply catchment area, is open to public access for recreational purposes (Mighty River Power, 2008).

The biodiversity assets of the reserve also represent a highly significant value for biodiversity assets (PNCC, 2004b). Indigenous vegetation makes up 54% of the vegetation in the area, constituting one of the few remnants of indigenous forest in the Manawatu region (Cheyne, 2010). This forest and bush-clad skyline ridge is highly visible from both the valley and Palmerston North city, adding value to the scenic features of the Tararua Ranges (Cheyne, 2010; Horizons Regional Council, 1998). Within the reserve, the existing infrastructure includes a number of

access tracks and three wind monitoring masts. There are approximately 158 ha of pine plantation. Some of this plantation has been felled by the city council and is to be retired from plantation forestry (Mighty River Power, 2008).

In January 2003, the Turitea Reserve was classified under the Reserves Act 1977 as a 'Local Purpose Reserve (water supply and protection of indigenous flora and fauna)'. In October 2006, the PNCC approved a change of purpose to the reserve, adding 'renewable electricity generation' (PNCC, 2006). This change was gazetted in January 2007 and the decision was challenged via judicial review proceedings.

Today's Turitea Reserve Management Plan (PNCC, 2004a, 2004b, 2006), describes the objectives for which the reserve should be managed, as:

- Protecting water supply quality and storage
- Conserving and restoring flora and fauna, ecosystems and natural landscapes
- Protecting cultural and historic resources
- Providing outdoor recreation and education
- Commercial management of plantation forests
- Energy generation
- Facilitating research

The re-classification of the Turitea Reserve opened the way for the possibility of a wind farm to be built in the reserve. In 2005, Mighty River Power, a state owned electricity retailer and generator, was selected through a tender process by the PNCC to develop and build a wind farm in the Turitea Reserve and on adjacent private land (Mighty River Power, 2008). Outside the reserve, the private farmland involved in the project is located both around the northern boundary of the reserve and adjacent to Browns Flat. This land is mostly used for sheep and cattle grazing (Mighty River Power, 2008).

The electricity company developed the first design proposal in December 2008 (Mighty River Power, 2008). However, the wind farm layout was redesigned in

February of 2010, to better conform to the surrounding landform and to incorporate issues raised by stakeholder submitters during a hearing process carried out on by the Ministry for the Environment (Mighty River Power, 2010). In this thesis, the case study was analysed based on the redesigned proposal, to take account of the last layout of the project.

Application for resource consent was based on a series of general design parameters that detail the specific zones within which turbines will be sited, the maximum height and rotor diameter for the turbines, and the maximum number of turbines. In addition, the proposal included details of the construction, operation and maintenance of related activities, and provided parameters for other infrastructure that will be required as part of the wind farm. The main works to be undertaken included associated substations, internal electricity reticulation (underground cables and overhead transmission lines), and associated earthworks, vegetation clearance and discharges (Mighty River Power, 2008). A summary of technical details and activities included in the project are given in Appendix A.

4.3 IDENTIFYING THE KEY ATTRIBUTES AND THEIR MEASURES

The principal purpose of a wind farm is to harness a free natural resource (wind) and convert it to a commodity with human use value (electricity). There are economic benefits for wind farm operators, but also a variety of effects on third parties and on the wider environment, which need to be considered in the evaluation. For the goal of economic development, environmental protection and social acceptability, the attributes were chosen based on the checklist developed in this research. To do this, the checklist was used to summarise all possible effects of the wind farm project identified through the 'Resource consent applications and assessment of environmental effects' (Mighty River Power, 2008, 2010) submitted by the electricity company to decision-makers authorities. The full list of possible effects of the Turitea Wind Farm proposal is listed in Table 4.2.

To determine the magnitude and important of the effects, the information provided on the resource application was reviewed and interpreted. Where necessary, the data were supplemented through personal interviews with experts, official documentation from New Zealand Government and from literature relating to research conducted on the surrounded area. Effects were considered for inclusion as attributes in the REM where impacts were rated as being of moderate to high importance. Impacts of low importance were not included. Where mitigation was likely to reduce the impact to a negligent level, the impact was not included in the model, regardless of the importance rating of the impact. The key attributes for the Turitea Wind Farm proposal selected to be incorporated in the model are listed in Figure 4.2. In the paragraphs which follow, these key attributes are fully explained and where appropriate, qualitative or quantitative measures are provided.

Table 4.2 Full list of effects for the Turitea Wind Farm proposal

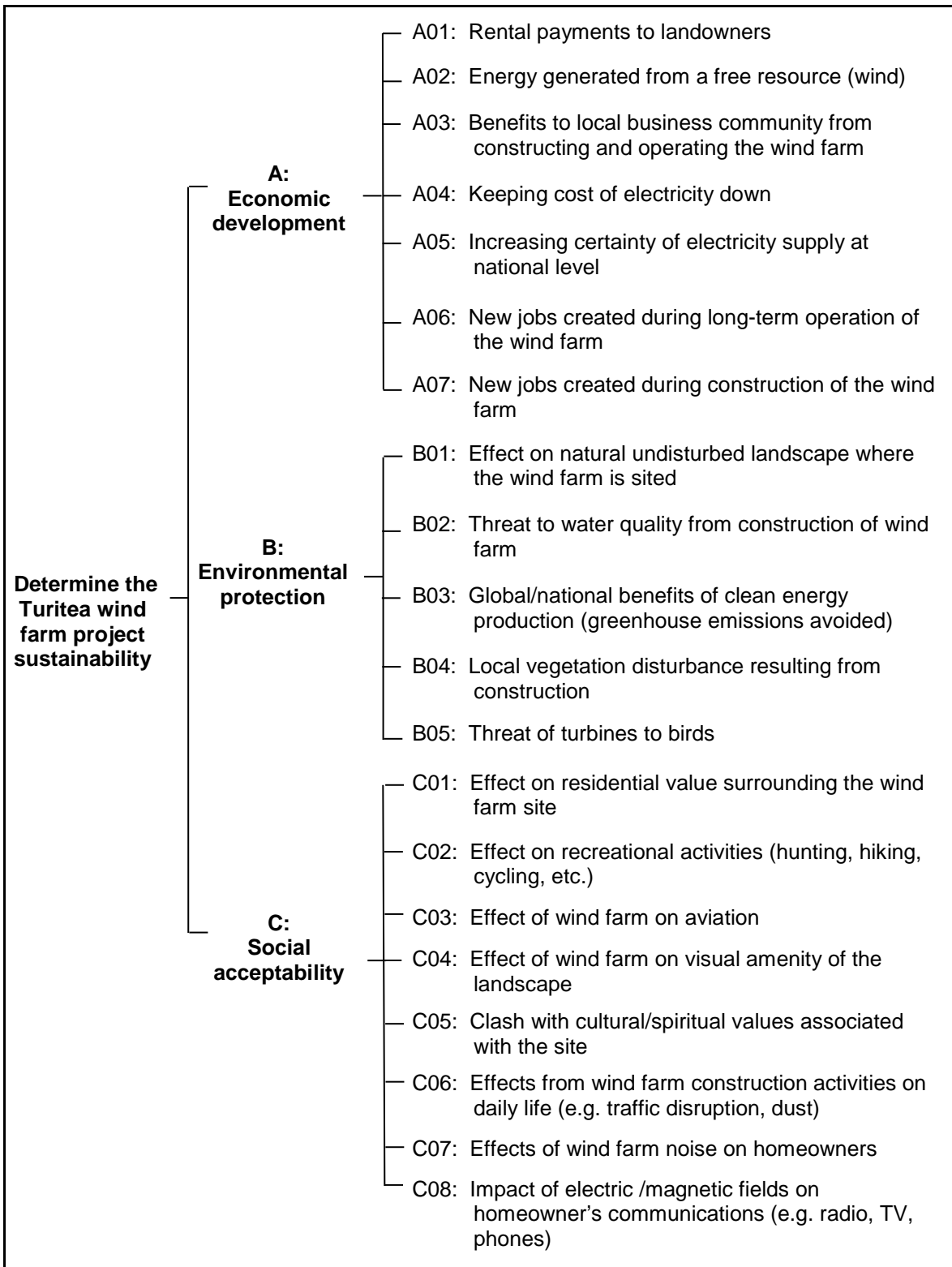
Goal	Attributes	Sub-Attributes	Effect	Data	Description	
A. Economic Development	Financial viability	Net Income	+2	no	Income perceived by the state owned electricity company	
	Spillover effects	Operational expenditure (Indirect effect on ratepayers)	+3	yes	Rental payment to landowners (including PNCC)	
	Efficiency of resource use	Use of a renewable resource		+4	yes	Quantity of energy generated from a free resource (wind)
		Reducing energy intensity of goods and services		+1	yes	Benefit for the displacement of long distance power transmission
		Synergies in joint operation		+2	yes	No additional infrastructure required to connect to transmission grid
	Effect across other sectors	Impact at the local commercial sector	+3	yes	Benefits to local business community	
	factors of production	Price reduction	+2	yes	Suppression on price rises	
	Security of supply	Energy security	+2	yes	Reduced probability of supply disruption	
	Employment	Skilled labour or permanent position		+2	yes	Jobs created during operation
		Unskilled labour or temporal position		+2	yes	Job created during construction
B. Environmental Protection	Effect in physical and chemical characteristics	Earth	Landform	-3	yes	Earthworks related to roads and turbines' platform
			Unique physical features	-3	yes	Effect on natural undisturbed landscape where the WF is sited
		Water	Quality	-2	yes	Threat to water quality from construction works
		Atmosphere	Quality	+1	yes	from machinery operation
			Climate	+2	yes	Greenhouse gases emissions avoided
		Processes	Deposition	-1	yes	Sediment run-off
	Effect in biological condition	Flora	Trees	-1	yes	vegetation disturbance
			Shrubs	-1	yes	vegetation disturbance
			Grass	-1	yes	vegetation disturbance
			Endangered species	-2	yes	clearance of indigenous vegetation
		Fauna	Birds	-2	yes	Increased collision risk for birds (including natives species)
			Land animals (incl.reptiles)	-1	yes	Effect on snail population
			Fish and shellfish	-1	yes	road crossing and sediments preventing fish passage
			Benthic organisms	-1	yes	Effect on benthic organisms derivate from changes in water quality

Goal	Attributes	Sub-Attributes	Effect	Data	Description	
C. Social Acceptability	Concerns about social well-being	Change on land use	Wilderness & open spaces	-1	yes	Land use change according with the Turitea Reserve management plan
		Change on recreation activities	Hunting	+2	yes	Disruption on recreational activities (Hunting, hiking, cycling)
			Aviation activities	-2	yes	Effect on aviation activities
			Facilities for outdoor activities	+2	yes	Establishment of an Eco-Park
		Change on human interest & community resources	Scenic views and vistas	-3	yes	Effect on visual amenity of the landscape
			Parks and reserves	-2	yes	To be located in reserve, but in line with the management plan
	Historical/ archaeological sites		-1	yes	Three heritage sites are contained in the WF site	
	Individual & family changes	Residential stability		-3	no	Effect on residential value surrounding the WF site
		Cultural patterns		-2	yes	Clash with cultural/spiritual values associated with the site
		Daily life activities		-2	yes	Effects from WF construction activities on daily life
		Health and Safety	Risk of health illness	-1	yes	Electric and magnetic fields effect on health
			Noise	-2	yes	Effects of WF noise on homeowners
	Community & Institutional Structures	Man-made facilities and activities	Transportation network	-2	yes	Increase on public road traffic during construction
			Utility networks	-2	yes	Impact of electric/magnetic fields on homeowner's communications
			Waste disposal	1	yes	All waste is to be collected and removed from site

MAGNITUD	
4	Significant positive effect
3	Moderate positive effect
2	Minor positive effect
1	Negligible positive effect
-1	Negligible negative effect
-2	Minor negative effect
-3	Moderate negative effect
-4	Significant negative effect

IMPORTANCE	
Low Importance	
Moderate Importance	
High Importance	
POTENTIAL MITIGATION OF IMPACT	
Low Importance	
Moderate Importance	
High Importance	

Figure 4.2 Key attributes of Turitea Wind Farm project evaluation



4.3.1 MEASURES OF ECONOMIC DEVELOPMENT

The assessment of the economic development value of this wind farm project is based on its contribution to the economic well-being of the wider community. This economic value includes the benefits provided to both producers and consumers of electricity, and the multiplier effect on the local, regional and national economy.

A01: Rental payments to landowners

Landowners on which the wind turbines are situated receive rental payments from the power company. This forms part of the producer surplus, or economic rent derived from the wind farm, comprising the difference between output value and the costs of procuring that output. Thus the land on which the turbine is situated has an increase in value from its previous usage, thus increasing the efficiency of that land use. One of the significant differentiators between the Turitea Wind Farm and other wind farms in the area, is that this project will involve the direct injection of revenue to local ratepayers. This is due to the fact that PNCC is a key benefitting landowner, as the owner of the Turitea Reserve. This means that revenue from the Turitea Wind Farm will flow directly to residents and ratepayers of Palmerston North city.

Nationally, around 1.5-2.5% of gross revenue from wind farms accrues to the landowners, the precise amount being a matter of negotiation between land owners and wind farm owners on the distribution of the proceeds from its operation. The actual payments are subject to confidential agreements between landowners and the company. However, if it is assumed that the land rentals are 2.0% of the gross revenue of the wind farm, and that the wholesale price of electricity (net of carbon charges introduced in 2010), averages \$80/MWh, then at 39% utilisation the land rental is, on average, \$1.6 million per year for a 288 MW plant (Clough & Layton, 2008).

A02: Energy generated from a free resource

The principal benefit of a wind farm comes from harnessing a free natural resource and converting it to electricity. Because it would be connected to the national electricity grid, the economic benefits of the wind farm will not be confined to the local region. There will be times when the benefit will be to the local consumers of electricity, by providing an additional source of supply in the region, thus diversifying against the risk of the shortage of hydroelectricity or some other constraint, but it is not dependent on the region's electricity demand. Primarily, the effect on electricity generation needs to be viewed in terms of a national economic benefit.

According to the company's estimation, the wind farm could have a maximum installed capacity of 288 MW, capable of generating between 1025 and 1230 GWh at 39% utilisation (Mighty River Power, 2010). It must be noted that each GWh despatched from the wind farm will equate to less than one GWh of consumption due to transmission losses between the region and the markets served. On average, transmission losses across the network are 3.7% of power despatched, which may be taken as a conservative assumption of losses of power despatched from the wind farm (Mighty River Power, 2008).

In this evaluation, the output value of energy generated from a free resource entered into the model is the maximum capacity of energy generation, equivalent to 288 MW, to reflect the potential energy that, in an ideal situation, could be consumed. However, for the wind farm project, the measure is 108.16 MW, obtained after adjusting the expected level of utilization and transmission losses according to current technology.

A03: Benefits to the local business community from the construction and operation of the wind farm

An economic impact analysis examines the effects of new economic activity brought into an economy by a new development, tracing both the direct impact of the project itself and indirect impacts on other sectors from new expenditure in the

economy. It is most informative to look at impacts on a local economy, where a project registers a more noticeable impact than in the larger national economy (Clough & Layton, 2008).

The direct expenditure on construction of the wind farm is estimated to be \$750 million for a 288 MW installed capacity wind farm. From previous experience of New Zealand wind farms, around 80% of the capital cost is spent on importing of equipment and consulting skills, with the remaining expenditure impacting the local economy. If this ratio holds for the Turitea Wind Farm, the impact on local business community of construction will be of the order of \$150 million, depending on the final number and configuration of turbines (Mighty River Power, 2010).

Indirect impacts arise from the further spending in the local economy by the recipients of the direct expenditures, and can be estimated by means of economic multipliers. However, indirect impacts are also related to other conditions (for example impacts are generally off-site or may occur in foreign countries) and the probability of their occurrence is difficult to estimate (Lenzen, Murray, Korte, & Dey, 2003). Much of the operating and maintenance expenditure after commissioning is likely to be payments for goods or services imported from elsewhere with little direct implication for local expenditure (Mighty River Power, 2008). Therefore, indirect impacts and operating and maintenance expenditure were not included in this analysis.

A04: Keeping the cost of electricity down

In principle, the proposed wind farm should result in reduced power prices and an increase in consumer surplus, since every time it is selected to dispatch power, it will be displacing other higher cost electricity generation. In practice, because of the way the wholesale electricity market operates, consumers are not likely to directly benefit from this reduced cost electricity production in the short run. Most electricity consumers, including residential, commercial and small industrial, receive electricity on supply contracts which act as fixed price contracts. Day to day fluctuations in the cost of electricity are not passed onto consumers, but rather are absorbed by retailers, who only adjust their tariffs when marked and sustained

shifts in power costs occur. The main impact of increasing electricity production using wind power will be to enhance the producer surplus of generators and retailers, which are generally vertically integrated companies. As producer surplus is a part of economic welfare and, as the company is currently a state owned enterprise owned by the New Zealand government, this enhanced producer surplus represents a national welfare gain (Clough & Layton, 2008). In addition, electricity consumers will benefit from the wind farm through the suppression of price rises due to the displacement of higher cost generation sources, as well as the deferment of grid investments, the cost of which ultimately gets passed on to consumers (Mighty River Power, 2008). The overall effect of keeping the cost of electricity down has been estimated to be of a minor positive effect.

A05: Increasing certainty of electricity supply at the national level

Growth in electricity consumption is driven by a number of factors, including population growth, economic growth, large industrial developments and the level of energy consumption (Dawber, 1994). Currently, electricity demand in New Zealand is growing at around 2% per annum. Providing for rising electricity demand requires increasing generation at existing stations/sources or alternatively finding new sources. At present, approximately 65% of electricity is derived from renewable sources. However, the significant majority of this is hydro-electric generation, the reliability of which depends on rainfall. A further 16% is generated from natural gas, 9% from coal and 6% from geothermal. Currently, only 4% of New Zealand's generation comes from wind or other sources (Renewable Energy & Energy Efficiency Partnership, 2010). Experience in Denmark and other countries with longer histories of wind utilisation, suggest that up to 20% of total supply could come from wind generation (Center for Politiske Studier, 2009).

There are some limits to the proportion of wind electricity generation that can be accommodated before the variability of the resource affects the reliability of the energy supply. Wind generation needs to be operated in combination with other sources of generation, if it is to provide a substantial portion of the generation capacity. Where there are good connections with back-up generation to balance

wind variability, wind energy can provide higher proportions of electricity generation than currently generated in New Zealand (Mighty River Power, 2008). The proposed wind farm will diversify the methods of generation providing electricity network resilience against drought or other factors that may affect other generation methods. Recent concerns over the vulnerability of the electricity supply system reinforce this risk to the New Zealand economy (Clough & Layton, 2008). Wind energy at this location is amongst the best in the world, and hence will provide additional benefits not only in terms of renewable energy, but also in reliability of supply and has been estimated to have a moderate positive effect on New Zealand economic development.

A06 & A07: New jobs created

At the height of the construction stage, the wind farm should stimulate employment by the equivalent of 5.5% of the current construction labour force in the local area, and 0.4% of total employment in the area. During the operational phase it will have less impact on total local employment; however it should stimulate a 10% increase on the current level of employment in the region's electricity, gas and water supply sector (Mighty River Power, 2008). These are sizeable additions to local employment in these sectors, but not so large as to be overwhelming and distort labour markets in the region. The new jobs created can be separated into:

- New jobs created during the construction of the wind farm: the total of which is estimated to be approximately 100 to 250 full time equivalent jobs.
- New jobs created during the long-term operation of the wind farm: estimated to be between 10 to 15 jobs per year for the operational lifetime of the windfarm (Mighty River Power, 2010).

The lower possible number of new jobs associated to the project development were the final measures entered in REM to reflect a conservative criterion.

4.3.2 MEASURES OF ENVIRONMENTAL PROTECTION

Mighty River Power commissioned various specialist consultants to build up an Environmental Assessment of the proposed wind farm. This section examines the

potential environment effects associated with the development of the wind farm. It also raises potential measures and practices to be undertaken for the electric company to avoid, remedy or mitigate against adverse effects. The task is to consider and weigh these environmental effects, to determine whether they, when taken together with the range of mitigation measures proposed, will promote the sustainable management of the natural and physical resources in the area.

B01: Effect on the natural undisturbed landscape where the wind farm is sited

Even when pre-existing human made conditions has been development at the reserve (such as water reservoirs, access tracks, monitoring masts and pine plantation), the Turitea Reserve represents a highly significant landscape feature for the Palmerston North city area and contains the most intact and largest natural ecosystem area within the city's jurisdiction (PNCC, 2004a). High quality management of the water supply catchment and the wider reserve is essential to ensuring a sustainable natural environment.

The reserve is important in its current and potential provision of a variety of biodiversity pathways or linkages. These include current ecological sequences providing linkages from the crests of the Tararua Range to lowland forest remnants, the potential linkages via scrubland and remnant forest areas, and potential 'green corridors' via waterways such as the Turitea and Kahuterawa streams to Palmerston North city (PNCC, 2004b). The area is also significant at the local and national level in containing large areas of indigenous vegetation and also providing opportunities for research, for example in the examination of forest collapse following major pressure from introduced browsing animals (Esler, 1978).

As it is today, the Turitea Reserve contributes a significant positive effect to the landscape, since it is an outstanding natural landscape and the skyline of the reserve is an outstanding natural feature under the RMA (Cheyne, 2010). Operations such as vegetation clearance or construction of structures or vehicle tracks on the ridgeline area could compromise these values. This means, the loss of 'naturalness' from the introduction of structures such as wind turbines.

Lastly, introduction of such structures could make the site less appealing for other values, such as research, tourism and recreational activities (Mighty River Power, 2008). The wind farm as proposed by Mighty River Power would have a moderate adverse effect on these outstanding features and landscapes, since the natural character cannot be fully protected.

B02: Threat to water quality from construction of the wind farm

The Turitea Reserve is the catchment which provides the majority of the water for Palmerston North city. Therefore, specific concerns surrounding construction in the reserve include the potential contamination of the reservoirs from a number of sources.

Necessary vegetation clearance and earthworks for access ways, turbine foundations and platforms, transmission line structures, substations and disposal sites for spoils may have the potential to adversely affect in-stream communities downstream of construction activities. Nine stream crossings are required for the construction of access ways within this site. The majority of the works will be culvert crossings of ephemeral watercourses at the extreme headwaters of the catchments and located in relatively small catchments. The largest catchment area affected is approximately 90 ha. No construction within the waterways is proposed to establish turbine platforms (Mighty River Power, 2008).

The most likely threat to water quality would be increased sediment loading to watercourses, accidental oil leakage from machinery into watercourses, and concrete products from temporary concrete batching plants entering watercourses (Coffey, 2008). Due to the exposed, windy conditions along the ridgelines there is also the potential for fine sediment to enter watercourses as windblown dust and loess (loamy deposit) from earthwork areas. However, limiting exposed areas and controlling the generation of windblown sediment via dust control could minimise the amount of airborne sediment generated during earthworks (Mighty River Power, 2008).

Vegetation removed from areas will be placed as mulch on adjacent vegetation where it will act as a stabiliser. The decaying mulch may increase nutrient concentration and biological oxygen demand in surface receiving waters in the short term (Mighty River Power, 2008).

According to Mighty River Power, mitigation plans will be prepared by the company to minimise effects on water quality. A construction management plan will include careful sediment and erosion control during construction, including best practice techniques when working in watercourses and a storm-water management plan would include new and widened tracks to allow infiltration (Mighty River Power, 2008). The risk of accidental spills of oil and other potentially harmful substances during construction could be minimised by the adoption of best management practices such as refuelling in bounded sites out of sensitive sub-catchments and regular servicing/maintenance of hydraulic hoses on heavy machinery. These practices will be outlined in a Construction and Environmental Management Plan (Mighty River Power, 2010). Given the location of the wind turbines and the fact that the majority of the proposed access ways are along ridgelines and spurs that are separated from perennial reaches of surface receiving waters, the discharge of contaminants into storm-water would be minimised (Mighty River Power, 2008). If best industry practices are adopted and implemented, the negative effects of constructing the Turitea Wind Farm on the water quality are expected to be minor.

B03: Global/national benefits of clean energy production (Greenhouse gas emissions avoided)

The generation of electricity from a renewable source results in a reduction in greenhouse gas emissions. With growing awareness of the challenges of energy generation, particularly in the global context of climate change caused by anthropogenic greenhouse gas emissions, the ability to generate electricity from renewable sources is seen as an increasingly positive activity. If the proposed wind farm displaces a thermal generation plant, it not only provides power at lower cost, but also avoids the greenhouse gas emissions of a thermal plant. In addition

to incurring higher costs of generation, thermal plants are also the highest emitters of greenhouse gases (Mighty River Power, 2008).

The Turitea Wind Farm will generate up to 109 MWh of electricity per annum from renewable sources. According to the economic assessment done by Clough and Layton (2008), producing this energy from coal would generate a conservative estimate of over a million tonnes of CO₂ per annum, or approximately half of million tonnes of CO₂ per annum in the case of producing this energy from gas. Utilising wind power on this scale will reduce dependency on fossil fuels which represents a minor positive effect in terms of the reduction of greenhouse gases in the atmosphere and will positively assist New Zealand to meet its international obligations under the Kyoto Protocol.

B04: Local vegetation disturbance resulting from construction of the wind farm

The biodiversity resources of the Turitea Reserve are significant at a district level, since the reserve is predominantly covered in native vegetation comprising around 90% of areas all native vegetation within the city boundary and as such contributes most of the biodiversity for Palmerston North (Miskell, 2002). From areas of tawa forest at low altitude, to exposed scrublands on the main range, the site has been identified as an area of significant ecological value (PNCC, 2004b) and, according to Esler (1978), this is one of the best preserved forests in the Manawatu district.

According to the ecological assessment prepared by Wildland Consultants Ltd., today's predominant vegetation within the Turitea reserve are:

- Tawa-dominant forest with emergent rimu confined to the northern part of Turitea Reserve and covers an area of approximately 600 ha.
- Secondary broadleaved forest, which includes patches of tawa-dominant forest, adjoins the rimu/tawa forest and also occurs on the western side of the main ridge below approximately 400 m.

- Mixed broadleaved forest with sparsely scattered remnant emergent podocarps is present in the main valley south of the water supply dams, and extends up to the main ridge in places, covering an area of approximately 400 ha.
- Horopito forest and scrub covers the largest part of the Reserve (approximately 1,100 ha), including most of the main ridge. Secondary broadleaved forest is also scattered throughout, as are small areas of toetoe (*Cortaderia fulvida*) tussockland and exotic grassland (Wildland Consultants Ltd., 2008, p. 15).

Substantial earthworks will need to be done to construct a wind farm at Turitea. Vegetation removal would be required for the creation and upgrading of access ways, transmission line structures, turbine foundations and substation platforms (Mighty River Power, 2008). The greatest ecological impact is vegetation clearance, especially associated with steep terrain and currently unroaded areas. In addition, the location of the wind farm will necessitate the removal of up to 18 ha of indigenous vegetation within the Turitea Reserve. Most of the proposed vegetation clearance is to be confined to ridge tops, which is predominantly horopito forest and scrub (Wildland Consultants Ltd., 2010). An overview of the key effects from the Turitea Wind Farm on indigenous vegetation are presented in the below Table 4.3.

Even when the intervention of intact indigenous vegetation is well below the upper limit of 25 ha set by PNCC, it represents a significant ecological effect described as 'not minor' by Wildland Consultants Ltd. (2008). In this matter, the consultant agency has proposed a comprehensive mitigation package, which when implemented, would contribute to balance those effects. This mitigation will include the rehabilitation and re-vegetation of about one third of the up to 18 ha to be cleared during construction. In addition, there will be indigenous re-vegetation of 70 ha of former pine forest (including 60 ha of managed natural regeneration and 10 ha of planting), and an ongoing weed monitoring and control (Wildland

Consultants Ltd., 2008). After the mitigation plan, the resulting local vegetation disturbance is expected to have a minor adverse effect.

Table 4.3 Relative significance and expected effects of Wind Farm on local vegetation

Feature	Relative Significance	Effects	Discussion
Tawa-dominant forest in Turitea Reserve lower catchment and secondary mixed broadleaf	Very high	None	Potential turbine and transmission pylon locations in Tawa-dominant forest have been removed from proposed layout
Horopito-dominant forest and scrub in Turitea Reserve	Moderate	More than minor (clearance of 18 ha)	Effects depend, in part, on the formation of new roads, particularly on very steep terrain
Rank pasture at Brown's Flat	Low	Minor	Effects are minor subject to avoidance of small wetlands at Brown's Flat
Pasture on private Farmland.	Low	Minor	Clearance and earthworks will, subject to sediment control, have only minor effects
Streams and indigenous riparian vegetation on private farmland	Low-moderate	Minor	Some small streams will require culverts but effects will be minor, subject to sediment controls
Horopito scrub and other indigenous species on private farmland	Low	Minor	Only relatively small scale clearance is required

Source: Extrapolated from Wildland Consultants Ltd (2008, p. 42)

B05: Threat of turbines to birds

Key concerns surrounding the effects of the wind farm on birds include the potential for mortality or injury resulting from birds colliding with the turbines and other structures, the potential for turbine barrier effects to force birds to alter their flight paths and the potential for the habitat displacement of birds (Powlesland, 2009). A range of bird species have been recorded in the Turitea Reserve and surrounding area. These records include those from the Ornithological Society of New Zealand (OSNZ), and previous surveys and fieldwork undertaken for this project.

The impacts of wind farms on birds are highly variable and depend on a wide range of factors including the specification of the development, the topography of the surrounding land, the habitats affected and the number and species of birds present (Drewitt & Langston, 2006). According to the literature, significant levels of bird fatalities are more likely to occur when wind turbines are located in close proximity to areas of high bird density or frequency of movements, such as migration routes and waders staging areas (Powlesland, 2009). However, there is some uncertainty around the impact of wind farms in the nearby area on birds, and further monitoring is proposed.

To date, few birds and no bats have been reported killed by wind turbine blade-strike in New Zealand but there has been virtually no formal, scientifically robust monitoring in place (Powlesland, 2009). In line with the assessment undertaken by Wildland Consultants Ltd. (2008), commissioned by the energy company to specifically evaluate the impact of the proposed wind farm on flora and fauna, they have reported that no migratory waders have been recorded on the wind farm site. This report also indicated that the only seasonal migratory species on which the Turitea Wind Farm project may have an impact are shining cuckoo (*Chrysococcyx lucidus*), long-tailed cuckoo (*Eudynamus taitensis*) and the New Zealand falcon (*Falco novaeseelandiae*). According to the information collected and reported by Wildland Consultants Ltd. (2008) they have concluded that even when it is not possible to accurately predict which indigenous species will accommodate or avoid turbines in their habitat, based on the previous experience from other wind farm located in the area, the overall negative effect from the proposal wind farm on birds is expected to be minor.

4.3.3 MEASURES OF SOCIAL ACCEPTABILITY

The provision of renewable electricity generation is considered to be the primary contribution of the wind farm to improve societal welfare. While at a national and regional level it seems clear that the project will provide significant benefits to the social wellbeing of people, there are local communities that may potentially be adversely affected. The social wellbeing of local people and communities may be adversely affected by activities related to both the construction and the

ongoing operation of the turbines. These potential adverse effects can, in some instances, be minimised and mitigated by appropriate planning and operating 'constraints'. However, in other cases, there is less ability to avoid, remedy or mitigate adverse effects. The evaluation of the project needs to take account of these potential impacts, alongside the expected positive impact on societal wellbeing at the national level.

C01: Effect on residential property values in close proximity to the wind farm site

A large number of rural residential properties are situated in close proximity to the proposal wind farm. The area immediately to the west of the site is characterised by rural and rural lifestyle properties. The nearest residential area is the Ngahere Park subdivision, located to the north-west of the Turitea water supply reservoirs on Turitea Road. The proposed wind farm location is on the foothills of the Tararua Ranges where there are no main roads or industrial activity (Mighty River Power, 2008). Those choosing to live here, do so to escape the close confines of residential or urban living, valuing the peacefulness and beauty of the area.

Evidence of increasing objection to wind farms development has lately been evidenced in New Zealand, with residents of these properties having major concerns regarding visual and noise effects, but also the impact of the wind farm on its property value (McCarthy & Balli, 2011). Due to the worldwide recognition that the presence of wind farms could have a negative impact on house prices (Hoen, Wiser, Cappers, Thayer, & Sethi, 2010; McCarthy & Balli, 2011; Nadaï & Van der Horst, 2009; Sims, Dent, & Oskrochi, 2008), this evaluation has included this criteria as an attribute of social acceptability, even when the impact assessment submitted by the energy company to local authorities has not explicitly included residential values in their evaluation.

In the literature review by Hoen, et al. (2010), it was found that while wind projects have been predicted to negatively impact residential property values when pre-construction surveys are conducted, statistically significant negative impacts have

largely failed to materialize post-construction when actual transaction data become available for analysis. McCarthy and Balli (2011) have conducted the most comprehensive study to date in the area, using information from 945 open market house sales occurred between 1995 and 2008. The study was based on Ashhurst, a township of almost 900 houses located about 15 km from Palmerston North. Ashhurst is within 8 km of two existing wind farms (Tararua and Te Apiti) developed between 1998 and 2007 on the Turitea range. Using a hedonic regression model to investigate the potential effect of wind farm visibility on house values, they concluded that the presence of turbines had no significant impact on house sale prices of Ashhurst residential properties. Nevertheless, the analysis was conducted on a township area and cannot dismiss the possibility that a small number of life-style properties, located in rural areas or in close proximity to wind turbines, might be negatively impacted. Based on this information, the effects on residential property values near the Turitea Wind Farm are expected to be moderately adverse.

C02: Effect on recreational activities

There are many hunting opportunities on public land in the Tararua and Ruahine Forest Parks, within a distance of one to two hours drive from Palmerston North. However, the Turitea Reserve is the only hunting opportunity of this type within close proximity (less than a half hour drive) to Palmerston North. As a water supply catchment, hunting is by permit only, and existing permit holders will continue to be able to access the reserve. Currently then, the reserve has a minor positive effect on recreation. With the development of the wind farm hunters may potentially be subject to some minor disruptions and restrictions during wind farm construction activities. To date, there are no recreation or tourism activities within the reserve that can be affected by the Turitea Wind Farm. To the contrary, as a significant additional benefit associated with the project, a proposed Eco-Park may provide increased opportunity for controlled recreational access to the reserve outside the water supply catchment areas (hiking, cycling, etc.) (Mighty River Power, 2008). Therefore, the impact on recreational activities in the Turitea

Reserve is expected to increase from having a minor benefit to a significant positive effect.

C03: Effect of the wind farm on aviation

As stated in the Palmerston North City District Plan, section 20: “No structure, building, tree or other object shall impinge within the take-off climb surfaces or the approach surfaces for the main sealed runway, transitional side surfaces or the horizontal and conical surfaces above the airport”, where...“Each take-off climb and approach surface is symmetrically disposed about the extended centre line of the main runway and extends for a horizontal distance of 12.5 kilometres (or for a slightly shorter distance where the Tararua Ranges rise higher than 30 metres below the approach surface near its south-eastern extremity, south of the Manawatu River)” (PNCC, 2004d, p. 41). The proposed wind farm is not located within the Palmerston North Airport ‘take-off’ or ‘approach surface’ outlined in the Palmerston North District Plan. However, the site is located within navigable airspace and therefore may present an aviation obstacle. The Civil Aviation Authority (CAA) is responsible for establishing civil aviation safety and security standards. The CAA rules state that any structure 120m or higher is a hazard in navigable airspace and, depending on the circumstances of a proposal, a structure between 60m and 120m high may also present a hazard. As a result, the proposed wind turbines and possibly the permanent meteorological monitoring masts of the wind farm will be required to have aviation obstacle lighting (Mighty River Power, 2008).

Another aviation concern that may occur is the potential interference on aviation radar systems. The problem arises because the moving blades of the wind turbines can impart a significant ‘Doppler shift’³ onto the received radar signal that

³ “Airport surveillance radars typically operate at frequencies around 1 GHz and 3 GHz, and track the position and speed of aircraft in their surrounding airspace using pulsed Doppler radar techniques. Such radars are equipped with signal processing software that eliminates the radar returns from spurious targets, such as large buildings, terrain clutter and road traffic. The filtering out of stationary and slow moving targets is relatively straight forward as, although they may

is comparable with that expected from an aircraft (Tennant & Chambers, 2005). Air traffic control users are mainly concerned about potential wind farm clutter detections. The types of interference that can appear on radar screens are either, actual traces but with potentially distorted information about height and location or false 'targets' (Hills, Armstrong, & Pereira, 2008), which could be perceived by air traffic control operators as aircraft or could obscure genuine aircraft detections. This could compromise safety obligation to maintain safe aircraft separations (Jackson, 2007).

An Airways Ballance Radar is located within 2 km of the proposed wind farm site (Mighty River Power, 2008). Consultation was undertaken with Airways and experts to identify any effects on this radar. This consultation identified the Ballance site as secondary surveillance radar, and as such less sensitive than primary radars. The radar relies on interrogation from the radar and a response from the transponder on a plane, meaning that only planes with transponders will be picked up by this radar. Top dressing planes fly on visual aids and therefore do not use the radar. If there are any effects on the radar these will arise from the turbines obstructing the line of sight from the radar (Hills et al., 2008). However, the elevation of the radar, relative to the wind farm and the potential receivers, makes this scenario unlikely. Due to radio wave diffractions, the radio waves may bend around and/or see through the tower and maintain communications with the plane. The conical shape of the turbine towers makes the surface less sensitive in terms of interfering with radio waves (Hills et al., 2008). In this location, the wind farm project will have a minor negative effect on aviation.

C04: Effect of the wind farm on the visual amenity of the landscape

According to the consultation results presented by Mighty River Power, three main aspects should be addressed to estimate any impact on the visual amenity of the landscape. These are: viewer perception, viewshed area and the cumulative impact given by the proximity of this proposal to other wind farms (Wyatt, 2008).

produce a large reflected signal, the associated Doppler shift will be zero or below a preset threshold" (Tennant & Chambers, 2005, p. 489).

Viewer perception is an important issue to consider for wind farm proposals, especially in areas near tourist destinations or heritage areas. The visual impact of a wind farm ultimately depends on the opinion of the viewer. In this sense, the degree of visual impact partly depends on how the viewer perceives renewable energy, the wind turbines and the landscape within which the wind farm turbines are situated (Wyatt, 2008). At national level, a public perception study done by Graham, Stephenson & Smith (2009) showed that the significance of the landscape context was one of the primary concerns of the public. This is consistent with Wolsink (2007) and Ellis, Barry & Robison (2007), who separately concluded that the impact of wind farms on landscape values is the main determining factor in explaining opposition to, or support of wind farms. The presence of wind turbines in the Turitea Reserve will change the existing landscape character of this locality, and the local community concern is whether the proposed wind farm will create irreversible damage to the landscape values and negatively impact the amenity of the area (Mighty River Power, 2008). The landscape values evident within and around the Turitea Wind Farm site, are high levels of naturalness, a distinctively New Zealand character (in terms of both landform and vegetation cover) and high values overall. By contrast, those landscapes already subject to significant modification, whether for plantation forestry, farming, rural-residential development or existing power generation, display reduced levels of appeal (Wyatt, 2008).

The viewshed corresponds to the specific area that may potentially be visually affected by a development. According to the information provided by the consultants, an 18 km viewshed has been used and the subsequent analysis of the viewshed has shown that the topography may restrict views from many locations. Also, while the relevant planning policies and provisions highlight the sensitivity of the Tararua Ranges and particularly the areas within the Tararua Forest Park, the viewshed analysis has shown that there are few viewing opportunities from the Tararua Forest Park to the proposed wind turbines within the Turitea Wind Farm. This has been based on topography only and would further reduce when the screening effects of existing vegetation within the park was taken into account (Wyatt, 2008).

A major issue in the assessment of the Turitea Wind Farm Project is whether the cumulative impact of the Turitea Wind Farm, given the existence of three other wind farms in the area, would be such that adding the turbines of another wind farm would be unacceptable. In part, this need to be assessed against the potential for the existing wind farms and the proposed Turitea Wind Farm to be seen 'as a whole', where there could be the potential for a number of wind farms to appear as a 'continuous fence' in the landscape. In this matter, the landscape and visual impact assessment conducted by Wyatt (2008) has demonstrated that existing wind farms on nearby sites, agricultural activity in the surrounding alluvial plain, associated structures and other signs of human intervention have created a landscape that can absorb further change. The area with the greatest potential to view the Turitea Wind Farm is located within a man-modified landscape.

Mitigation plans include avoidance of the most sensitive sites regarding design, re-vegetation and screen planting, use of low-reflective coating and the use of a single type of turbine. In summary, the evidence present by the company suggests that the landscape and visual effects of the revised proposal within the surrounding landscape would remain acceptable and the wind farm would have a moderate negative effect on the visual amenity of the landscape (Mighty River Power, 2008, 2010).

C05: Clash with cultural/spiritual values associated with the site

The Tararua Range is culturally, spiritually and historically significant to Rangitaane O Manawatu, the Maori tribe indigenous to area of study (McEwen, 1986). There are four sites of particular cultural significance in the vicinity of the Turitea Wind Farm proposal which are largely related to natural peaks. The main cultural concern regarding the Turitea Wind Farm proposal is its impact on the source of 'Mauri' (spirit) from the Turitea Ranges and on intrinsically linked sites of significance, particularly the peaks Arawaru, Te Mata, and Tirohanga. Presently the sites that could be affected by the building of the wind farm are sites that are considered to be locations that provide the Mauri for Rangitaane (Mighty River Power, 2008).

To mitigate the impact on the cultural values of the site, a working relationship was established between Mighty River Power and Rangitaane O Manawatu through consultation. Consultation with local iwi⁴, combined with a detailed assessment of local archaeological and heritage sites (Clough & Associates Ltd., 2008) confirms that there are no sites of cultural significance that will be disturbed as a result of the project. However, to ensure that the potential for adverse effects on cultural wellbeing is avoided, there are various consultation protocols and on-site requirements during construction that can be implemented. With adherence to these protocols, the establishment of the Turitea Wind Farm is unlikely to have a minor adverse impact on the cultural wellbeing of local people and communities (Mighty River Power, 2008).

C06: Effects from wind farm construction activities on daily life (e.g. traffic disruption, dust)

The initial construction activities proposed by the Turitea Wind Farm project will focus on civil earthworks for the creation of key access routes within and to the site. Access to the site is primarily via the Pahiatua Aokautere Road. The Pahiatua Aokautere Road is classified as a principal road or secondary (District) arterial and serves the key function of connecting State Highway 2 with State Highway 57. In this role it provides an important alternative route when the Manawatu Gorge Road is closed (as it was previously for 12 months due to slips). Other site access routes, including Greens and Kahuterawa Roads, are classified as local roads. These key access routes will allow the delivery of materials and components for the subsequent construction activities (Beca Carter Hollings & Ferner Ltd., 2008). According with the project specifications, the overall level of truck traffic generated during construction will be highest at the start of construction when the Pahiatua Aokautere Road will carry a combined total of around 70 truck movements per

⁴ Iwi is defined as a “set of people bound together by descent from a common ancestor or ancestors; literally: bone; modern meaning: tribe” (Te Ara - the Encyclopedia of New Zealand, 2012)

day and Greens Road access will carry around 50 truck movements per day (Angell & Galloway, 2008).

Also, improvements are required on some secondary road network to accommodate oversize loads. Works would include sealing to provide a smooth alignment of the centre line and an area of the access will be excavated to enable in excess of 100m of sight distance in both directions. A number of curves will also require 'easing' to accommodate large construction vehicles and to provide an arc wide enough to get the up to 45m long turbine blades around (Angell & Galloway, 2008).

The analysis of 96 local submissions from three previous wind farms developed around New Zealand revealed that a main local concern from the impacts of construction was the large number of truck movements on narrow local roads, causing driver delays and congestion, but also increased driver hazard, local road damage, and negative impact on daily farming business activities (Graham *et al.*, 2009).

A Construction Traffic Management Plan has been proposed by a consultation group tasked by Mighty River Power to ensure that the project can be undertaken safely with no more than minor effects on the convenience of road users and the amenity of nearby residents. Moreover, local improvements to the road network in order to accommodate over-dimension vehicles will have a beneficial result of improving sight distances through some bends (Angell & Galloway, 2008). This assessment shows that with the implementation of the local road improvements and an effective Construction Traffic Management Plan, the transport-related effects of the project will be minor.

It has also been demonstrated that the construction process is proposed to utilise a range of best practice techniques for sediment control, dust management, and safe handling of potentially hazardous substances (Beca Carter Hollings & Ferner Ltd., 2008). If these plans and practices are properly implemented, the effects from the wind farm construction activities could be minimised to have a negligible

adverse effect on daily life of nearby residents. However the measure used in the model was a minor negative effect, applying a conservative criterion.

C07: Effects of wind farm noise on homeowners

The Turitea Wind Farm site is located in a rural area, clear of any industrial activity, although some secondary roads are nearby. In these baseline conditions, the existing noise environment is derived from farm activities, traffic on the roading network and noise associated with wind (Mighty River Power, 2008).

An assessment of the potential noise effects of the Turitea Wind Farm was undertaken for the project by Hegley Acoustic Consultants Ltd. This assessment identified the following three sources of potential noise:

- Noise from the construction of the wind farm. This includes the construction of roading within the site, the erection of the wind turbine generators and noise from construction traffic on the internal site roads and the public roading network,
- Noise from temporary support works, which include controlled blasting, extraction works, aggregate crushing and concrete batching, and
- Operational wind electrical generation noise from each of the wind turbine generators (Hegley, 2008, p. 3).

Since, the noise assessment concludes that construction, temporary support works and traffic noises will be heard, but will be temporal and well within a reasonable level within the requirements of New Zealand Acoustics Construction Noise Standards at all times, this evaluation has only taken into account operational noise.

During the operational phase, wind turbine generators cause mechanical and aerodynamic noise. All mechanical noise sources will be located within the turbine nacelle on the top of the tower. The noise from the gearbox and drive motors will be controlled by the manufacturer's design, making any mechanical noise secondary to the aerodynamic noise from the wind turbine blades rotating (Hegley, 2008).

An issue with turbine blades rotation noise is that it is not consistently audible and the nature of the sound is variable depending on wind directions and strength. Wind turbine or wind farm noise has the potential to adversely affect an individual due to amenity interference (exterior to a dwelling) and disturbance (inside a dwelling). In both instances an individual can become annoyed and sleep disturbance is a potential issue for some individuals (Thorne, 2009).

As mitigation measures, Mighty River Power has including an operational management plan to regulate turbines in certain conditions to avoid adverse noise effects on specific adjoining landowners, and hence complies with the noise requirements of the NZS6808:1998, Acoustics – The Assessment and Measurement of Sound from Wind Turbine Generators (New Zealand Standard, 1998). On this basis, it is concluded that the adverse effects on adjoining landowners or other sensitive activities as a result of noise from the operation of the Turitea Wind Farm will be no more than minor.

C08: Impact of electric/magnetic fields on homeowner's communications

An assessment of the potential effects of the Wind Farm on licensed radio communications within the area has been reported by the company. The potential effect reported includes radio, TV and phone interference. The assessment found that, in some circumstances, it is possible for wind turbines to negatively affect wireless communication systems, due to interference with radio waves which are used by the system to relay information from a transmitter to a receiver. The assessment identifies that analogue television coverage, aviation RADAR and a VHF land mobile repeater service are the only licensed radio services at risk of experiencing interference caused by the Wind Farm (Hills et al., 2008).

According with Mighty River Power, once the Wind Farm is operational, any adverse effects on analogue broadcast television reception caused by the wind turbines would be identified. As stated by the company, an experienced radio engineer would be contracted to do visual inspection of the interference and analysis of the ghosting pattern. The following mitigation practices could be undertaken if interference is shown to occur:

- Checking that the receive antennas are correctly installed and well maintained, and
- Assist with alternative signal reception options such as satellite digital TV reception (Mighty River Power, 2008).

Where interference does occur, there are relatively straightforward mitigation options available, and on this basis the overall effect on radio and communications is considered less than minor.

4.4 OBJECTIVE OF THE STUDY

Using the REM, the project evaluation undertaken here was to determine whether the Turitea Wind Farm project should be accepted, rejected or whether it would require further more detailed analysis. In order to undertake the evaluations, the alternatives compared were:

- Turitea Reserve with the wind farm project, versus
- Turitea Reserve without the project

The alternative 'Turitea Reserve without the project' is also known as the project baseline. This means that the proposed project is compared against the conditions prevailing in the target areas before the start of interventions, so that estimation of the level of changes as a result of the wind farm project could be measured against baseline conditions in order to establish the net benefit of the project.

4.5 DETERMINING THE WEIGHTS FOR EACH ATTRIBUTE

To set priorities for the 20 key attributes identified earlier (seven for the economic development goal, five for the environmental protection goal and eight attributes for the social acceptability goal) a methodology based on AHP was used, as described in the previous chapter. A questionnaire, using the nine point scale of Saaty (1990), was prepared to obtain pair-wise comparison results of the importance of key attributes toward achieving the overall objective. The full questionnaire developed for the wind farm model is given in Appendix A.

A group of experts, considered to be proficient in social, environmental and economic fields, were invited to respond this questionnaire. All invited were members of the local community. This allowed them to have previous knowledge regarding the project. However, it is important to highlight that they were not classified as stakeholders because they were not directly affected by the project. In this way, any conflict of interest that could influence or bias the results were avoided. Nine experts were chosen and confirmed to participate in this inquiry. The process, which took six months (from 20th July to 2nd September, 2010), was conducted in three rounds. Each round and its results are described below.

4.5.1 ROUND ONE OF THE INTERACTIVE PROCESS

Each expert was approached for an individual meeting in order to get their independent input. During this first visit, general information of the Turitea Wind Farm proposal was presented by the researcher, as was the methodology to weight the attributes and the characteristics of the model. The experts were then asked to complete the survey questionnaire. The meeting took about one hour: 40 minutes for the introductory talk and about 20 minutes to answer the questionnaire. Once the responses for Round One were received, using the Logical Decision® software, responses were aggregated and analysed to obtain a single set of weights for each attribute, by (a) entering raw data from questionnaire into the pair-wise comparison matrix from the software, the weight assigned by each expert to each criterion was calculated, and (b) calculating the mean and coefficient of variation of these values. The final results are shown in Tables 4.4, 4.5 and 4.6.

Table 4.4 Weights of economic development attributes from Round One

Participant	Attributes of Economic Development													
	A01		A02		A03		A04		A05		A06		A07	
	%	Rank	%	Rank	%	Rank	%	Rank	%	Rank	%	Rank	%	Rank
1	4.4	7	22.4	2	6.6	5	17.1	3	36.3	1	8.3	4	4.9	6
2	5.6	7	9.3	4	22.3	2	8.5	6	8.6	5	21.4	3	24.3	1
3	7.0	6	21.9	2	16.7	3	26.7	1	11.5	5	14.3	4	1.9	7
4	4.4	6	52.4	1	10.5	3	3.6	7	9.6	4	8.3	5	11.2	2
5	18.5	3	11.8	5	18.8	2	4.1	7	17.3	4	20.7	1	8.7	6
6	4.2	5	25.2	2	12.6	3	1.6	7	47.3	1	2.5	6	6.6	4
7	1.6	7	44.9	1	5.0	5	14.4	3	22.8	2	8.5	4	2.8	6
8	3.0	7	27.3	2	9.7	4	17.4	3	29.8	1	7.4	5	5.3	6
9	2.5	7	16.1	3	6.2	4	39.3	1	25.3	2	5.3	5	5.3	5
MEAN	5.7	7	25.7	1	12.0	3	14.7	4	23.2	2	10.7	5	7.9	6
CV	0.89		0.56		0.50		0.83		0.56		0.62		0.86	

A01: Rental payments to landowners

A02: Energy generated from a free resource

A03: Benefits to the local business community from the construction and operation of the wind farm

A04: Keeping the cost of electricity down

A05: Increasing certainty of electricity supply at the national level

A06: New jobs created during the long-term operation of the wind farm

A07: New jobs created during the construction of the wind farm

CV: Coefficient of variation.

Table 4.5 Weights of environmental protection attributes from Round One

Participant	Attributes of Environmental Protection									
	B01		B02		B03		B04		B05	
	%	rank	%	rank	%	rank	%	rank	%	rank
1	28.1	2	5.2	5	32.6	1	14.1	4	20.0	3
2	20.5	3	25.7	2	11.7	5	29.5	1	12.6	4
3	20.0	2	10.8	3	61.0	1	3.0	5	5.2	4
4	6.3	4	51.7	1	26.2	2	12.2	3	3.7	5
5	12.1	3	7.5	4	48.8	1	26.9	2	4.8	5
6	16.5	2	16.4	3	48.9	1	16.3	4	1.8	5
7	23.3	2	5.6	4	57.4	1	11.3	3	2.4	5
8	24.7	2	4.7	5	38.0	1	18.6	3	14.1	4
9	23.3	2	15.3	4	5.5	5	38.3	1	17.5	3
MEAN	19.4	2	15.9	4	36.7	1	18.9	3	9.1	5
CV	0.35		0.95		0.53		0.57		0.76	

B01: Effect on the natural undisturbed landscape where the wind farm is sited

B02: Threat to water quality from construction of the wind farm

B03: Global/national benefits of clean energy production (Greenhouse gas emissions avoided)

B04: Local vegetation disturbance resulting from construction of the wind farm

B05: Threat of turbines to birds

CV: Coefficient of variation.

Table 4.6 Weights for the social acceptability attributes from Round One

Participant	Attributes of Social Acceptability															
	C01		C02		C03		C04		C05		C06		C07		C08	
	%	rank	%	rank	%	rank	%	rank	%	rank	%	rank	%	rank	%	rank
1	4.6	7	8.6	3	4.4	8	27.9	2	6.5	5	6.3	6	34.4	1	7.2	4
2	14.3	3	7.4	5	1.9	8	4.9	6	14.6	2	3.4	7	41.3	1	12.2	4
3	10.7	5	15.8	3	3.3	7	28.2	1	15.6	4	8.3	6	16.1	2	1.9	8
4	5.1	5	4.4	6	2.2	7	24.9	2	40.2	1	7.5	4	14.0	3	1.7	8
5	13.2	4	15.5	3	4.7	8	24.1	1	9.9	6	17.4	2	10.4	5	4.9	7
6	10.0	4	6.9	5	4.2	7	17.6	2	5.7	6	16.6	3	35.4	1	3.7	8
7	1.3	8	13.7	3	2.2	7	3.5	6	43.0	1	22.0	2	5.2	5	9.2	4
8	25.0	2	3.1	7	1.7	8	10.5	4	28.8	1	6.8	5	19.0	3	5.0	6
9	17.4	3	8.5	4	6.2	7	24.5	1	24.0	2	3.7	8	7.9	5	7.8	6
MEAN	11.3	4	9.3	6	3.4	8	18.5	3	20.9	1	10.2	5	20.4	2	6.0	7
CV	0.64		0.50		0.45		0.53		0.67		0.65		0.65		0.58	

C01: Effect on residential property values in close proximity to the wind farm site

C02: Effect on recreational activities

C03: Effect of the wind farm on aviation

C04: Effect of the wind farm on the visual amenity of the landscape

C05: Clash with cultural/spiritual values associated with the site

C06: Effects from wind farm construction activities on daily life (e.g. traffic disruption, dust)

C07: Effects of wind farm noise on homeowners

C08: Impact of electric/magnetic fields on homeowner's communications

CV: Coefficient of variation.

The means of the weights obtained from the experts were then entered into the LDW to obtain the inverse matrices for the aggregated weights for each of the attributes (shown in Tables 4.7, 4.8, 4.9). The eigenvalues (the off-diagonal values, highlighted in blue) indicate the degree of preference for one attribute with respect to another from the pair-wise comparisons in the survey. The matrix generates two reciprocal eigenvalues (for each pair-wise comparison), from which only eigenvalues ≥ 1 are used. These eigenvalues were added to each expert's questionnaire responses, to indicate the collective response as compared to the expert's individual response. Since the eigenvalues generated by the inverse matrix were calculated from the means, they are expressed as decimal values. These decimal values were rounded to the nearest whole number; however, eigenvalues with a decimal of 0.5 were marked in between the two whole numbers. For example, an eigenvalue of 4.509 was marked at 4.5 rather than being rounded up to 5 on the questionnaire.

Table 4.7 Inverse matrix for the weightings of the economic development attributes from Round One

I-max = 7.000 C.I. = 0.000 C.R. = 0.000	A01	A02	A03	A04	A05	A06	A07
A01	0.057	0.222	0.475	0.388	0.246	0.533	0.722
A02	4.509	0.257	2.142	1.748	1.108	2.402	3.253
A03	2.105	0.467	0.120	0.816	0.517	1.121	1.519
A04	2.579	0.572	1.225	0.147	0.634	1.374	1.861
A05	4.070	0.903	1.933	1.578	0.232	2.168	2.937
A06	1.877	0.416	0.892	0.728	0.461	0.107	1.354
A07	1.386	0.307	0.658	0.537	0.341	0.738	0.079

A01: Rental payments to landowners

A02: Energy generated from a free resource

A03: Benefits to the local business community from the construction and operation of the wind farm

A04: Keeping the cost of electricity down

A05: Increasing certainty of electricity supply at the national level

A06: New jobs created during the long-term operation of the wind farm

A07: New jobs created during the construction of the wind farm

Table 4.8 Inverse matrix for the weightings of the environmental protection attributes from Round One

I-max = 5.000 C.I. = 0.000 C.R. = 0.000	B1	B2	B3	B4	B5
B1	0.194	1.220	0.529	1.026	2.132
B2	0.820	0.159	0.433	0.841	1.747
B3	1.892	2.308	0.367	1.942	4.033
B4	0.974	1.189	0.515	0.189	2.077
B5	0.469	0.572	0.248	0.481	0.091

B01: Effect on the natural undisturbed landscape where the wind farm is sited

B02: Threat to water quality from construction of the wind farm

B03: Global/national benefits of clean energy production (Greenhouse gas emissions avoided)

B04: Local vegetation disturbance resulting from construction of the wind farm

B05: Threat of turbines to birds

Table 4.9 Inverse matrix for the weightings of the social acceptability attributes from Round One

I-max = 8.000 C.I. = 0.000 C.R. = 0.000	C1	C2	C3	C4	C5	C6	C7	C8
C1	0.113	1.215	3.324	0.611	0.541	1.108	0.554	1.883
C2	0.823	0.093	2.735	0.503	0.445	0.912	0.456	1.550
C3	0.301	0.366	0.034	0.184	0.163	0.333	0.167	0.567
C4	1.637	1.989	5.441	0.185	0.885	1.814	0.907	3.083
C5	1.850	2.247	6.147	1.130	0.209	2.049	1.025	3.483
C6	0.903	1.097	3.000	0.551	0.488	0.102	0.500	1.700
C7	1.805	2.194	6.000	1.103	0.976	2.000	0.204	3.400
C8	0.531	0.645	1.765	0.324	0.287	0.588	0.294	0.060

- C01: Effect on residential property values in close proximity to the wind farm site,
 C02: Effect on recreational activities,
 C03: Effect of the wind farm on aviation,
 C04: Effect of the wind farm on the visual amenity of the landscape,
 C05: Clash with cultural/spiritual values associated with the site,
 C06: Effects from wind farm construction activities on daily life (e.g. traffic disruption, dust),
 C07: Effects of wind farm noise on homeowners,
 C08: Impact of electric/magnetic fields on homeowner's communications.

4.5.2 ROUND TWO OF THE INTERACTIVE PROCESS

In order to promote a better understanding among the experts, the combined results from Round One were shared with each expert in the group, thereby allowing the participants to consider the other experts' opinions alongside their own and if desired, refine their own estimates before meeting up with rest of the expert participants. Thus Round Two results, shown in the next set of tables (Tables 4.10, 4.11, 4.12), represent the new aggregated values of the weights obtained after a second round of responses from each expert, once they had taken into consideration the combined results from Round One.

Due to the differing background and expertise of the participants on the panel of experts, it was expected to find within the group different assumptions, viewpoints, and interpretations of the issues concerning each of the attributes, which would then be reflected in the weightings they gave to each attribute. The coefficients of variation obtained for each attribute from this second round were particularly relevant for the final round of this approach. The attributes with the greater coefficients of variation indicated the attributes for which there was least

agreement in terms of the weightings assigned. Therefore it would be these attributes that required more attention in order to reach consensus in the last interactive round.

Table 4.10 Weightings for the economic development attributes from Round Two

Participant	Attributes of Economic Development													
	A01		A02		A03		A04		A05		A06		A07	
	%	Rank	%	Rank	%	Rank	%	Rank	%	Rank	%	Rank	%	Rank
1	4.9	7	23.3	2	7.4	5	16.8	3	33.5	1	8.9	4	5.2	6
2	5.2	7	11.5	4	21.5	2	7.6	6	9.5	5	20.5	3	24.1	1
3	3.9	6	23.4	2	19.8	3	25.4	1	10.5	5	14.6	4	2.5	7
4	4.9	6	48.6	1	11.5	3	3.7	7	10.4	4	8.9	5	12.0	2
5	18.0	3	9.8	5	21.5	2	4.6	7	13.8	4	23.3	1	9.0	6
6	2.9	7	26.2	2	13.1	3	4.6	6	39.2	1	6.4	5	7.6	4
7	1.6	7	44.9	1	5.0	5	14.4	3	22.8	2	8.5	4	2.8	6
8	3.0	7	27.3	2	9.7	4	17.4	3	29.8	1	7.4	5	5.3	6
9	2.5	7	16.1	3	6.2	4	39.3	1	25.3	2	5.3	5	5.3	5
MEAN	5.2	7	25.7	1	12.9	4	14.9	3	21.6	2	11.5	5	8.2	6
CV	0.95		0.52		0.51		0.79		0.51		0.56		0.81	

A01: Rental payments to landowners

A02: Energy generated from a free resource

A03: Benefits to the local business community from the construction and operation of the wind farm

A04: Keeping the cost of electricity down

A05: Increasing certainty of electricity supply at the national level

A06: New jobs created during the long-term operation of the wind farm

A07: New jobs created during the construction of the wind farm

CV: Coefficient of variation.

Table 4.11 Weightings for the environmental protection attributes from Round Two

Participant	Attributes of Environmental Protection									
	B01		B02		B03		B04		B05	
	%	Rank	%	rank	%	rank	%	rank	%	rank
1	27.0	2	6.6	5	38.5	1	13.9	4	14.0	3
2	23.4	3	25.8	2	12.0	5	25.9	1	12.9	4
3	20.0	2	10.8	3	61.0	1	3.0	5	5.2	4
4	7.5	5	49.7	1	24.3	2	13.0	3	5.5	5
5	13.7	3	8.6	4	46.6	1	25.8	2	5.3	5
6	16.9	3	17.3	2	45.3	1	16.7	4	3.9	5
7	23.3	2	5.6	4	57.4	1	11.3	3	2.4	5
8	24.7	2	4.7	5	38.0	1	18.6	3	14.1	4
9	23.3	2	15.3	4	5.5	5	38.3	1	17.5	3
MEAN	20.0	2	16.0	4	36.5	1	18.5	3	9.0	5
CV	0.31		0.89		0.52		0.56		0.62	

B01: Effect on the natural undisturbed landscape where the wind farm is sited

B02: Threat to water quality from construction of the wind farm

B03: Global/national benefits of clean energy production (Greenhouse gas emissions avoided)

B04: Local vegetation disturbance resulting from construction of the wind farm

B05: Threat of turbines to birds

CV: Coefficient of variation.

Table 4.12 Weightings for the social acceptability attributes from Round Two

Participant	Attributes of Social Acceptability															
	C01		C02		C03		C04		C05		C06		C07		C08	
	%	rank	%	rank	%	rank	%	rank	%	rank	%	rank	%	rank	%	rank
1	5.4	7	9.6	3	3.8	8	24.1	2	8.6	4	6.9	6	33.3	1	8.2	5
2	14.3	3	7.4	5	1.9	8	4.9	6	14.6	2	3.4	7	41.3	1	12.2	4
3	11.1	5	13.4	4	3.6	7	29.2	1	15.4	3	8.2	6	17.1	2	2.0	8
4	5.2	5	4.3	6	2.3	7	25.7	2	38.8	1	7.8	4	14.2	3	1.9	8
5	13.6	4	14.5	3	4.8	8	24.6	1	10.4	6	16.4	2	10.6	5	5.0	7
6	8.2	6	8.3	5	3.2	8	18.1	2	11.3	4	15.7	3	31.0	1	4.2	7
7	1.3	8	13.7	3	2.2	7	3.5	6	43.0	1	22.0	2	5.2	5	9.2	4
8	25.0	2	3.1	7	1.7	8	10.5	4	28.8	1	6.8	5	19.0	3	5.0	6
9	17.4	3	8.5	4	6.2	7	24.5	1	24.0	2	3.7	8	7.9	5	7.8	6
MEAN	11.3	4	9.2	6	3.3	8	18.3	3	21.7	1	10.1	5	20.0	2	6.2	7
CV	0.64		0.44		0.45		0.53		0.59		0.63		0.63		0.56	

- C01: Effect on residential property values in close proximity to the wind farm site,
- C02: Effect on recreational activities,
- C03: Effect of the wind farm on aviation,
- C04: Effect of the wind farm on the visual amenity of the landscape,
- C05: Clash with cultural/spiritual values associated with the site,
- C06: Effects from wind farm construction activities on daily life (e.g. traffic disruption, dust),
- C07: Effects of wind farm noise on homeowners,
- C08: Impact of electric/magnetic fields on homeowner's communications.
- CV: Coefficient of variation.

For unforeseen reasons one of the participants failed to complete the second stage. A limitation of this analysis is that since the data is aggregated, the expert's input cannot be removed partway through the process. To continue the exercise it was assumed that this person did not change his set of preferences during the second round and third round. Therefore, it was assumed that he was not willing to compromise in the search for consensus, which will affect the end result. Since this case study is a demonstration of the implementation of the model, the final answer as to whether to accept or reject the project is not the primary aim of this study, had it been, it may have had an impact on the final results and thus on the decision-making process. This issue highlights the importance of the input by the experts.

Again, the inverse matrix procedure was used to obtain the eigenvalues that indicate the degree of preference for one attribute with respect to another (from the pair-wise comparisons in the survey). In order to do so, the aggregated

weights obtained from the experts in the second round were entered into the LDW to obtain the inverse matrices (Tables 4.13, 4.14, 4.15).

Table 4.13 Inverse matrix for the weightings of the economic development attributes from Round Two

I-max = 7.000 C.I. = -0.000 C.R. = 0.000	A01	A02	A03	A04	A05	A06	A07
A01	0.052	0.202	0.403	0.349	0.241	0.452	0.634
A02	4.942	0.257	1.992	1.725	1.190	2.235	3.134
A03	2.481	0.502	0.129	0.866	0.597	1.122	1.573
A04	2.865	0.580	1.155	0.149	0.690	1.296	1.817
A05	4.154	0.840	1.674	1.450	0.216	1.878	2.634
A06	2.212	0.447	0.891	0.772	0.532	0.115	1.402
A07	1.577	0.319	0.636	0.550	0.380	0.713	0.082

A01: Rental payments to landowners

A02: Energy generated from a free resource

A03: Benefits to the local business community from the construction and operation of the wind farm

A04: Keeping the cost of electricity down

A05: Increasing certainty of electricity supply at the national level

A06: New jobs created during the long-term operation of the wind farm

A07: New jobs created during the construction of the wind farm

CV: Coefficient of variation.

Table 4.14 Inverse matrix for the weightings of the environmental protection attributes from Round Two

I-max = 5.000 C.I. = 0.000 C.R. = 0.000	B1	B2	B3	B4	B5
B1	0.200	1.250	0.548	1.081	2.222
B2	0.800	0.160	0.438	0.865	1.778
B3	1.825	2.281	0.365	1.973	4.056
B4	0.925	1.156	0.507	0.185	2.056
B5	0.450	0.562	0.247	0.486	0.090

B01: Effect on the natural undisturbed landscape where the wind farm is sited,

B02: Threat to water quality from construction of the wind farm,

B03: Global/national benefits of clean energy production (Greenhouse gas emissions avoided),

B04: Local vegetation disturbance resulting from construction of the wind farm,

B05: Threat of turbines to birds.

Table 4.15 Inverse matrix for the weightings of the social acceptability attributes from Round Two

I-max = 8.000 C.I. = 0.000 C.R. = 0.000	C1	C2	C3	C4	C5	C6	C7	C8
C1	0.113	1.228	3.424	0.617	0.521	1.119	0.565	1.823
C2	0.814	0.092	2.788	0.503	0.424	0.911	0.460	1.484
C3	0.292	0.359	0.033	0.180	0.152	0.327	0.165	0.532
C4	1.619	1.989	5.545	0.183	0.843	1.812	0.915	2.952
C5	1.920	2.359	6.576	1.186	0.217	2.149	1.085	3.500
C6	0.894	1.098	3.061	0.552	0.465	0.101	0.505	1.629
C7	1.770	2.174	6.061	1.093	0.922	1.980	0.200	3.226
C8	0.549	0.674	1.879	0.339	0.286	0.614	0.310	0.062

- C01: Effect on residential property values in close proximity to the wind farm site,
 C02: Effect on recreational activities,
 C03: Effect of the wind farm on aviation,
 C04: Effect of the wind farm on the visual amenity of the landscape,
 C05: Clash with cultural/spiritual values associated with the site,
 C06: Effects from wind farm construction activities on daily life (e.g. traffic disruption, dust),
 C07: Effects of wind farm noise on homeowners,
 C08: Impact of electric/magnetic fields on homeowner's communications.

4.5.3 ROUND THREE OF THE INTERACTIVE PROCESS

Finally, a focus group meeting was conducted to come to a consensus on final values. The focus group meeting had the advantage of allowing the participants to consider, by listening to the others experts, aspects that they had not previously considered. The standard deviation and coefficient of variation (CV) had been calculated to identify the attributes in which the experts had significant differences of opinion. The more controversial attributes with the higher CVs were then highlighted during the focus group meeting and expert discussion was centred on those attributes. Finally, after listening to the opinions of the others, each was asked to incorporate this new information into their thinking and refine their estimates one more time. The results form Round Three are shown in Tables 4.16 to 4.18.

Table 4.16 Weightings for the economic development attributes from Round Three

Participant	Attributes of Economic Development													
	A01		A02		A03		A04		A05		A06		A07	
	%	Rank	%	Rank	%	Rank	%	Rank	%	Rank	%	Rank	%	Rank
1	5.1	7	21.8	2	7.7	5	17.9	3	32.4	1	9.7	4	5.4	6
2	5.2	7	11.6	4	21.5	2	6.9	7	10.4	5	20.2	3	24.2	1
3	4.0	6	26.7	1	14.9	4	23.7	2	17.3	3	10.8	6	2.5	7
4	6.5	6	45.8	1	12.4	3	4.9	7	12.8	2	9.7	4	7.8	5
5	18.0	3	9.8	5	21.5	2	4.6	7	13.8	4	23.3	1	9.0	6
6	2.9	7	26.7	2	13.4	3	5.0	6	37.6	1	6.8	5	7.7	4
7	1.6	7	44.9	1	5.0	5	14.4	3	22.8	2	8.5	4	2.8	6
8	4.4	6	27.5	2	9.7	4	17.2	3	29.8	1	7.2	5	4.3	7
9	3.3	7	16.1	3	5.9	4	39.6	1	25.3	2	4.1	6	5.7	5
MEAN	5.7	7	25.6	1	12.4	4	14.9	3	22.5	2	11.2	5	7.7	6
CV	0.86		0.50		0.49		0.78		0.42		0.57		0.85	

A01: Rental payments to landowners

A02: Energy generated from a free resource

A03: Benefits to the local business community from the construction and operation of the wind farm

A04: Keeping the cost of electricity down,

A05: Increasing certainty of electricity supply at the national level,

A06: New jobs created during the long-term operation of the wind farm,

A07: New jobs created during the construction of the wind farm.

CV: Coefficient of variation.

Table 4.17 Weightings for the environmental protection attributes from Round Three

Participant	Attributes of Environmental Protection									
	B01		B02		B03		B04		B05	
	%	rank	%	rank	%	rank	%	rank	%	rank
1	26.0	2	6.5	5	38.6	1	13.8	4	15.2	3
2	23.4	3	25.9	1	11.9	5	25.9	1	12.9	4
3	20.9	2	13.6	3	57.9	1	2.9	5	4.7	4
4	9.2	4	36.0	1	30.9	2	18.0	3	5.9	5
5	12.7	4	13.0	3	46.6	1	22.1	2	5.5	5
6	16.9	3	17.3	2	45.3	1	16.7	4	3.9	5
7	23.3	2	5.6	4	57.4	1	11.3	3	2.4	5
8	25.2	2	5.3	5	39.0	1	18.5	3	12.0	4
9	26.6	2	20.2	3	9.3	4	37.7	1	6.2	5
MEAN	20.5	2	15.9	4	37.4	1	18.5	3	7.6	5
CV	0.30		0.65		0.47		0.52		0.59	

B01: Effect on the natural undisturbed landscape where the wind farm is sited,

B02: Threat to water quality from construction of the wind farm,

B03: Global/national benefits of clean energy production (Greenhouse gas emissions avoided),

B04: Local vegetation disturbance resulting from construction of the wind farm,

B05: Threat of turbines to birds.

CV: Coefficient of variation.

Table 4.18 Weightings for the social acceptability attributes from Round Three

Participant	Attributes of Social Acceptability															
	C01		C02		C03		C04		C05		C06		C07		C08	
	%	rank	%	rank	%	rank	%	rank	%	rank	%	rank	%	rank	%	rank
1	5.4	7	9.6	3	3.8	8	24.1	2	8.6	4	6.9	6	33.3	1	8.2	5
2	14.4	3	7.5	5	1.9	8	5.0	6	14.7	2	3.4	7	40.8	1	12.3	4
3	11.0	5	13.7	4	3.6	7	29.5	1	15.5	3	7.4	6	17.2	2	2.1	8
4	6.7	5	5.5	6	2.5	7	27.6	2	30.0	1	8.2	4	17.0	3	2.4	8
5	13.6	4	14.5	3	4.8	8	24.6	1	10.4	6	16.4	2	10.6	5	5.0	7
6	8.2	6	8.3	5	3.2	8	18.0	2	11.2	4	15.6	3	31.8	1	3.8	7
7	1.3	8	13.7	3	2.2	7	3.5	6	43.0	1	22.0	2	5.2	5	9.2	4
8	25.4	2	4.7	6	1.8	8	9.7	4	28.7	1	4.7	7	19.1	3	5.9	5
9	16.6	3	3.0	7	2.9	8	29.0	2	30.6	1	4.8	6	5.7	5	7.4	4
ME	11.4	4	9.0	6	3.0	8	19.0	3	21.4	1	9.9	5	20.1	2	6.3	7
CV	0.63		0.47		0.34		0.55		0.56		0.65		0.63		0.54	

C01: Effect on residential property values in close proximity to the wind farm site,

C02: Effect on recreational activities,

C03: Effect of the wind farm on aviation,

C04: Effect of the wind farm on the visual amenity of the landscape,

C05: Clash with cultural/spiritual values associated with the site,

C06: Effects from wind farm construction activities on daily life (e.g. traffic disruption, dust),

C07: Effects of wind farm noise on homeowners,

C08: Impact of electric/magnetic fields on homeowner's communications.

CV: Coefficient of variation.

4.5.4 QUANTIFYING THE EVOLUTION OF AGREEMENT AMONG THE EXPERTS

The coefficients of variation and the coefficients of Kendall were calculated for each round, with the purpose of estimating the level of experts' agreement achieved from the three interactive rounds. Details of these calculations can be found in Section 3.5.4.

Coefficient of Variation (CV)

The CVs were calculated from each attribute's weighting, at each interactive round. The results are graphically presented in Figures 4.3, 4.4 and 4.5. The graphs show the evolution of agreement amongst the experts on the weightings assigned to each of the economic, environmental and social attributes from the interactive process. A CV of less than 0.5 indicates a good degree of consensus, a CV between 0.5 and 0.8 indicates a less than satisfactory degree of consensus, and a CV greater than 0.8 means a poor degree of consensus was reached within the panel of experts.

Figure 4.3 Coefficients of variation for the weightings of the economic development attributes for each round

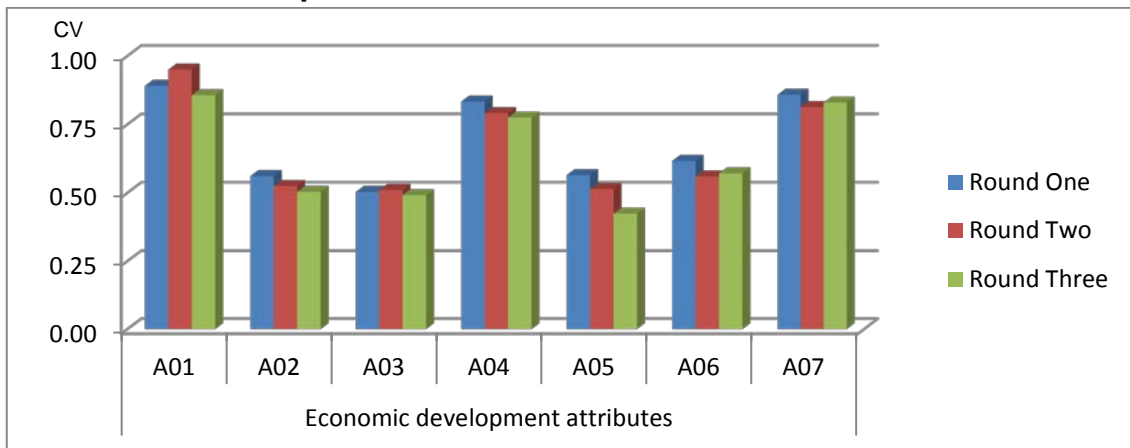


Figure 4.3 shows a decrease in the coefficients of variation when comparing the first round with the last round for the economic development attributes. This can be interpreted as an incremental movement toward consensus on the weightings of the attributes by the experts. However, in the second round, an increase in the degree of disagreement can be observed for attributes A01 and A03. It also occurred in the last stage (Round Three) for attributes A06 and A07. For attributes A01, A04, A06 and A07 the final CVs were over 0.5 (which the literature suggests is not an acceptable degree of consensus). It indicates quite a degree of controversy in relation to the importance or contribution that these attributes play toward the goal of economic development.

Figure 4.4 Coefficient of variation for the weightings of the environmental protection attributes for each round

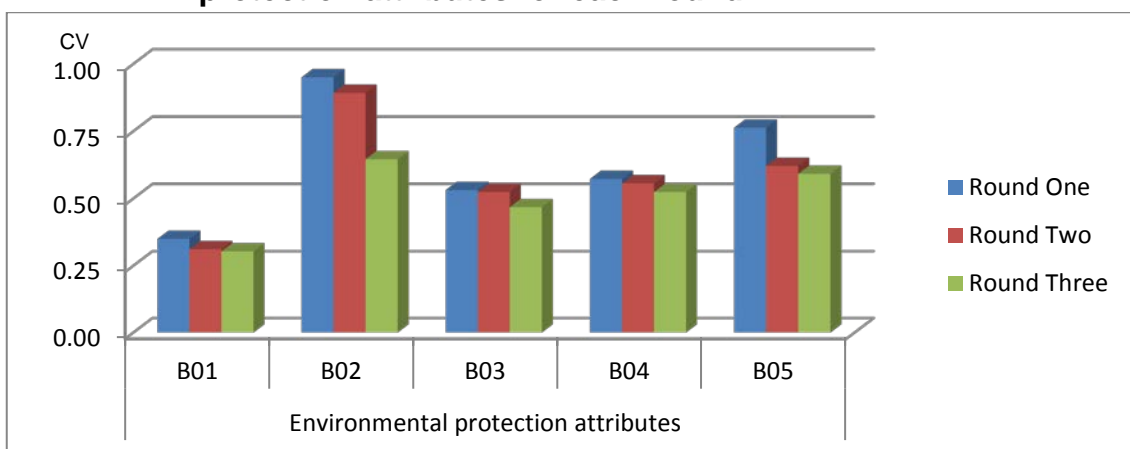
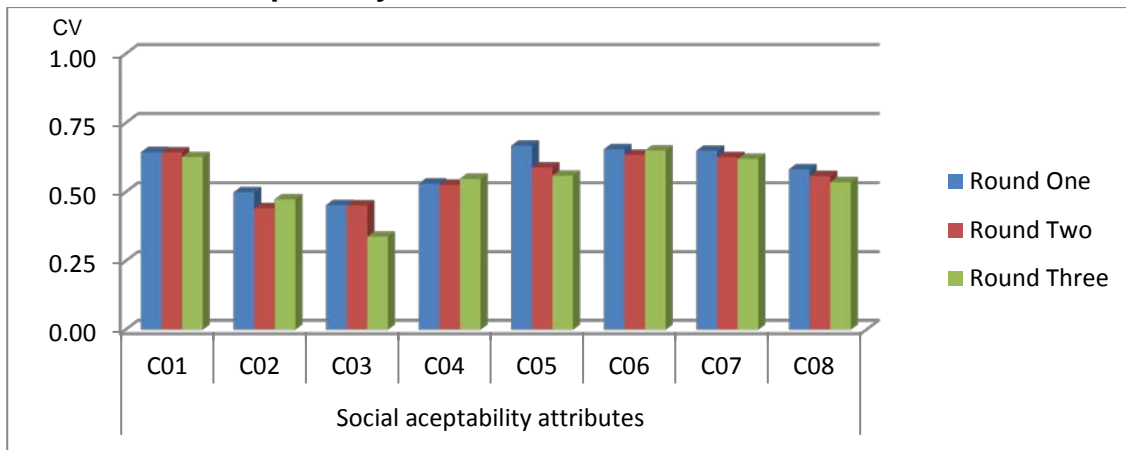


Figure 4.4 shows a decrease in the CVs through the consecutive rounds for the environmental protection attributes, which indicate an incremental movement toward consensus on these weightings by the panel of experts. Most attributes obtained a CV lower than 0.5, indicating a good degree of consensus. The exceptions were B02 and B05, both of which were more controversial than the other attributes.

Figure 4.5 Coefficients of variation for the weightings of the social acceptability attributes for each round



For the attributes of social acceptability, Figure 4.5 shows a decrease in the coefficients of variation through the consecutive rounds for the attributes C01, C03, C05, C07 and C08. This can be interpreted as an incremental movement toward consensus on the weightings of these attributes, by the experts. Nevertheless, CV results for the attributes C02, C04, and C06 indicate a lesser degree of consensus reached. In the case of C02 and C06, experts have moved toward consensus from Round One to Round Two, but in Round Three they have moved away from the second level of consensus reached, moving back to the level of disagreement obtained from Round One, before receiving feedback from the other experts. C04 was the only attribute that got a CV higher than the level obtained at Round One, indicating that the experts disagree on the final weight that this particular attribute should have, and the interactive weighting process has not contributed at all to building agreement regarding the importance of this particular attribute.

Coefficient of Kendall (W)

This coefficient is based on the rank obtained by each attribute when the weights are estimated. The coefficient of Kendall was calculated for the set of attributes for the economic development; environmental protection and social acceptability goals at each round (see the calculation matrices in Appendix A). *W* also provides information about the degree of agreement reached in each interaction by the group of experts. A high value for *W* essentially means that the experts are using the same criteria to evaluate the attributes. An adequate level of agreement is reached when *W* is greater than 0.5. The results of the coefficients of Kendall are presented in Table 4.19.

Table 4.19 Coefficients of Kendall for economic, environmental and social attribute weightings for the three rounds

Interactive Round	Kendall's Coefficient of agreement		
	Economic development	Environmental protection	Social acceptability
Round 1	0.34	0.30	0.35
Round 2	0.37	0.28	0.50
Round 3	0.42	0.35	0.50

The coefficients of Kendall increased through each successive round, demonstrating increased agreement at each round. However, only *W* for social acceptability reached a value ≥ 0.5 . It is clear from the relatively low values for the coefficients of Kendall that there is not agreement between the experts regarding the weightings for the economic development and environmental protection attributes. However, following the focus group meeting the panel of experts agreed to adopt the average values for the weightings from the Round Three results.

Finally, from all the results of round three, the final weightings for each of the attributes have been summarized into one table, Table 4.20.

Table 4.20 Final attributes weightings

Goal	Attributes	Weights (%)
Economic development	A01 Rental payments to landowners	5.7
	A02 Energy generated from a free resource (wind)	25.6
	A03 Benefits to local business community from constructing and operating the WF	12.4
	A04 Keeping cost of electricity down	14.9
	A05 Increasing certainty of electricity supply at national level	22.5
	A06 New jobs created during long-term operation of the wind farm	11.2
	A07 New jobs created during construction of the wind farm	7.7
Total		100
Environmental protection	B01 Effect on natural undisturbed landscape where the wind farm is sited	20.5
	B02 Threat to water quality from construction of wind farm	15.9
	B03 Global/national benefits of clean energy production	37.4
	B04 Local vegetation disturbance resulting from construction	18.5
	B05 Threat of turbines to birds	7.6
Total		100
Social Acceptability	C01 Effect on residential property values in close proximity to the wind farm site	11.4
	C02 Effect on recreational activities (hunting, hiking, cycling, etc.)	9.0
	C03 Effect of the wind farm on aviation	3.0
	C04 Effect of the wind farm on the visual amenity of the landscape	19.0
	C05 Clash with cultural/spiritual values associated with the site	21.4
	C06 Effects from wind farm construction activities on daily life	9.9
	C07 Effects of wind farm noise on homeowners	20.1
	C08 Impact of electric /magnetic fields on homeowner's communications	6.3
Total		100

4.6 RANKING THE ALTERNATIVES

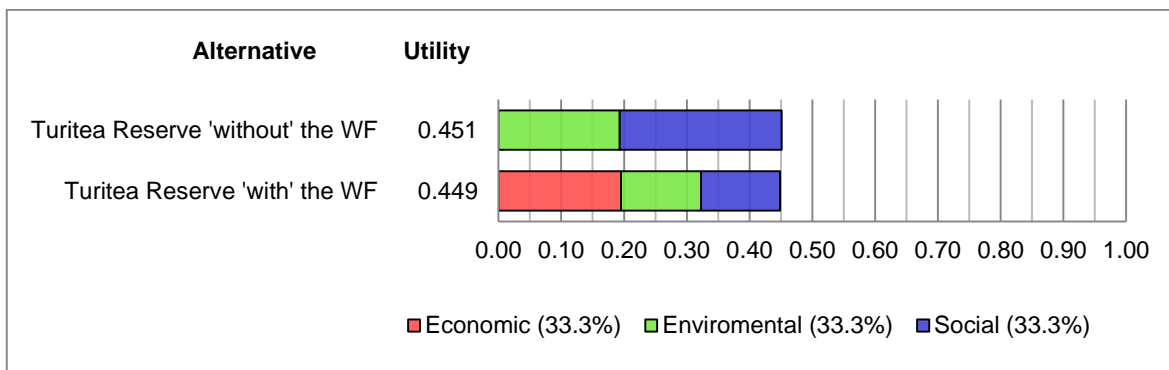
This study aimed to compare two alternatives: the Turitea Reserve 'with' the Wind Farm project and 'without' the Wind Farm project. In order to do this, the alternatives were analysed following the procedures undertaken for the REM in the LDW software.

Once the data were entered for each attribute for the individual alternatives, the most and least preferred measures were indicated. Care was taken to ensure that for the negative impacts the most preferred level of a measure was specified as zero or none. Measures were then converted to units of utility. Common unit conversions were undertaken using single-measure utility functions (SUFs) for

point-estimate data, and direct assessment was used for descriptive labels. The summary list of attributes, their final weights and their resulting net benefits (including quantitative and qualitative data), are given in Table 4.21.

LDW ranking results are presented in terms of utilities and the ranking results are shown in Figure 4.6. In each of the stacked bar graphs, economic development is shown in red (where a longer bar represents a higher economic benefit), environmental protection is shown in green (where a longer bar represents a lesser threat to the environment), and social benefits are shown in blue (where a longer bar represents fewer negative social impacts).

Figure 4.6 Ranking of alternatives for the Turitea Wind Farm project evaluation



From Figure 4.6 it can be seen that, when using an equal distribution of weightings for economic, environmental and social goals (i.e. weighting each at 33.3%), the overall utility scores are similar for both the 'with' and 'without' project alternatives. Therefore, while the individual economic, environmental and social impacts are very different for the 'with' and 'without' project alternatives, their combined utility scores are almost the same. This leaves the decision makers to consider how important it is to give the same weighting for each of the three goals. The alternative 'without the project' is particularly important for the achievement of social and environmental goals; however, it excludes economic development. If economic development is an important consideration, then the 'with the wind farm project' alternative provides a more balanced consideration of the three goals.

Table 4.21 Turitea attributes net benefits under the different alternatives

Goal	Attributes	Weights (%)	Net benefit of Turitea Reserve with the wind farm project	Net benefit of Turitea Reserve Without the wind farm project
Economic development	Rental payments to landowners	5.7	\$1.6m/year	\$0m/year
	Energy generated from a free resource (wind)	25.6	108.16 MW	0 MW
	Benefits to local business community from constructing and operating the wind farm	12.4	\$150m	\$0m
	Keeping cost of electricity down	14.9	minor positive effect	no effect
	Increasing certainty of electricity supply at national level	22.5	moderate positive effect	no effect
	New jobs created during long-term operation of the wind farm	11.2	10	0
	New jobs created during construction of the wind farm	7.7	100	0
			100	
Environmental protection	Effect on natural undisturbed landscape where the wind farm is sited	20.5	moderate adverse effect	significant positive effect
	Threat to water quality from construction of wind farm	15.9	minor adverse effect	no effect
	Global/national benefits of clean energy production (Greenhouse emissions avoided)	37.4	minor positive effect	No effect
	Local vegetation disturbance resulting from construction	18.5	minor adverse effect	no effect
	Threat of turbines to birds	7.6	minor adverse effect	no effect
			100	
Social acceptability	Effect on residential property values in close proximity to the wind farm site	11.4	moderate adverse effect	moderate positive effect
	Effect on recreational activities (hunting, hiking, cycling, etc.)	9.0	significant benefit effect	minor benefit effect
	Effect of the wind farm on aviation	3.0	minor adverse effect	no effect
	Effect of the wind farm on the visual amenity of the landscape	19.0	moderate adverse effect	moderate positive effect
	Clash with cultural/spiritual values associated with the site	21.4	minor adverse effect	no effect
	Effects from wind farm construction activities on daily life (e.g. traffic disruption, dust)	9.9	minor adverse effect	no effect
	Effects of wind farm noise on homeowners	20.1	minor adverse effect	no effect
	Impact of electric /magnetic fields on homeowner's communications (e.g. radio, TV, phones)	6.3	minor adverse effect	no effect
			100	

4.7 SENSITIVITY ANALYSES

Sensitivity analyses can be used to measure the impact on the overall outcome when the relative weightings of the three goals, economic development, environmental protection and social acceptability are varied. In the previous section, the three goals were given equal weighting (33% weighting for each). Now these relative weightings will be changed to observe the resulting impacts. In this regard, sensitivity analyses can provide additional information to check the robustness of the final solution.

Consider first the economic development goal. The weighting assigned to the economic development goal is varied from 0%, so that it is not considered at all, through to 100%, where it is the only goal considered. Simultaneously, the other two goals must be varied accordingly (so that the combined weightings of the three goals are always 100%) and the remaining weighting is split evenly between the other two goals, environmental protection and social acceptability. These changing weightings are graphed in Figure 4.7 (a). The relative utilities are represented on the vertical axis and the weighting assigned to the economic development goal (as a percentage) appears on the horizontal axis. The green line represents the overall utility for the alternative Turitea Reserve 'with' the wind farm when varying the weightings assigned to the economic development goal. Observation is made where the utility of accepting the 'with' wind farm project equals the utility of rejecting the project. This is where the green line intersects the red line, which represents the 'without' project. It indicates the weighting of the economic development goal required in order for the utilities of both alternatives ('with' or 'without' the project) to be equal.

The black vertical line represents a 33.3% weighting for the economic development goal, and consequently where the three goals are given equal weightings or importance. The process of varying the weightings assigned to the goals was repeated for the environmental protection goal (and the results presented in Figure 4.7 (b)) and again for the social acceptability goal (as shown in Figure 4.7 (c)).

Figure 4.7 Results of the impact of changing the relative weightings of each goal (economic, environmental and social) under the two alternatives for the Turitea Reserve

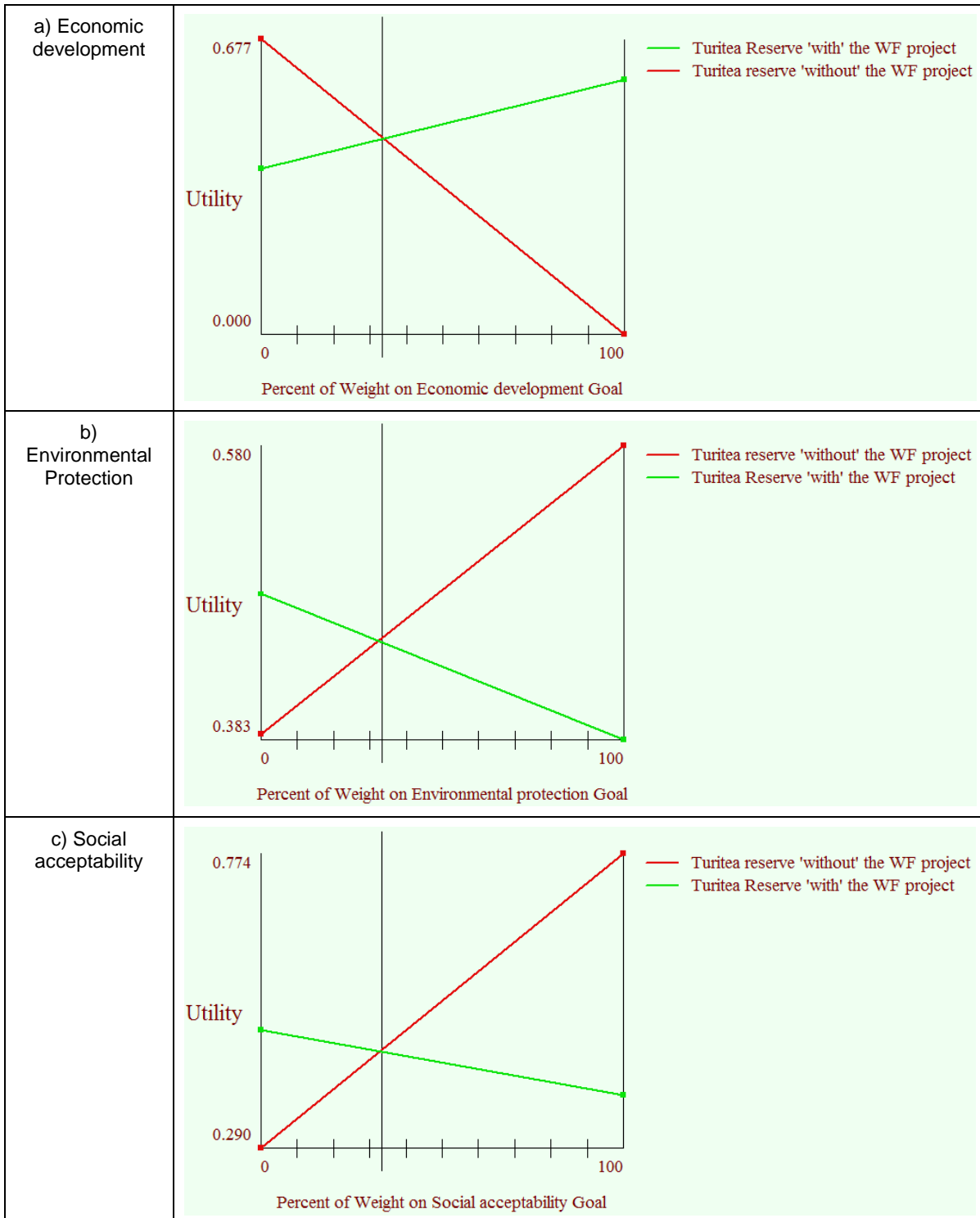


Figure 4.7 (a) shows that economic development would have to represent at least 33.3% (one-third) of the decision preference, which means that the other two goals would also each contribute at most one-third toward the decision, for the Turitea

Reserve 'with' the wind farm to be accepted. Figures 4.7 (b) and (c) also verify this result, that environmental protection and social acceptability must each contribute at most one-third toward the decision, for the wind farm project to be accepted. Further, if greater consideration is to be given to either environmental protection or social acceptability, then the Turitea wind farm project should be rejected.

4.8 MAKING THE RECOMMENDATION

The results obtained are not unequivocal. If equal consideration is to be given to each of the three goals, economic development, environmental protection and social acceptability, then the utility gained from accepting the wind farm project is no different than that gained by rejecting the wind farm project. If less consideration is to be given to the goal of economic development, then the wind farm project should be rejected. This would suggest that further analysis, at a greater depth, should be undertaken to establish a more unambiguous outcome. To this end it is also suggested that a wider range of attributes for each of the goals might be considered, particularly since there was a relatively poor level of agreement amongst the experts regarding the weightings of the attributes considered here.

This is perhaps not surprising given the nature of the project. While the wind farm represents an energy strategy, its location is to be in what was previously a reserve, designated as such under the Reserves Act 1977. If a little more weight is to be given to environmental protection or social acceptability, then the wind farm project should be rejected. Therefore, with further analysis recommended, it is suggested that the energy company putting forward the proposal also looks at what it can do to both mitigate against negative environmental outcomes and to improve the social acceptability of the project. This would go some way toward reducing the trade-off in terms of gains in economic development versus losses of environmental protection and social acceptability.

CHAPTER FIVE - CASE STUDY 2: ABATTOIR

5.1 INTRODUCTION

This section describes the procedure followed in applying the model to a second case study, involving evaluation of the proposed Cisne Austral Lamb Export Abattoir project. The focus is on determining the desirability of a lamb exporting abattoir to be established in the Aysén Region of Chile. According to the Chilean Environmental Act, 1994 (Law No. 19,300)⁵, any activity or project with potential to cause a negative environmental impact requires assessment via the Environmental Impact Assessment System (EIAS) (CONAMA, 1994). Depending on the characteristics of the project and the significance of the impacts, the EIAS distinguishes between two categories of evaluation: an Environmental Impact Study (which is a full environmental assessment) or an Environmental Declaration Report. In line with this law, the Cisne Austral Abattoir project was classified under the second category, thus the submitters were compelled to submit a Declaration Report to local authorities.

The data used in this case study include both primary and secondary data. Primary data was obtained from a weighting assessment undertaken by the researcher with a panel of experts knowledgeable in the economic, environmental and social aspects of project evaluation. The experts were required to score a given set of attributes by articulating their preferences through weights which were applied to a list of attributes relevant to this project. Secondary data were derived from the project's Environmental Declaration Report presented by the submitter to the local authorities, and were used to construct the list of attributes and identify their measures. Data were complemented by information gathered from Chilean Environmental Law and Regulations and relevant literature. The combined data

⁵ Bases generales para el medio ambiente. Ministerio Secretaría General de la Presidencia. Legislación Chilena. 1994.

were then organised in accordance with the categories and measures required for the structure of the model.

5.2 BACKGROUND TO THE PROJECT

The Aysén region in Chilean Patagonia, is widely known by its unique ecological characteristics, including an unspoiled habitat for numerous native terrestrial and aquatic species. The region covers 108,000 km² and has an exceptionally low population density, with less than one person per km². Cattle and sheep grazing has been one of the main economic activities in the region, since settlement began early in the 20th century. As a result, livestock farming and the agricultural sector plays an important role in the local culture and in the Aysén community identity (Martinez Saavedra, 2005).

Livestock production systems are extensive, using large areas of rangelands and semi-arid land to graze sheep and beef cattle, providing high quality food from land, much of which is not suitable for other types of agricultural production (Cobo, 1991). Aysén has approximately 310,000 sheep, two-thirds of which are breeding ewes. With an average productivity indicator equivalent to a 75% rate of survival from birth to weaning, today regional production is around 150,000 lambs each season. Of these, 30,000 are kept for breeder replacement purposes with the remaining 120,000 annually destined for the abattoir (FUCAO, 2011).

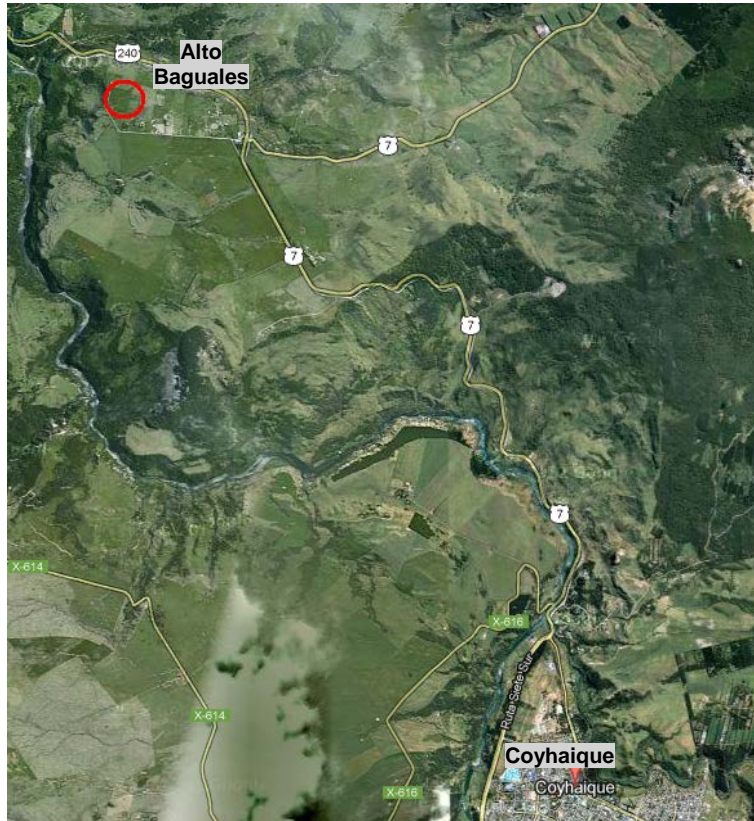
The Aysén region is also characterized by extreme weather and a difficult topography, with long distances and poor connectivity with the rest of the country (Romero, Vásquez, & Smith, 2008). The resulting high transport costs of stock to the market have seen the stagnation of the livestock production sector in the region (Dirección de Planeamiento, 2004). Even when the government has identified sheep production as a sector with high economic potential, the last two decades has seen sheep numbers decline (Instituto Nacional de Estadística, 2010). During the 80s and 90s, the lead cause of the decline in sheep production at the national level was attributed to low profitability caused by a sustained fall in wool prices alongside already low meat prices (Agraria, 2005). At the regional level, this situation was exacerbated due to high transportation costs.

The main meat works serving the largest domestic markets are located in the central part of Chile, about 1000 km from the Aysén region. This means that lambs are transported live for a journey of at least two days, adding considerable cost to sheep meat production (Mera, 2008). The possibility of a regional abattoir could make feasible the possibility of directly exporting from the region, hence directly accessing larger international markets (Brzovic & Jones, 1979; Gobierno Regional de Aysén, 2009).

The project proposal includes the construction and operation of a lamb export abattoir by the company Cisne Austral Ltda. The project site, some 4 ha (indicated by the red circle in Figure 5.1), is located 12.5 km from Coyhaique City and 1.5 km from the rural village of Alto Baguales. This project includes the construction of the slaughter room, the refrigerating and packing area, roofed paddocks, and a wastewater treatment plant. Construction will cover a total area of 3,250 m². Maximum production capacity will reach 500 sheep per day in an 8 hour workday. Annual production is estimated at 150 tonnes/month from January to April, 7 tonnes/month from May to July, and 3-5 tonnes/month from October to December. During the months of August and September, production activity will be reduced almost to zero due to sheep production seasonality and the low supply of animals to slaughter during these months (Faenadora Cisne Austral Ltda, 2011).

The project includes a water treatment system for processing wastewater generated in the process of slaughtering and clean up. Finally, the treated water will be released into a stream which is a tributary of the Simpson River. The organic solid waste (OSW), consisting of bones, pieces of leather, inedible viscera and heads, are estimated at 1,100 kilograms per day during peak operating. These OSW will be stabilized by a steam treatment and sent to Coyhaique City's landfill, together with municipal household waste. In the case of solids obtained from the wastewater treatment plant (blood solids), these will be converted into humus to be reused as fertilizer (Faenadora Cisne Austral Ltda, 2011).

Figure 5.1 General location of the Cisne Austral Abattoir proposal



5.3 OBJECTIVE OF THE STUDY

In order to determinate whether the Cisne Austral Abattoir project should be accepted, rejected or requires a more detailed analysis, the rapid evaluation model developed in this study will be used to compare the two alternatives:

- Development of the Cisne Austral Abattoir
- Status quo, 'without' the development of the Cisne Austral Abattoir

Changes will be measured considering the difference in a number of aspects, between the status quo (baseline situation) and the situation after the implementation of the abattoir project.

5.4 IDENTIFYING THE KEY ATTRIBUTES AND THEIR MEASURES

The Cisne Austral Export Abattoir project proposes to introduce a new service into the agro-industrial sector, reducing the cost of lamb meat products from the Aysén region. New developments in lamb production have the potential to play an

important role both in the local economy and the rural community. There will be benefit for the abattoir project owners and the sheep farmers, but also a variety of potential effects on third parties, the local community and the environment, which should be considered in the project evaluation.

This section identifies and describes all relevant impacts on existing economic, social and bio-physical environments in and around the proposed abattoir development location. These should all be considered when deciding on the Cisne Austral Lamb Export Abattoir project.

Identification of possible effects of a local abattoir was executed using the checklist developed in this research, and it is presented in Table 5.1. The impact values (including magnitude, importance and potential mitigation of impact) were obtained from the 'Environmental Declaration Report' submitted by the company, Cisne Austral Ltda, to the local decision-making authority, and complemented with relevant literature, predetermined policy regulation and/or expert opinion.

From the list of impacts presented in Table 5.1, key attributes were chosen for the model according to the importance rating of the impact. Impacts indicating a low importance were excluded from the model. Impacts with medium to high importance ratings were included in the model regardless of whether mitigation was likely to reduce the impact to a negligent level. This criterion was used in order to take into account impacts that may technically have a low level of impact, but could implicate some level of uncertainties or risk associated with the project management. In this way the selected attribute should demonstrate the characteristics and nature of the project. The final list of attributes for the Cisne Austral Abattoir proposal to be entered into the model for evaluation is summarised in Figure 5.2.

Table 5.1 Full list of effects for the Cisne Austral Lamb Export Abattoir

Goal	Attributes	Sub-Attributes		Effect	Data	Description of measures
A. Economic Development	Productivity growth			+2	no	Promoting the development of sheep production in the region
	Efficiency of resource use	Reducing energy intensity of goods and services		+3	yes	Benefit from the reduced of transportation cost
	Effect across other sectors	Displacement of economic activities		-2	no	negative impact on the livestock transport sector
		Impact at the local commercial sector		+2	yes	Benefits to local business community from investment expenditure
	Economic factors	Price reduction		+1	no	Suppression of meat price rises
	Security of supply	Food security		+1	no	Increase of local food security
	Effect on markets	Access to new markets		+2	no	Improving access of smallholders to new export markets
	Employment	Permanent positions		+2	yes	Number of job during operation
		Temporary positions		+2	yes	Number of new job during construction
B. Environmental Protection	Effect in physical and chemical characteristics	Water	Underground	-2	yes	Threat to availability of water resources
		Atmosphere	Quality	-1	yes	Air pollution during construction and operation Round
	Effect in biological condition	Flora	Grass	-1	yes	Local vegetation disturbance resulting from construction
		Fauna	Fish and shellfish	-2	yes	Effect on aquatic life from the discharge of liquid industrial waste
	Effect in ecological relationships			-2	yes	Risk of solid waste pollution

Goal	Attributes	Sub-Attributes		Effect	Data	Description of measures	
C. Social Acceptability	Population Characteristics	Influx or outflows of temporary workers		-2	yes	Impact of new workforce in the village	
	Concerns about social well-being	Change in land use	Grazing	-2	yes	Change from pastoral to industrial land use	
		Change in aesthetics and Human Interest	Landscape design	-2	yes	Effects on aesthetic perception of the landscape by residents	
	Individual & family changes	Residential stability	Effect on private property		-1	yes	Effects on residential value in surrounding properties
		Perceptions of risk, health & safety	Pest & diseases dissemination		-2	yes	Risk of proliferation of pests and diseases
			Daily life activities		-2	yes	Effects from construction activities on daily life
			Noise		-2	yes	Effects of operational noise on homeowners
		Odours		-2	yes	Undesired odours from the slaughtering process and the paddock areas	
	Institutional Structures	Man-made facilities and activities	Waste management	-2	yes	Use of public facilities (Coyhaique landfill) for solid waste disposal	

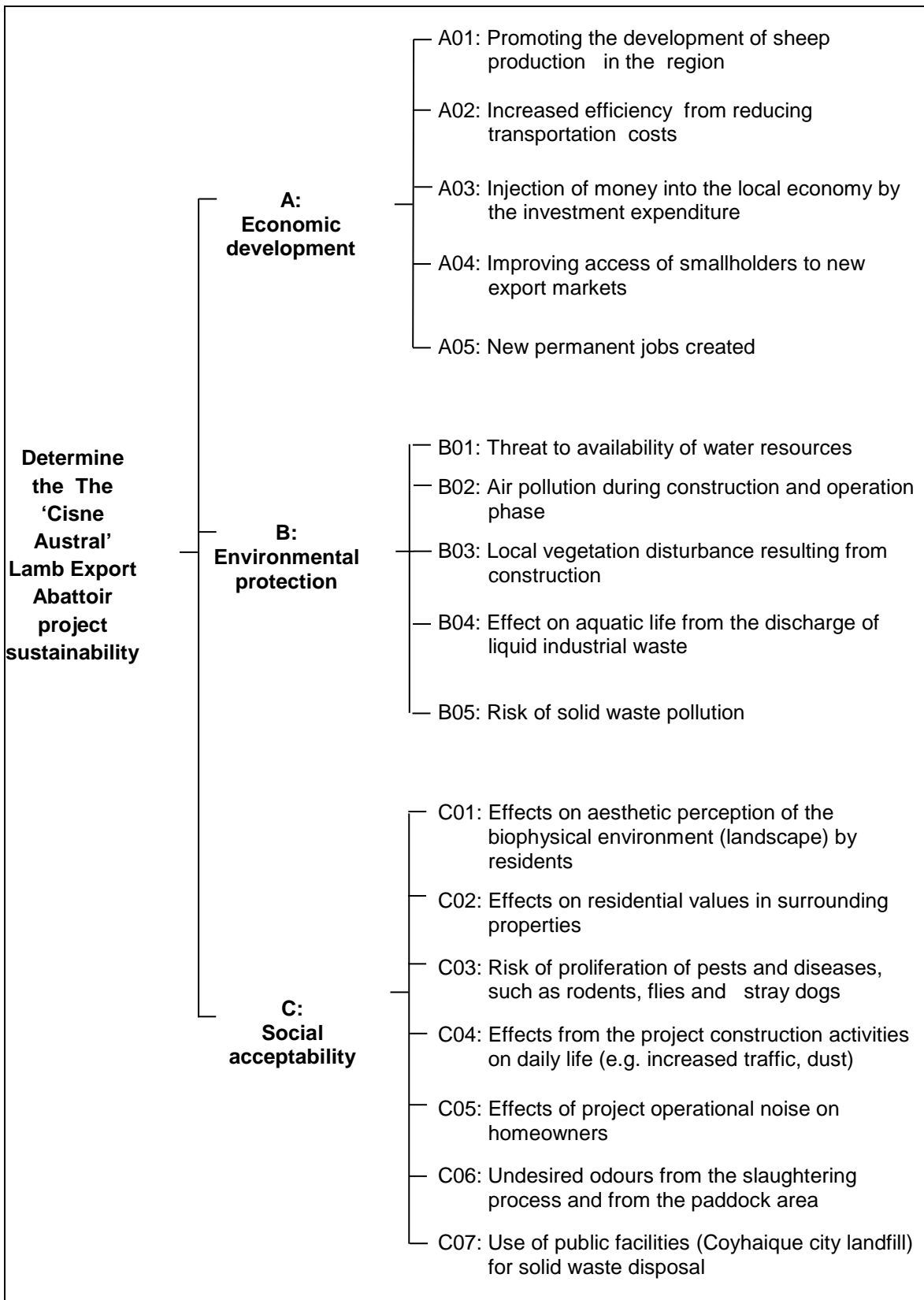
LEGEND

MAGNITUDE	
4	Significant positive effect
3	Moderate positive effect
2	Minor positive effect
1	Negligible positive effect
-1	Negligible negative effect
-2	Minor negative effect
-3	Moderate negative effect
-4	Significant negative effect

IMPORTANCE
Low Importance
Medium Importance
High Importance

POTENTIAL MITIGATION OF IMPACT
Low Importance
Medium Importance
High Importance

Figure 5.2 Key attributes of the Cisne Austral Lamb Export Abattoir project evaluation



In the following sections, these key attributes and their effects on the economic, social and environmental welfare of the region are discussed in depth and where appropriate, qualitative or quantitative measures are provided.

5.4.1 MEASURES OF ECONOMIC DEVELOPMENT

The Patagonian territory is a vast area, in which agriculture has been the economic mainstay for a long time. Farmers have primary responsibility for stewardship of approximately 50% of the land area of the Aysén region (Bachmann, Delgado, & Marin, 2007), and the future of the agricultural sector is of particular importance to the socio-economic future of the region. It is acknowledged that the economy must grow in order to improve the welfare of the community. This abattoir project proposal is aligned with both government policies and the regional plan, adding value to the agricultural sector of the area, and keeping money within the local economy by providing a local service.

This section examines the effects this proposed development project will have on the local economy, tracing both direct impacts of the project itself and indirect impacts on other sectors resulting from subsequent expenditure in the local economy. Since economic aspects of this project were not taken into consideration in the decision-making process and no economic information from the company was requested by the local authorities, the only economic attributes derived from the assessment report undertaken by the company was data related to investment expenditure and the number of jobs associated with the project. All other economic information has been obtained from relevant literature and government department web sites.

A01: Promoting the development of sheep production in the region

The sheep meat export sector is currently experiencing an upward trend in international prices due to increasing demand for the consumption of sheep meat (M. Hervé, 2013). The price increase reflects the lowest sheep stocks in Chile's recent history, and particularly in the Aysén region, with total sheep numbers just

over 300,000, which is less than half the traditional sheep numbers for the region (ARDP Aysén, 2008; Hepp, 2004).

According to Hepp (2004), significant progress has been made on improving the pastoral conditions in Aysén (part of the humid ecosystem zone of Patagonia) and also in technological improvements to enhance primary sheep production. Therefore, there is the potential to sustain greater sheep numbers in the future. As a target in the short to medium term, it is reasonable to expect the region's numbers to increase to around 750,000 sheep, and possibly one million sheep in the long term. In this context of expected growth in sheep numbers, a priority would be to be able to process at least some meat production within the region. A lamb slaughtering plant, therefore, would be of great benefit to the region (FUCAO, 2011).

The proposed abattoir will have a capacity of 50,000 lambs per year, accounting for around 40% of production in the region (FUCAO, 2011), which means it will reduce the number of lambs needing to be sent further afield for processing. Under this analysis, the Cisne Austral Abattoir project is expected to have a minor positive effect on promoting the development of sheep production in the region.

A02: Increased efficiency from reduced transportation costs

The lamb livestock produced in the Aysén region are mostly destined for abattoirs located outside of the region, because there are not enough abattoirs accredited for export in the region and because prices for the lambs are higher at markets outside the region (Tadich, Gallo, Brito, & Broom, 2009). There is not published information available on the transportation price per lamb that farmers pay to get their lambs to the abattoir. However, a study done by INECON for the Ministry of Transport (INECON, 1998) indicated that freight transportation costs from Puerto Chacabuco (main maritime port in the Aysén Region) to Puerto Montt (the next closest maritime port) are 54% higher than the transportation cost for the same distance in central Chile. From this, the Instituto Latinoamericano y del Caribe de Planificación Económica y Social (ILPES, 2002), estimated that the cost of transportation to the meatworks increases the total cost of production by 8% for

Aysén farmers in the livestock sector. A graphical representation of the cost and the time taken to transport livestock from the Aysén Region, carried out by (Romero et al., 2008) indicated that the relative distances were greater than the real distances (Refer to Appendix B, Figure B.1).

A study on the physical condition of lambs arriving at the abattoirs was carried out by Carter & Gallo (2008) by comparing lambs that travelled only 12 hours to abattoirs within the region with those that were transported to abattoirs outside the region, requiring both sea-ferry and truck transportation of up to 46 hours. Comparing both the live-weight loss and the carcass-weight loss of Corriedale lambs from the same area, they found significant difference between the two groups. The loss in both live-weight and carcass weight of the lambs transported for 46 hours was significantly higher than those for the lambs transported within the region for only 12 hours. This represents an additional indirect cost associated with transportation of lambs to abattoirs outside the region.

Therefore, the Cisne Austral Abattoir project has the potential to significantly reduce both direct and indirect transportation costs for farmers able to send their lambs to the proposed local abattoir.

A03: Injection of money into the local economy from the project's capital expenditure

There will be an initial economic impact on the region from the project as a result of construction spending. The capital investment spending carried out by the Cisne Austral Company (on a new plant, machinery and buildings) will represent an injection of money into the local economy in terms of a circular flow of income, over and above consumers' current income. The direct expenditure on construction of the lamb export abattoir is expected to be US\$ 4.85 million (Faenadora Cisne Austral Ltda, 2011). While this impact will have a one-time effect on the local economy, it will generate additional economic activity for the local business community and the construction sector.

Based on the nature of the project and previous experience of abattoir construction in Chile, the proportion of capital expenditure that is captured by the local economy is estimated to be around 60%, since most of the construction activity is likely to be locally sourced. If this ratio holds for the Cisne Austral Abattoir, the local economic impact of construction will be to the order of US\$ 2.91 million. This value represents the amount of the expenditure which will remain within the local economy.

A04: Improving access of smallholders to new export markets

In the last decade, free trade agreements have greatly improved the economic outlook for the sheep production sector in Chile. Sheep-meat exports have grown steadily from US\$ 6.4 billion in 1994 to US\$ 20 million in 2004, representing an average annual growth of 12% (Agraria, 2005). For example, the trade agreement with the European Union has established a tariff-free quota of 5,000 tonnes, with increases of 200 tonnes per year for an indefinite period. This is in excess of the current Chilean export supply, so that this represents a clear benefit for the Aysén Region (Dirección de Planeamiento, 2004).

These benefits are realized principally by farmers of large holdings, whose production levels enable them to absorb the additional cost of sending their lambs to abattoirs outside the region which are accredited to export and so receive export prices for their sheep-meat. In the case of small and medium holdings, lambs are sold either to intermediary agents, such as livestock traders or directly to saleyards for the local market, excluding them from participation in the export market. In this context, the need for a local abattoir with export accreditation has been widely recognised by different government institutions (FUCAO, 2011).

Implementation of the Cisne Austral Abattoir project would incorporate world-class innovations and quality standards, and increase Chilean participation in international sheep-meat trade. The main impact would be at the regional level, giving smallholders opportunity to access the export market, thus giving the project an estimated moderate positive effect.

A05: Permanent jobs created

The project will create over 80 direct and indirect full time equivalent (FTE) jobs. These jobs include temporary and permanent positions. Temporary short-term jobs are mainly generated from the one-off construction activities and are expected to involve about 50 people. The construction company that will perform the civil works and installation of the project will be in charge of personnel required for these positions. These jobs do not represent a significant impact on the local economy, since the construction company and its workers would otherwise be working on another infrastructure project (Faenadora Cisne Austral Ltda, 2011).

The manpower required for operating the plant is estimated at 30 workers. These jobs are associated with each stage of the production process from unloading the lambs, to the slaughter line, through to delivery of the final meat products. In addition, another 10 people will be required for administrative and technical support and services. Permanent positions will offer employment for people not currently working in the meat industry, therefore, job training would be offered by the company (Faenadora Cisne Austral Ltda, 2011). These jobs will enable professional skills development and new labour opportunities having a positive contribution to local employment.

5.4.2 MEASURES OF ENVIRONMENTAL PROTECTION

The principal objective of the inclusion of environmental criteria in REM is to evaluate degradation on pre-existing bio-physical, chemical and ecological conditions of the environment associated with the impacts of proposed project development. The criteria that were selected as key indicators of likely impacts on the environment are described in the subsections which follow (including the potential magnitude of their effects).

B01: Threat to availability of water resources

The meat processing sector (slaughtering and processing) is a heavy user of water, especially during the slaughtering process (Colby & Punda, 2009). All

slaughter premises must have a dependable source of clean water or what is normally referred to as potable water, preferably pipe-borne, to maintain hygienic and sanitary services in the plant. The water must be well distributed in terms of point location inside the premises and must be hot, where possible, for the hygienic washing of products, equipment and facilities. In the absence of pipe-borne water, primarily groundwater sourced from wells, surface water from rivers can be used on the premises to guard against shortages (Heinz, 2008). Impact on water resources refers primarily to groundwater, but can also refer to surface water, and each source has its own sensitivity to availability.

Regulations in Chile indicate that, for the slaughter of livestock, the water requirement is 100 litres per animal during slaughter, or a lesser amount provided it complies with health and safety regulations regarding processing and the quality of the final product⁶. It is also a legal requirement to provide of water for the staff. For human consumption, legislation indicates that the water availability should be, at least, 100 litres/day per person⁷. To meet these standards, the required water will be supplied from two complementary sources: 1) the rural community water supply system from Alto Baguales village, to cover the requirement for the dining hall and toilet facilities, and 2) a deep water well, with an extraction rate of 3 litres/sec during periods of maximum plant performance. The amount of water required for the maximum plant performance in the project design is equivalent to 40,000 litres per day (Faenadora Cisne Austral Ltda, 2011).

The potential direct negative environmental impacts of the use of groundwater arise from over-extraction (withdrawing water in excess of the recharge rate). This can result in the lowering of the water table, land subsidence, and decreased water quality. The abattoir project will be placed in an area of low sensitivity to risk of disrupting water availability; moreover, no other project development or economic activities are extracting water from deep water wells in the nearby vicinity. The only consideration with respect to water quantity that could be of

⁶ Artículo 2, Decreto N ° 61, Ministerio de Agricultura. Legislación Chilena. 2004

⁷ Artículo 14, Decreto Supremo N ° 594/1999, Ministerio de Salud. Legislación Chilena. 1999

concern regarding surface water would be if the abattoir required water to such an extent that it compromised availability to the municipal water supply system for the village. Based on the above analysis the conclusion is that that the project will have a negligent negative impact on water availability.

B02: Air pollution during construction and operation phase

During the construction Round of Cisne Austral Abattoir, the main source of air pollution discharges will be related to engine equipment and vehicles resulting in crankcase emissions, exhaust and dust being released. The motor vehicles and machinery used will primarily produce emissions of nitrogen oxides (NO_x), oil, and suspended particulates along with limited quantities of sulphur dioxide (SO₂), which will result from the use of diesel fuel. Air discharges occurring at the site will be for a short duration, and licensed vehicles will have registration papers and technical reviews updated, to ensure that atmospheric emissions will be kept to a minimum level. The use of trucks and other vehicles to transport materials and equipment to the construction site along 3.5 km of gravel road will cause the generation of particulate emissions and dust. The potential environmental effects from dust to arise during the construction process will be mitigated by watering the road surface to suppress dust (Faenadora Cisne Austral Ltda, 2011).

Once the abattoir plant is operational, the main impact on air quality will be particulate emissions from the boiler. Due to the geographical and climatic characteristics of the location, dispersion of pollutants is likely to be rapid, therefore, gas emissions will not be significant in terms of concentration, nor are they dangerous in nature, therefore, will not present a risk to the environment.

Impact on air quality as a result of atmospheric emissions from an abattoir development are usually only short term and minor, and do not represent a major environmental concern (Comisión Nacional de Medio Ambiente, 1998). Air pollution generated during construction and operation of the Cisne Austral Abattoir is likely to have a negligent negative impact on air quality.

B03: Local vegetation disturbance resulting from construction

Construction of an abattoir and associated services will have an impact on flora and fauna habitat. Recovery will depend on the predominance of the particular flora and ecosystem features.

The dominant vegetation type in the vicinity of the abattoir site corresponds to degraded grasslands. A large proportion of the site has been cleared of original vegetation for farming purposes, and stands of remnant native vegetation are confined to the slopes and the bank of the river corridor. The site itself does not include any species listed as vulnerable, rare or insufficiently known, under the national lists of endangered species.

The project also requires the construction of an access road onto the property, interior roads and parking lots, besides the plant facilities. The construction areas will need to be cleared and vegetation removed. This disturbance will make the site vulnerable to invasive plants and weeds. Therefore, construction will have a negligent negative effect on local vegetation.

B04: Effect on aquatic life from the discharge of liquid industrial waste

The main potential impact on the site and on surface and groundwater quality is the highly polluting discharge from slaughterhouse activities, which will be produced whenever waste degrades or decomposes (Comisión Nacional de Medio Ambiente, 1998). Typical contaminants are organic acids, ammonia, which pollute groundwater by percolation, and surface water by seepage and runoff and which have a high biochemical oxygen demand (BOD) (Kist, Moutaqi, & Machado, 2009; Sangodoyin & Agbawhe, 1992).

Effluent from the slaughter process will be subjected to secondary treatment to remove the majority of BOD, however, there may be some localised impact to freshwater flora and fauna as a result of the discharge. Increased nutrient concentrations in the vicinity of the final discharge may result in a shift in normal phytoplankton populations and minor algal blooms. Whilst the majority of bacteria

will be removed from the slaughterhouse, all micro-organisms cannot be guaranteed to be removed, therefore, some will be discharged along with the effluent. Fish and other aquatic life can be severely affected by slaughterhouse effluent pollution in the river. This has the potential for eutrophication of the water body making the water uninhabitable for fish and other aquatic life and unsuitable for irrigation or for drinking purposes (Manjunath, Mehrotra, & Mathur, 2000).

The wastewater from the slaughterhouse contains large amounts of organic material and nitrogen as well as residues of cleaning agents. The high concentration of pollutants in the wastewater will largely be traced to the tripe dressing plants and to the treatment of waste blood. Pollutants in the water consist of dissolved and emulsified organic substances. These cannot be separated by filtering or by grease or sludge separators. The implementation of a spill contingency or containment plan will reduce the risk of pollution from slaughterhouse effluent. The project guarantees that the treatment of slaughterhouse effluent will be undertaken before discharge. This treatment will reduce the presence of ammonia and BOD. All contaminated water will be collected prior to treatment (Faenadora Cisne Austral Ltda, 2011).

Other potential sources of surface and groundwater contamination are from fuel, oil or chemical spillage from maintenance and storage areas. Water pollution can affect its suitability for drinking purposes. There are also likely to be additional adverse effects on aquatic ecosystems. The operation of heavy equipment for trenching and pipe installation during construction may result in direct and indirect impacts on benthic fauna (Comisión Nacional de Medio Ambiente, 1998). Benthic and pelagic communities may be affected by sedimentation resulting from disturbance and suspension of freshwater sediments in the water column. However, given the inherent resilience of benthic and pelagic species, recolonisation is usually quite rapid (Manjunath et al., 2000).

The scale or severity of these effects will depend on factors such as the current condition of the water quality, the final composition of treated effluent and the

management of the water pollution risk by the contingency plan. The impact is expected to have a moderate negative effect on aquatic life.

B05: Risk of solid waste pollution

In this context, waste is defined as the by-products of animal slaughter that are either low-value materials (e.g. edible offal) or of no value (inedible remains). Excluding the low-value edible by-products (such as livers, kidneys and intestines), the abattoir will produce four main waste streams:

1. Large volumes of residual material resulting from sheep slaughter that is not destined for human consumption (e.g. internal organs, and hide and skin);
2. Waste solids from red liquid industrial waste: Red liquid industrial waste is generated in the slaughtering Round and is composed of washing water of carcasses and blood. It is gravity-collected in trays; this procedure involves obtaining blood clotting plasma separation of solids. The liquid waste is sent to the water treatment plant and the solids are processed by direct steam treatment (a pressure cooking process);
3. Waste solids from green liquid industrial waste: green liquid industrial waste is generated when the stomach and gut contents are emptied. These are sent for pre-treatment in which the solids are mechanically separated from the liquid, using a trapezoidal mesh filter (with a diameter of 0.5 cm). These solids are then sent to a compacting treatment system which is a medium filter that removes up to 90% of the water from the filtered solids of the previous Round;
4. Packaging and domestic waste: The risk of solid waste pollution will depend on both how it is managed and its final disposal, resulting in either no effect through to minor negative effects.

5.4.3 MEASURES OF SOCIAL ACCEPTABILITY

In selecting a site for a proposed abattoir due consideration must be given to, where possible, avoiding residential areas (particularly densely developed residential areas) and recreational areas (Cobo, 1991; Fontes, Fontes, & Carneiro, 2009). The Cisne Austral abattoir project will be situated in a rural area, 1.5 km from a small village, which is home to a group of 27 families. Most of the social acceptability measures relate to this community, since they are the ones potentially impacted by the project.

C01: Effects on aesthetic perceptions of the biophysical environment (landscape) by residents

Of consideration here are two separate but closely related aspects. The first relates to visual impact, focusing on the extent to which the new development will be seen. The site of the project will only be visible from one point on Route 7, and the design of the facilities will include rounded lines and colours that will blend into the local environment.

The second relates to impact on the character of the landscape. This was identified by evaluating responses toward the combined effects of the proposed abattoir. This is complex because it encompasses many other impacts such as noise, odour and even ecology. The construction of an abattoir will impact on views in as much as it will result in the loss of mature trees and vegetation and interruption of the rolling topography. However, such impacts will be minimised by site rehabilitation and restoration, so that overall, aesthetic effects are likely to be minor and negative.

C02: Effects on the residential value of surrounding properties

Whilst there is real concern regarding the effect on property values for communities living in close proximity to industrial areas, there have been no studies conducted to ascertain the impact of new industry on property values in rural Chile. In a New Zealand study conducted by (Grimes & Young, 2009), they

maintained that the establishment of a meatworks or abattoir in non-urban areas may bring social benefits to rural towns. These benefits include urban growth, access to better education and health services and others, which can have a positive effect on property values. They suggested that an abattoir is a form of infrastructure, often servicing multiple suppliers and as such provides the commercial substance to attract other service providers to the locality. De Vor and de Groot (2010) stated that while industrial sites can be considered important contributors to the local economy, concerns have been raised about the possible negative external effects of these industrial activities, particularly on households. These negative effects are closely related to direct impacts such as incremental increases in noise levels, traffic and congestion, air pollution and obstruction of view. De Vor and de Groot (2010) basing their estimations on other studies (Smolen et al., 1991; Mendelsohn et al., 1992) have reported evidence of adverse impacts on property values ranging from as low as 0.24% to as high as 25%, depending on the extent of pollution and the location of the property. Visser and Van Dam (2006) (cited by de Vor and de Groot (2010)) also concluded that property values are negatively affected by 'disamenities' like the presence of industrial sites, and their proximity to those properties.

Whilst no formal study has been carried out, personal communication with the inhabitants of Alto Baguales suggest that the effect of the proposed Cisne Austral Abattoir on the property values is not expected to be significant. This small community is not a growing one, with virtually no demand for new sites to build houses and also because the abattoir buildings are going to be located out of sight of the town residential area.

C03: Risk of proliferation of pests (and their associated diseases), such as rodents, flies and stray dogs

Health risks can occur due to poor hygiene practices at the operational and waste management level. Hygiene measures deal with the operational aspects of slaughter and the creation of conditions under which animals, activities and personnel can be secure without risk of contamination. Sanitation is focused on

the establishment and maintenance of a healthy work environment and appropriate conditions congenial to the attainment of a sanitised product (Heinz, 2008).

In this context, the scope of sanitation will be identified broadly with structures and facilities, i.e. the construction and maintenance of the premises, and the installation and maintenance of the equipment. In addition, sanitation covers specific slaughter operations that are likely to cause contamination, e.g. offal cleaning, waste disposal and infestation by pests, etc.

The premises will be fenced to keep out undesirable individuals and to prevent animals from entering the yard. The term 'vermin' is applied to creatures which by nature like living close to man, scavenging on food and filth. In slaughter premises common vermin are rats, mice, flies and cockroaches. All multiply in great numbers within a short time. The dangers posed by these creatures is that they live in hidden places such as splits, holes and crevices in floors and walls gathering dirt on their skin, appendages, mouth or mouthparts with which they contaminate food. Furthermore, by their contamination of food, they are capable of transmitting disease to humans. In the case of rats, they can cause food poisoning, rabies, typhus fever and bubonic plague, among other diseases (Faenadora Cisne Austral Ltda, 2011).

Cleanliness and general sanitation keeps them away. In contrast, accumulation of waste, refuse, manure etc. soon attracts them to the slaughter premises. Doors and windows should be secured against all possible openings to ward off vermin. The insect group are usually kept away by fly-proof and fly trap devices as well as gauze screenings, while rodents are best exterminated by chemical poisons. However, caution should be exercised in the use of chemical exterminators as some of them often have harmful effects on humans. With appropriate hygiene and sanitation, the effect of the risk of pests and their associated diseases are likely to be minor and negative.

C04: Effects from SH construction activities on daily life (e.g. increased traffic, dust)

The construction of an abattoir will result in an increase in traffic in the vicinity of the site, as a result of construction workers and construction vehicles accessing the site. Once it is operational, there will be minimal traffic activity associated with the abattoir. One to two stock trucks (with a carrying capacity of 200 to 400 lambs) will be required daily at peak production periods, and sludge from the abattoir will need to be removed by truck. However, overall, effects will be negative and minor.

C05: Effects of SH noise on homeowners

Construction of an abattoir may cause temporary, localised increases in background ambient sound. The specific impact will depend on the method of construction and the equipment used. Noise levels emitted during the construction may well exceed levels that normally characterise the project area and will depend on whether it is a rural or urban location (Comisión Nacional de Medio Ambiente, 1998). The principal noise sources associated with abattoir construction activities include heavy equipment such as bulldozers, scrapers, and trucks. However, these noise sources will only have a temporary impact for the duration of the construction.

Transport to and from the abattoir, as well as the unloading of stock and the loading of products to market may cause noise disturbances. Noise from the stock holding pens and from fans, refrigeration equipment and similar machines may also cause disturbance. Noise emissions from the operation of the abattoir will be continuous, and since night time limits are more restrictive than daytime limits, these should be used as the appropriate noise criteria for evaluating potential impacts to noise sensitive receptors. It is usual to design such abattoirs to meet the night time criterion of 45dB(A), thereby minimising impacts of noise emissions (Maclean, 2009).

Since noise levels diminish at least 6dB per doubling of distance from the noise source, noise emissions will be localised. Also, due to the distance of the proposal

abattoir from the village, noise impacts are expected to have a minor negative effect.

C06: Undesirable odours from the slaughter process and from the paddock area

Odours associated with the abattoir will mainly be those produced by the operation of the facility. Any odours from oil spills will be those associated with the operation of construction equipment, and will be of a temporary and localised nature.

Operations at the abattoir may cause problems with unpleasant odours. Unpleasant odours come primarily from the disposal of offal and waste, but can also come from parts of the internal waste water treatment and from the holding pens. The intensity depends on how much of the contents of the stomach, intestines and the waste (mainly manure) are treated (Comisión Nacional de Medio Ambiente, 1998).

The generation of odours is a by-product of the decomposition of biodegradable waste, the effluent treatment plant, the rendering unit, composting, and the carcass incinerator. Suitable bio filters will be installed to contain odours either by absorption or another medium or by incineration.

Mitigation practises adopted will include (Faenadora Cisne Austral Ltda, 2011):

- Biofiltration to remove odorous compounds;
- Condensation of cooking/rendering steam, sub-cooling of condensate;
- Chemical scrubbing;
- Good housekeeping: prompt removal of dung, spilt body contents or by-products such as blood and fats.

The generation of odours will have a minor negative effect.

C07: Use of public facilities (Coyhaique landfill) for solid waste disposal

The abattoir processing plant will dispose of final solid waste in the Coyhaique landfill, where it will be required to pay for the disposal of waste materials. It will also incur transport and handling costs. The impact is expected to be minor and negative.

5.5 DETERMINING THE WEIGHTS FOR EACH ATTRIBUTE

To determine the priorities of each selected attribute (five from each of economic development and environmental protection, and seven from social acceptability) and weight them accordingly, a survey instrument was developed using the analytical hierarchy process (AHP). This methodology allows for the comparison of every attribute with every other attribute in turn, in a pair-wise manner. The full questionnaire developed for the Cisne Austral Abattoir model is given in Appendix B, Section B.2. The calculation of the attribute weightings will be described in the paragraphs which follow.

The attribute weightings were obtained from a group exercise conducted with a panel of experts in the fields of economic, environmental and social aspects of project evaluation. The experts invited to participate were chosen from the local community. A requirement to form part of the panel was that they should have prior knowledge of the nature of the project and its implications whilst not being classified as stakeholders. The reason for this requirement was to avoid any conflict of interest and keep the weighting assessment unbiased. Eight experts agreed to complete the questionnaire and participate in this research. This part of the analysis took 5 weeks (from 14th October – 18th November 2011). Following the method described in Chapter Three, the weighting procedure was conducted in three rounds. Each round and its results are described below.

5.5.1 ROUND ONE OF THE INTERACTIVE PROCESS

An individual meeting was conducted with each expert in order to obtain their independent input. During this first visit, general project information was presented

by the researcher as was the methodology to weight the attributes and the characteristics of the model. The experts then completed the survey questionnaire. The meeting took about one hour: 40 minutes for the introductory talk and about 20 minutes to answer the questionnaire.

Results from the questionnaires were analysed and aggregated to obtain Round one results. The LDW software was used to calculate the weights for this study, by entering the raw data from the questionnaires into the pair-wise comparison matrix from the Logical Decision software. The AHP method automatically calculated the weighting after each pair-wise comparison was completed. The weights assigned by each expert to each attribute are summarized in the tables which follow (Table 5.2, 5.3, 5.4), and the mean and coefficient of variation of the aggregated values were calculated to obtain an overall weight for each attribute based on the Round One results from the expert panel.

Table 5.2 Weightings for the economic development attributes from Round One

Participants	Attributes									
	A01		A02		A03		A04		A05	
	%	rank	%	rank	%	rank	%	rank	%	rank
1	12.58	3	40.12	2	3.51	4	40.48	1	3.31	5
2	24.32	2	19.89	3	6.68	4	5.50	5	43.61	1
3	22.28	2	19.38	3	3.85	5	48.34	1	6.15	4
4	31.02	2	35.68	1	8.35	4	19.07	3	5.88	5
5	17.28	3	4.99	5	16.26	4	20.51	2	40.96	1
6	27.44	2	21.92	3	3.43	5	38.85	1	8.35	4
7	11.25	4	5.48	5	33.09	2	16.03	3	34.15	1
8	37.06	1	35.19	2	9.56	4	12.04	3	6.14	5
MEAN	22.91	2	22.83	3	10.59	5	25.10	1	18.57	4
CV	0.39		0.59		0.95		0.61		0.95	

A01: Promoting the development of sheep production in the region,

A02: Increased efficiency from reduced transportation cost,

A03: Injection of money into the local economy by the investment expenditure,

A04: Improving access of smallholders to new export markets,

A05: New permanent jobs created.

CV: Coefficient of variation.

Table 5.3 Weightings for the environmental protection attributes from Round One

Participants	Attributes									
	B01		B02		B03		B04		B05	
	%	rank	%	rank	%	rank	%	rank	%	rank
1	21.29	2	58.76	1	6.17	4	9.88	3	3.89	5
2	44.84	1	13.34	4	4.24	5	21.94	2	15.63	3
3	27.54	2	4.91	4	4.73	5	51.74	1	11.09	3
4	46.94	1	10.10	3	5.10	5	28.74	2	9.12	4
5	51.06	1	13.68	3	4.57	5	12.52	4	18.17	2
6	52.49	1	16.61	3	2.67	5	19.16	2	9.07	4
7	6.04	4	19.09	2	3.31	5	61.27	1	10.28	3
8	26.68	2	8.01	4	5.58	5	48.15	1	11.59	3
MEAN	34.61	1	18.06	3	4.55	5	31.67	2	11.11	4
CV	0.48		0.94		0.25		0.61		0.39	

B01: Threat to availability of water resources,

B02: Air pollution during construction and operation Round,

B03: Local vegetation disturbance resulting from construction,

B04: Effect on aquatic life from the discharge of liquid industrial waste,

B05: Risk of solid waste pollution,

CV: Coefficient of variation.

Table 5.4 Weightings for the social acceptability attributes from Round One

Participants	Attributes													
	C01		C02		C03		C04		C05		C06		C07	
	%	rank	%	rank	%	rank	%	rank	%	rank	%	rank	%	rank
1	15.95	4	1.13	7	13.51	5	23.92	1	18.82	2	16.34	3	10.33	6
2	3.19	7	18.41	3	18.89	2	17.08	4	7.43	5	27.67	1	7.32	6
3	13.35	3	29.13	2	5.36	5	2.42	7	6.53	4	39.93	1	3.27	6
4	6.57	6	10.67	5	23.13	1	15.53	4	21.75	2	19.66	3	2.70	7
5	2.47	7	13.20	4	27.33	1	19.25	3	12.66	5	20.90	2	4.19	6
6	2.94	7	3.91	6	40.14	1	17.32	3	6.21	5	8.34	4	21.14	2
7	22.05	2	36.93	1	11.98	4	5.06	6	7.24	5	14.74	3	2.00	7
8	9.02	5	24.34	2	17.28	3	5.19	6	13.69	4	25.57	1	4.91	7
MEAN	9.44	7	17.22	4	19.70	2	13.22	3	11.79	5	21.64	1	6.98	6
CV	0.75		0.72		0.54		0.60		0.51		0.44		0.91	

C01: Effects on aesthetic perception of biophysical environment (landscape) by residents,

C02: Effects on residential value in surrounding properties,

C03: Risk of proliferation of pests and diseases' vectors,

C04: Effects from construction activities on daily life,

C05: Effects of operational noise on homeowners,

C06: Undesired odours from slaughtering process and from the paddock area,

C07: Use of public facilities (Coyhaique landfill) for solid waste disposal,

CV: Coefficient of variation.

The aggregated weights (given by the means) obtained from the experts was then directly entered into the LDW to obtain the inverse matrix for the aggregated weights of for each of the attributes (Tables 5.5, 5.6, 5.7). The eigenvalues (the

values off the diagonals, highlighted in blue) indicate the degree of preference for one attribute with respect to another (from the pair-wise comparisons in the survey). The matrix generates two reciprocal eigenvalues (for each pair-wise comparison), from which only eigenvalues ≥ 1 are used. These eigenvalues were added to each expert's questionnaire responses, to indicate the collective response as compared to the expert's individual response. Since the eigenvalues generated by the inverse matrix were calculated from the means, they are expressed as decimal values. These decimal values were rounded to the nearest whole number; however, eigenvalues with a decimal of 0.5 were marked in between the two whole numbers. For example, an eigenvalue of 4.509 was marked at 4.5 rather than being rounded up to 5 on the questionnaire.

Table 5.5 Inverse matrix for the weightings of the economic development attributes from Round One

I-max = 5.000 C.I. = 0.000 C.R. = 0.000	A01	A02	A03	A04	A05
A01	0.229	1.004	2.163	0.913	1.234
A02	0.997	0.228	2.156	0.910	1.229
A03	0.462	0.464	0.106	0.422	0.570
A04	1.096	1.099	2.370	0.251	1.352
A05	0.811	0.813	1.754	0.740	0.186

A01: Promoting the development of sheep production in the region,

A02: Increased efficiency from reduced transportation cost,

A03: Injection of money into the local economy by the investment expenditure,

A04: Improving access of smallholders to new export markets,

A05: New permanent jobs created.

Table 5.6 Inverse matrix for the weightings of the environmental protection attributes from Round One

I-max = 5.000 C.I. = 0.000 C.R. = 0.000	B01	B02	B03	B04	B05
B01	0.346	1.916	7.607	1.093	3.115
B02	0.522	0.181	3.969	0.570	1.626
B03	0.131	0.252	0.045	0.144	0.410
B04	0.915	1.754	6.960	0.317	2.851
B05	0.321	0.615	2.442	0.351	0.111

B01: Threat to availability of water resources,

B02: Air pollution during construction and operation Round,

B03: Local vegetation disturbance resulting from construction,

B04: Effect on aquatic life from the discharge of liquid industrial waste,

B05: Risk of solid waste pollution.

Table 5.7 Inverse matrix for the weightings of the social acceptability attributes from Round One

I-max = 7.000 C.I. = 0.000 C.R. = 0.000	C01	C02	C03	C04	C05	C06	C07
C01	0.094	0.548	0.479	0.714	0.801	0.436	1.352
C02	1.824	0.172	0.874	1.303	1.461	0.796	2.467
C03	2.087	1.144	0.197	1.490	1.671	0.910	2.822
C04	1.400	0.768	0.671	0.132	1.121	0.611	1.894
C05	1.249	0.685	0.598	0.892	0.118	0.545	1.689
C06	2.292	1.257	1.098	1.637	1.835	0.216	3.100
C07	0.739	0.405	0.354	0.528	0.592	0.323	0.070

C01: Effects on aesthetic perception of biophysical environment (landscape) by residents,
 C02: Effects on residential value in surrounding properties,
 C03: Risk of proliferation of pests and diseases' vectors,
 C04: Effects from construction activities on daily life,
 C05: Effects of operational noise on homeowners,
 C06: Undesired odours from slaughtering process and from the paddock area,
 C07: Use of public facilities (Coyhaique landfill) for solid waste disposal.

5.5.2 ROUND TWO OF THE INTERACTIVE PROCESS

In order to promote a better understanding among the experts, the combined results from Round One were shared with each expert in the group, thereby allowing the participants to consider the other experts' opinions alongside their own and if desired, refine their own estimates before meeting up with rest of the expert participants. Thus Round Two results, shown in the next set of tables (Tables 5.8, 5.9, 5.10), represent the new aggregated values of the weights obtained after a second round of responses from each expert, taking into consideration the combined results from Round One.

Due to the differing background and expertise of the participants on the panel of experts, it was expected to find within the group different assumptions, viewpoints, and interpretations of the issues concerning each of the attributes, which would then be reflected in the weightings they gave to each attribute. The coefficients of variation obtained for each attribute from this second round were particularly relevant for the final round of this approach. The attributes with the greater coefficients of variation indicated the attributes for which there was least agreement in terms of the weightings assigned. Therefore it would be these attributes that required more attention in order to reach consensus in the last interactive round.

Table 5.8 Weightings for the economic development attributes from Round Two

Participants	Attributes									
	A01		A02		A03		A04		A05	
	%	rank	%	rank	%	rank	%	rank	%	rank
1	17.22	3	34.24	2	6.89	4	34.96	1	6.69	5
2	26.77	1	23.11	3	9.49	5	16.55	4	24.08	2
3	24.07	2	20.08	3	5.04	5	42.16	1	8.65	4
4	28.14	2	34.04	1	10.38	4	20.81	3	6.63	5
5	17.72	4	5.68	5	18.11	3	21.27	2	37.21	1
6	27.47	2	22.22	3	4.58	5	35.69	1	10.05	4
7	15.43	4	5.89	5	32.94	1	15.67	3	30.06	2
8	32.72	1	28.47	2	10.99	4	19.31	3	8.51	5
MEAN	23.69	2	21.72	3	12.30	5	25.80	1	16.49	4
CV	0.26		0.51		0.76		0.39		0.74	

A01: Promoting the development of sheep production in the region,

A02: Increased efficiency from reduced transportation cost,

A03: Injection of money into the local economy by the investment expenditure,

A04: Improving access of smallholders to new export markets,

A05: New permanent jobs created.

CV: Coefficient of variation.

Table 5.9 Weightings for the environmental protection attributes from Round Two

Participants	Attributes									
	B01		B02		B03		B04		B05	
	%	rank	%	rank	%	rank	%	rank	%	rank
1	26.07	2	48.10	1	4.99	5	12.65	3	8.19	4
2	39.40	1	13.21	3	4.17	5	31.02	2	12.19	4
3	29.64	2	11.50	3	4.42	5	43.03	1	11.41	4
4	42.39	1	13.95	3	5.30	5	29.64	2	8.71	4
5	43.63	1	14.76	4	4.25	5	22.19	2	15.18	3
6	53.37	1	16.54	3	2.89	5	19.33	2	7.88	4
7	7.29	4	18.57	2	3.00	5	60.64	1	10.50	3
8	29.63	2	11.51	4	4.85	5	41.82	1	12.20	3
MEAN	33.93	1	18.52	3	4.23	5	32.54	2	10.78	4
CV	0.41		0.66		0.21		0.48		0.23	

B01: Threat to availability of water resources,

B02: Air pollution during construction and operation Round,

B03: Local vegetation disturbance resulting from construction,

B04: Effect on aquatic life from the discharge of liquid industrial waste,

B05: Risk of solid waste pollution.

Table 5.10 Weightings for the social acceptability attributes from Round Two

Participants	Attributes													
	C01		C02		C03		C04		C05		C06		C07	
	%	rank	%	rank	%	rank	%	rank	%	rank	%	rank	%	rank
1	17.62	3	4.09	7	10.35	5	22.01	2	10.37	4	25.77	1	9.80	6
2	4.85	7	18.17	3	18.93	2	16.25	4	11.48	5	21.89	1	8.44	6
3	10.52	4	16.90	3	20.13	2	4.78	6	9.73	5	33.38	1	4.56	7
4	8.24	6	21.43	2	22.32	1	10.56	5	13.58	4	19.74	3	4.13	7
5	3.06	7	11.46	5	24.00	1	20.16	3	13.62	4	22.73	2	4.96	6
6	3.33	7	4.63	6	34.49	1	18.45	3	7.28	5	9.91	4	21.91	2
7	20.40	2	28.99	1	14.64	4	6.83	6	9.89	5	15.25	3	4.01	7
8	9.86	5	21.07	2	21.08	3	8.06	6	11.52	4	22.46	1	5.95	7
MEAN	9.73	6	15.84	3	20.74	2	13.39	4	10.94	5	21.39	1	7.97	7
CV	0.66		0.54		0.34		0.50		0.19		0.33		0.75	

C01: Effects on aesthetic perception of biophysical environment (landscape) by residents,

C02: Effects on residential value in surrounding properties,

C03: Risk of proliferation of pests and diseases' vectors,

C04: Effects from construction activities on daily life,

C05: Effects of operational noise on homeowners,

C06: Undesired odours from slaughtering process and from the paddock area,

C07: Use of public facilities (Coyhaique landfill) for solid waste disposal.

Again, the inverse matrix procedure was used to obtain the eigenvalues that indicate the degree of preference for one attribute with respect to another (from the pair-wise comparisons in the survey). In order to do so, the aggregated weights obtained from the experts in the second round were entered into the LDW to obtain the inverse matrices (Tables 5.11, 5.12, 5.13)

Table 5.11 Inverse matrix for the weightings of the economic development attributes from Round Two

I-max = 5.000 C.I. = 0.000 C.R. = 0.000	A01	A02	A03	A04	A05
A01	0.237	1.091	1.926	0.918	1.437
A02	0.917	0.217	1.766	0.842	1.317
A03	0.519	0.566	0.123	0.477	0.746
A04	1.089	1.188	2.098	0.258	1.565
A05	0.696	0.759	1.341	0.639	0.165

A01: Promoting the development of sheep production in the region,

A02: Increased efficiency from reduced transportation cost,

A03: Injection of money into the local economy by the investment expenditure,

A04: Improving access of smallholders to new export markets,

A05: New permanent jobs created.

Table 5.12 Inverse matrix for the weightings of the environmental protection attributes from Round Two

I-max = 5.000 C.I. = 0.000 C.R. = 0.000	B01	B02	B03	B04	B05
B01	0.339	1.832	8.021	1.043	3.147
B02	0.546	0.185	4.378	0.569	1.718
B03	0.125	0.228	0.042	0.130	0.392
B04	0.959	1.757	7.693	0.325	3.019
B05	0.318	0.582	2.548	0.331	0.108

B01: Threat to availability of water resources,
 B02: Air pollution during construction and operation Round,
 B03: Local vegetation disturbance resulting from construction,
 B04: Effect on aquatic life from the discharge of liquid industrial waste,
 B05: Risk of solid waste pollution.

Table 5.13 Inverse matrix for the weightings of the social acceptability attributes from Round Two

I-max = 7.000 C.I. = 0.000 C.R. = 0.000	C01	C02	C03	C04	C05	C06	C07
C01	0.097	0.614	0.469	0.727	0.889	0.455	1.221
C02	1.628	0.158	0.764	1.183	1.448	0.741	1.987
C03	2.132	1.309	0.207	1.549	1.896	0.970	2.602
C04	1.376	0.845	0.646	0.134	1.224	0.626	1.680
C05	1.124	0.691	0.527	0.817	0.109	0.511	1.373
C06	2.198	1.350	1.031	1.597	1.955	0.214	2.684
C07	0.819	0.503	0.384	0.595	0.729	0.373	0.080

C01: Effects on aesthetic perception of biophysical environment (landscape) by residents,
 C02: Effects on residential value in surrounding properties,
 C03: Risk of proliferation of pests and diseases' vectors,
 C04: Effects from construction activities on daily life,
 C05: Effects of operational noise on homeowners,
 C06: Undesired odours from slaughtering process and from the paddock area,
 C07: Use of public facilities (Coyhaique landfill) for solid waste disposal.

5.5.3 ROUND THREE OF THE INTERACTIVE PROCESS

In the third round the experts were brought together in a focus group setting to discuss the attribute weightings in order to come to a consensus on the final values those weightings should take. From Round Two, the attributes with the greatest coefficients of variation were those for which the experts had least agreement in the weightings they had each assigned to that attribute. For this reason, discussion at the focus group meeting concentrated on those attributes which had the highest coefficients of variation. Finally, the experts were asked, in light of the discussion, to refine their estimates one more time. The results from Round Three are shown in Tables 5.14 to 5.16.

Table 5.14 Weightings for the economic development attributes from Round Three

Participants	Attributes									
	A01		A02		A03		A04		A05	
	%	rank	%	rank	%	rank	%	rank	%	rank
1	17.22	3	34.24	2	6.89	4	34.96	1	6.69	5
2	26.77	1	23.11	3	9.49	5	16.55	4	24.08	2
3	24.07	2	20.08	3	5.04	5	42.16	1	8.65	4
4	28.14	2	34.04	1	10.38	4	20.81	3	6.63	5
5	14.78	4	6.40	5	22.43	3	22.94	2	33.46	1
6	27.47	2	22.22	3	4.58	5	35.69	1	10.05	4
7	18.20	4	16.24	5	20.02	3	20.58	2	24.95	1
8	32.72	1	28.47	2	10.99	4	19.31	3	8.51	5
MEAN	23.67	2	23.10	3	11.23	5	26.62	1	15.38	4
CV	0.27		0.40		0.59		0.36		0.68	

A01: Promoting the development of sheep production in the region,
A02: Increased efficiency from reduced transportation cost,
A03: Injection of money into the local economy by the investment expenditure,
A04: Improving access of smallholders to new export markets,
A05: New permanent jobs created.

Table 5.15 Weightings for the environmental protection attributes from Round Three

Participants	Attributes									
	B01		B02		B03		B04		B05	
	%	rank	%	rank	%	rank	%	rank	%	rank
1	27.57	2	38.28	1	3.34	5	22.47	3	8.34	4
2	39.40	1	13.21	3	4.17	5	31.02	2	12.19	4
3	29.64	2	11.50	3	4.42	5	43.03	1	11.41	4
4	42.39	1	13.95	3	5.30	5	29.64	2	8.71	4
5	43.63	1	14.76	4	4.25	5	22.19	2	15.18	3
6	42.30	1	16.26	3	3.53	5	26.94	2	10.97	4
7	7.29	4	18.57	2	3.00	5	60.64	1	10.50	3
8	29.63	2	11.51	4	4.85	5	41.82	1	12.20	3
MEAN	32.73	1	17.25	3	4.11	5	34.72	2	11.19	4
CV	0.37		0.51		0.19		0.38		0.19	

B01: Threat to availability of water resources,
B02: Air pollution during construction and operation Round,
B03: Local vegetation disturbance resulting from construction,
B04: Effect on aquatic life from the discharge of liquid industrial waste,
B05: Risk of solid waste pollution.

Table 5.16 Weightings for the social acceptability attributes from Round Three

Participants	Attributes													
	C01		C02		C03		C04		C05		C06		C07	
	%	rank	%	rank	%	rank	%	%	rank	%	rank	%	rank	%
1	15.09	4	6.78	7	20.35	1	18.81	3	10.87	5	19.42	2	8.67	6
2	4.85	7	18.17	3	18.93	2	16.25	4	11.48	5	21.89	1	8.44	6
3	10.52	4	16.90	3	20.13	2	4.78	6	9.73	5	33.38	1	4.56	7
4	8.24	6	21.43	2	22.32	1	10.56	5	13.58	4	19.74	3	4.13	7
5	3.06	7	11.46	5	24.00	1	20.16	3	13.62	4	22.73	2	4.96	6
6	3.56	7	4.79	5	37.97	1	16.29	2	7.56	6	14.89	4	14.95	3
7	20.40	2	28.99	1	14.64	4	6.83	6	9.89	5	15.25	3	4.01	7
8	9.86	5	21.08	3	21.07	2	8.06	6	11.52	4	22.46	1	5.95	7
MEAN	9.45	6	16.20	3	22.43	1	12.72	4	11.03	5	21.22	2	6.96	7
CV	0.63		0.50		0.31		0.46		0.18		0.27		0.53	

C01: Effects on aesthetic perception of biophysical environment (landscape) by residents,

C02: Effects on residential value in surrounding properties,

C03: Risk of proliferation of pests and diseases' vectors,

C04: Effects from construction activities on daily life,

C05: Effects of operational noise on homeowners,

C06: Undesired odours from slaughtering process and from the paddock area,

C07: Use of public facilities (Coyhaique landfill) for solid waste disposal.

5.5.4 QUANTIFYING THE EVOLUTION OF AGREEMENT AMONG THE EXPERTS

With the purpose of estimating the level of experts' agreement achieved from the three interactive rounds, the coefficients of variation and the coefficients of Kendall have been calculated for each round. Details of these calculations can be found in Section 3.5.4.

Coefficient of Variation (CV)

The CVs were calculated from each attribute's weighting, at each interactive round. The results are graphically presented in Figures 5.3, 5.4 and 5.5. The graphs show the evolution of agreement amongst the experts on the weightings assigned to each of the economic, environmental and social attributes from the interactive process.

Figure 5.3 Coefficients of variation for the weightings of the economic development attributes for each round

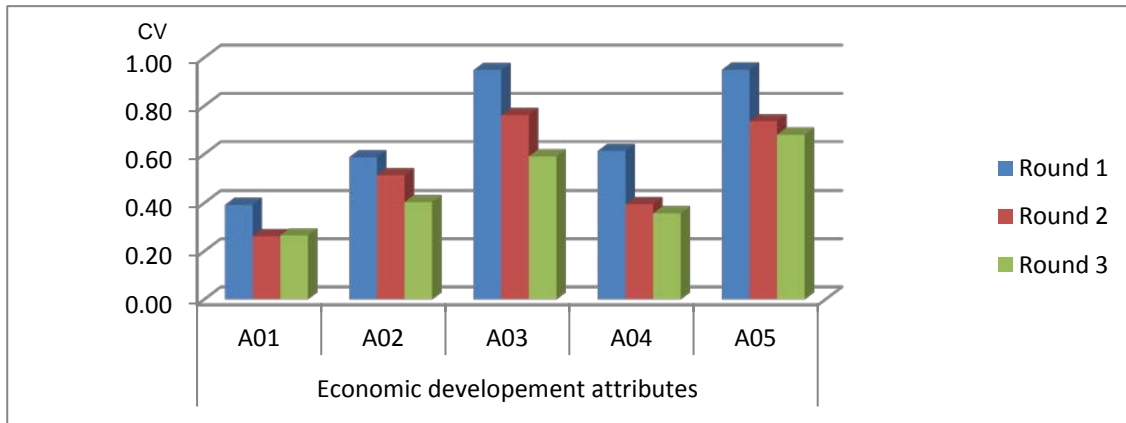


Figure 5.3 shows a decrease in the coefficients of variation through the consecutive rounds for the economic development attributes. This can be interpreted as an incremental movement toward consensus on the weightings of the attributes, by the experts. However, for attributes A03 and A07 the CV was still over 0.5 (which the literature suggests is an acceptable degree of consensus). It indicated some degree of controversy in relation to the importance or contribution that these attributes play toward a goal of economic development.

Figure 5.4 Coefficients of variation for the weightings of the environmental protection attributes for each round

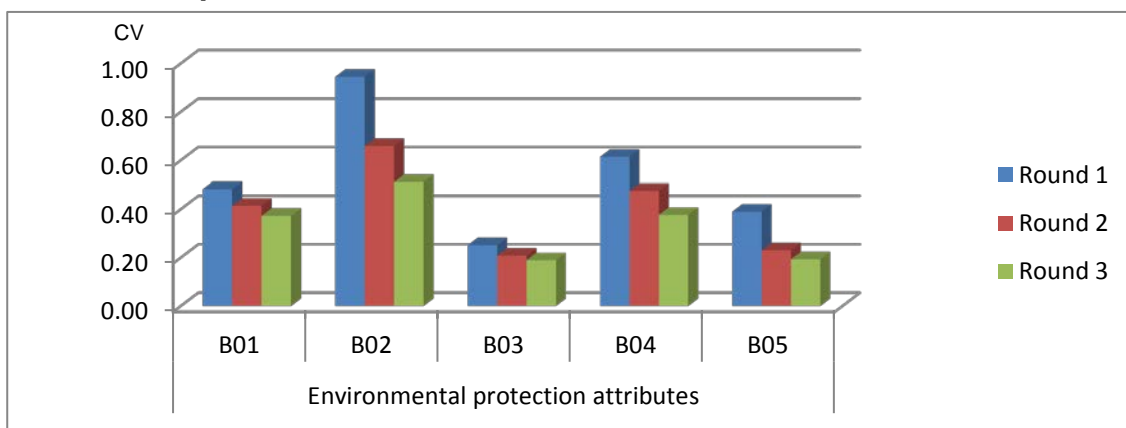
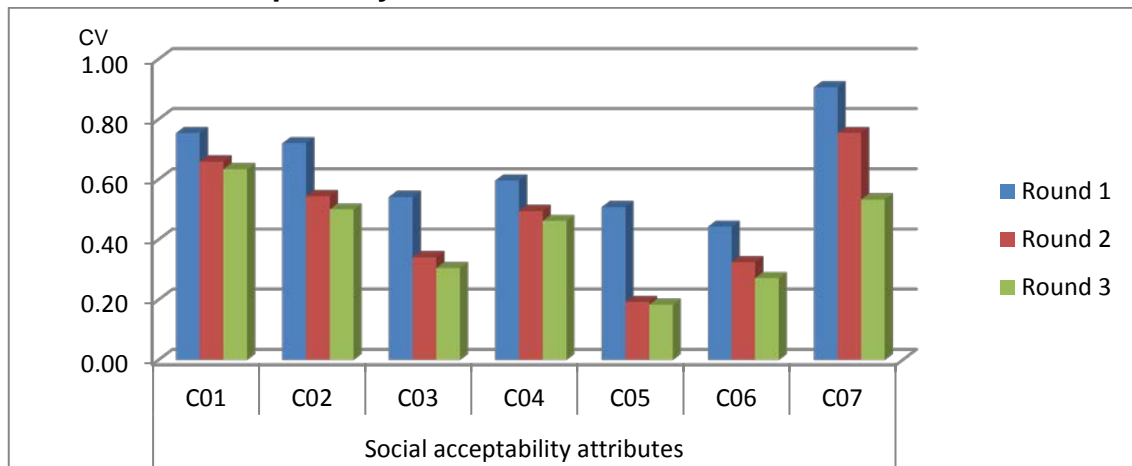


Figure 5.4 shows a decrease in the coefficients of variation through the consecutive rounds for the environmental protection attributes. This can be interpreted as an incremental movement toward consensus on the weightings of the attributes, by the experts. All attributes obtained a CV lower than 0.5, indicating a good degree of consensus.

Figure 5.5 Coefficients of variation for the weightings of the social acceptability attributes for each round



As with the other sets of attributes, Figure 5.5 shows a decrease in the coefficients of variation through the consecutive rounds for the environmental protection attributes. This can be interpreted as an incremental movement toward consensus on the weightings of the attributes, by the experts. Most attributes obtained a CV less than 0.5, indicating a good degree of consensus. The exceptions were C01 and C07, both of which were more controversial than the other attributes.

Coefficient of Kendall (w)

The coefficient of Kendall was calculated to determine the degree of agreement reached in each interaction by the group of experts. This coefficient is based on the rank obtained by each attribute when the weights are estimated. W was calculated for the set of attributes for economic development, environmental protection and social acceptability at each round (see the calculation matrices in Appendix B). These coefficients of Kendall for each round are presented in Table 5.17.

Table 5.17 Coefficients of Kendall for economic, environmental and social attribute weightings for the three rounds

Interactive Round	Kendall's Coefficient of agreement		
	Economic development	Environmental protection	Social acceptability
Round 1	0.18	0.62	0.34
Round 2	0.20	0.75	0.44
Round 3	0.26	0.75	0.55

The coefficients of Kendall, show that the final weightings for the environmental protection attributes remained at the same relatively high level of agreement for Rounds 2 and 3. For the social acceptability attributes, the coefficients of Kendall increased through each successive round demonstrating increased agreement at each round. It is clear from the relatively low values for the coefficients of Kendall that there is not agreement between the experts regarding the weightings for the economic development attributes. However, following the focus group meeting the panel of experts agreed to adopt the average values for the weightings from the Round Three results.

Finally, combining all the data for this section, the final weightings for each of the attributes have been summarized into one table, Table 5.18.

Table 5.18 Final attributes weightings

Goal	Attributes		Weights (%)
Economic development	A01	Promoting the development of sheep production in the region	23.7
	A02	Increased efficiency from reduced transportation cost	23.1
	A03	Injection of money into the local economy (US\$m)	11.2
	A04	Improving access of smallholders to new export markets	26.6
	A05	Permanent jobs created	15.4
	Total		100
Environmental protection	B01	Threat to availability of water resources	32.7
	B02	Air pollution during construction and operation Round	17.3
	B03	Local vegetation disturbance resulting from construction	4.1
	B04	Effect on aquatic life from liquid industrial waste discharge	34.7
	B05	Risk of solid waste pollution	11.2
	Total		100
Social Acceptability	C01	Effects on aesthetic perception of the environment by residents	9.5
	C02	Effects on residential value in surrounding properties	16.2
	C03	Risk of proliferation of pests and diseases' vectors	22.4
	C04	Effects from construction activities on daily life	12.7
	C05	Effects from SH construction activities on daily life	11.0
	C06	Undesirable odors from slaughtering process and paddocks	21.2
	C07	Use of public facilities for solid waste disposal	7.0
	Total		100

5.6 RANKING THE ALTERNATIVES

Remembering back to the introduction to this case study, the objective was to use the REM to compare two alternatives: the 'with' the Cisne Austral Abattoir project and 'without' the Cisne Austral Abattoir project. The alternatives were analysed following the procedure undertaken for the REM in the LDW software. Once the data were entered for each attribute for the individual alternatives, the most and least preferred measures were indicated. Care was taken to ensure that for the negative impacts the most preferred level of a measure was specified as zero or none. Measures were then converted to units of utility. Common unit conversions were undertaken using single-measure utility functions (SUFs) for point-estimate data, and direct assessment was used for descriptive labels.

The nature of this abattoir project means that there is potential risk to human health. Consideration needs to be given to the possibility of failure regarding the mitigation measures for the abattoir project, which might lead directly to profound

adverse health and safety consequences. Therefore, it is important that such a scenario is stated and considered. For the Cisne Austral Export Abattoir project three scenarios were considered to represent possible future outcomes. The scenarios are: 1) Optimistic, representing the best-case scenario, 2) Realistic, representing the most likely situation expected (by the developers) to occur, and 3) Pessimistic, which describes the worst-case scenario.

Alongside the list of attributes and their associated weightings, their baseline 'net benefits' (both quantitative and qualitative) are presented, as well as estimates of 'net benefits' under each of the three scenarios in Table 5.19.

Finally, the analysis was conducted and the rankings for each of the scenarios are shown in Figure 5.6. In each of the stacked bar graphs, economic development is shown in red (where a longer bar represents a higher economic benefit), environmental protection is shown in green (where a longer bar represents a lesser threat to the environment), and social benefits are shown in blue (where a longer bar represents fewer negative social impacts).

Figure 5.6 Ranking of alternatives scenarios for the Cisne Austral Abattoir project

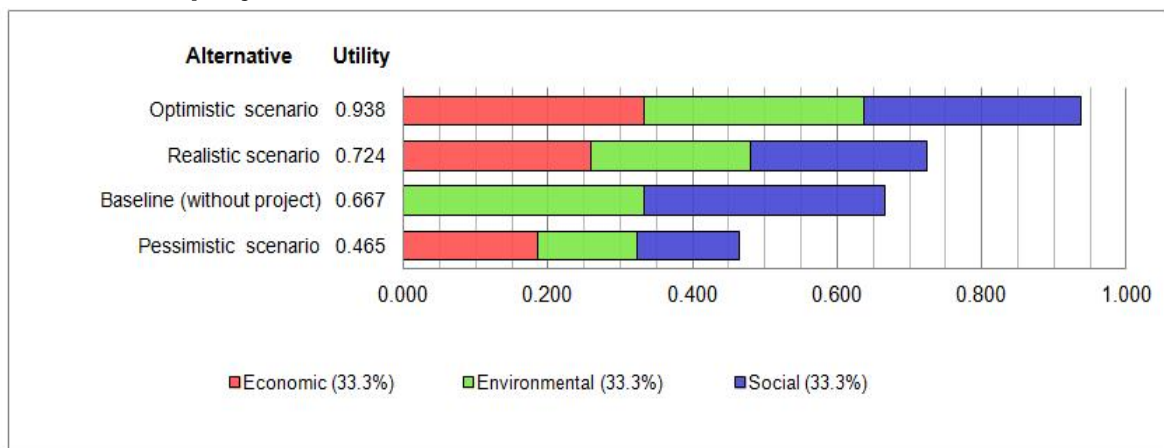


Table 5.19 Abattoir net benefits associated with attribute scenarios

Goal	Attributes	Weights (%)	Net benefits from the abattoir project under four different scenarios			
			Baseline	Optimistic	Realistic	Pessimistic
Economic development	Promoting the development of sheep production in the region	23.7	no effect	moderate positive effect	minor positive effect	negligible positive effect
	Increased efficiency from reduced transportation cost	23.1	no effect	significant positive effect	moderate positive effect	minor positive effect
	Injection of money into the local economy (US\$m)	11.2	0	3.5	2.9	2.4
	Improving access of smallholders to new export markets	26.6	no effect	significant positive effect	moderate positive effect	minor positive effect
	Permanent jobs created	15.4	0	40	35	30
		100				
Environmental protection	Threat to availability of water resources	32.7	no effect	no effect	negligible adverse effect	minor adverse effect
	Air pollution during construction and operation Round	17.3	no effect	no effect	negligible adverse effect	minor adverse effect
	Local vegetation disturbance resulting from construction	4.1	no effect	no effect	negligible adverse effect	minor adverse effect
	Effect on aquatic life from the discharge of liquid industrial waste	34.7	No effect	negligible adverse effect	minor adverse effect	moderate adverse effect
	Risk of solid waste pollution	11.2	no effect	no effect	negligible adverse effect	minor adverse effect
		100				
Social acceptability	Effects on aesthetic perception of the biophysical environment (landscape) by residents	9.5	no effect	no effect	negligible adverse effect	minor adverse effect
	Effects on residential value in surrounding properties	16.2	no effect	no effect	negligible adverse effect	minor adverse effect
	Risk of proliferation of pests and diseases' vectors , such as rodents, flies and stray dogs	22.4	no effect	no effect	negligible adverse effect	minor adverse effect
	Effects from SH construction activities on daily life (e.g. increased traffic, dust)	12.7	no effect	negligible adverse effect	minor adverse effect	moderate adverse effect
	Effects of SH noise on homeowners	11.0	no effect	negligible adverse effect	minor adverse effect	moderate adverse effect
	Undesirable odours from the slaughtering process and from the paddock area	21.2	no effect	no effect	negligible adverse effect	minor adverse effect
	Use of public facilities (Coyhaique landfill) for solid waste disposal	7.0	no effect	negligible adverse effect	minor adverse effect	moderate adverse effect
		100				

From Figure 5.6 it can be seen that, when using an equal distribution of weights for economic, environmental and social goals (i.e. weighting each at 33.3%), the 'optimistic' and 'realistic' scenarios have achieved a greater relative utility score, when compared to the baseline ('without' the project) alternative. This means that the project development is preferred when a realistic or optimistic scenario is assumed. However, if a pessimistic scenario were to occur, the corresponding utility would be lower than the utility derived from the baseline (without the project), therefore the project would not be acceptable and the alternative of not building the abattoir would be the preferred option.

5.7 SENSITIVITY ANALYSES

In the previous section, the three goals, economic development, environmental protection and social acceptability were themselves given equal weighting (33% weighting for each). Now sensitivity analyses are required to test the impact of changing the relative weightings of these goals for the three scenarios (optimistic, realistic and pessimistic). Conceiving of worst-case scenarios is a common form of strategic planning to prepare for and minimize contingencies that could result in accidents, quality problems, or other issues. Of particular interest are the rankings under a pessimistic scenario, since it is this scenario which is particularly relevant for the precautionary principle. The worst-case scenario was obtained by combining poorer outcomes for both environmental and economic attributes. Since, most of the time, it is likely that poor environmental outcomes would be associated with higher economic outcomes and vice versa; this combination will ensure to reflect the most severe possible outcome that can be projected to occur.

Consider first the economic development goal. The weighting assigned to the economic development goal is varied from 0%, so that it is not considered at all, through to 100%, where it is the only goal considered. Simultaneously, the other two goals must be varied accordingly (so that the combined weightings of the three goals are always 100%) and the remaining weighting is split evenly between the other two goals, environmental protection and social acceptability. These changing weightings are graphed in Figure 5.7 (a). The relative utilities are represented on the vertical axis and the weighting assigned to the economic

development goal (as a percentage) appears on the horizontal axis. The coloured lines represent the overall utilities for each of the scenarios when varying the weightings assigned to the economic development goal. Observation is made where the utility of rejecting the project equals the utility of accepting the project. Therefore, the red line (base line representing the 'without' project) is observed where it in turn intersects the green line (optimistic scenario), the blue line (realistic scenario) and the yellow line (pessimistic scenario). These indicate the weighting of the economic development goal required in order for the utilities of both alternatives ('with' or 'without' the project) to be equal. Where this intersection occurs provides the utility of that alternative and scenario. The highest line represents the most preferred alternative (overall) for a given weighting of the economic development goal.

The black vertical line represents a 33.3% weighting for the economic development goal, and consequently where the three goals are given equal weightings or importance. The process of varying the weightings assigned to the goals was repeated for the environmental protection goal (and the results presented in Figure 5.7 (b)) and again for the social acceptability goal (as shown in Figure 5.7 (c)).

By examining Figure 5.7 (a) it seems that if economic development is not considered (giving it a weight of 0%), the 'without' the project alternative is preferred. However, as more weight is placed on the achievement of economic development, the 'with' project alternatives (under all three scenarios) become increasingly preferred. If, for example, economic development is given a weighting of 10%, the project can be accepted under an optimistic scenario, but not under a realistic or pessimistic scenario. If the weighting assigned to economic development is increased to 28%, the project can be accepted under a realistic scenario. And even under a pessimistic (or worst case) scenario, the project can be accepted when the economic development goal is given a 51% weighting.

Figure 5.7 Results of the impact of changing the relative weightings of each goal (economic, environmental and social) under the three scenarios

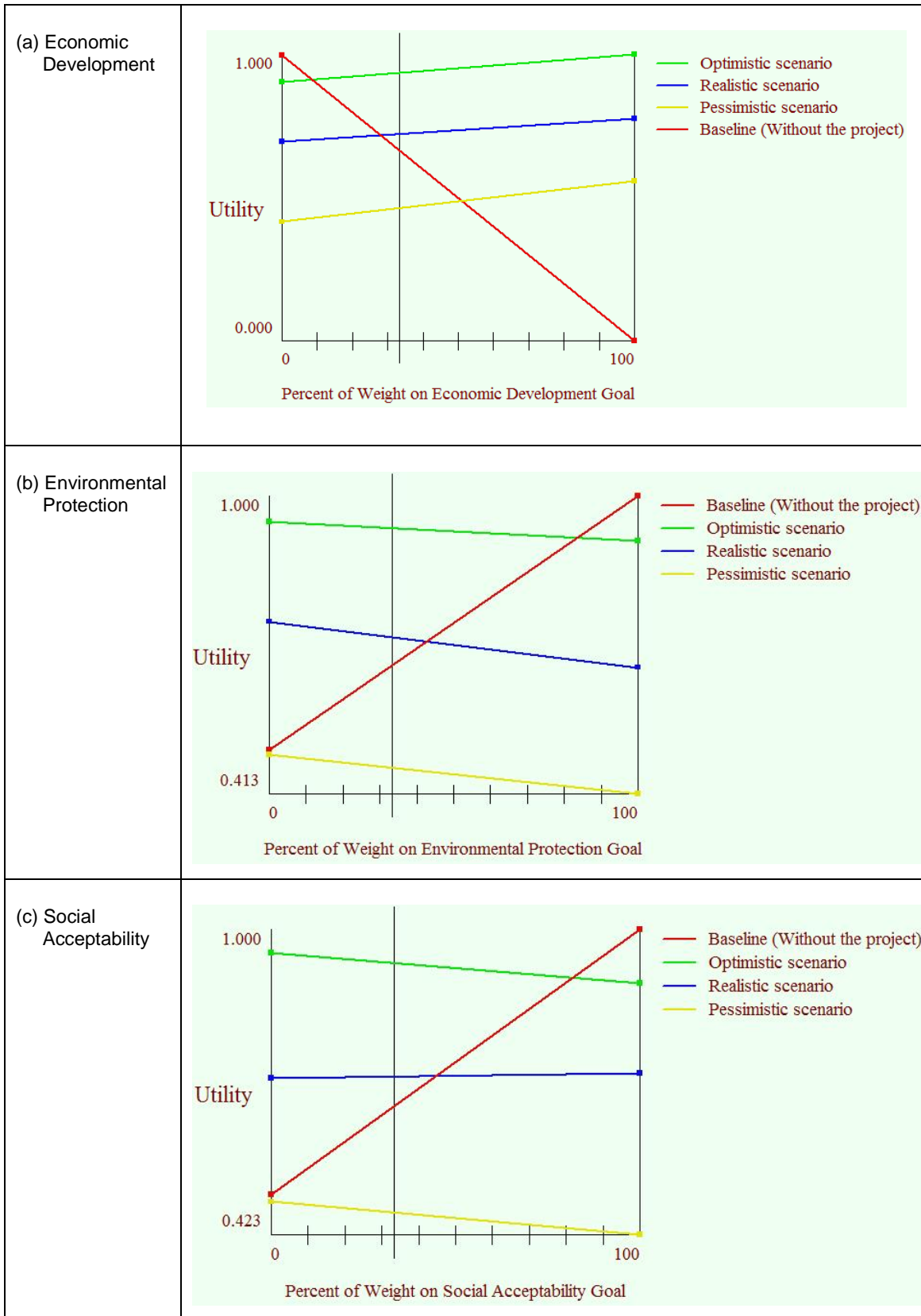


Figure 5.7 (b) indicates that when environmental protection is given no consideration (a weighting of 0%), the project can be accepted, even under the worst-case scenario, where the 'with' and 'without' alternatives are almost equally preferred. However, when consideration for environmental protection increases (expressed by an increasing weighting), if there is any possibility of a pessimistic scenario occurring, the project would immediately be rejected. The same is the case regarding the sensitivity analysis for the goal of social acceptability, as shown in Figure 5.7 (c). If social acceptability is to be considered at all (that is having weightings above 0%), then under a pessimistic scenario the project should be rejected.

In conclusion, consider the comparison of the pessimistic scenario (worst-case situation under the 'with' project development) with the baseline situation ('without' the project). In order to accept the project, there would need to be a bias toward economic development, so that the goal of economic development would require a weighting of 51%, thus reducing the weightings for environmental protection and social acceptability to 24.5% each $((100-51)/2$ each). However, there is no environmental protection weighting or social acceptability weighting for which the pessimistic or worst-case scenario would ever allow the project to be accepted.

5.8 MAKING THE RECOMMENDATION

The Cisne Austral Abattoir project development is expected to generate an overall net benefit when the analysis is based on either the realistic or optimistic scenarios. However, the sensitivity analyses indicated that under a pessimistic scenario the impact on environmental protection attributes and on social acceptability attributes would not be acceptable, so that under a pessimistic scenario it would be advisable to reject the project.

Therefore, it is recommended that the Cisne Austral Abattoir project be accepted, with the proviso that everything be done to avoid the pessimistic scenario outcome. To avoid this outcome, much attention should be directed toward environmental protection practices and social acceptability strategies. According to the expert's preference set, the attributes with the highest weightings relative to

the environmental protection goal were: the effect on aquatic life of the discharge of liquid industrial waste (34.7%) and the threat to the availability of water (32.7%). The attributes with the highest weightings relative to the social acceptability goal were: the risk of proliferation of pests and associated diseases (22.4%) and the generation of undesirable odours from the slaughter process (21.2%). Therefore these results highlight the most important areas to target, monitoring and mitigating against negative outcomes, in order to ensure that when the project were to proceed, it would be sustainable.

CHAPTER SIX - CASE STUDY 3: SALMON FARMING

6.1 INTRODUCTION

In this section, the REM is used to analyse a project for the selection of one of two net-cage systems to be utilised by the salmon farming industry in southern Chile. An ongoing concern and growing challenge for the aquaculture sector is the accumulation of aquatic organisms and algae (collectively known as fouling organisms) on the nets. Biofouling in the salmon aquaculture industry is a costly problem, with both environmental and socio-economic consequences. The accumulation of fouling organisms on fish cages that are not cleaned on a regular basis, allows for the build-up of waste which can lead to disease. As a consequence, the fish do not receive the nutrients and oxygen they require, resulting in a decline in productivity. In addition, the biofouling physically damages the nets and the aquafarm infrastructure. Therefore, the aquaculture sector is looking for solutions to the biofouling of net-cages, in order to increase the efficiency of their systems and their production capacity.

The adoption of more efficient production systems is essential for the sustainable growth of the aquaculture sector to meet increasing demand by a growing population as well as increasing per capita consumption. Within this context, the Chilean government supports projects which, through innovation and the application of new and applied knowledge, contribute to improving efficiency and growth in productivity.

The two salmon net-cage systems evaluated in this research consist of two alternative projects developed by the private sector to contribute to solving the biofouling problem. Both projects applied for financial support to the Production

Development Corporation of Chile, CORFO⁸. One project consisted of the implementation of an aquaculture net-cage servicing facility for cage cleaning and repair, and the other project focused on financial support (in the form of a subsidy) to encourage salmon farmers to switch from their current net-cages to a more expensive antifouling net-cage constructed using a copper alloy (anti-fouling) material. Both projects were assessed individually and both received from CORFO, the financial support requested.

For the purpose of this research, however, a hypothetical assumption is made that CORFO has to apply capital rationing as it has insufficient funds to support both proposed projects. In order to advise CORFO, the projects must be ranked against each other and against the Status Quo ('without' the development of either project). In order to test the model, the proposed projects were considered in single assessments and then compared and ranked. The focus of this study was to determine which of these two alternatives would better contribute to sustainably increasing the productivity of salmon farming whilst taking into account southern Chile's socio-economic and environmental considerations.

To inform REM, a list of attributes and their associated measures was collated from information derived from the reports presented by the two submitters to CORFO. Due to the sensitivity of comparing two private projects intending to solve the same problem and competing in the same market, the names of the companies involved will not be disclosed. Therefore, when using information presented from the submitters' reports, these will be referred to as Alternative A: Nylon net-cage washing service, and Alternative B: Adoption of copper alloy net-cages.

Where necessary, the data were complemented by information gathered from studies and research carried out by private and public institutions from the aquaculture sector within the country, reports from Chilean government institutions and studies from relevant international literature. The combined data were then

⁸ CORFO stand for the acronym (in Spanish) of the government institution: Corporación de Fomento a la Producción.

organised in accordance with the key attributes and measures required for the structure of the model.

When the model was constructed, primary data for the weighting assessment were garnered by the researcher through surveys and discussion with a panel of experts knowledgeable in the economic, environmental and social aspects of project evaluation. The experts were required to score a given set of attributes by articulating their preferences through weightings which were applied to a list of attributes relevant to this project.

6.2 BACKGROUND TO THE PROJECT

The global aquaculture industry has grown dramatically by at least 10% per year since 1980. In 2008 the aquaculture industry accounted for more than 50% of global seafood human consumption (Bostock et al., 2010). Growth in demand continues consistently in most markets and it is expanding geographically, in particular for farmed Atlantic salmon. Norway and Chile are the world's leading aquaculture producers of salmon, accounting for 36% and 28% respectively, of world production (FAO, 2010). Substantial expansion of salmon farming in particular, and aquaculture production in general, is expected in Chile for this and the coming decades, provided that public and private actions and strategies are consistent with both environmental sustainability and economic efficiency. (Barton, 1997).

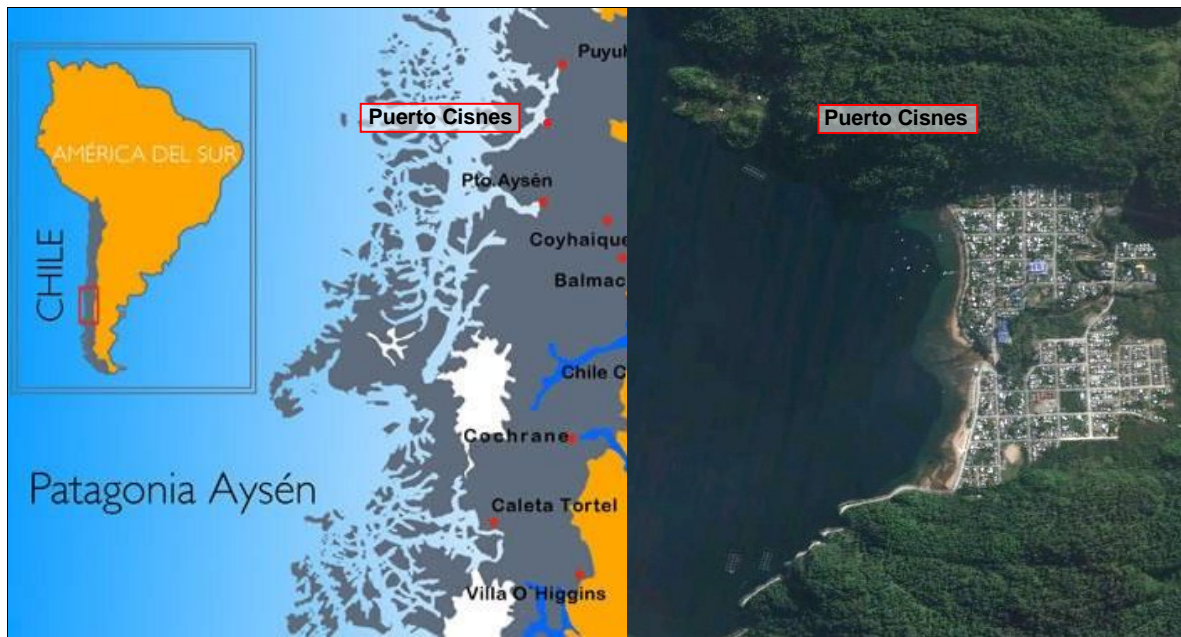
Atlantic salmon (*Salmo salar*) production is the most farmed fish species in Chile, principally due to its high market value and its universally acknowledged health benefits. This species is exotic to Chile and was first introduced at the end of the twentieth century (Doren, Gabella, Ruz, & Pizarro, 2001). Today, there exists a thriving industry based on intensive farming that produces around 570,000 metric tons of salmon per year, valued at over US\$1.4 billion in 2004. Salmon is the single most important food item in Chilean exports, and the industry has a strong influence on the economy of southern Chile (Leung, Lee, & O'Bryen, 2008). Aquaculture activity is mainly concentrated in the south of the country, due to the region's geographic characteristics, the presence of wave-protected bays, fiords

and channels (Buschmann, Lopez, & Medina, 1996) and environmental conditions, namely, salinity levels, water temperature and water quality (Lindbergh, 1993).

In Chile, the saltwater salmon farms are widely distributed between the X and XI regions and to a lesser extent the XII region (Refer to Appendix C, Figure 6.5). Originally, almost 80% of the production centers were located around Chiloé, an island located in the X region (Montero, 2004). In 2007, the Chilean salmon industry suffered an epidemic of the ISA (infectious salmon anaemia) virus (Fløysand, Haarstad, & Barton, 2010). This forced the salmon industry to leave the contaminated area and move south to less exploited and cleaner locations, like Puerto Cisnes, Melinka, Puerto Aysén and many other fiords within the XI region. Nowadays almost 50% of the farmed salmon is produced in this region. However, these are remote locations, and coastline connectivity is difficult (Siderakis, 2011). These fiords have geographic disadvantages making land access difficult and land infrastructure minimal. As a consequence most access to these salmon farms is by sea, creating problems with logistics – getting fish to processing plants and to final destinations (Barton & Fløysand, 2010).

Puerto Cisnes is a small coastal village, with approximately 6,166 inhabitants in the district and a workforce of 2,681 people. Before the fish farms arrived in the region, the local population was employed mainly in primary small scale industry, such as artisanal fisheries, cattle farming, forestry and diverse services and commerce (Ministerio de Desarrollo Social, 2012). This village is the location for the development of the Alternative A project (currently nets must go to Puerto Montt for washing and repair). While the copper alloy net-cages are manufactured in Puerto Montt, it is Puerto Cisnes that will be the focus for Alternative B, where salmon farmers will be offered a subsidy toward the cost of the copper alloy net-cages, to encourage conversion from existing net-cages to net-cages made of the anti-fouling material.

Figure 6.1 The location for both the proposed projects



Source: Adapted from www.desafioaysen.com & Google Earth.

Biofouling poses a constant challenge to aquaculture producers, in Chile and worldwide. During the initial phase of aquaculture production in the early 1980s, the first nets used in salmon aquaculture were adapted from the experiences of large-scale capture fisheries. Chilean producers did not consider that keeping the nets permanently underwater for 12 months or more would result in the adherence of encrusted living organisms such as algae and mussels, along with other marine organisms, which is known as biofouling (Tang, 2006).

The use of net-cage systems in salmon aquaculture has two main purposes: to keep the fish in captivity (fish nets) and to protect fish from predators (predator nets or sea-lion nets). The growth of biofouling on these nets causes several problems, such as the obstruction of water flow, which decreases the availability of oxygen, the potential opportunity for fish pathogens and an increase in the overall weight of the nets, which could cause them to tear and allow fish to escape. This last problem impacts on the safety and buoyancy of the net-cages (and hence on production) as the average weight of a nylon net-cage increases seven to eight times after being submerged for 6 months, increasing from approximately 400kg to 3,000kg (depending on the size of the cage) (González, Hurtado, Gace, & Augsburger, 2013).

The rapidly increasing density of salmon production facilities in Chile has been accompanied by a variety of unintended, adverse effects, drawing the attention of numerous stakeholders. Regulators, fish farmers, and consumers have become more aware of adverse environmental impacts, food quality, and animal welfare (Barton, 1997).

In an effort to keep pen volumes and fish welfare unaffected throughout the production cycle, several technical improvements were implemented (for example, the use of sinker tubes in circular cages, point weights in square pens and improvements in the design of mooring systems, among others). Nevertheless, these technical improvements have been unable to significantly reduce the problems generated by excess biofouling (González et al., 2013). Existing management techniques, such as copper based anti-fouling dips, pose potential environmental and fish health concerns, are of limited effectiveness, and may reduce net durability.

In an attempt to mitigate the excess biofouling of the net-cages, whilst avoiding adverse environmental effects, two companies have come up with different solutions to the problem. One is a net-cage washing service and the other, subsidising the up-take of anti-fouling copper alloy net-cages.

6.3 OBJECTIVE OF THE STUDY

The REM developed in this research will be used to compare the two project proposals, the net-cage washing and repair service, and the manufacture of copper alloy net-cages. This study aims to determine the net benefits of each alternative and then ranks the two alternatives against each other and against the Status Quo. Included in the analysis will be economic development, environmental protection and social acceptability considerations.

Alternative A: Nylon net-cage washing service

Alternative A is a proposal for the development of a local aquaculture net-cage servicing facility to both clean and repair net-cages. The facility incorporates

environmentally sustainable practices in the treatment of its wastewater. It will create local employment and enable a cleaning and repair service to be offered to aquaculture clients throughout the region.

Alternative B: Copper alloy net-cage.

Alternative B is a proposal to encourage (through a subsidy) the up-take by salmon farmers of the new net-cages made with innovative anti-fouling technology using a copper alloy material to make the net-cages. The anti-microbial attributes of copper make this net-cage material resistant to organic fouling. This new technology, while initially more expensive, does offer cost saving potential through reducing the need for the use of anti-fouling agents, net inspections conducted by divers, traditional net cleaning, and through increasing the longevity of the net-cages.

Alternative C: Status Quo, 'without' the development of either project.

Impacts will be measured considering the difference in a number of economic, environmental and social attributes, between the Status Quo (baseline situation) and the situation after the implementation of either the new cleaning service or the new technology.

6.4 IDENTIFYING THE KEY ATTRIBUTES AND THEIR MEASURES

Both the identified projects propose to address the current loss of productivity in the salmon aquaculture sector generated through biofouling. They have the potential, not only to play an important role in increasing productivity of salmon farms but also in positively impacting the bio-physical environment, and having a positive impact on local employment.

This section identifies and describes all relevant impacts, of both Alternatives A and B, on the existing economic, social and bio-physical environments. Special attention is given to identifying attributes relevant for both the projects, in order to aid comparison. The identification of possible effects was executed using the

checklist developed in this research, and it is presented in Table 6.1. The impact values were obtained from the project development reports submitted by each company, and were complemented by relevant literature.

From the list of impacts presented in Table 6.1, key attributes were chosen for use in the model according to the importance rating of the impact. Impacts indicating a low importance were excluded from the model. Impacts with medium to high importance ratings were included in the model regardless of their size of impact.

The final list of attributes for the selection of net-cage systems in the salmon farming industry, to be entered into the model for evaluation, is summarised in Figure 6.2.

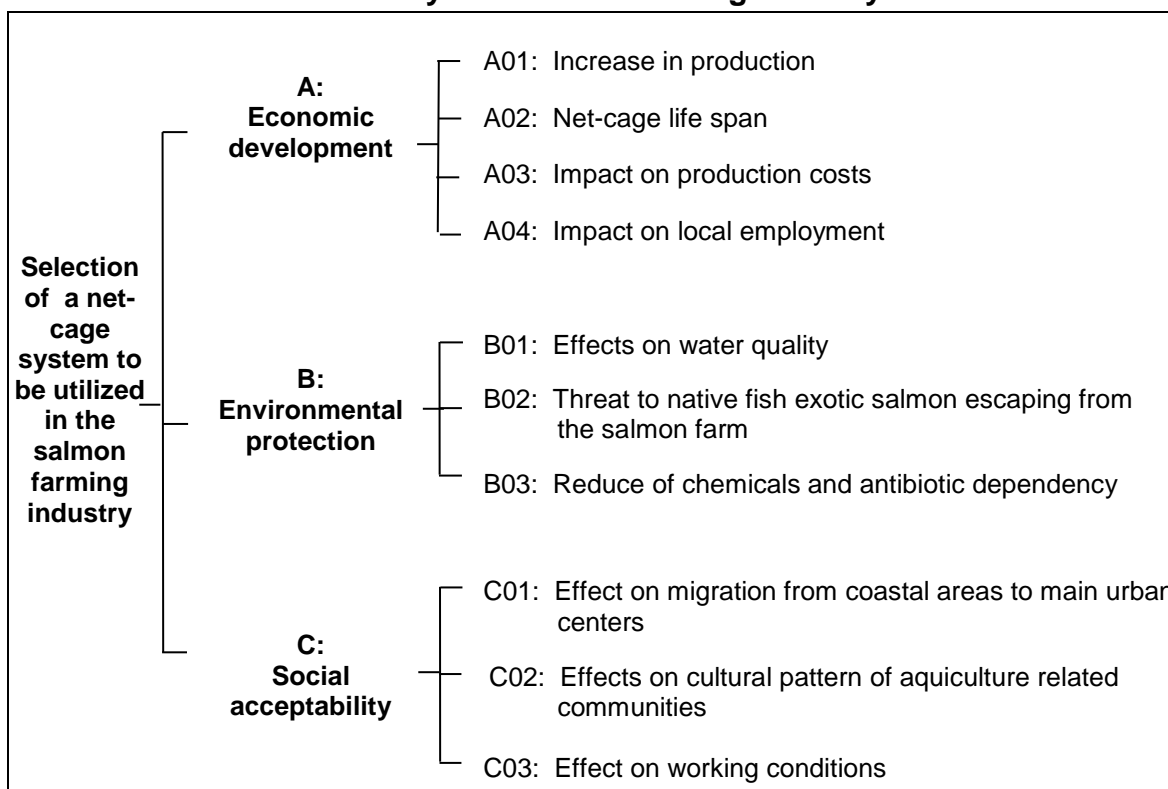
Table 6.1 Full list of effects for the selection of a net-cage system for use in the salmon farming industry

Goal	Criteria	Sub-criteria	Projects Effect		Data	Measures	
			A	B			
A. Economic development	Financial viability	Net income	+2	+2	yes	Financial net benefit (income)	
	Productivity growth	Capability for converting resources into outputs	+1	+4	yes	Increase in production	
	Efficiency of resource use	Extending product durability	+2	+4	yes	Net-cage life span (and recyclability)	
	Effect across other sectors	Effect on the primary sector, as:	Fisheries (river or sea)	-1	-1	no	Effect on other services associated with the sector
	Economic factors	Cost reduction		+2	-2	yes	Effects on production costs
	Employment	Local – non-local employment		+3	-2	yes	Impact on local employment
B. Environmental Protection	Effect in physical & chemical characteristics	Water	Ocean	-1	-1	no	Effect on sea pollution
			Quality	-2	+3	yes	Effect on water quality
	Effect in biological condition	Fauna	Fish & shellfish	+1	+4	yes	Threat to native fish from salmon escaping from salmon farm
	Effect in ecological relationships	Other		+1	+4	yes	Reduction of chemicals and antibiotic dependency
C. Social Acceptability	Population Characteristics	Relocated populations		+3	-2	yes	Migration from coastal areas to main urban centres
	Individual & family changes	Cultural patterns		+2	-1	yes	Effects on cultural heritage of aquaculture communities
		Perceptions of risk, health & safety	Risk of health illness		-2	+3	yes

LEGEND

MAGNITUD		IMPORTANCE
4	Significant positive effect	Low Importance
3	Moderate positive effect	Medium Importance
2	Minor positive effect	High Importance
1	Negligible positive effect	
POTENTIAL MITIGATION OF IMPACT		
-1	Negligible negative effect	Low Importance
-2	Minor negative effect	Medium Importance
-3	Moderate negative effect	High Importance
-4	Significant negative effect	High Importance

Figure 6.2 Key attributes for evaluation when selecting a net-cage system to be utilized by the salmon farming industry in Chile



In the following sections, these key attributes and their effects on the economic, social and environmental welfare of the region are discussed in depth and where appropriate, qualitative or quantitative measures are provided.

6.4.1 MEASURES OF ECONOMIC DEVELOPMENT

Activities relating to the aquaculture sector, both directly and indirectly in terms of transportation, fishfeed, diving, and both equipment and servicing of that equipment, has led to an economic revival of the region and new employment opportunities that this brings for both the fish farming and the processing. In this section attributes for the goal of economic development are analyzed to examine the effect that each proposed project will bring to the local economy.

A01: Increase in production

Biofouling impedes the flow of clean, oxygenated water to the fish and provides a growth environment for parasites and pathogens that can infect the fish, slowing their growth rate, inhibiting waste removal, thus causing diseases and loss of production (Braithwaite, Carrascosa, & McEvoy, 2007). This makes the fish lethargic, lowering their food intake and leads to increased mortality. In economic terms, this lengthens the investment recovery period, increasing salmon cost per unit weight produced, while decreasing site availability for subsequent harvests (Cisternas, Delle Donne, Durán, Polgatiz, & Weintraub, 2013). Common polymer cages can become fouled within weeks, consequently these net-cages must be changed frequently, cleaned in situ, or be treated with antifouling coatings to ensure water flow (Dwyer & Stillman, 2009). The periodic process of cleaning and replacing traditional cages, requires fish handling which promotes stress and diminishes weight gain ratios, with a consequent loss of production (Hodson, Lewis, & Burkea, 1997). Stress to the fish can also result in mortality, which has been estimated at 2% (Willemsen, 2005).

Both projects have the potential to increase production levels by controlling growth in biofouling, thus improving fish health by providing adequate water flow through the cage, and reducing the presence of parasites and diseases. However, the productivity benefit of having a new washing service within the region is difficult to predict and Alternative A is not expected to result in major gain in productivity, since net washing is currently the most common practice used by the salmon industry in the area.

From the literature, a number of benefits associated with copper alloy mesh has been reported. In a recent study conducted by (González et al., 2013), four aquaculture productivity indicators were estimated and compared to analyze the performance of copper alloy mesh nets versus nylon nets, at the net-cage level. The index included survival rate (SR), cage fish density (FD), growth rate for

average individual weight (GR) and feed conversion rate (FCR)⁹. Results from this study showed that copper alloy net-cages obtained a 20% higher SR and 10% lower cumulative FCR on average, than nylon nets. No statistical differences were found for FD and cumulative GR. From these results (González et al., 2013) concluded that copper alloy mesh net-cages yielded higher productivity indices than those of nylon net-cages with anti-fouling coating. (Dwyer & Stillman, 2009) have also reported that the use of copper alloy mesh generates an increment in the food conversion rate during the growth cycle, which reduces the quantity of fish food required to produce a specific amount of market-ready fish, and therefore it directly improves production efficiency.

Copper alloy mesh is observed to be stronger and therefore help prevent fish escaping the net-cages. In Tasmania, copper net-cages are used for growing the salmon at Van Diemen Aquaculture. Compared to traditional nylon nets, fish escaping has been reduced from 3-5% to less than 0.01% (The International Copper Association, 2012).

In Chile, two 30x30x15m net-cages have been installed for one year without any structural problems (Dwyer & Stillman, 2009). Sea lions learned in several days following stocking that it was pointless trying to attack the fish (Tang, 2006) as the nets were too stiff to deform, bite through or break (The International Copper Association, 2012). It also improves production by reducing stress caused by crowding, as copper alloy mesh cages do not deform under adverse weather conditions as traditional polymer cages do (Beveridge, 2004; Braithwaite et al., 2007). Therefore, there is a reduction in mortality and losses by predators as a result of using copper net-cages (Dwyer & Stillman, 2009).

⁹ FCR (Feed Conversion Rate) is the feed conversion ratio, which is estimated as the amount of food required to obtain a 1 kg increase in body weight on an average fish, during the production cycle.

When comparing with the baseline situation:

- Alternative A was determined to have a negligent positive impact on production.
- Alternative B was determined to have a significant positive impact since it represents an improvement in production as a direct result of reduced fish handling and therefore reduced stress, decline in mortality and injury, increased growth rate and increased feed conversion ratio, and reduction of losses due to predator attacks.

A02: Net-cage life span

Aquaculture net-cage life spans are known to be variable, depending on environmental conditions, maintenance practices, and technical specification (i.e. size or type of material used for the net-cage). In freshwater production systems, for example, cages are usually limited to metallic frames of at most 15m². Smaller cages for freshwater systems allow for better access and control, facilitating managing operations such as classifying, transportation, vaccination, and net replacement. For seawater systems, fish are not handled often, therefore large structures are utilized (Halwart, Soto, & Arthur, 2008).

Common nylon net cages have a variable life span, from those needing replacement every two to four months (where neither antifouling or maintenance practices are used), to up to five years, where cages have been cleaned regularly and direct exposure to sunlight has been avoided (Okorie, 2004). It has also been reported that synthetic mesh bags often have relatively short lives, due to the volume of fish contained in them and the risk of loss, many operators buy new nets every production cycle (Huguenin, 1997).

Common for ocean aquaculture in Chile, are plastic frame cages covered in nylon netting, 90m in circumference and a depth of 20m (12,900m³). These aquaculture centers may also utilize metallic 20x20m frame cages with 20m depth (8.000m³) (Rojas & Wadsworth, 2008). An intermediate-sized net-cage of 25x25m frame with

17m depth (10.625m³), is also commonly used in the Chilean industry¹⁰. These types of cages have an estimated life of two to four years (González et al., 2013; ProChile, 2012).

Copper alloy mesh cages have been used in seawater cultures in northeast USA, Japan and Tasmania, with life spans of over five years, in which the only necessary cleaning treatment is a wipe or shake once or twice per year to remove trapped seaweed (The International Copper Association, 2012). (Powell & Stillman, 2009) indicated that abrasion and corrosion combined can significantly shorten the operational lifetime of copper net-cages. In addition, nets made from 4mm diameter wire have been shown to provide a service life of around four years in semi-protected sea conditions with up to 1.5m waves (Powell & Stillman, 2009). Recent improvements on hot galvanization on metallic cages have helped to reduce corrosion, extending the life span up to ten years (Halwart et al., 2008).

Based on this previous experience, the projects' proponents have estimated the following life spans:

- Alternative A, nylon net-cage with regular maintenance will have a cage life span of four years.
- Alternative B, copper alloy net-cage will have a life span of ten years.

A03: Impact on production costs

Production costs (or operating costs) are the expenses necessary to maintain a plant, processing line or equipment in production. The production costs included here are only the costs expected to change as a consequence of the system to be implemented by either of the projects. Other operational cost (such as stocking smolts, feeding, administrative, fixed labour of the production center and processing, transport and storage costs) were not considered in this analysis, as all are independent of the implementation of either project.

¹⁰ From a confidential unpublished report by Alternative A

The cost of the net-cages for a traditional seawater salmon farm represents up to 60% of the total production costs, 40% of which is spent on net maintenance¹¹. Nylon nets need to be replaced for cleaning treatments which are carried out several times each year. On average, common nylon nets need to be replaced every three months in summer and every five months in winter (Cisternas et al., 2013). All this requires complicated logistics and high operational costs (González et al., 2013). Regular net maintenance involves various stages and players. First a dedicated net boat visits the aquaculture center to change any nets found to be torn or dirty. After replacing them with clean ones in good condition, the removed nets are transported to the closest port where they are then trucked to a net maintenance facility for cleaning and repair. The net owner may also decide to have them treated, during this stage, with anti-fouling products to reduce algae adhesion (Cisternas et al., 2013). Cage salmon treatment practices include setting up, replacement, removal for, washing and repair and, can cost up to US\$ 4,500 per cage each time¹².

The management of conventional net-cages consumes about 35% of the time of the boats involved in large scale aquaculture, representing a fuel consumption of about 500 gallons of fuel/day (Dwyer & Stillman, 2009). Net boat rental and diver hire, marine fuel and truck rental for transport to the nearest port and on to the facility, represent at least 10% of the total maintenance cost¹³. Both projects will be able to reduce transport costs as a result of not requiring net-cages to be transported out of the region for cleaning and repair.

Today, copper alloy net-cages are not available for purchase in the national market, since implementation is at the initial stage. Their only availability is for rental at a cost of US\$ 6,000 per month per unit. This price varies, depending on the specifications of the systems in terms of depth and type (square or circular)

¹¹ From a confidential unpublished report by Alternative A

¹² From a confidential unpublished report by Alternative B.

¹³ From a confidential unpublished report by Alternative A.

and according to installation sites. It is also influenced by the world trading price of copper (CODELCO, 2009).

According to data obtained from the reports by the project submitters, and a study conducted by (González et al., 2013), the production costs associated with each net–cage system were calculated for each alternative, assuming a project duration time of 10 years. These results are presented in Table 6.2.

Table 6.2 Cost of alternatives net-cage systems

Cost	Unit	Value	Baseline	Alternative A	Alternative B
Fish net replacement	US\$	6,000	15,000	15,000	
Predator net replacement	US\$	8,000	20,000	20,000	
Fish net washing treatment	US\$/year	8,910	89,100	89,100	
Predator net washing treatment	US\$/year	24,663	246,630	246,630	
Net transporting cost	% of washing cost	10%	33,573		
Rental of copper net	US\$/month	6,000			720,000
Life span Nylon net	year	4			
Life span Copper	year	10			
Project duration	year	10			
TOTAL			404,303	370,730	720,000

Alternative A was determined to have the lower production costs (US\$ 370.730). It will also produce an increase in the processing capacity allowing a faster and better net maintenance service. This will represent an improvement for the fish farms that in certain seasons can overload the net maintenance plants, generating delays and poor quality service, which can end up reducing the time between services and therefore incurring a higher cost.

Alternative B was determined to have the higher cost (US\$ 720,000), which is almost double the cost for Alternative A.

A04: Impact on local employment

The introduction of new technology can have varying effects on local employment. Small producers are occasionally displaced by large producers, and workers may be replaced by labour-saving innovations (De Janvry & Sadoulet, 2002). In the aquaculture sector of Chile, for example, automation of the feeding process in the

salmon farming industry since 1992 led to a 40% decline in jobs in the industry by 2002. The least skilled workers have been hardest hit by redundancies, and a larger proportion of workers are now casual labour, only brought back into the industry during peak periods (Barrett, Caniggia, & Read, 2002).

The impact that the two projects in this case study will have on local employment is not known with certainty, as the local farm fishing industry is relatively new in the region, and it cannot be accurately compared with the industry in other areas. However, previous experience suggests that a significant change in technology has the potential to significantly affect local employment.

The net servicing company, Alternative A will create up to 70 new jobs¹⁴, which represents 2.6% of the local active workforce of Puerto Cisnes village (Congreso Nacional de Chile, 2012). It is therefore, expected to generate a moderate, positive effect on local employment.

Alternative B will reduce the need for net-cage cleaning and maintenance, which will impact the workforce associated with net servicing. Given the small size of the local workforce, the implementation of this new technology is expected to have a moderate, negative effect on local employment.

6.4.2 MEASURES OF ENVIRONMENTAL PROTECTION

Aquaculture is a fast growing industry in Chile and this accelerated growth of the industry has resulted in a series of developments that may have detrimental environmental outcomes (Cabello, 2006). The industry and the government are combining efforts to identify and implement environmentally friendly practices that can move the salmon farming sector toward a more sustainable future.

¹⁴ From a confidential unpublished report by Alternative A.

B01: Effects on water quality

The Chilean environmental regulation for aquaculture, contained in the Chilean Environmental Act, 1994 (Law No. 19,300)¹⁵ makes mandatory protection of the environment by fish farm producers. In Article No.9 of the law, it establishes that salmon producers are required to use only facilities with adequate treatment systems for industrial liquid and solid residues for their net-cage maintenance. It also declares that liquid or solid residues may only be disposed in such a way as to not result in harm to ground or surface water and the surrounding environment. In addition, this environmental regulation states that the cleaning process for nets and any other fish culture equipment must be performed only in facilities that allow effluent treatment, which must be within the emission standards set by Article No.40. However, these regulations are often overlooked and salmon farmers send their nets to be serviced where the cost is least, and these facilities often do not have compliant equipment or facilities to carry out the processing in accordance with the law (Melillanca & Medina, 2006). During 2005, the National Commission of the Environment (CONAMA¹⁶) identified infractions by all the net cleaning facilities in the XI region and the commission estimates that a proportion of them still work without legal permits.

Anti-fouling solutions used to dip traditional nylon nets are known sources of pollution from aquaculture and are responsible for elevated levels of copper close to fish farms. In addition, net washing plants have problems dealing with the copper contained in the waste and sludge (Brooks & Mahnken, 2003). In developed countries, such as Norway or Scotland, the waste must be specially disposed of and such environmental safeguards increase the cost of waste disposal (Willemsen, 2005).

¹⁵ Bases generales para el medio ambiente. Ministerio Secretaría General de la Presidencia. Legislación Chilena. 1994.

¹⁶ CONAMA stand for the acronym (in Spanish) of the government institution: Comisión Nacional del Medio Ambiente.

According to the Alternative A project report, the company incorporates environmentally sustainable practices in the treatment of its wastewater. Therefore, the company's main focus for the net cleaning process is to have it work in conjunction with the wastewater treatment process, and to remove the sludge in an environmentally sustainable manner.

Currently, wastewater is discarded into an open pit, and sludge is handled by machinery allowing contaminated substances to be exposed. To avoid contamination, the company for Alternative A will implement a three phase system. First, wastewater will be collected into a sealed unit allowing for correct disposal of algae and sludge. The wastewater discharge from this unit, which contains the remainder of the anti-fouling copper-based paint, will be collected in filtering pans to reduce the contamination of the solids. These separated solid residues containing bio-fouling and any remaining copper-based paint will be collected in containers and sent to a processing plant to be treated as hazardous waste, and the liquid residue from the net washing will be treated in situ to avoid contamination of both fresh and saltwater resources.

Alternative A is expected to reduce the negative impact on water quality imposed by current net servicing facilities. However, it will still need to use large amounts of water and will have a minor negative impact on quality.

Alternative B was determined to have a moderately positive impact on water quality for two reasons. Firstly, the use of copper alloy mesh should eliminate the use of antifouling paint on the net-cages. Secondly, the need for maintenance should be significantly reduced, therefore, use of water resources will be diminished and the production of solid and liquid residues will be reduced as will previously resultant contamination of fresh water sources.

B02: Threat to native fish from exotic salmon escaping from the salmon farm

The escape of caged salmon occurs virtually everywhere that salmon are farmed. The introduction of a species to an area inevitably has unforeseen consequences. Salmon that escape from aquaculture operations can cause a wide range of

impacts, including competition for food and spawning habitats with both wild salmon and other species. Furthermore, they can interbreed causing genetic changes that reduce the robustness of wild salmon. In addition, they can spread diseases that either did not previously exist in the area or were not previously a problem for wild populations (Naylor et al., 2005).

In Norway as many as 1.3 million salmon escape each year, and one-third of the salmon spawning in coastal rivers are of escaped origin (FAO, 2010). During heavy storms in 1994 – 1995, salmon farms in southern Chile lost several million fish from the most commonly farmed species, rainbow trout (*Oncorhynchus mykiss*), coho salmon (*Oncorhynchus kisutch*) and atlantic salmon (*Salmo salar*) (Soto, Jara, & Moreno, 2001). (Cisternas et al., 2013), based on the experience of operators, estimated that torn mesh results in the loss of around 9,000 salmon (10% of those in aquafarms), once every two or three years in one of Chile's largest salmon farms.

A significant problem caused by the release of large salmon populations in the wild is the potential impact on the native fauna, habitats, and ecosystem services; however, their effect as exotic species in the ocean is less known in the Southern Hemisphere (Rojas & Wadsworth, 2008). In Chile, the introduction of these exotic species has only recently been considered a potential threat to preservation of local biodiversity. Even when artisanal fishing may control escaped salmon, the escaped fish have the best chance of becoming established in the remote XI and XII Regions, where artisanal fishing pressure is less intense (Soto et al., 2001).

The impact that Alternative A may have on escaped salmon is considered to be a negligent positive effect, since the project consists of providing better net maintenance services offshore, by increasing local net service capacity and quality. It is assumed that a better net service, closer to the fish farms should help to keep traditional cages in optimal condition and therefore reduce the likelihood of escaped salmon.

Alternative B is considered to have a significant positive effect on the threat to native fish from culture salmon escapees, as one the characteristics of the copper

alloy mesh is to be highly resistant to rupture from abrasion, corrosion, and attack by sea lions. In countries with more experience on the use of alloy nets, such as Japan and Australia, the percentage of escaped fish has been reduced from 3-5% to less than 0.01% (Dwyer & Stillman, 2009).

B03: Reduction of chemicals and antibiotic dependency

As is the case in all animal food production systems, it is often necessary to treat farmed fish for parasites and diseases. Chemicals used in salmon aquaculture may include pesticides and drugs, antifoulants, anaesthetics and disinfectants. From these, the most relevant are the anti-fouling and antimicrobial treatments (Burrige, Weis, Cabello, Pizarro, & Bostick, 2010; Millanao et al., 2011).

Toxic antifouling paints are most often used to protect nets against biofouling, however, this toxic layer created at the surface of the paint causes the leaching of biocides (Braithwaite et al., 2007). Thus elevated levels of copper are detected in close proximity to fish-farms. Organic biocides which are better for the environment (as they are biodegradable), are available, but these are generally not used by the aquaculture industry (Costello et al., 2001). Environmental degradation resulting from commonly used biocides in aquaculture have led to increasingly restrictive legislation and the banning of some compounds for use on vessels and in aquaculture (IMO, 2002). “In the next years the choice and availability of biocides for use as antifoulants will become much more restrictive” (Willemsen, 2005, p. 3).

The growth of fish farming has been accompanied by a rapid increase in therapeutic and prophylactic use of antimicrobials, and approximately 80% of the still active ingredients enter the environment (Cabello et al., 2013). The use and abuse of antimicrobials is a major problem in the Chilean aquaculture industry (Burrige et al., 2010; Buschmann et al., 2009). A 2008 authorized report, published on Marine Harvest’s web site¹⁷ reported that during 2007 and 2008 0.02 and 0.07g respectively, of antibacterial products were used per tonne of salmon

¹⁷ Marine Harvest is one of the largest salmon producers in Chile and Norway.

produced in Norway. In contrast, in Chile, for the same years, 732 and 560g respectively, of antibacterial products were used per tonne of salmon produced. Therefore, for Chile, the same company used 36,600 times more antibacterial products per tonne of salmon in 2007 and 8,000 times more in 2008 than was used in Norway (Millanao et al., 2011). Antimicrobials used in aquaculture are mostly administered to fish in their food and rarely by bathing or injection, which means that the antimicrobials are supplied to both healthy and unwell fish. Unconsumed medicated food (perhaps as much as 30% of that supplied to fish that are diseased or undernourished) accumulates in the sedimentation under and around aquaculture sites (Sørum, 2006, cited by Cabello et al., 2013). Studies on marine sediments in Chile by Buschmann et al. (2006, 2012), suggest that the current use of large amounts of antimicrobials in Chilean aquaculture has the potential to create antimicrobial-resistant bacteria. Experience in Australia¹⁸, where copper alloy mesh has been in use since 2005, where water is of high quality, due to the absence of disease in some aquafarms, the use of antimicrobials has been unnecessary (Mundoacuicola, 2010).

Alternative A, does not address the use of chemicals and antibiotic dependences. It would provide a local and improved net washing facility, however, use of chemicals and antibiotics would continue as with the *status quo*.

Alternative B has potential to decrease the use of antimicrobials and antifouling coating used in the salmon industry. Therefore, it is expected to have a significant positive effect on reducing chemicals and antibiotic dependency.

6.4.3 MEASURES OF SOCIAL ACCEPTABILITY

“Large-scale aquaculture operations have immediate effects on local livelihoods and local access to marine resources, so the sector is intricately connected to issues of social justice and local stakeholder participation.” (Fløysand et al., 2010, p. 199). The salmon farming boom has brought many jobs to small coastal

¹⁸ From an interview given by Mr Michael Hortle (the general manager of Van Diemen Aquaculture in Australia) to a local aquaculture magazine in a Chilean National Aquaculture Conference.

economies, and is therefore a critical component of social sustainability (Barrett et al., 2002).

C01: Effect on migration from coastal areas to main urban centres

The ideal aquaculture conditions of southern Chile have been critical for the region's growth since the early 1980s. Prior to this the region had been experiencing net migration out of the region as a result of high unemployment, and had experienced stagnation of its traditional foodstuffs and capture fisheries sectors (Grenier, 1984).

The concentration of cage culture operations in specific locations has attracted other related activities such as manufacturing, net-cage maintenance services, veterinary services and insurance companies to form an industrial cluster that spans more than 200 companies (Montero, 2004). This "salmon cluster" has had a significant impact on localities that were previously recorded as having one of the lowest living standards in the country (Salmon Chile (2005), cited by Rojas & Wadsworth, 2008). Thus, salmon farming has had a major effect on coastal communities, and managed to reduce the migration of rural youth to the cities because of the availability of new opportunities within the aquaculture sector (Phyne & Mansilla, 2003; Rojas & Wadsworth, 2008). The slowing of regional migration contributes to the government objective of reducing the concentration of its population in main urban centres, encouraging growth in regional areas. In research conducted by (Amtmann & Blanco, 2001), they reported that reducing regional migration has been valued positively by rural households and local authorities. Their report highlighted the migration as intraregional migration, where people from agricultural farms moved to regional small cities and towns near to the salmon farms, to work in associated services and processing plants, where they can maintain a close link with the countryside and with family members remaining in the rural agricultural areas. A similar effect on migration patterns is expected to occur in Puerto Cisnes, with further development of the salmon industry there.

Alternative A, the nylon net-cage washing service has a moderate, positive effect (that is, the slowing of migration to urban centres).

For Alternative B, the adoption of copper alloy net-cages, may result in the migration of a small portion of the workforce from the area to the main urban centre is perceived as a minor negative effect.

C02: Effects on the cultural heritage of aquaculture communities

In an institutional report conducted by Terram (Claude et al., 2000, p. 30), the social and cultural impact of the introduction of aquaculture into a community has been remarkable. Men traditionally engaged in fishing, harvesting of shellfish and algae, as well as small-scale agriculture, have migrated and whereas once they were self-supporting, they now depend on third parties to earn their living. Most have sold their lands, impoverished their families and frequently developed undesirable habits (such as increased incidence of alcoholism), thus contributing to the loss of their distinctive culture.

The claim is that the aquaculture industry has accelerated a cultural disintegration process in Chiloe that begun with the collapse of the capture fisheries. One argument is that the overexploitation of marine resources and the subsequent decline in small-scale fishing has forced artisan fishers to become labourers in the salmon farming industry (Doren, Gabella, Ruz, & Pizarro, 2001). Traditional Chilota culture, the isolated, hybrid culture that had emerged over 300 years of contact between the indigenous Huilliches (people of the sea) and the Spanish settlers, is seen to be threatened by this development. For centuries local subsistence based on fisher-farmer households contributed to a largely self-sufficient island economy. The new industrialism, combined with the decline of traditional pursuits, has led, to some extent, to the abandonment of traditional values by the young. However, according to (Barrett et al., 2002), evidence has indicated that the traditional lifestyle of fishing-farming subsistence households, has not been abandoned as rapidly as expected.

Alternative A was determined to have a minor, positive impact as it does “maintain” part of the traditional activities of the communities. Before the arrival of the fish farming industry, a large percentage of the population was already

occupied by small scale net fishing, therefore net maintenance (without the application of anti-fouling chemicals) was part of their normal routine work.

Alternative B was determined to have no impact as it does not generate a direct change on local traditional activities.

C03: Effect on working conditions

Economic activity should ensure a growing welfare of workforce, reflected in an increase in employment, income and working conditions, especially in the security field (Doren et al., 2001). However, working conditions are usually not good for laborers on the Chilean salmon industry. Several examples of this statement can be found in the study released by Barrett et al., (2002). Their findings in terms of labor conditions have indicated that the main issues are low wages and the physical nature of the work, tendency toward replacing permanent workers with temporary ones, and massive firings due to new technology.

“Most of the divers working in the industry were originally shellfish divers without training, and often lack basic knowledge of diving safety and are used to working with poor equipment, such as garden hoses bought in hardware stores. These divers are typically subcontracted, which creates a grey market of informal and precarious employment where small-scale operators compete on costs and responsibility is passed on to the individual diver. The Navy trains and licenses divers, but few pass the tests, partly because of illiteracy” (Fløysand et al., 2010, p. 205)

The workers at cage sites interviewed, spoke the health problems workers face (for example women fainting on the job) when antifouling paint which is applied to the salmon cage nets. Two workers have died as a result of collapsed lungs. No safety equipment is used when this is sprayed on nets, and indoor air quality is detrimental as there is no ventilation.

For this attribute, Alternative A was determined to have minor negative impact in relation to *status quo*, since anti-fouling paint application can be dangerous if

safety equipment is not used, therefore it is to expect this safety conditions are considered at the time of upgrading the net maintenance services.

Alternative B was determined to have a moderate, positive impact as the incorporation of copper alloy nets would change the risk level of accidents as it would reduce hours of diving and heavy lifting tasks involved with net maintenance.

6.5 DETERMINING THE WEIGHTS FOR EACH ATTRIBUTE

To determine the priorities of each selected attribute (four for the economic development goal and three each for the environmental protection and social acceptability goals) and weight them accordingly, a survey instrument was developed using the analytical hierarchy process (AHP). This methodology allows for the comparison of every attribute with every other attribute in turn, in a pair-wise manner. The full questionnaire developed for the salmon net-cage selection model is given in Appendix C. The calculation of the attribute weightings will be described in the paragraphs which follow.

The attribute weightings were obtained from a group exercise conducted with a panel of experts in the fields of economic, environmental and social aspects of project evaluation. The experts invited to participate were chosen from the local community. A requirement to form part of the panel was that they should have prior knowledge of the nature of the project and its implications whilst not being classified as stakeholders. The reason for this requirement was to avoid any conflict of interest and keep the weighting assessment unbiased. Nine experts agreed to complete the questionnaire and participate in this research. This part of the analysis took 4 weeks (from 04 November – 02 December 2011). Following the method described in Chapter Three, the weighting procedure was conducted in three rounds. Each round and its results are described below.

6.5.1 ROUND ONE OF THE INTERACTIVE PROCESS

An individual meeting was conducted with each expert in order to obtain their independent input. During this first visit, general project information was presented by the researcher as was the methodology to weight the attributes and the characteristics of the model. The experts then completed the survey questionnaire. The meeting took about one hour: 40 minutes for the introductory talk and about 20 minutes to answer the questionnaire.

Results from the questionnaires were analysed and aggregated to obtain Round One results. The LDW software was used to calculate the weights for this study, by entering the raw data from the questionnaires into the pair-wise comparison matrix from the Logical Decision software. The AHP method automatically calculated the weighting after each pair-wise comparison was completed. The weights assigned by each expert to each attribute are summarized in the tables which follow (Table 6.3, 6.4, 6.5), and the mean and coefficient of variation of the aggregated values were calculated to obtain an overall weight for each attribute based on the Round One results from the expert panel.

Table 6.3 Weightings for the economic development attributes from Round One

Participants	Attributes							
	A01: Increase in production		A02: Net-cage life span		A03: Impact on production costs		A04: Impact on local employment	
	%	rank	%	rank	%	rank	%	rank
1	20.8	2	6.8	4	51.4	1	21.0	3
2	26.8	2	11.3	4	45.3	1	16.6	3
3	59.2	1	6.5	4	18.1	2	16.2	3
4	23.0	3	13.5	4	34.1	1	29.4	2
5	23.1	2	8.7	4	21.1	3	47.1	1
6	29.8	2	10.8	3	51.7	1	7.7	4
7	34.1	2	10.2	4	42.9	1	12.9	3
8	30.6	2	10.8	4	15.3	3	43.3	1
9	23.0	2	9.8	4	49.3	1	17.9	3
MEAN	30.9	2	9.8	4	35.0	1	24.3	3
CV	0.4		0.2		0.4		0.6	

CV: Coefficient of variation.

Table 6.4 Weightings for the environmental protection attributes from Round One

Participants	Attributes					
	B01: Effects on water quality		B02: Threat to native fish from exotic salmon escaping from the salmon farm		B03: Reduction of chemicals and antibiotic dependency	
	%	rank	%	rank	%	rank
1	55.0	1	24.0	2	21.0	3
2	57.0	1	33.3	2	9.7	3
3	30.8	2	9.6	3	59.6	1
4	16.3	3	54.0	1	29.7	2
5	21.1	2	8.4	3	70.5	1
6	19.3	2	10.6	3	70.1	1
7	41.0	1	39.0	2	20.0	3
8	21.0	3	55.0	1	24.0	2
9	20.0	3	41.0	2	39.0	1
MEAN	31.2	2	30.5	3	38.3	1
CV	0.5		0.6		0.6	

CV: Coefficient of variation.

Table 6.5 Weightings for the social acceptability attributes from Round One

Participants	Attributes					
	C01: Effect on migration from coastal areas to main urban centres		C02: Effects on cultural pattern of aquaculture related communities		C03: Effect on working conditions	
	%	rank	%	rank	%	rank
1	26.0	3	41.3	1	32.7	2
2	65.7	1	19.6	2	14.7	3
3	16.3	3	29.7	2	54.0	1
4	29.7	2	16.3	3	54.0	1
5	22.6	2	67.3	1	10.1	3
6	54.0	1	29.7	2	16.3	3
7	14.2	3	40.9	2	44.9	1
8	44.0	2	44.8	1	11.2	3
9	52.7	1	33.3	2	14.0	3
MEAN	36.1	2	35.9	1	28.0	3
CV	0.5		0.5		0.7	

CV: Coefficient of variation.

The aggregated weights (given by the means) obtained from the experts was then directly entered into the LDW to obtain the inverse matrix for the aggregated weights for each of the attributes (Tables 6.6, 6.7, 6.8). The eigenvalues (the values off the diagonals, highlighted in blue) indicate the degree of preference for one attribute with respect to another (from the pair-wise comparisons in the survey). The matrix generates two reciprocal eigenvalues (for each pair-wise comparison), from which only eigenvalues ≥ 1 are used. These eigenvalues were

added to each expert's questionnaire responses, to indicate the collective response as compared to the expert's individual response. Since the eigenvalues generated by the inverse matrix were calculated from the means, they are expressed as decimal values. These decimal values were rounded to the nearest whole number; however, eigenvalues with a decimal of 0.5 were marked in between the two whole numbers. For example, an eigenvalue of 4.509 was marked in between the numbers 4 and 5 on the questionnaire.

Table 6.6 Inverse matrix for the weightings of the economic development attributes from Round One

I-max = 4.000 C.I. = 0.000 C.R. = 0.000	A01: Production growth	A02: Life span	A03: Production cost	A04: Employment
A01: Production growth	0.309	3.153	0.883	1.272
A02: Life span	0.317	0.098	0.280	0.403
A03: Production cost	1.133	3.571	0.350	1.440
A04: Employment	0.786	2.480	0.694	0.243

Table 6.7 Inverse matrix for the weightings of the environmental protection attributes from Round One

I-max = 3.000 C.I. = 0.000 C.R. = 0.000	B01: Effects on water quality	B02: Threat to native fish from exotic salmon escaping from the salmon farm	B03: Reduction of chemicals and antibiotics dependency
B01: Effects on water quality	0.312	1.023	0.815
B02: Threat to native fish from escaped of salmon farm	0.978	0.305	0.796
B03: Reduce of chemicals and antibiotics dependency	1.228	1.256	0.383

Table 6.8 Inverse matrix for the weightings of the social acceptability attributes from Round One

I-max = 3.000 C.I. = 0.000 C.R. = 0.000	C01: Effect on migration from coastal areas to main urban centres	C02: Effects on cultural pattern of aquiculture related communities	C03: Effect on working conditions
C01: Effect on migration from coastal areas to main urban centres	0.361	1.006	1.289
C02: Effects on cultural pattern of aquiculture related communities	0.994	0.359	1.282
C03: Effect on working conditions	0.776	0.780	0.280

6.5.2 ROUND TWO OF THE INTERACTIVE PROCESS

In order to promote a better understanding among the experts, the combined results from Round One were shared with each expert in the group, thereby allowing the participants to consider the other experts' opinions alongside their own and if desired, refine their own estimates before meeting up with the other expert participants. Thus Round Two results, shown in the next set of tables (Tables 6.9, 6.10, 6.11), represent the new aggregated values of the weights obtained after a second round of responses from each expert, taking into consideration the combined results from Round One.

Due to the differing background and expertise of the participants on the panel of experts, it was expected to find within the group different assumptions, viewpoints, and interpretations of the issues concerning each of the attributes, which would then be reflected in the weightings they gave to each attribute. The coefficients of variation obtained for each attribute from this second round were particularly relevant for the final round of this approach. The attributes with the greater coefficients of variation indicated the attributes for which there was least agreement in terms of the weightings assigned. Therefore it would be these attributes that required more attention in order to reach consensus in the last interactive round.

Table 6.9 Weightings for the economic development attributes from Round Two

Participants	Attributes							
	A01: Increase in production		A02: Net-cage life span		A03: Impact on production costs		A04: Impact on local employment	
	%	rank	%	rank	%	rank	%	rank
1	20.4	3	7.4	4	48.0	1	24.2	2
2	29.5	2	10.8	3	43.0	1	16.7	3
3	51.8	1	7.2	4	21.4	2	19.6	3
4	25.5	3	10.9	4	34.6	1	29.0	2
5	23.9	2	8.9	4	23.8	3	43.4	1
6	29.2	2	9.8	4	47.9	1	13.2	3
7	32.5	2	12.0	4	41.7	1	13.8	3
8	31.8	2	11.4	4	18.2	3	38.6	1
9	24.8	2	8.7	4	49.1	1	17.4	3
MEAN	29.9	2	9.7	4	36.4	1	24.0	3
CV	0.3		0.2		0.3		0.5	

CV: Coefficient of variation.

Table 6.10 Weightings for the environmental protection attributes from Round Two

Participants	Attributes					
	B01: Effects on water quality		B02: Threat to native fish from exotic salmon escaping from the salmon farm		B03: Reduction of chemicals and antibiotic dependency	
	%	rank	%	rank	%	rank
1	50.0	1	24.0	3	26.0	2
2	54.0	1	29.7	2	16.3	3
3	33.3	2	14.0	3	52.7	1
4	19.6	3	49.3	1	31.1	2
5	26.8	2	11.8	3	61.4	1
6	29.7	2	16.3	3	54.0	1
7	41.3	1	32.7	2	26.0	3
8	22.1	3	46.0	1	31.9	2
9	26.0	3	32.7	2	41.3	1
MEAN	33.6	2	28.5	3	37.9	1
CV	0.4		0.5		0.4	

CV: Coefficient of variation.

Table 6.11 Weightings for the social acceptability attributes from Round Two

Participants	Attributes					
	C01: Effect on migration from coastal areas to main urban centres		C02: Effects on cultural pattern of aquaculture related communities		C03: Effect on working conditions	
	%	rank	%	rank	%	rank
1	26.0	3	41.3	1	32.7	2
2	59.4	1	24.9	2	15.7	3
3	19.6	3	31.1	2	49.3	1
4	34.9	2	16.8	3	48.4	1
5	24.7	2	62.2	1	13.1	3
6	49.3	1	31.1	2	19.6	3
7	19.6	3	49.3	1	31.1	2
8	44.3	1	38.7	2	16.9	3
9	48.4	1	33.3	2	16.8	3
MEAN	36.2	2	36.5	1	27.1	3
CV	0.4		0.4		0.5	

CV: Coefficient of variation.

Again, the inverse matrix procedure was used to obtain the eigenvalues that indicate the degree of preference for one attribute with respect to another (from the pair-wise comparisons in the survey). In order to do so, the aggregated weights obtained from the experts in the second round were entered into the LDW to obtain the inverse matrices (Tables 6.12, 6.13, 6.14).

Table 6.12 Inverse matrix for the weightings of the economic development attributes from Round Two

I-max = 4.000 C.I. = 0.000 C.R. = 0.000	A01: Production growth	A02: Life span	A03: Production cost	A04: Employment
A01: Production growth	0.299	3.082	0.821	1.246
A02: Life span	0.324	0.097	0.266	0.404
A03: Production cost	1.217	3.753	0.364	1.517
A04: Employment	0.803	2.474	0.659	0.240

Table 6.13 Inverse matrix for the weightings of the environmental protection attributes from Round Two

I-max = 3.000 C.I. = 0.000 C.R. = 0.000	B01: Effects on water quality	B02: Threat to native fish from exotic salmon escaping from the salmon farm	B03: Reduction of chemicals and antibiotic dependency
B01: Effects on water quality	0.336	1.179	0.887
B02: Threat to native fish from escaped of salmon farm	0.848	0.285	0.752
B03: Reduce of chemicals and antibiotics dependency	1.128	1.330	0.379

Table 6.14 Inverse matrix for the weightings of the social acceptability attributes from Round Two

I-max = 3.000 C.I. = 0.000 C.R. = 0.000	C01: Effect on migration from coastal areas to main urban centres	C02: Effects on cultural pattern of aquiculture related communities	C03: Effect on working conditions
C01: Effect on migration from coastal areas to main urban centres	0.363	0.992	1.341
C02: Effects on cultural pattern of aquiculture related communities	1.008	0.366	1.352
C03: Effect on working conditions	0.746	0.740	0.271

6.5.3 ROUND THREE OF THE INTERACTIVE PROCESS

In the third round the experts were brought together in a focus group setting. The meeting served as the liaison and provided an exchange of opinions with the goal of achieving group consensus. From Round Two, the attributes with the greatest coefficients of variation were those for which the experts had least agreement in the weightings they had each assigned to that attribute. For this reason, discussion at the focus group meeting concentrated on those attributes which had

the highest coefficients of variation. During the focus group meeting, the experts were asked to reconsider previous answers in reference to the mean group response and to provide a rationale for answers to questions that were outside the mean. The results from Round Three are shown in Tables 6.15 to 6.17.

Table 6.15 Weightings for the economic development attributes from Round Three

Participants	Attributes							
	A01: Increase in production		A02: Net-cage life span		A03: Impact on production costs		A04: Impact on local employment	
	%	rank	%	rank	%	rank	%	rank
1	23.9	2	8.9	4	43.4	1	23.8	3
2	26.5	2	11.0	4	43.8	1	18.7	3
3	47.1	1	9.0	4	23.2	2	20.7	3
4	25.0	3	10.0	4	36.0	1	29.0	2
5	24.5	3	8.9	4	29.2	2	37.4	1
6	29.2	2	9.8	4	47.8	1	13.2	3
7	30.8	2	12.6	4	42.8	1	13.8	3
8	33.3	1	11.7	4	27.6	2	27.4	3
9	25.4	2	9.3	4	47.6	1	17.7	3
MEAN	29.5	2	10.1	4	37.9	1	22.4	3
CV	0.26		0.14		0.24		0.36	

CV: Coefficient of variation.

Table 6.16 Weightings for the environmental protection attributes from Round Three

Participants	Attributes					
	B01: Effects on water quality		B02: Threat to native fish from exotic salmon escaping from the salmon farm		B03: Reduction of chemicals and antibiotic dependency	
	%	rank	%	rank	%	rank
1	41.3	1	26.0	3	32.7	2
2	40.1	1	39.9	2	20.0	3
3	31.1	2	19.6	3	49.3	1
4	26.0	3	41.3	1	32.7	2
5	34.9	2	16.8	3	48.4	1
6	31.1	2	19.6	3	49.3	1
7	41.3	1	32.7	2	26.0	3
8	26.0	3	41.3	1	32.7	2
9	26.0	3	32.7	2	41.3	1
MEAN	33.1	2	30.0	3	36.9	1
CV	0.19		0.35		0.31	

CV: Coefficient of variation.

Table 6.17 Weightings for the social acceptability attributes from Round Three

Participants	Attributes					
	C01: Effect on migration from coastal areas to main urban centres		C02: Effects on cultural pattern of aquiculture related communities		C03: Effect on working conditions	
	%	rank	%	rank	%	rank
1	26.0	3	41.3	1	32.7	2
2	41.3	1	32.7	2	26.0	3
3	26.0	3	41.3	1	32.7	2
4	32.7	2	26.0	3	41.3	1
5	28.1	2	58.4	1	13.5	3
6	39.9	2	40.1	1	20.0	3
7	41.3	1	32.7	2	26.0	3
8	44.3	1	38.8	2	16.9	3
9	48.4	1	34.8	2	16.8	3
MEAN	36.44	2	38.46	1	25.10	3
CV	0.21		0.25		0.37	

CV: Coefficient of variation.

6.5.4 QUANTIFYING THE EVOLUTION OF AGREEMENT AMONG THE EXPERTS

With the purpose of estimating the level of experts' agreement achieved from the three interactive rounds, the coefficients of variation and the coefficients of Kendall have been calculated for each round. Details of these calculations can be found in Section 3.5.4.

Coefficient of Variation (CV)

The CVs were calculated from each attribute's weighting, at each interactive round. The results are graphically presented in Figures 6.3, 6.4 and 6.5. The graphs show the evolution of agreement amongst the experts on the weightings assigned to each of the economic, environmental and social attributes from the interactive process.

Figure 6.3 Coefficients of variation for the weightings of the economic development attributes for each round

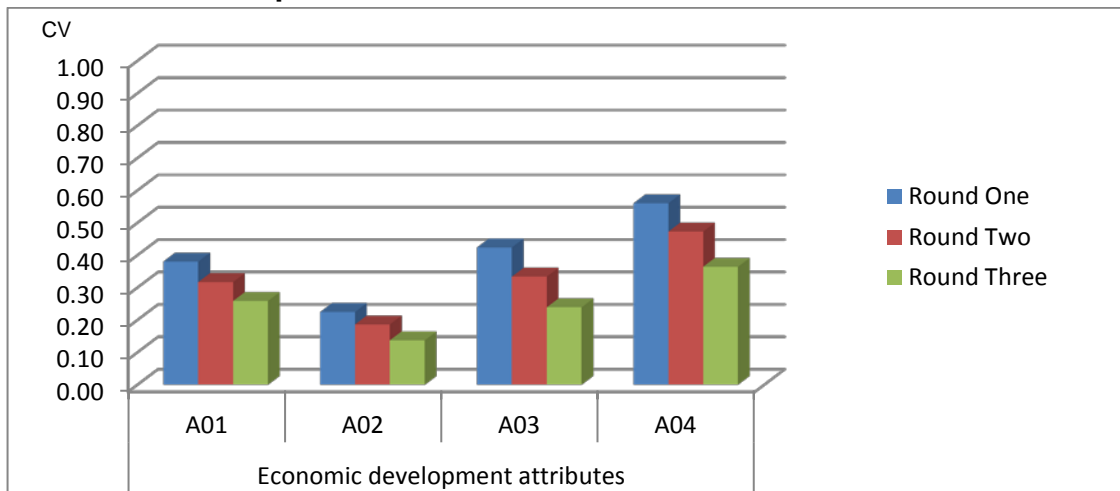


Figure 6.3 shows a decrease in the coefficients of variation through the consecutive rounds for the economic development attributes. This can be interpreted as an incremental movement toward consensus on the weightings of the attributes, by the experts. All final round CVs were under 0.5, which the literature suggests is an acceptable degree of consensus.

Figure 6.4 Coefficients of variation for the weightings of the environmental protection attributes for each round

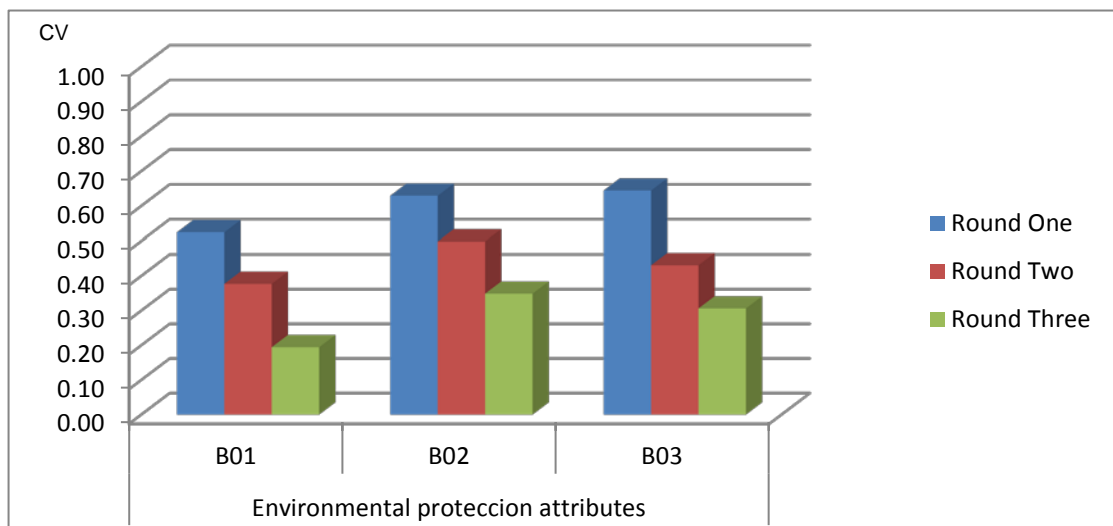
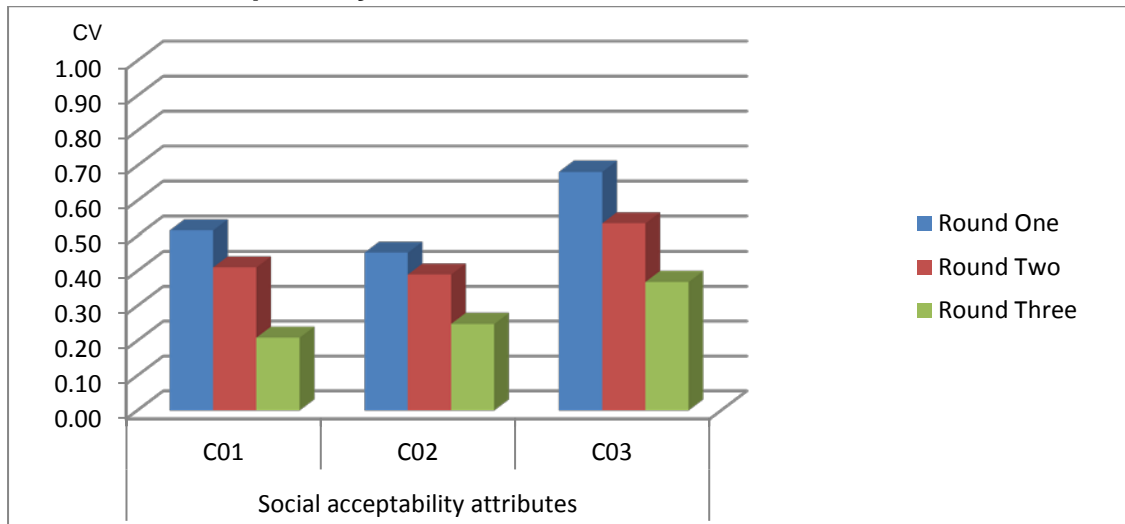


Figure 6.4 shows a decrease in the coefficients of variation through the consecutive rounds for the environmental protection attributes. This can be interpreted as an incremental movement toward consensus on the weightings of

the attributes, by the experts. All attributes for the final round obtained a CV lower than 0.5, indicating a good degree of consensus.

Figure 6.5 Coefficients of variation for the weightings of the social acceptability attributes for each round



As with the other sets of attributes, Figure 6.5 shows a decrease in the coefficients of variation through the consecutive rounds for the social acceptability attributes. This can be interpreted as an incremental movement toward consensus on the weightings of the attributes, by the experts. Again all attributes for the final round obtained a CV less than 0.5, indicating a good degree of consensus.

Coefficient of Kendall (w)

The coefficient of Kendall was calculated to determine the degree of agreement reached in each interaction by the group of experts. This coefficient is based on the rank obtained by each attribute when the weights are estimated. W was calculated for the set of attributes for economic development, environmental protection and social acceptability at each round (see the calculation matrices in Appendix C). These coefficients of Kendall for each round are presented in Table 6.18.

Table 6.18 Coefficients of Kendall for economic, environmental and social attribute weightings for the three rounds

Interactive Round	Kendall's Coefficient of agreement		
	Economic development	Environmental protection	Social acceptability
Round 1	0.61	0.01	0.05
Round 2	0.66	0.05	0.09
Round 3	0.78	0.05	0.23

For all three set of attributes, the coefficients of Kendall increased through each successive round demonstrating increased agreement at each round. The coefficients of Kendall show that the economic development attributes obtained a relatively high level of agreement for the final weightings ranks ($w > 0.5$). In the case of environment protection and social acceptability attributes, it is clear from the relatively low values for these coefficients of Kendall ($w < 0.5$), that there is not agreement between the experts regarding the ranking of each set of attributes. This is particularly so for the environmental protection attributes. This can be partially explained by the small number of attributes for each of these goals (only three attributes), combined with a homogenous distribution of weights between attributes, which reflected that there was not a strong preference for any particular attribute over another, according to the experts.

Following the focus group meeting the panel of experts agreed to adopt the average values for the weightings from the Round Three results. Finally, combining all the data for this section, the final weightings for each of the attributes have been summarized into one table, Table 6.19.

Table 6.19 Final attributes weightings

Goal	Attributes		Weights (%)
Economic development	A01	Increase in production	29.52
	A02	Net-cage life span	10.13
	A03	Impact on production costs	37.93
	A04	Impact on local employment	22.41
Total			100
Environmental protection	B01	Effects on water quality	33.09
	B02	Threat to native fish exotic salmon escaping from the salmon farm	29.99
	B03	Reduce of chemicals and antibiotic dependency	36.93
Total			100
Social Acceptability	C01	Effect on migration from coastal areas to main urban centers	36.44
	C02	Effects on cultural pattern of aquiculture related communities	38.46
	C03	Effect on working conditions	25.10
Total			100

6.6 RANKING THE ALTERNATIVES

This study aimed to compare two project proposals, the net-cage washing and repair service, and the manufacture of copper alloy net-cages, in order to determine the net benefits of each alternative and then rank the two alternatives against each other and against the Status Quo. The alternatives were analysed following the procedure undertaken for the REM in the LDW software. To do so, the most and least preferred measures were specified and the data were entered for each attribute for the individual alternatives. Measures were then converted to units of utility. Common unit conversions were undertaken using single-measure utility functions (SUFs) for point-estimate data, and direct assessment was used for descriptive labels.

Table 6.20 presents the list of attributes and their associated weightings alongside the measure estimates of 'net benefits' under each of the three alternatives.

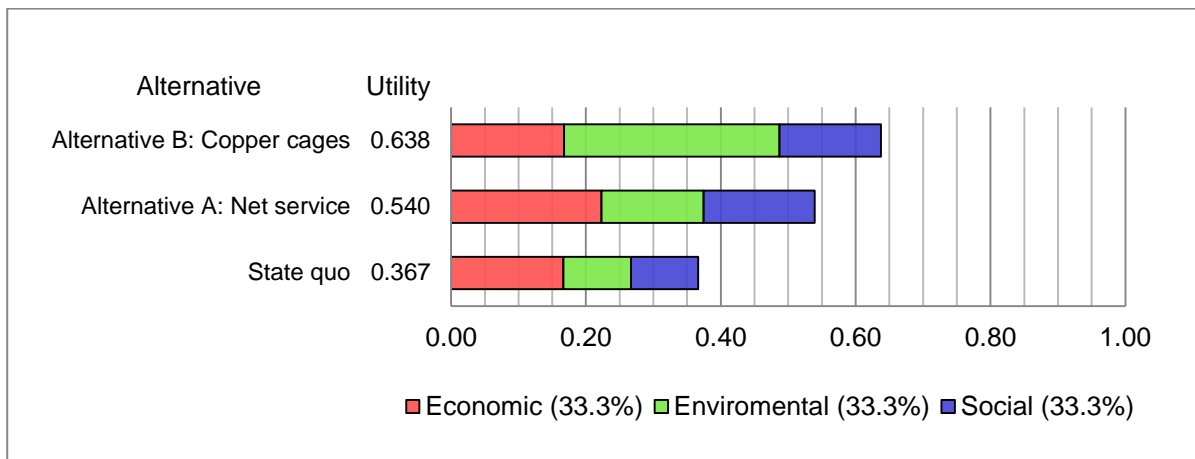
Table 6.20 Net benefits associated with each attribute under the different alternatives for the selection of one of two net-cage systems to be utilised by the salmon farming industry in southern Chile

Goal	Attributes	Weights (%)	Net benefits for each of the different alternatives		
			Status quo	Alternative A	Alternative B
Economic development	Increase in production	29.52	no effect	negligible positive effect	significant positive effect
	Net-cage life span	10.13	2 years	4 years	10 years
	Impact on production costs	37.93	USD \$404,303	USD \$370,730	USD \$720,000
	Impact on local employment	22.41	no effect	moderate positive effect	minor adverse effect
		100			
Environmental protection	Effects on water quality	33.09	moderate adverse effect	minor adverse effect	moderate positive effect
	Threat to native fish from exotic salmon escaping from the salmon farm	29.99	minor adverse effect	negligible positive effect	significant positive effect
	Reduction of chemicals and antibiotic dependency	36.93	no effect	no effect	significant positive effect
		100			
Social acceptability	Effect on migration from coastal areas to main urban centres	36.44	no effect	moderate positive effect	minor adverse effect
	Effects on cultural heritage of aquiculture related communities	38.46	no effect	minor positive effect	no effect
	Effect on working conditions	25.10	no effect	minor adverse effect	moderate positive effect
		100			

Finally, the analysis was conducted and the rankings for each of the alternatives are shown in Figure 6.6. In each of the stacked bar graphs, economic development is shown in red (where a longer bar represents a higher economic benefit), environmental protection is shown in green (where a longer bar

represents a lesser threat to the environment), and social benefits are shown in blue (where a longer bar represents greater social benefit).

Figure 6.6 Ranking of alternatives for the selection of one of two net-cage systems to be utilised by the salmon farming industry in southern Chile



From Figure 6.6 it can be seen that, when using an equal distribution of weights for economic, environmental and social goals (i.e. weighting each at 33.3%), the Alternative A and Alternative B have achieved a greater relative utility score, when compared to the Status Quo ('without' any project) alternative. This means that both project alternatives contribute to improving the current situation. However, when comparing the two alternative net-cage project proposals, Alternative B obtained the highest score, corresponding to the preferred option.

6.7 SENSITIVITY ANALYSES

In the previous section, the three goals, economic development, environmental protection and social acceptability were themselves given equal weighting (33% weighting for each). Now sensitivity analyses are required to test the impact of changing the relative weightings of these goals for the three alternatives (Alternative A, Alternative B and Status Quo). Of particular interest are the rankings under a pessimistic scenario, since it is this scenario which is particularly relevant for the precautionary principle. Combining poorer outcomes for both environmental and economic attributes provides a worst-case scenario, since it is

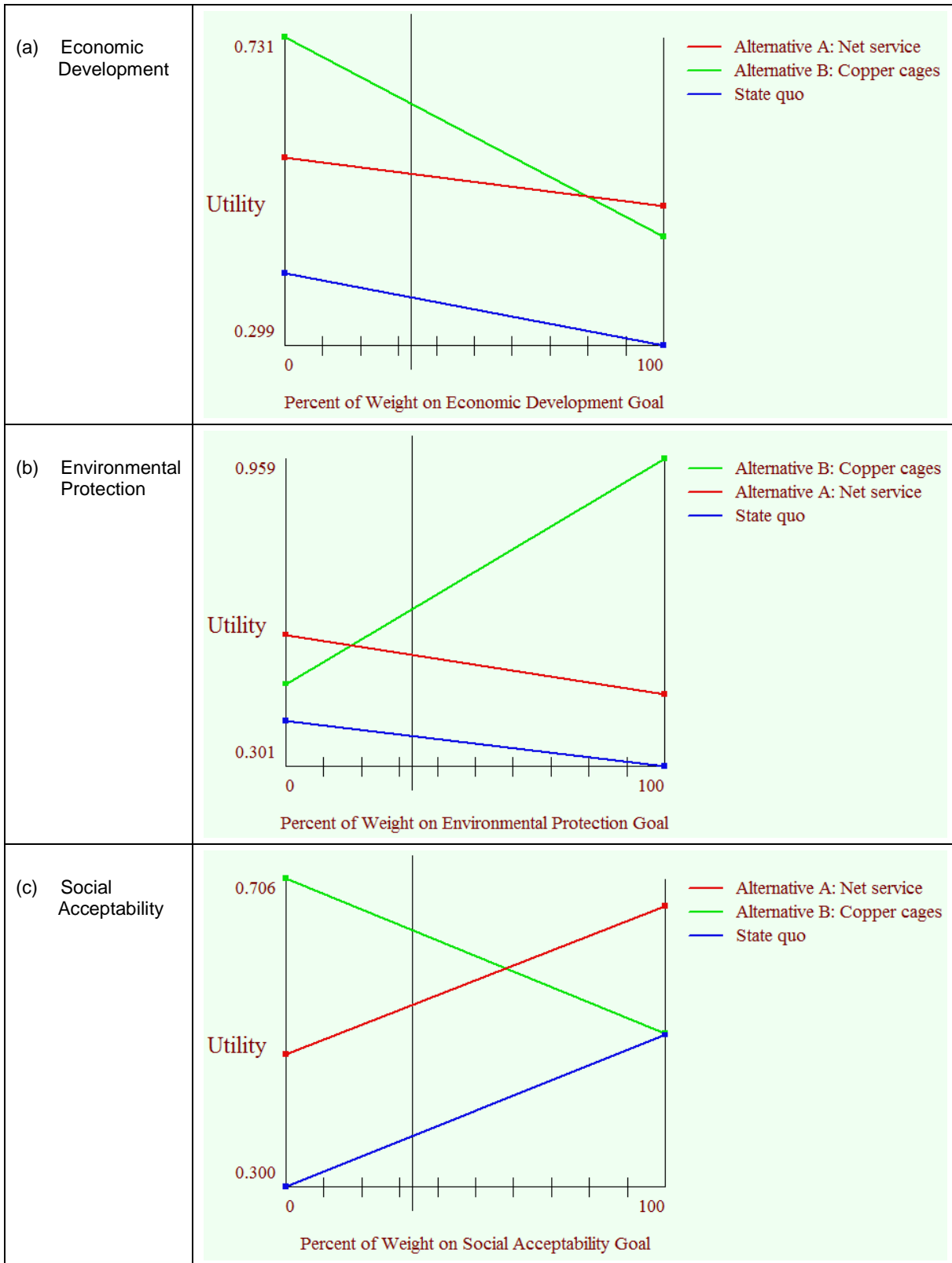
likely that poor environmental outcomes would be associated with higher economic outcomes and vice versa.

Consider first the economic development goal. The weighting assigned to the economic development goal is varied from 0%, so that it is not considered at all, through to 100%, where it is the only goal considered. Simultaneously, the other two goals must be varied accordingly (so that the combined weightings of the three goals are always 100%) and the remaining weighting is split evenly between the other two goals, environmental protection and social acceptability. These changing weightings are graphed in Figure 6.7 (a). The relative utilities are represented on the vertical axis and the weighting assigned to the economic development goal (as a percentage) appears on the horizontal axis. The coloured lines represent the overall utilities for each of the alternatives when varying the weightings assigned to the economic development goal.

Since both alternative project proposals clearly showed they were an improvement on the Status Quo (shown in Figure 6.6), the sensitivity analyses focus on where the utility of accepting Alternative A equals the utility of accepting Alternative B. Therefore, the red line (base line representing Alternative A) is observed where it in turn intersects the green line (Alternative B). It indicates the weighting of the economic development goal that is required in order for the utilities of both alternatives ('Net service' or 'Copper cages') to be equal. The highest line represents the most preferred alternative (overall) for a given weighting of the economic development goal.

The black vertical line represents a 33.3% weighting for the economic development goal, and consequently where the three goals are given equal weightings or importance. The process of varying the weightings assigned to the goals was repeated for the environmental protection goal (and the results presented in Figure 6.7 (b)) and again for the social acceptability goal (as shown in Figure 6.7 (c)).

Figure 6.7 Results of the impact of changing the relative weightings of each goal (economic, environmental and social) for the final utility score of each alternative.



By examining Figure 6.7 (a) it seems that economic development would have to represent more than 80% of the decision preference (with the remaining 20% of weighting distributed among environmental protection (10%) and social acceptability (10%) goal) to result in Alternative A being preferred.

Figure 6.7 (b) indicates that when environmental protection is given no consideration (a weighting of 0%) Alternative A can be accepted. However, when consideration for environmental protection increases (expressed by an increasing weighting) up to 18%, then Alternative B is considered the best option. It indicates that while Alternative A is an improvement on the Status Quo, when compared with Alternative B it can be rejected because of a relatively poor performance on attributes of environmental protection.

The last graph (Figure 6.7 (c)) shows the sensitivity analysis for the goal of social acceptability. In this case, if social acceptability is given no consideration, preference for Alternative B far outweighs that for Alternative A. However, as the goal of social acceptability increases in relevance (as its weightings increase), the differences between the utilities of Alternatives A and B reduce. While the percentage of weight on social acceptability will need to be above 56%, at that point Alternative A becomes the best option. This graph also indicates that if all consideration is given to the social acceptability goal, then Alternative B would contribute little more than the current (Status Quo) situation.

In conclusion, considering the comparison of the two alternatives against each other and against the Status Quo situation ('without' the implementation of either project). Both project alternatives can be selected, as they demonstrate a better performance than the current (Status Quo) situation. In order to select Alternative A, there would need to be a bias toward social acceptability, so that the goal of social acceptability had a weighting of at least 56%, thus reducing the weightings for economic development and environmental protection to 22% each $((100-56)/2$ each). If the decision were to have a bias toward economic development, then in order to select Alternative A, the goal of economic development would require a

weighting of 80%, thus reducing the weightings for environmental protection and social acceptability to 10% each $((100-80)/2$ each).

6.8 MAKING THE RECOMMENDATION

Under a situation of capital rationing where the funding agency (in this case CORFO) did not have sufficient capital to fund both projects, it is clear from the REM analysis that the project for the adoption of copper alloy net-cages (Alternative B) is expected to generate a higher overall net benefit than the implementation of an aquaculture net-cage servicing facility (Alternative A). The most notable benefit is the much improved environmental protection. If, however, CORFO had sufficient capital to financially support both projects, the analysis has shown that both proposed projects provide net benefits beyond that of the current (Status Quo) situation. In particular, both demonstrate improved environmental protection and increased social acceptability.

CHAPTER SEVEN – DISCUSSION AND CONCLUSION

In this final chapter a discussion of the Rapid Evaluation Method (REM) proposed in this research is presented and conclusions are drawn. Initially, discussion is had around what makes this framework a REM and what makes it novel. Discussion then moves to the contribution of the three case studies in testing and refining the method. Finally, conclusions are drawn, limitations discussed and suggestions for further research are presented.

7.1 WHAT MAKES THIS FRAMEWORK A REM

When projects are put forward for consideration for funding and/or approval by local or central authorities, technical and other considerations have already been undertaken. In addition, the proposers of the project are usually required to submit evidence of improved welfare to the economy in terms of overall anticipated socio-economic benefits. Increasingly, evidence of likely overall environmental impact resulting from the proposed project is also required. Therefore, by the time a project proposal is ready for submission, key economic, social and environmental data have also been collected to accompany the submission. However, these are not necessarily full Cost-Benefit Analyses (CBA), Environmental Impact Assessments (EIA) or Social Impact Assessments (SIA).

The REM presented in this research proposes taking this submitted information and any other readily available information (such as that which was publically available and made use of in Case Study 1 or, information gained directly from discussion with submitters) and collating it for use in a multi-criteria analysis (MCA) approach. Independent experts were used to arrive at an acceptable level of consensus regarding the relative weightings of the attributes under consideration. These weightings then give rise to measures of utility that can be ranked and from which an overall

recommendation can be made. This recommendation takes the form of an acceptance or rejection of the proposed project or, alternatively, that a full and independent MCA be undertaken.

The challenge for a good project assessment model is that it needs to be practical and applied in nature (Gough & Ward, 1994), and it must balance the need to keep enough information to make a good choice, with the need to simplify the situation sufficiently to make it possible to come to a conclusion in a reasonable length of time. The REM fits these criteria.

In a MCA the identification of attributes for evaluation is of prime importance. For a set of attributes to be considered an adequate assessment for a project, Keeney and Raiffa (1993) suggested that they be; complete, operational, decomposable, non-redundant and minimal. Keeping these requirements in mind, a checklist was designed for the REM that would be applicable for a wide range of project situations and potential impacts. The checklist is based on the Leopold matrix, which provides both a scale of magnitude and a scale of significance to evaluate impacts. Particular attention was paid to avoid any overlap between economic development, environmental protection and social acceptability, to avoid double counting. The checklist is used to identify possible impacts of a project, but only includes those that have a significant impact so as to keep the set of attributes from becoming too cumbersome. Thus, the REM does not require a full CBA, EIA and SIA to be conducted unless application of the REM results in a recommendation that a full MCA is required. The focus of the REM is that key attributes (rather than all possible attributes) be included in the evaluation.

Stufflebeam (2001) noted that a general checklist provides a convenient aid that can be customised to suit a particular situation. However, Hassan & Hutchinson (1992) said that a common limitation with checklists is that, while they address well the economic aspects of resource information, they may not necessarily touch on those points that have the greatest social and political significance, either locally or nationally. Particular care was taken so that the checklist for the REM gave equal emphasis to economic development, environmental protection and social

acceptability. The checklist provides a systematic and comprehensive list of most requirements that might be considered necessary to decide on the worth of a project. It is a checklist, therefore it is acknowledged that there must always be opportunity to add attributes which capture any unique issues that would be confronted in a specific locale.

The reliability of any decision model is dependent upon the information available and since this information may be presented in different metrics or formats, any robust decision model should be able to accommodate these different data formats (Munda, Nijkamp, & Rietveld, 1994). The usefulness of available data or information is also dependent upon the data transformation methods to ensure consistency and reliability with respect to model outcomes and the generation of knowledge (Nijkamp, Rietveld, & Voogd, 1990). Depending upon the characteristics of the project proposed (such as, legislation requirements, project size, institutional body involved in the decision-making) data can be presented in different ways. An advantage of applying the REM is that it is a tool that can utilize heterogeneous data from different sources, which can then be organized and integrated to assist decision-makers.

When collecting data from reports submitted by project proposers, it was noted that a great deal of the data was qualitative. Nijkamp et al. (1990) also observed that qualitative information was more likely than not, to be for projects concerning socio-economic and physical planning. Ascough, Maier, Ravalico & Strudley, (2008, p. 284) concurred, saying that “environmental management problems and their solutions are often value-laden and subjective; consequently standard or traditional decision-making approaches that rely on quantifiable and objective data often fail”. However, qualitative aspects are harder to deal with in traditional models, thus there is a need for methods that incorporate both qualitative and quantitative measures. Hence, the ability of the REM to accommodate qualitative data, expert opinions, or experiential knowledge gives it an advantage over quantitative only methodology.

7.2 WHAT MAKES THE METHOD NOVEL

Outcomes of project assessments are highly sensitive to the attributes and weightings used (van Pelt, Kuyvenhoven & Nijkamp, 1990). Further, it is important that the weights and any resulting trade-offs are a true reflection of the participants' preferences (Proctor & Qureshi, 2005). The Analytic Hierarchy Process (AHP) was used to weight the measures, as this is a well-established approach in environmental MCA literature (Ho, 2008). The AHP method uses pairwise comparisons, requiring each of a number of individual assessors to assess weight ratios for all possible pairs of attributes for each objective, thus reflecting their preferences regarding the trade-offs. A linear algebraic approach is then used to compute a best-fit set of weights based on the ratios entered. The method chosen in this research to aim for consensus regarding the trade-offs is the Delphi approach as it was deemed by MacMillan and Marshall (2006) to be the most appropriate because of its convenience, reliability and cost effectiveness.

Under a Delphi approach, each panellist is asked to assess the situation independently. The results are then pooled and analysed. Each panellist is then allowed to study his own response along with the pooled group response and is then asked to review his own answers in light of the group consensus. Since panellists may change their opinion based on the feedback that they receive from the analyst (or facilitator), it is expected that the level of agreement among them will increase in every subsequent round (Meijering, Kampen, & Tobi, 2013) as they see their results combined with those of the other panellists. This process can continue until responses converge. As von der Gracht (2012) has indicated, consensus measurement is a valuable component of data analysis and interpretation of results. While there are advantages, if the process continues through too many iterations it can be time-consuming. The literature review by von der Gracht (2012) found that in reality, in many cases the number of rounds was determined *a priori* (independently of the consensus level reached) due to budget or time constraints.

The practical approach adopted in this research reduces the number of participants, the time required to assess submissions as well as, potentially, variable

and fixed costs. Other important characteristics of the Delphi approach include its effectiveness in data poor environments, the relatively short time period required to implement it, and its cost effectiveness in an environment where experimental models cannot be used. If the procedure includes the opportunity for ample debate and consensus building, the likelihood of achieving a reliable and unbiased project outcome are maximised (MacMillan & Marshall, 2006).

The framework used in this research includes the contribution of independent experts from economic, environmental and social backgrounds to make the REM weighting process more transparent and reliable. In this research, a panel of experts (for each case study) was employed to collectively determine the attribute weightings utilized in the model. By doing so, expert knowledge is used to obtain the attributes' weights based on expert collective agreement. What makes the approach novel is the use of a modified Delphi approach.

In the REM approach, the first two rounds operate as with the conventional Delphi approach, thus incorporating its strengths, namely, that a number of assessors work independently and anonymously and their collective responses are pooled into a group response. However, the REM approach proposes that the third round be an interactive round. For the third round the experts are brought together in a focus group setting where they have the results of the second pooled group response and again refine their individual responses. Then in the focus group setting they first listen to each other putting forward their expert viewpoints and have a discussion moving closer to agreement on the final values that the weightings should take. This restricts the method to a three round approach, with a more likely arrival at an acceptable consensus for the attribute weightings to be used in the model.

7.3 THE USE OF CASE STUDIES TO TEST AND REFINE THE METHOD

In this research, case studies were selected in order to test and refine the REM and demonstrate its applicability to real-world projects. The case studies were chosen to provide variation in project scope and scale, and to test applicability of

the method in both developed and developing economies. In terms of differing scope, these were from the infrastructural level of an energy sector project to the private industrial sector. Scale differed in terms of the potential to impact economic, environmental and social settings at the national, regional or local levels. The first of these projects was the New Zealand based Turitea wind-farm project with implications at the national level for the energy sector as it moves toward greater use of renewable resources. In addition, regarding the direct environmental impact of the project's infrastructure, as it was the first time in New Zealand that a proposed project would be situated within a designated reserve protected under the Reserves Act 1977, requiring a re-classification of the reserve prior to consideration of the project proposal. The second was smaller in scale, the Cisne Austral abattoir project, proposed by the privately owned Cisne Austral Ltda and situated in Chilean Patagonia, to construct and operate a local abattoir to process lamb for the export market. For both of these projects, evaluation centred around a 'with project' versus a 'without project' analysis. The third case study involved the comparison of two proposed projects and the selection of just one of these. As such, it was an analysis to select of one of two net-cage systems to be utilised by the salmon farming industry in southern Chile. Thus, despite the model having been built principally to determine whether a project should be accepted or not, it can also be used by public agencies to make a decision on how to allocate resources between competing projects.

For each of these case studies, the REM was easily adapted to fit each project's characteristics, decision attributes, and the information available. The REM checklist was helpful and time-saving for the identification of attributes in the three case studies. It was also helpful in identifying gaps in key information required, so the analyst could seek out that information. For example, in case study two (the proposed Cisne Austral Lamb Export Abattoir project), no specific economic information from the company was requested by the local authorities, therefore the only economic attributes derived from the assessment report undertaken by the company, was data related to investment expenditure and the number of jobs associated with the project. However, when the checklist was applied other economic attributes were revealed, which required consideration. To do so,

additional information was obtained from relevant literature and government department web sites, to make a final inclusion of five economic attributes in the decision process. Tested with such varied case studies, it appears that the checklist developed in this research will be widely applicable to other project proposals submitted to decision makers.

The application of the assessment method to real world case studies also allowed for the identification of current or potential barriers to the implementation of the REM. Two key areas of concern relate to data availability and data quality. Generally speaking, the information provided by submitters for project assessments is limited and this was the case for the private project case studies (Case Studies 2 and 3). It was, therefore, necessary to complement submitted project data with information from other studies in the literature and from governmental reports. This situation is particularly the case for smaller scale projects where resources are limited regarding the provision of detailed information. This will have implications for the speed of the execution of the REM. It was also noted that limitations were imposed by the quality of the data, such as the inadequacy of the baseline (inventory) data. This may be particularly so for projects located in developing countries. When necessary, the method has been refined to compensate for these limitations by the execution of scenarios analyses. For Case Study 2, for example, optimistic, pessimistic and realistic scenarios were undertaken.

From the case studies presented it can be verified that the analysis process in Logical Decisions® for Windows™ is repeatable, transparent, and quick. The case studies also demonstrate how the attribute weightings (determined by the group of experts) are used to measure the utility of each project alternative. This modified Delphi approach can, if desired, allow for interaction between the decision maker and the group of experts, which may be beneficial.

7.4 WHAT MAKES THE MODEL USEFUL

The appeal of the REM approach lies in its simplicity, as it endeavours to take explicit account of multiple attributes and multiple measures, and articulates these

into a structured and coherent management solution. Further, it may be expressed in a numerical format to allow rational, transparent and defensible decisions to be made in a timely manner.

The results of the research show that the REM provides a convenient structure to accommodate the three-fold analysis required, facilitating the incorporation of key economic, social, and environmental data in an explicit and logical manner. Such an approach is suited to evaluations that are characterised by the involvement of different institutional agencies, competing and conflicting objectives, interdependent socio-economic and environmental components, and a need for a timely and less resource intensive decision-making process. The checklist facilitates quick identification of the key criteria and the modified Delphi approach is a transparent and relatively time-efficient way to determine weightings these criteria. Institutions that may benefit from the use of the REM to evaluate project proposals are: central, regional and local authorities, trust funds, development agencies, and urban and regional planning agencies.

7.5 CONCLUSION

Today MCAs are widely used for project appraisals. In order to include the short and long-term consequences that a project can have, most MCA models are built on a project specific basis. In addition, there is a proliferation of projects being put forward for consideration, thus the work of decision makers has become extremely time and resource consuming, as a full and unique MCA has to be repeated for each individual project appraisal.

The aim of this research was to develop and test an integrated method for project appraisal that can be used by decision makers to evaluate a diverse range of project proposals in a timely and resource efficient manner. This led to the creation of a generic method that could be applied to all projects in the first instance. The research employed a modified Leopold matrix to create a checklist to be used as an initial tool to select key attributes for inclusion in the decision-making analysis. This standardized approach allows decision makers to work with available data in the first instance to avoid excessive time and resource expenditure.

MCA was chosen as the decision-making framework due to its ability to be able to integrate key economic, social and environmental data in a coherent manner. Once the MCA approach is taken, the AHP is used to weight the measures. The AHP process is undertaken by a group of independent experts following a modified Delphi approach. This approach limits the number of rounds or iterations to three, with the third round being undertaken in a discussion group setting with the likelihood of an improved consensus measure being reached for each of the weights. The analyst then uses the weights to calculate the utility scores, conduct sensitivity analyses and make recommendations regarding the proposed project. At this point an 'accept' or 'reject' decision might be made or, alternatively a decision is made to recommend that a full independent MCA be executed. Taking this approach means that a unique and independent MCA will only be required for some projects. Therefore, this method accelerates the project decision-making process and reduces the overall resources needed for the appraisals.

Most project proposals include compartmentalized assessments of social, economic, financial, environmental and institutional factors. This research, on the other hand, has demonstrated that it is possible to integrate these factors into a single system to inform decision makers.

There are several limitations to the REM put forward here. Regan, Davis, Andelman, Widyanata, and Freese (2007) observe that one of the limitations of MCA models is their reliance upon the assumption of independence between criteria, which can result in double counting between attributes. For example, there may be a correlation between effects on landscape and property value. As the REM utilizes a MCA approach, this could also be a limitation of the REM. Another limitation comes with the modified Delphi approach. The experts who take part in the REM for a project appraisal need to commit to involvement in all rounds of the process. Since each round generates aggregated information the expert's input cannot be removed partway through the process. This did occur with case study one, where an expert had to withdraw just prior to round two. To continue the exercise it had to be assumed that this expert did not change her/his set of preferences during the second round and third round. Thus it was assumed that

s/he was not willing to compromise in the search for consensus, which did affect the end result. Since this case study is a demonstration of the implementation of the model, the final answer as to whether to accept or reject the project is not the primary aim of this study. Had it been, it may have had an impact on the final results and thus on the decision making process. This issue highlights the importance of the input by the experts.

The REM presented in this research has potential and warrants further research. It is recommended that those institutions and agencies involved with project appraisals meet and discuss ways to further the approach presented in this research. This could involve developing and calibrating the model further with standardised systems of data reporting, training staff, and implementing the model. More can also be done regarding sensitivity and scenario analyses. Finally, it is recommended that decision makers remain up-to-date with software development, for new MCA software that is user-friendly, inexpensive and provides an improved platform for integrative studies.

The REM approach seeks to take explicit account of multiple data and multiple measures to articulate these into a structured and coherent management solution. Whether the data are originally submitted in quantitative or qualitative form, they, along with the final outcome, may be expressed in a numerical format to allow rational, transparent and defensible decisions to be made. Overall, the research has shown that the REM has merit in using a generic framework to evaluate complex project proposals submitted for discretionary funding. It achieves this by identifying those project proposals which require their own unique and independent MCA and those for which an 'accept' or 'reject' decision can be made following implementation of the REM.

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APPENDIX A – CASE STUDY ONE

This section provides supplementary material for case study one, including technical specifications of the Turitea Wind Farm project proposal, a copy of the survey questionnaire developed to assess expert opinion regarding the weights for each set of attributes, and the matrices used to calculate the coefficients of Kendall to determine the degree of agreement reached in each interaction of the weighting process.

A.1 TECHNICAL SPECIFICATIONS

Table A.1 Turitea Wind Farm technical specifications

Item	Detail	Designed criteria
Turbines	Maximum turbine locations	105
	Maximum number of turbines	104
	Maximum number of turbines within the Turitea Reserve	61
	Maximum number of turbines on land outside the reserve	43
	Maximum turbine height (existing ground level to blade tip)	125 m
Wind Monitoring Masts	Three monitoring masts	Up to 80m in height
	Road width	Up to 10 m (during construction) Down to 5 m (post rehabilitation)
	New roads within the wind farm site	28 km
	Upgraded roads within the wind farm site	24km
External Road Network	Road width	7 m
Substations	Browns Flat	220/33 kV
	Pine Plantation	220/33 kV
Internal 220 kV Transmission Line	Approximate length	6.1 km
	Number of structures (lattice)	Up to 20
	Steel lattice tower design	Up to 56 m in height and 800 m spans
External 220 kV Transmission Line	Approximate length	5.2 km
	Number of structures (pole)	Up to 22
	Monopole design	Up to 45 m in height

Item	Detail	Designed criteria
Vegetation Removal (includes clearance for substations and transmission towers)	Total area of exotic and native vegetation clearance (not including grassland and pasture) within wind farm footprint	27 ha
	Total areas of grassland and pasture clearance within wind farm footprint	62 ha
Earthworks	Total site clearance area (roads and platforms)	90 ha
	Topsoil removal	214,000 m ³
	Cut	1,420,000 m ³
	Fill	420,000 m ³
Disposal Sites	Total disposal estimate	1,000,000 m ³
	Total area estimate	33 ha

Sources: Mighty River Power (2010, Appendix 2)

A.2 Survey Questionnaire

Dear Sir/Madam,

Following our discussion, I am very pleased that you have been able to meet with me to help with my studies.

RESEARCHER: I am a student from the Institute of Natural Resources at Massey University, working on a PhD in Environmental Management.

STUDY: My research considers the application of multiple criteria analysis to develop a rapid environmental decision-making model to improve project evaluation. This research adopts an integrated approach where aspects of three project evaluation assessment: Cost Benefit Analysis, Environmental Impact Assessment and Social Impact Analysis techniques are integrated into a broader evaluation framework.

REQUEST: In order to establish the weightings required for my model, I would like to gather the experience of a knowledge group of people on economic, social and environmental aspect of project evaluation.

Participants will be asked to complete a short survey. Feedback from the surveys will be analysed and incorporated into the model. Finally, the group will meet to agree upon final values.

CONFIDENTIALITY: The information obtained from this survey will be used for research purposes only and your personal contribution will be kept confidential.

FOCUS GROUP DATE: Friday 2nd of September.

TIME: 10 am.

VENUE: AHB1.40A, AgHort B Building, Turitea campus, Massey University.

ANTICIPATED LENGTH OF MEETING: 1 hour.

I WILL PROVIDE: Coffee/tea & snacks.

CONTACTS DETAILS: Phone: 06 356 9099 ext 7799. Email: C.Reyes@massey.ac.nz.

Camila Reyes

This project has been evaluated by peer review and judged to be low risk. Consequently, it has not been reviewed by one of the University's Human Ethics Committees. The researcher(s) named above are responsible for the ethical conduct of this research. If you have any concerns about the conduct of this research that you wish to raise with someone other than the researcher(s), please contact Professor John O'Neill, Director, Research Ethics, telephone 06 350 5249, email: humanethics@massey.ac.nz

Turitea Wind Farm Study

The proposed wind farm (WF), near Palmerston North, comprises of 104 turbines to be constructed in a designated reserve (61) and adjoining farmland (43). The area is surrounded by three other WFs (Te Apiti, Tararua and Te Rere Hau wind farm), with a total number of 286 existing turbines.

At the Turitea Reserve, the existing infrastructure includes a number of access tracks, three wind monitoring masts, and two storage dams for Palmerston North city. Within the reserve, most of the vegetation is native (54%). The surrounding farmland is mostly for sheep and cattle grazing.

The proposed WF includes associated substations, internal electricity reticulation (made up of underground cables and overhead transmission lines), and associated earthworks, vegetation clearance and discharges.

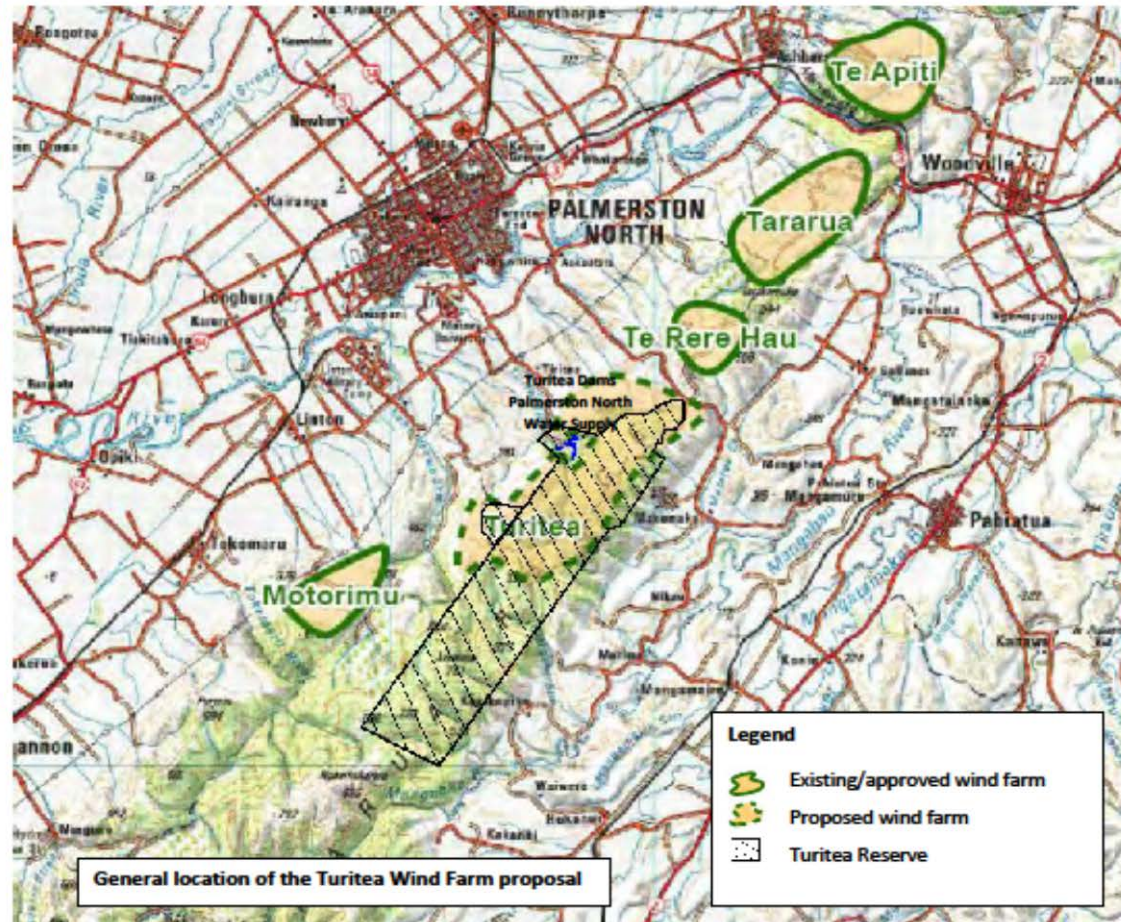
Aim of the model

To evaluate whether the wind farm should be built.

Your contact details

Name:

Email:



Key attributes for the Turitea wind farm (WF) project

Goal	Attributes
Economic development	New jobs created during construction of the WF
	New jobs created during long-term operation of the WF
	Increasing certainty of electricity supply at national level
	Rental payments to landowners
	Energy generated from a free resource (wind)
	Keeping cost of electricity down
	Benefits to local business community from constructing and operating the WF
Environmental protection	Effect on natural undisturbed landscape where the WF is sited
	Threat to water quality from construction of WF
	Global/national benefits of clean energy production (Greenhouse emissions avoided)
	Local vegetation disturbance resulting from construction
	Threat of turbines to birds
Social acceptability	Effect on residential value surrounding the WF site
	Effect on recreational activities (hunting, hiking, cycling, etc.)
	Effect of WF on aviation
	Effect of WF on visual amenity of the landscape
	Clash with cultural/spiritual values associated with the site
	Effects from WF construction activities on daily life (e.g. traffic disruption, dust)
	Effects of WF noise on homeowners
	Impact of electric /magnetic fields on homeowner's communications (e.g. radio, TV, phones)

Note: Attributes are the yardstick to measure achievement of objectives.

Economic development with respect to the construction & operation of the wind farm (WF)

First, from your knowledge, tick which of the two issues is more important to achieve economic development.

Second, how much more important is your choice compared with the alternative (circle).

			equally important		more important										
1	a) New jobs created during construction of the WF	<input type="checkbox"/>	1	2	3	4	5	6	7	8	9				
	b) Increasing certainty of electricity supply at national level	<input type="checkbox"/>													
2	a) Energy generated from a free resource (wind)	<input type="checkbox"/>	1	2	3	4	5	6	7	8	9				
	b) New jobs created during long-term operation of the WF	<input type="checkbox"/>													
3	a) New jobs created during construction of the WF	<input type="checkbox"/>	1	2	3	4	5	6	7	8	9				
	b) Energy generated from a free resource (wind)	<input type="checkbox"/>													
4	a) Rental payments to landowners	<input type="checkbox"/>	1	2	3	4	5	6	7	8	9				
	b) New jobs created during long-term operation of the WF	<input type="checkbox"/>													
5	a) Energy generated from a free resource (wind)	<input type="checkbox"/>	1	2	3	4	5	6	7	8	9				
	b) Increasing certainty of electricity supply at national level	<input type="checkbox"/>													
6	a) Rental payments to landowners	<input type="checkbox"/>	1	2	3	4	5	6	7	8	9				
	b) Keeping cost of electricity down	<input type="checkbox"/>													
7	a) New jobs created during construction of the WF	<input type="checkbox"/>	1	2	3	4	5	6	7	8	9				
	b) Keeping cost of electricity down	<input type="checkbox"/>													
8	a) Energy generated from a free resource (wind)	<input type="checkbox"/>	1	2	3	4	5	6	7	8	9				
	b) Benefits to local business community from constructing and operating the WF	<input type="checkbox"/>													
9	a) New jobs created during construction of the WF	<input type="checkbox"/>	1	2	3	4	5	6	7	8	9				
	b) Rental payments to landowners	<input type="checkbox"/>													

			equally important			more important			much more important	
10	a) Increasing certainty of electricity supply at national level	<input type="checkbox"/>								
	b) Benefits to local business community from constructing and operating the WF	<input type="checkbox"/>	1	2	3	4	5	6	7	8 9
11	a) New jobs created during construction of the WF	<input type="checkbox"/>								
	b) New jobs created during long-term operation of the WF	<input type="checkbox"/>	1	2	3	4	5	6	7	8 9
12	a) New jobs created during long-term operation of the WF	<input type="checkbox"/>								
	b) Keeping cost of electricity down	<input type="checkbox"/>	1	2	3	4	5	6	7	8 9
13	a) Energy generated from a free resource (wind)	<input type="checkbox"/>								
	b) Keeping cost of electricity down	<input type="checkbox"/>	1	2	3	4	5	6	7	8 9
14	a) Rental payments to landowners	<input type="checkbox"/>								
	b) Energy generated from a free resource (wind)	<input type="checkbox"/>	1	2	3	4	5	6	7	8 9
15	a) Benefits to local business community from constructing and operating the WF	<input type="checkbox"/>								
	b) Rental payments to landowners	<input type="checkbox"/>	1	2	3	4	5	6	7	8 9
16	a) Increasing certainty of electricity supply at national level	<input type="checkbox"/>								
	b) Keeping cost of electricity down	<input type="checkbox"/>	1	2	3	4	5	6	7	8 9
17	a) New jobs created during long-term operation of the WF	<input type="checkbox"/>								
	b) Benefits to local business community from constructing and operating the WF	<input type="checkbox"/>	1	2	3	4	5	6	7	8 9
18	a) Increasing certainty of electricity supply at national level	<input type="checkbox"/>								
	b) New jobs created during long-term operation of the WF	<input type="checkbox"/>	1	2	3	4	5	6	7	8 9
19	a) Benefits to local business community from constructing and operating the WF	<input type="checkbox"/>								
	b) New jobs created during construction of the WF	<input type="checkbox"/>	1	2	3	4	5	6	7	8 9
20	a) Keeping cost of electricity down	<input type="checkbox"/>								
	b) Benefits to local business community from constructing and operating the WF	<input type="checkbox"/>	1	2	3	4	5	6	7	8 9
21	a) Rental payments to landowners	<input type="checkbox"/>								
	b) Increasing certainty of electricity supply at national level	<input type="checkbox"/>	1	2	3	4	5	6	7	8 9

Environmental protection with respect to the construction & operation of the wind farm (WF)

First, from your knowledge, tick which of the two issues is **more important** to achieve environmental protection.

Second, how much more important is your choice compared with the alternative (circle).

			equally important		more important																	
1	a) Threat to water quality from construction of WF	<input type="checkbox"/>		1	2	3	4	5	6	7	8	9										
	b) Local vegetation disturbance resulting from construction	<input type="checkbox"/>																				
2	a) Global/national benefits of clean energy production (Greenhouse emissions avoided)	<input type="checkbox"/>		1	2	3	4	5	6	7	8	9										
	b) Local vegetation disturbance resulting from construction	<input type="checkbox"/>																				
3	a) Effect on natural undisturbed landscape where the WF is sited	<input type="checkbox"/>		1	2	3	4	5	6	7	8	9										
	b) Threat of turbines to birds	<input type="checkbox"/>																				
4	a) Effect on natural undisturbed landscape where the WF is sited	<input type="checkbox"/>		1	2	3	4	5	6	7	8	9										
	b) Global/national benefits of clean energy production (Greenhouse emissions avoided)	<input type="checkbox"/>																				
5	a) Effect on natural undisturbed landscape where the WF is sited	<input type="checkbox"/>		1	2	3	4	5	6	7	8	9										
	b) Threat to water quality from construction of WF	<input type="checkbox"/>																				
6	a) Local vegetation disturbance resulting from construction	<input type="checkbox"/>		1	2	3	4	5	6	7	8	9										
	b) Threat of turbines to birds	<input type="checkbox"/>																				
7	a) Threat to water quality from construction of WF	<input type="checkbox"/>		1	2	3	4	5	6	7	8	9										
	b) Threat of turbines to birds	<input type="checkbox"/>																				
8	a) Global/national benefits of clean energy production (Greenhouse emissions avoided)	<input type="checkbox"/>		1	2	3	4	5	6	7	8	9										
	b) Threat of turbines to birds	<input type="checkbox"/>																				
9	a) Threat to water quality from construction of WF	<input type="checkbox"/>		1	2	3	4	5	6	7	8	9										
	b) Global/national benefits of clean energy production (Greenhouse emissions avoided)	<input type="checkbox"/>																				
10	a) Effect on natural undisturbed landscape where the WF is sited	<input type="checkbox"/>		1	2	3	4	5	6	7	8	9										
	b) Local vegetation disturbance resulting from construction	<input type="checkbox"/>																				

Social acceptability with respect to the construction & operation of the wind farm (WF)

First, from your knowledge, tick which of the two issues is more important to achieve social acceptability.

Second, how much more important is your choice compared with the alternative (circle).

		equally important	more important					much more important		
		1	2	3	4	5	6	7	8	9
1	a) Effects of WF noise on homeowners	<input type="checkbox"/>								
	b) Impact of electric /magnetic fields on homeowner's communications (e.g. radio, TV, phones)	<input type="checkbox"/>								
2	a) Effect on recreational activities (hunting, hiking, cycling, etc.)	<input type="checkbox"/>								
	b) Effects from WF construction activities on daily life (e.g. traffic disruption, dust)	<input type="checkbox"/>								
3	a) Effect on residential value surrounding the WF site	<input type="checkbox"/>								
	b) Impact of electric /magnetic fields on homeowner's communications (e.g. radio, TV, phones)	<input type="checkbox"/>								
4	a) Effect of WF on aviation	<input type="checkbox"/>								
	b) Effect of WF on visual amenity of the landscape	<input type="checkbox"/>								
5	a) Effect on recreational activities (hunting, hiking, cycling, etc.)	<input type="checkbox"/>								
	b) Clash with cultural/spiritual values associated with the site	<input type="checkbox"/>								
6	a) Effect of WF on aviation	<input type="checkbox"/>								
	b) Effects from WF construction activities on daily life (e.g. traffic disruption, dust)	<input type="checkbox"/>								
7	a) Clash with cultural/spiritual values associated with the site	<input type="checkbox"/>								
	b) Impact of electric /magnetic fields on homeowner's communications (e.g. radio, TV, phones)	<input type="checkbox"/>								
8	a) Effect of WF on visual amenity of the landscape	<input type="checkbox"/>								
	b) Effects of WF noise on homeowners	<input type="checkbox"/>								
9	a) Effects from WF construction activities on daily life (e.g. traffic disruption, dust)	<input type="checkbox"/>								
	b) Impact of electric /magnetic fields on homeowner's communications (e.g. radio, TV, phones)	<input type="checkbox"/>								

Calculations to Determine the Coefficients of Kendall for Case Study One

This section presents the matrices used to calculate the coefficients of Kendall from the ranking of economic development, environmental protection and social acceptability attributes, obtaining from the weighting process. These calculations follow the procedure described in Chapter 3, Section 3.5.4.

Table A.2 Evolution of experts' agreement on weights for economic development from the interactive process

No	Attributes	Experts									ΣA_i	Δ	Δ^2	Relevant		
		E1	E2	E3	E4	E5	E6	E7	E8	E9				yes	No	
1	A01	7	7	6	6	3	5	7	7	7	55.0	19	361		x	
2	A02	2	4	2	1	5	2	1	2	3	22.0	-14	196	x		
3	A03	5	2	3	3	2	3	5	4	4	31.0	-5	25	x		
4	A04	3	6	1	7	7	7	3	3	1	38.0	2	4		x	
5	A05	1	5	5	4	4	1	2	1	2	25.0	-11	121	x		
6	A06	4	3	4	5	1	6	4	5	6	38.0	2	4		x	
7	A07	6	1	7	2	6	4	6	6	5	43.0	7	49		x	
FÓRMULA $\Sigma A_i = \Sigma E_n$ y $\Delta = \Sigma A_i - T$											$\Sigma \Sigma A_i$	252	$\Sigma \Delta^2$	760		
$T = \Sigma \Sigma A_i / k$ $W = 12 \Sigma \Delta^2 / (m^2(k^3 - k))$		T			36.00						If, $w \geq 0.5$ Agreement was reached $w < 0.5$ Disagreement					
		W			0.34											
TERM k = Quantity of attributes m = Number of experts		INPUT														
		7								First round						
		9														

No	Attributes	Experts									ΣA_i	Δ	Δ^2	Relevant		
		E1	E2	E3	E4	E5	E6	E7	E8	E9				yes	No	
1	A01	7	7	6	6	3	7	7	7	7	57.0	21	441		x	
2	A02	2	4	2	1	5	2	1	2	3	22.0	-14	196	x		
3	A03	5	2	3	3	2	3	5	4	4	31.0	-5	25	x		
4	A04	3	6	1	7	7	6	3	3	1	37.0	1	1		x	
5	A05	1	5	5	4	4	1	2	1	2	25.0	-11	121	x		
6	A06	4	3	4	5	1	5	4	5	6	37.0	1	1		x	
7	A07	6	1	7	2	6	4	6	6	5	43.0	7	49		x	
FÓRMULA $\Sigma A_i = \Sigma E_n$ y $\Delta = \Sigma A_i - T$											$\Sigma \Sigma A_i$	252	$\Sigma \Delta^2$	834		
$T = \Sigma \Sigma A_i / k$ $W = 12 \Sigma \Delta^2 / (m^2(k^3 - k))$		T			36.00						If, $w \geq 0.5$ Agreement was reached $w < 0.5$ Disagreement					
		W			0.37											
TERM k = Quantity of attributes m = Number of experts		INPUT														
		7								Second round						
		9														

No	Attributes	Experts									ΣAi	Δ	Δ ²	Relevant		
		E1	E2	E3	E4	E5	E6	E7	E8	E9				yes	No	
1	A01	7	6	6	6	3	7	7	6	7	55.0	19	361		x	
2	A02	2	4	1	1	5	2	1	2	3	21.0	-15	225	x		
3	A03	5	2	4	3	2	3	5	4	4	32.0	-4	16	x		
4	A04	3	7	2	7	7	6	3	3	1	39.0	3	9		x	
5	A05	1	5	3	2	4	1	2	1	2	21.0	-15	225	x		
6	A06	4	3	5	4	1	5	4	5	6	37.0	1	1		x	
7	A07	6	1	7	5	6	4	6	7	5	47.0	11	121		x	
EQUATION Σ Ai= Σ En y Δ=Σ Ai -T											ΣΣ Ai	252	ΣΔ ²	958		
T=ΣΣ Ai / k W= 12 Σ Δ ² / (m ² (k ³ -k))		T			36.00						If, w ≥ 0.5 Agreement was reached w < 0.5 Disagreement					
		W			0.42											
TERM k = Quantity of attributes m= Number of experts		INPUT														
		7									Third round					
		9														

Table A.3 Evolution of experts' agreement on weights for environmental protection from the interactive process

No	Attributes	Experts									ΣAi	Δ	Δ ²	Relevant		
		E1	E2	E3	E4	E5	E6	E7	E8	E9				yes	No	
1	B1	2	3	2	4	3	2	2	2	2	22.0	-5.0	25.0		x	
2	B2	5	2	3	1	4	3	4	5	4	31.0	4.0	16.0		x	
3	B3	1	5	1	2	1	1	1	1	5	18.0	-9.0	81.0	x		
4	B4	4	1	5	3	2	4	3	3	1	26.0	-1.0	1.0		x	
5	B5	3	4	4	5	5	5	5	4	3	38.0	11.0	121.0		x	
FÓRMULA Σ Ai= Σ En y Δ=Σ Ai -T											ΣΣ Ai	135.0	ΣΔ ²	244.0		
T=ΣΣ Ai / k W= 12 Σ Δ ² / (m ² (k ³ -k))		T			27						If, w ≥ 0.5 Agreement was reached w < 0.5 Disagreement					
		W			0.30											
TERM k = Quantity of attributes m= Number of experts		DATOS														
		5									First round					
		9														

No	Attributes	Experts									ΣAi	Δ	Δ ²	Relevant		
		E1	E2	E3	E4	E5	E6	E7	E8	E9				yes	No	
1	B1	2	3	2	4	3	3	2	2	2	23.0	-4.0	16.0		x	
2	B2	5	2	3	1	4	2	4	5	4	30.0	3.0	9.0		x	
3	B3	1	5	1	2	1	1	1	1	5	18.0	-9.0	81.0	x		
4	B4	4	1	5	3	2	4	3	3	1	26.0	-1.0	1.0		x	
5	B5	3	4	4	5	5	5	5	4	3	38.0	11.0	121.0		x	
FÓRMULA Σ Ai= Σ En y Δ=Σ Ai -T											ΣΣ Ai	135.0	ΣΔ ²	228.0		
T=ΣΣ Ai / k W= 12 Σ Δ ² / (m ² (k ³ -k))		T			27						If, w ≥ 0.5 Agreement was reached w < 0.5 Disagreement					
		W			0.28											
TÉRMINOS k = Quantity of attributes m= Number of experts		DATOS														
		5									Second round					
		9														

No	Attributes	Experts									ΣAi	Δ	Δ ²	Relevant		
		E1	E2	E3	E4	E5	E6	E7	E8	E9				yes	No	
1	B1	2	3	2	4	4	3	2	2	2	24.0	-3.0	9.0		x	
2	B2	5	2	3	1	3	2	4	5	3	28.0	1.0	1.0		x	
3	B3	1	5	1	2	1	1	1	1	4	17.0	-10.0	100.0	x		
4	B4	4	1	5	3	2	4	3	3	1	26.0	-1.0	1.0		x	
5	B5	3	4	4	5	5	5	5	4	5	40.0	13.0	169.0		x	
FÓRMULA Σ Ai= Σ En y Δ=Σ Ai -T											ΣΣ Ai	135.0	ΣΔ ²	280.0		
T=ΣΣ Ai / k W= 12 Σ Δ ² / (m ² (k ³ -k))		T			27			If, w ≥ 0.5 Agreement was reached w < 0.5 Disagreement								
TÉRMI k = Quantity of attributes m= Number of experts		DATOS														
		5														
		9						Third round								

Table A.4 Evolution of experts' agreement on weights for social acceptability from the interactive process

No	Attributes	Experts									ΣAi	Δ	Δ ²	Relevant		
		E1	E2	E3	E4	E5	E6	E7	E8	E9				yes	No	
1	C1	7	3	5	5	4	4	8	2	3	41.0	0.5	0.25	x		
2	C2	3	5	3	6	3	5	3	7	4	39.0	-1.5	2.25	x		
3	C3	8	8	7	7	8	7	7	8	7	67.0	26.5	702.25		x	
4	C4	2	6	1	2	1	2	6	4	1	25.0	-15.5	240.25	x		
5	C5	5	2	4	1	6	6	1	1	2	28.0	-12.5	156.25	x		
6	C6	6	7	6	4	2	3	2	5	8	43.0	2.5	6.25	x		
7	C7	1	1	2	3	5	1	5	3	5	26.0	-14.5	210.25	x		
8	C8	4	4	8	8	7	8	4	6	6	55.0	14.5	210.25		x	
FÓRMULA Σ Ai= Σ En y Δ=Σ Ai -T											ΣΣ Ai	324.0	ΣΔ ²	1528.0		
T=ΣΣ Ai / k W= 12 Σ Δ ² / (m ² (k ³ -k))		T			40.5			If, w ≥ 0.5 Agreement was reached w < 0.5 Disagreement								
TÉRMI k = Quantity of attributes m= Number of experts		DATOS														
		8														
		9						First round								

No	Attributes	Experts									ΣAi	Δ	Δ ²	Relevant		
		E1	E2	E3	E4	E5	E6	E7	E8	E9				yes	No	
1	C1	7	3	5	5	4	6	8	2	3	43.0	2.5	6.25	x		
2	C2	3	5	4	6	3	5	3	7	4	40.0	-0.5	0.25	x		
3	C3	8	8	7	7	8	8	7	8	7	68.0	27.5	756.25		x	
4	C4	2	6	1	2	1	2	6	4	1	25.0	-15.5	240.25	x		
5	C5	4	2	3	1	6	4	1	1	2	24.0	-16.5	272.25	x		
6	C6	6	7	6	4	2	3	2	5	8	43.0	2.5	6.25	x		
7	C7	1	1	2	3	5	1	5	3	5	26.0	-14.5	210.25	x		
8	C8	5	4	8	8	7	7	4	6	6	55.0	14.5	210.25		x	
FÓRMULA Σ Ai= Σ En y Δ=Σ Ai -T											ΣΣ Ai	324.0	ΣΔ ²	1702.0		
T=ΣΣ Ai / k W= 12 Σ Δ ² / (m ² (k ³ -k))		T			40.5			If, w ≥ 0.5 Agreement was reached w < 0.5 Disagreement								
TÉRMI k = Quantity of attributes m= Number of experts		DATOS														
		8														
		9						Second round								

No	Attributes	Experts									ΣAi	Δ	Δ ²	Relevant		
		E1	E2	E3	E4	E5	E6	E7	E8	E9				yes	No	
1	C1	7	3	5	5	4	6	8	2	3	43.0	2.5	6.25	x		
2	C2	3	5	4	6	3	5	3	6	7	42.0	1.5	2.25	x		
3	C3	8	8	7	7	8	8	7	8	8	69.0	28.5	812.25		x	
4	C4	2	6	1	2	1	2	6	4	2	26.0	-14.5	210.25	x		
5	C5	4	2	3	1	6	4	1	1	1	23.0	-17.5	306.25	x		
6	C6	6	7	6	4	2	3	2	7	6	43.0	2.5	6.25	x		
7	C7	1	1	2	3	5	1	5	3	5	26.0	-14.5	210.25	x		
8	C8	5	4	8	8	7	7	4	5	4	52.0	11.5	132.25		x	
FÓRMULA Σ Ai= Σ En y Δ=Σ Ai -T											ΣΣ Ai	324.0	ΣΔ ²	1686.0		
T=ΣΣ Ai / k		T			40.5			If, w ≥ 0.5 Agreement was reached w < 0.5 Disagreement								
W= 12 Σ Δ ² / (m ² (k ³ -k))		W			0.50											
TERM k = Quantity of attributes m= Number of experts		DATOS														
		8														
		9									Third round					

APPENDIX B – CASE STUDY TWO

This section provides supplementary material for case study two. The section present technical specifications of the Cisne Austral Export abattoir project proposal, a copy of the survey questionnaire developed to assess expert opinion regarding the weights for each set of attributes, and the matrices used to calculate the coefficients of Kendall.

B.1 TECHNICAL SPECIFICATIONS

Table B.1 Quantity and volume of products (including disposables) obtained from the slaughtering process at full capacity (500 lambs at 25 kg each)

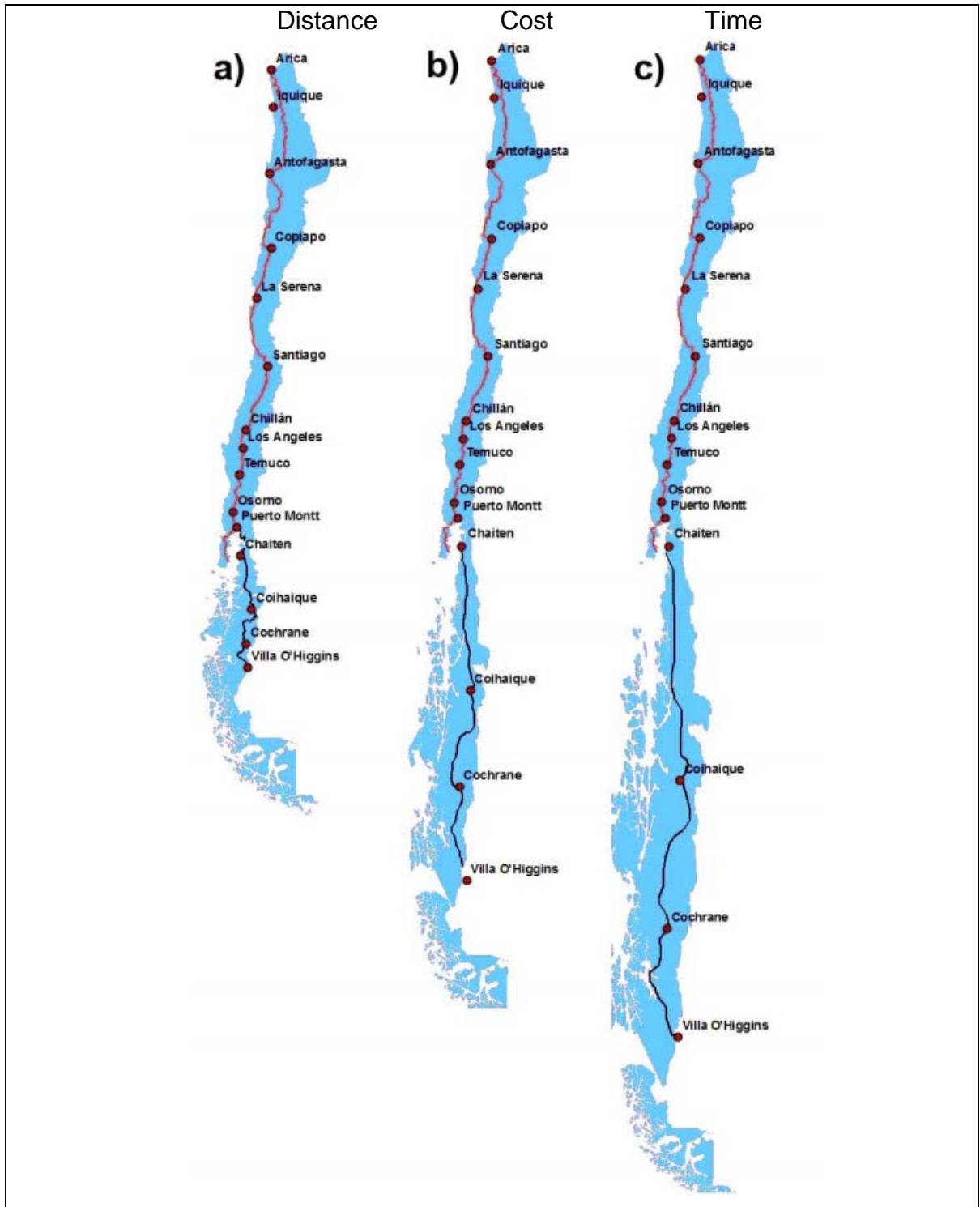
Product	Percentage (%)	Weight of product per lamb (Kg)	Weight of product per 500 lambs (Kg)	Treatment	Final destination
Carcass (meat & skeleton)	55	13.75	6,875	Refrigeration	Storage shed
Leather	11	2.75	1,375	Commercial product	Storage shed
Edible by-products	5	1.25	625	Washing and refrigeration	Storage shed
Entrails & gut	2	0.500	250	Washing and refrigeration	Storage shed
Hooves & feet	1.5	0.375	187.5	Skin removal	Storage shed
Inedible viscera	5	1.250	625	Direct stream & grinding of solid waste	Solids to (Coyhaique city)* landfill
Head	2	0.500	250	Direct stream & grinding of solid waste	Solids to (Coyhaique city)* landfill
Stomach & gut contents	14	3.500	1,200	Effluent press	Solids to rubbish dumps
Blood	4.5	1.125	520	50% to ILR & 50% to solid treatment	Humus and water (for ILR)*
Water used for washing, boiler cauldron & trucks	100	80	40,000	ILR	Treated & sterile water (to be discharged in Simpson River)*

ILR: Industrial liquid residue treatment plant,

* Not included in the original table, but taken from the report.

Source: Faenadora Cisne Austral Ltda. (2011, p. 29)

Figure B.1 Real distance (km) (a), and its equivalence in distance-cost km (b) and distance-time km (c) along the Carretera Panamericana Road (Ruta 5) and the Carretera Austral Road (Ruta 7).



Source: Extrapolated from (Romero et al., 2008, p. 10).

B.2 Survey Questionnaire of case study two

Dear Sir/Madam,

Following our discussion, I am very pleased that you have been able to meet with me to help with my studies.

RESEARCHER: I am a student from the institute of natural resources at Massey University (in New Zealand), working on a PhD in environmental management.

STUDY: My research considers the application of multiple criteria analysis to develop a rapid decision-making model to improve project evaluation. This research adopts an integrated approach where aspects of three project evaluation assessment: Cost Benefit Analysis, Environmental Impact Assessment and Social Impact Analysis techniques are integrated into a broader evaluation framework.

REQUEST: In order to establish the weightings required for my model, I would like to gather the experience of a knowledge group of people on economic, social and environmental aspect of project evaluation.

Participants will be asked to complete a short survey. Feedback from the surveys will be analysed and incorporated into the model. Finally, the group will meet to agree upon final values.

CONFIDENTIALITY: The information obtained from this survey will be used for research purposes only and your personal contribution will be kept confidential.

FOCUS GROUP DATE: Friday 18th of November.

TIME: 18.00 hrs.

VENUE: Avenida Baquedano 808, Coyhaique.

ANTICIPATED LENGTH OF MEETING: 1 hour.

I WILL PROVIDE: Coffee/tea & snacks.

CONTACTS DETAILS: +56-9-8745 4839. Email: C.Reyes@massey.ac.nz.

Camila Reyes

This project has been evaluated by peer review and judged to be low risk. Consequently, it has not been reviewed by one of the University's Human Ethics Committees. The researcher(s) named above are responsible for the ethical conduct of this research. If you have any concerns about the conduct of this research that you wish to raise with someone other than the researcher(s), please contact Professor John O'Neill, Director, Research Ethics, telephone 06 350 5249, email: humanethics@massey.ac.nz

CASE STUDY TWO: THE CISNE AUSTRAL ABATTOIR

This project proposal is located in Chile, in the Coyhaique Region, 3 km to the West from a rural town called Alto Baguales.

The project includes the construction and operation of a sheep abattoir, which will be placed in a 4 hectares terrain. The main buildings will be: roofed paddocks, slaughter room, refrigeration and packing area, and a wastewater treatment plant. Those constructions will use an area of 3,250 m² and would have an estimated investment cost of \$4,850,000 USD.

The maximum processing capacity will be 500 sheep per day in an 8 hour workday. The regime of annual production is estimated at 150 ton/month from January to April, 7 ton/month from May to July, and 3-5 ton/month from October to December. During the months of August and September production will be reduced almost to zero at the beginning of plant operation.



The project includes a water treatment system for processing the wastewater generated in the process of slaughtering and cleaning up the equipment. The final download will take place in a tributary stream of the Simpson River. Besides, the organic solid waste (OSW), consisting of bones, pieces of leather, inedible viscera and heads, are estimated at 1,100 kilos per day during peak operating. These OSW will be stabilized by a steam treatment and sent to Coyhaique City's landfill, as well as other domestic solid waste. Finally, solid waste from the red wastewater treatment (blood) will be converted into humus to be reused as fertilizer. The amount of water required for the project, equivalent to 40,000 litres per day, will be supplied from two complementary sources: 1) from the rural drinking water net from Alto Baguales Town, to supply the requirements for the dining hall and other facilities, and 2) by a deep water well, with an extraction rate of 3 l/s during periods of maximum plant performance.

Aim of the model: To evaluate whether the Cisne Austral Abattoir should be built.

Name: _____

Email: _____

Key attributes for the Cisne Austral Abattoir project evaluation.

Aim	Attribute
Economic development	Promoting the development of sheep production in the region
	Increased efficiency from reducing transportation cost
	Injection of money into the local economy by the investment expenditure
	Improving access of smallholders to new export markets
	New permanent jobs created
Environmental protection	Threat to availability of water resources
	Air pollution during construction and operation phase
	Local vegetation disturbance resulting from construction
	Effect on aquatic life from the discharge of liquid industrial waste
	Risk of solid waste pollution
Social acceptability	Effects on aesthetic perception of the biophysical environment (landscape) by residents
	Effects on residential value in surrounding properties
	Risk of proliferation of pests and diseases' vectors , such as rodents, flies and stray dogs
	Effects from the project construction activities on daily life (e.g. increased traffic, dust)
	Effects of project operational noise on homeowners
	Undesired odours from the slaughtering process and from the paddock area
	Use of public facilities (Coyhaique city landfill) for solid waste disposal

Economic development regarding Cisne Austral Abattoir's implementation and operation

First, from your knowledge, tick which of the two issues is more important to achieve economic development.

Second, how much more important is your choice compared with the alternative (circle).

			equally important			more important			much more important		
1	a) Injection of money into the local economy by the investment expenditure	<input type="checkbox"/>	1	2	3	4	5	6	7	8	9
	b) Increased efficiency from reducing transportation cost	<input type="checkbox"/>									
2	a) Injection of money into the local economy by the investment expenditure	<input type="checkbox"/>	1	2	3	4	5	6	7	8	9
	b) Improving access of smallholders to new export markets	<input type="checkbox"/>									
3	a) Promoting the development of sheep production in the region	<input type="checkbox"/>	1	2	3	4	5	6	7	8	9
	b) Improving access of smallholders to new export markets	<input type="checkbox"/>									
4	a) New permanent jobs created	<input type="checkbox"/>	1	2	3	4	5	6	7	8	9
	b) Increased efficiency from reducing transportation cost	<input type="checkbox"/>									
5	a) New permanent jobs created	<input type="checkbox"/>	1	2	3	4	5	6	7	8	9
	b) Promoting the development of sheep production in the region	<input type="checkbox"/>									
6	a) New permanent jobs created	<input type="checkbox"/>	1	2	3	4	5	6	7	8	9
	b) Improving access of smallholders to new export markets	<input type="checkbox"/>									
7	a) Improving access of smallholders to new export markets	<input type="checkbox"/>	1	2	3	4	5	6	7	8	9
	b) Increased efficiency from reducing transportation cost	<input type="checkbox"/>									
8	a) Promoting the development of sheep production in the region	<input type="checkbox"/>	1	2	3	4	5	6	7	8	9
	b) Increased efficiency from reducing transportation cost	<input type="checkbox"/>									
9	a) Promoting the development of sheep production in the region	<input type="checkbox"/>	1	2	3	4	5	6	7	8	9
	b) Injection of money into the local economy by the investment expenditure	<input type="checkbox"/>									
10	a) New permanent jobs created	<input type="checkbox"/>	1	2	3	4	5	6	7	8	9
	b) Injection of money into the local economy by the investment expenditure	<input type="checkbox"/>									

Environmental protection regarding Cisne Austral Abattoir's implementation and operation

First, from your knowledge, tick which of the two issues is more important to achieve environmental protection.

Second, how much more important is your choice compared with the alternative (circle).

			equally important		more important															
1	a) Effect on aquatic life from the discharge of liquid industrial waste	<input type="checkbox"/>	1	2	3	4	5	6	7	8	9									
	b) Air pollution during construction and operation phase	<input type="checkbox"/>																		
2	a) Risk of solid waste pollution	<input type="checkbox"/>	1	2	3	4	5	6	7	8	9									
	b) Effect on aquatic life from the discharge of liquid industrial waste	<input type="checkbox"/>																		
3	a) Effect on aquatic life from the discharge of liquid industrial waste	<input type="checkbox"/>	1	2	3	4	5	6	7	8	9									
	b) Threat to availability of water resources	<input type="checkbox"/>																		
4	a) Risk of solid waste pollution	<input type="checkbox"/>	1	2	3	4	5	6	7	8	9									
	b) Local vegetation disturbance resulting from construction	<input type="checkbox"/>																		
5	a) Local vegetation disturbance resulting from construction	<input type="checkbox"/>	1	2	3	4	5	6	7	8	9									
	b) Air pollution during construction and operation phase	<input type="checkbox"/>																		
6	a) Risk of solid waste pollution	<input type="checkbox"/>	1	2	3	4	5	6	7	8	9									
	b) Threat to availability of water resources	<input type="checkbox"/>																		
7	a) Threat to availability of water resources	<input type="checkbox"/>	1	2	3	4	5	6	7	8	9									
	b) Local vegetation disturbance resulting from construction	<input type="checkbox"/>																		
8	a) Effect on aquatic life from the discharge of liquid industrial waste	<input type="checkbox"/>	1	2	3	4	5	6	7	8	9									
	b) Local vegetation disturbance resulting from construction	<input type="checkbox"/>																		
9	a) Air pollution during construction and operation phase	<input type="checkbox"/>	1	2	3	4	5	6	7	8	9									
	b) Threat to availability of water resources	<input type="checkbox"/>																		
10	a) Risk of solid waste pollution	<input type="checkbox"/>	1	2	3	4	5	6	7	8	9									
	b) Air pollution during construction and operation phase	<input type="checkbox"/>																		

Social acceptability regarding Cisne Austral Abattoir's implementation and operation

First, from your knowledge, tick which of the two issues is more important to achieve social acceptability.

Second, how much more important is your choice compared with the alternative (circle).

		equally important	more important					much more important		
		1	2	3	4	5	6	7	8	9
1	a) Risk of proliferation of pests and diseases' vectors , such as rodents, flies and stray dogs	<input type="checkbox"/>								
	b) Effects on aesthetic perception of the biophysical environment (landscape) by residents	<input type="checkbox"/>								
2	a) Use of public facilities (Coyhaique city landfill) for solid waste disposal	<input type="checkbox"/>								
	b) Effects on aesthetic perception of the biophysical environment (landscape) by residents	<input type="checkbox"/>								
3	a) Risk of proliferation of pests and diseases' vectors , such as rodents, flies and stray dogs)	<input type="checkbox"/>								
	b) Effects on residential value in surrounding properties	<input type="checkbox"/>								
4	a) Risk of proliferation of pests and diseases' vectors , such as rodents, flies and stray dogs)	<input type="checkbox"/>								
	b) Use of public facilities (Coyhaique city landfill) for solid waste disposal	<input type="checkbox"/>								
5	a) Effects from the project construction activities on daily life (e.g. increased traffic, dust)	<input type="checkbox"/>								
	b) Effects on aesthetic perception of the biophysical environment (landscape) by residents	<input type="checkbox"/>								
6	a) Use of public facilities (Coyhaique city landfill) for solid waste disposal	<input type="checkbox"/>								
	b) Effects of project operational noise on homeowners	<input type="checkbox"/>								
7	a) Risk of proliferation of pests and diseases' vectors , such as rodents, flies and stray dogs)	<input type="checkbox"/>								
	b) Undesired odours from the slaughtering process and from the paddock area	<input type="checkbox"/>								
8	a) Effects of project operational noise on homeowners	<input type="checkbox"/>								
	b) Effects on aesthetic perception of the biophysical environment (landscape) by residents	<input type="checkbox"/>								
9	a) Effects on aesthetic perception of the biophysical environment (landscape) by residents	<input type="checkbox"/>								
	b) Effects on residential value in surrounding properties	<input type="checkbox"/>								
10	a) Effects from the project construction activities on daily life (e.g. increased traffic, dust)	<input type="checkbox"/>								
	b) Effects on residential value in surrounding properties	<input type="checkbox"/>								

			equally important		more important				much more important		
11	a) Use of public facilities (Coyhaique city landfill) for solid waste disposal	<input type="checkbox"/>	1	2	3	4	5	6	7	8	9
	b) Effects on residential value in surrounding properties	<input type="checkbox"/>									
12	a) Use of public facilities (Coyhaique city landfill) for solid waste disposal	<input type="checkbox"/>	1	2	3	4	5	6	7	8	9
	b) Undesired odours from the slaughtering process and from the paddock area	<input type="checkbox"/>									
13	a) Undesired odours from the slaughtering process and from the paddock area	<input type="checkbox"/>	1	2	3	4	5	6	7	8	9
	b) Effects on aesthetic perception of the biophysical environment (landscape) by residents	<input type="checkbox"/>									
14	a) Effects of project operational noise on homeowners	<input type="checkbox"/>	1	2	3	4	5	6	7	8	9
	b) Effects on residential value in surrounding properties	<input type="checkbox"/>									
15	a) Effects of project operational noise on homeowners	<input type="checkbox"/>	1	2	3	4	5	6	7	8	9
	b) Effects from the project construction activities on daily life (e.g. increased traffic, dust)	<input type="checkbox"/>									
16	a) Undesired odours from the slaughtering process and from the paddock area	<input type="checkbox"/>	1	2	3	4	5	6	7	8	9
	b) Effects from the project construction activities on daily life (e.g. increased traffic, dust)	<input type="checkbox"/>									
17	a) Risk of proliferation of pests and diseases' vectors , such as rodents, flies and stray dogs)	<input type="checkbox"/>	1	2	3	4	5	6	7	8	9
	b) Effects from the project construction activities on daily life (e.g. increased traffic, dust)	<input type="checkbox"/>									
18	a) Effects of project operational noise on homeowners	<input type="checkbox"/>	1	2	3	4	5	6	7	8	9
	b) Undesired odours from the slaughtering process and from the paddock area	<input type="checkbox"/>									
19	a) Undesired odours from the slaughtering process and from the paddock area	<input type="checkbox"/>	1	2	3	4	5	6	7	8	9
	b) Effects on residential value in surrounding properties	<input type="checkbox"/>									
20	a) Risk of proliferation of pests and diseases' vectors , such as rodents, flies and stray dogs)	<input type="checkbox"/>	1	2	3	4	5	6	7	8	9
	b) Effects of project operational noise on homeowners	<input type="checkbox"/>									
21	a) Use of public facilities (Coyhaique city landfill) for solid waste disposal	<input type="checkbox"/>	1	2	3	4	5	6	7	8	9
	b) Effects from the project construction activities on daily life (e.g. increased traffic, dust)	<input type="checkbox"/>									

Can you suggest anyone else whom you think could contribute with this research by answering this survey?

B.3 CALCULATIONS TO DETERMINE THE COEFFICIENTS OF KENDALL FOR CASE STUDY TWO

This section presents the matrices used to calculate the coefficients of Kendall from the weighting process, for economic development, environmental protection and social acceptability, in case study two. This procedure is described in Chapter 3, Section 3.5.4.

Table B.2 Coefficient of Kendall (W) for each economic development attribute for each of the three rounds

No	Attributes	Experts								ΣAi	Δ	Δ ²	Relevant				
		E1	E2	E3	E4	E5	E6	E7	E8				yes	No			
1	A01	3	2	2	2	3	2	4	1	19.0	-5	25	x				
2	A02	2	3	3	1	5	3	5	2	24.0	0	0		x			
3	A03	4	4	5	4	4	5	2	4	32.0	8	64		x			
4	A04	1	5	1	3	2	1	3	3	19.0	-5	25	x				
5	A05	5	1	4	5	1	4	1	5	26.0	2	4		x			
ECUATION Σ Ai= Σ En y Δ=Σ Ai -T										ΣΣ Ai	120	ΣΔ ²	118				
T=ΣΣ Ai / k =		T				24				If, W ≥ 0.5 agreement was reached W < 0.5 disagreement							
W= 12 Σ Δ ² / (m ² (k ³ -k)) =		W				0.18											
TERM k = Quantity of attributes =		INPUT										First round					
m= Number of experts =		8															

No	Attributes	Experts								ΣAi	Δ	Δ ²	Relevant				
		E1	E2	E3	E4	E5	E6	E7	E8				yes	No			
1	A01	3	1	2	2	4	2	4	1	19.0	-5	25	x				
2	A02	2	3	3	1	5	3	5	2	24.0	0	0		x			
3	A03	4	5	5	4	3	5	1	4	31.0	7	49		x			
4	A04	1	4	1	3	2	1	3	3	18.0	-6	36	x				
5	A05	5	2	4	5	1	4	2	5	28.0	4	16		x			
ECUATION Σ Ai= Σ En y Δ=Σ Ai -T										ΣΣ Ai	120	ΣΔ ²	126				
T=ΣΣ Ai / k =		T				24				If, W ≥ 0.5 agreement was reached W < 0.5 disagreement							
W= 12 Σ Δ ² / (m ² (k ³ -k)) =		W				0.20											
TERM k = Quantity of attributes =		INPUT										Second round					
m= Number of experts =		8															

No	Attributes	Experts								ΣAi	Δ	Δ ²	Relevant		
		E1	E2	E3	E4	E5	E6	E7	E8				yes	No	
1	A01	3	1	2	2	4	2	4	1	19.0	-5	25	x		
2	A02	2	3	3	1	5	3	5	2	24.0	0	0		x	
3	A03	4	5	5	4	3	5	3	4	33.0	9	81		x	
4	A04	1	4	1	3	2	1	2	3	17.0	-7	49	x		
5	A05	5	2	4	5	1	4	1	5	27.0	3	9		x	
ECUATION Σ Ai= Σ En y Δ=Σ Ai -T										ΣΣ Ai	120	ΣΔ ²	164		
T=ΣΣ Ai / k =		T		24		If, W ≥ 0.5 agreement was reached W < 0.5 disagreement									
W= 12 Σ Δ ² / (m ² (k ³ -k)) =		W		0.26											
TERM k = Quantity of attributes =		INPUT													
		5													
m= Number of experts =		8													
												Third round			

Table B.3 Coefficient of Kendall (W) for each environmental protection attribute for each of the three rounds

No	Attributes	Experts								ΣAi	Δ	Δ ²	Relevant		
		E1	E2	E3	E4	E5	E6	E7	E8				yes	No	
1	B01	2	1	2	1	1	1	4	2	14.0	-10	100	x		
2	B02	1	4	4	3	3	3	2	4	24.0	0	0		x	
3	B03	4	5	5	5	5	5	5	5	39.0	15	225		x	
4	B04	3	2	1	2	4	2	1	1	16.0	-8	64	x		
5	B05	5	3	3	4	2	4	3	3	27.0	3	9		x	
ECUATION Σ Ai= Σ En y Δ=Σ Ai -T										ΣΣ Ai	120	ΣΔ ²	398		
T=ΣΣ Ai / k =		T		24		If, W ≥ 0.5 agreement was reached W < 0.5 disagreement									
W= 12 Σ Δ ² / (m ² (k ³ -k)) =		W		0.62											
TERM k = Quantity of attributes =		INPUT													
		5													
m= Number of experts =		8													
												First round			

No	Attributes	Experts								ΣAi	Δ	Δ ²	Relevant		
		E1	E2	E3	E4	E5	E6	E7	E8				yes	No	
1	B01	2	1	2	1	1	1	4	2	14.0	-10	100	x		
2	B02	1	3	3	3	4	3	2	4	23.0	-1	1	x		
3	B03	5	5	5	5	5	5	5	5	40.0	16	256		x	
4	B04	3	2	1	2	2	2	1	1	14.0	-10	100	x		
5	B05	4	4	4	4	3	4	3	3	29.0	5	25		x	
ECUATION Σ Ai= Σ En y Δ=Σ Ai -T										ΣΣ Ai	120	ΣΔ ²	482		
T=ΣΣ Ai / k =		T		24		If, W ≥ 0.5 agreement was reached W < 0.5 disagreement									
W= 12 Σ Δ ² / (m ² (k ³ -k)) =		W		0.75											
TERM k = Quantity of attributes =		INPUT													
		5													
m= Number of experts =		8													
												Second round			

No	Attributes	Experts								ΣAi	Δ	Δ ²	Relevant	
		E1	E2	E3	E4	E5	E6	E7	E8				yes	No
1	B01	2	1	2	1	1	1	4	2	14.0	-10	100	x	
2	B02	1	3	3	3	4	3	2	4	23.0	-1	1	x	
3	B03	5	5	5	5	5	5	5	5	40.0	16	256		x
4	B04	3	2	1	2	2	2	1	1	14.0	-10	100	x	
5	B05	4	4	4	4	3	4	3	3	29.0	5	25		x
ECUATION Σ Ai= Σ En y Δ=Σ Ai -T								ΣΣ Ai	120	ΣΔ ²	482			
T=ΣΣ Ai / k =		T		24		If, W ≥ 0.5 agreement was reached W < 0.5 disagreement								
W= 12 Σ Δ ² / (m ² (k ³ -k)) =		W		0.75										
TERM k = Quantity of attributes =		INPUT												
m= Number of experts =		5												
		8								Third round				

Table B.4 Coefficient of Kendall (W) for each social acceptability attribute for each of the three rounds

No	Attributes	Experts								ΣAi	Δ	Δ ²	Relevant	
		E1	E2	E3	E4	E5	E6	E7	E8				yes	No
1	C01	4	7	3	6	7	7	2	5	41.0	9	81		x
2	C02	7	3	2	5	4	6	1	2	30.0	-2	4	x	
3	C03	5	2	5	1	1	1	4	3	22.0	-10	100	x	
4	C04	1	4	7	4	3	3	6	6	34.0	2	4		x
5	C05	2	5	4	2	5	5	5	4	32.0	0	0		x
6	C06	3	1	1	3	2	4	3	1	18.0	-14	196	x	
7	C07	6	6	6	7	6	2	7	7	47.0	15	225		x
ECUATION Σ Ai= Σ En y Δ=Σ Ai -T								ΣΣ Ai	224	ΣΔ ²	610			
T=ΣΣ Ai / k =		T		32		If, W ≥ 0.5 agreement was reached W < 0.5 disagreement								
W= 12 Σ Δ ² / (m ² (k ³ -k)) =		W		0.34										
TERM k = Quantity of attributes =		INPUT												
m= Number of experts =		7												
		8								First round				

No	Attributes	Experts								ΣAi	Δ	Δ ²	Relevant	
		E1	E2	E3	E4	E5	E6	E7	E8				yes	No
1	C01	3	7	4	6	7	7	2	5	41.0	9	81		x
2	C02	7	3	3	2	5	6	1	2	29.0	-3	9	x	
3	C03	5	2	2	1	1	1	4	3	19.0	-13	169	x	
4	C04	2	4	6	5	3	3	6	6	35.0	3	9		x
5	C05	4	5	5	4	4	5	5	4	36.0	4	16		x
6	C06	1	1	1	3	2	4	3	1	16.0	-16	256	x	
7	C07	6	6	7	7	6	2	7	7	48.0	16	256		x
ECUATION Σ Ai= Σ En y Δ=Σ Ai -T								ΣΣ Ai	224	ΣΔ ²				
T=ΣΣ Ai / k =		T		32		If, W ≥ 0.5 agreement was reached W < 0.5 disagreement								
W= 12 Σ Δ ² / (m ² (k ³ -k)) =		W		0.44										
TERM k = Quantity of attributes =		INPUT												
m= Number of experts =		7												
		8								Second round				

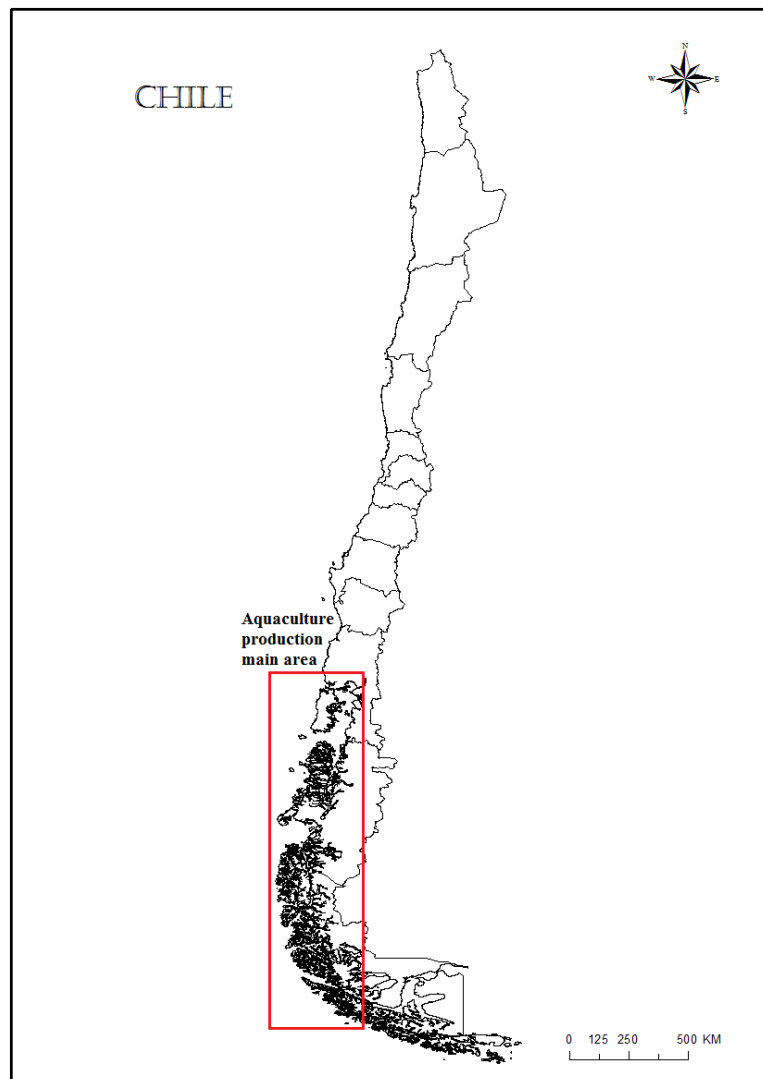
No	Attributes	Experts								ΣAi	Δ	Δ ²	Relevant	
		E1	E2	E3	E4	E5	E6	E7	E8				yes	No
1	C01	4	7	4	6	7	7	2	5	42.0	10	100		x
2	C02	7	3	3	2	5	5	1	3	29.0	-3	9	x	
3	C03	1	2	2	1	1	1	4	2	14.0	-18	324	x	
4	C04	3	4	6	5	3	2	6	6	35.0	3	9		x
5	C05	5	5	5	4	4	6	5	4	38.0	6	36		x
6	C06	2	1	1	3	2	4	3	1	17.0	-15	225	x	
7	C07	6	6	7	7	6	3	7	7	49.0	17	289		x
ECUATION $\Sigma Ai = \Sigma En y \Delta = \Sigma Ai - T$								ΣΣ Ai	224	ΣΔ ²	992			
$T = \Sigma \Sigma Ai / k =$ $W = 12 \Sigma \Delta^2 / (m^2(k^3 - k)) =$		T		32		If, $W \geq 0.5$ agreement was reached $W < 0.5$ disagreement								
		W		0.55										
TERM k = Quantity of attributes = m = Number of experts =		INPUT		Third round										
		7												
		8												

APPENDIX C – CASE STUDY THREE

This section provides supplementary material for case study three. The section present technical specifications for the projects proposal, a copy of the survey questionnaire developed to assess expert opinion regarding the weights for each set of attributes, and the matrices used to calculate the coefficients of Kendall.

C.1 TECHNICAL SPECIFICATIONS

Figure C.1 General location of the Chilean Salmon Industry



C.1 Survey Questionnaire of case study three

Dear Sir/Madam,

Following our discussion, I am very pleased that you have been able to meet with me to help with my studies.

RESEARCHER: I am a student from the Institute of Natural Resources at Massey University, New Zealand, and am completing a PhD in Environmental Management.

STUDY: My research considers the application of multiple criteria analysis to develop a rapid decision-making model to improve the process of project evaluation. This research adopts an integrated approach where aspects of three project evaluation assessments: Cost Benefit Analysis, Environmental Impact Assessment and Social Impact Analysis are integrated into a broader evaluation framework.

REQUEST: In order to establish the weightings required for my model, I would like to gather the experience of a group of experts on economic, social and environmental aspects of project evaluation.

Participants will be asked to complete a short survey. Feedback from the surveys will be analysed and incorporated into the model. Finally, the group will meet together to agree upon final values for the weightings.

CONFIDENTIALITY: The information obtained from this survey will be used for research purposes only and your personal contribution will be kept confidential.

FOCUS GROUP DATE: Friday 2nd of December.

TIME: 18.00 hrs.

VENUE: Avenida Baquedano 808, Coyhaique.

ANTICIPATED LENGTH OF MEETING: 1 hour.

I WILL PROVIDE: Coffee/tea & snacks.

CONTACTS DETAILS: +56-9-8745 4839. Email: C.Reyes@massey.ac.nz.

Camila Reyes

This project has been evaluated by peer review and judged to be low risk. Consequently, it has not been reviewed by one of the University's Human Ethics Committees. The researcher(s) named above are responsible for the ethical conduct of this research. If you have any concerns about the conduct of this research that you wish to raise with someone other than the researcher(s), please contact Professor John O'Neill, Director, Research Ethics, telephone 06 350 5249, email: humanethics@massey.ac.nz

CASE STUDY THREE: SELECTION OF A NET-CAGE SYSTEM TO BE UTILISED BY THE SALMON FARMING INDUSTRY

An ongoing concern and growing challenge for the aquaculture sector is the accumulation of aquatic organisms and algae (collectively known as fouling organisms) on the nets. Biofouling in the salmon aquaculture industry is a costly problem, with both environmental and socio-economic consequences.

The two salmon net-cage systems evaluated in this research consist of two alternative projects developed by the private sector to contribute to solving the biofouling problem. Both projects applied for financial support to the Production Development Corporation of Chile (CORFO).

This evaluation consists of the selection of one of two net-cage systems to be utilised by the salmon farming industry in southern Chile. Both projects proposal will be utilised in the Aysén Region, in Puerto Cisnes, 196 km to the north-west of the regional capital Coyhaique.

Alternative A: Nylon net-cage washing service

This proposal is for the development of an aquaculture net-cage servicing facility to clean and repair net-cages. It incorporates environmentally sustainable practices for its waste water. It will create jobs and enable this service to be offered to the aquaculture clients within the region.

Alternative B: Adoption of copper alloy net-cages in salmon farming

It is a proposal for encouraging the use of copper alloy mesh (an innovative anti-fouling technology) net-cages. The anti-microbial attributes of copper make this net-cage material resistant to organic fouling. While initially the cages are more expensive, this new technology offers cost saving potential through reducing the need for the use of anti-fouling agents, net inspections conducted by divers, traditional net cleaning, and through increasing the longevity of the net-cages.

Alternative C: Status quo, 'without' the development of either project.

The focus of this study was to determine which of these two alternatives would better contribute to sustainably increasing the productivity of salmon farming whilst taking into account southern Chile's socio-economic and environmental considerations.

Name: _____

Email: _____



General view of Puerto Cisnes

Key attributes for the selection of a net-cage system to be utilised by the salmon farming industry.

Aim	Attribute
Economic development	Increase in production
	Net-cage life span
	Impact on production costs
	Impact on local employment
Environmental protection	Effects on water quality
	Threat to native fish from exotic salmon escaped from salmon farms
	Reduction of chemicals and antibiotic dependency
Social acceptability	Migration from coastal areas to main urban centres
	Effects on cultural heritage of aquaculture related communities
	Effect on working conditions

Can you suggest anyone else whom you think could contribute with this research by answering this survey?

Environmental protection regarding the selection of a net-cage system to be utilised by the salmon farming industry

First, from your knowledge, tick which of the two issues is more important to achieve environmental protection.

Second, how much more important is your choice compared with the alternative (circle).

			equally important	more important					much more important		
1	a) Threat to native fish from exotic salmon escaping from salmon farms	<input type="checkbox"/>	1	2	3	4	5	6	7	8	9
	b) Reduction of chemicals and antibiotic dependency	<input type="checkbox"/>									
2	a) Effects on water quality	<input type="checkbox"/>	1	2	3	4	5	6	7	8	9
	b) Threat to native fish from escaped of salmon farm	<input type="checkbox"/>									
3	a) Effects on water quality	<input type="checkbox"/>	1	2	3	4	5	6	7	8	9
	b) Reduce of chemicals and antibiotics dependency	<input type="checkbox"/>									

Social acceptability regarding the selection of a net-cage system to be utilised by the salmon farming industry

First, from your knowledge, tick which of the two issues is more important to achieve social acceptability.

Second, how much more important is your choice compared with the alternative (circle).

			equally important	more important					much more important		
1	a) Migration from coastal areas to main urban centres	<input type="checkbox"/>	1	2	3	4	5	6	7	8	9
	b) Effect on working conditions	<input type="checkbox"/>									
2	a) Migration from coastal areas to main urban centres	<input type="checkbox"/>	1	2	3	4	5	6	7	8	9
	b) Effect on cultural patterns of aquiculture related communities	<input type="checkbox"/>									
3	a) Effects on cultural heritage of aquiculture related communities	<input type="checkbox"/>	1	2	3	4	5	6	7	8	9
	b) Effect on working conditions	<input type="checkbox"/>									

C.3 CALCULATIONS TO DETERMINE THE COEFFICIENTS OF KENDALL FOR CASE STUDY THREE.

This section presents the matrices used to calculate the coefficients of Kendall from the interactive process, for economic development, environmental protection and social acceptability. These calculations follow the procedure described in Chapter 3, Section 3.5.4.

Table C.1 Coefficient of Kendall (W) for each economic development attribute for each of the three rounds

No	Attributes	Experts									ΣAi	Δ	Δ ²	Relevant	
		E1	E2	E3	E4	E5	E6	E7	E8	E9				yes	No
1	A01	2	2	1	3	2	2	2	2	2	18	-4,5	20.25	x	
2	A02	4	4	4	4	4	3	4	4	4	35	12,5	156.25		x
3	A03	1	1	2	1	3	1	1	3	1	14	-8,5	72.25	x	
4	A04	3	3	3	2	1	4	3	1	3	23	0,5	0.25		x
ECUATION											90	ΣΔ ²	249		
Σ Ai= Σ En y Δ=Σ Ai -T															
T=ΣΣ Ai / k =		T			22.5						W ≥ 0.5 agreement was reached W < 0.5 disagreement				
W= 12 Σ Δ ² / (m ² 2(k ³ -k)) =		W			0.61										
TERM		INPUT									First round				
k = Quantity of attributes =		4													
m= Number of experts =		9													

No	Attributes	Experts									ΣAi	Δ	Δ ²	Relevant	
		E1	E2	E3	E4	E5	E6	E7	E8	E9				yes	No
1	A01	3	2	1	3	2	2	2	2	2	19	-3,5	12.25	x	
2	A02	4	4	4	4	4	4	4	4	4	36	13,5	182.25		x
3	A03	1	1	2	1	3	1	1	3	1	14	-8,5	72.25	x	
4	A04	2	3	3	2	1	3	3	1	3	21	-1,5	2.25		x
ECUATION											90	ΣΔ ²	269		
Σ Ai= Σ En y Δ=Σ Ai -T															
T=ΣΣ Ai / k =		T			22.5						W ≥ 0.5 agreement was reached W < 0.5 disagreement				
W= 12 Σ Δ ² / (m ² 2(k ³ -k)) =		W			0.66										
TERM		INPUT									Second round				
k = Quantity of attributes =		4													
m= Number of experts =		9													

No	Attributes	Experts									ΣAi	Δ	Δ ²	Relevant	
		E1	E2	E3	E4	E5	E6	E7	E8	E9				yes	No
1	A01	2	2	1	3	3	2	2	1	2	18	-4,5	20.25	x	
2	A02	4	4	4	4	4	4	4	4	4	36	13,5	182.25		x
3	A03	1	1	2	1	2	1	1	2	1	12	-10,5	110.25	x	
4	A04	3	3	3	2	1	3	3	3	3	24	1,5	2.25		x
ECUATION											90	ΣΔ ²	315		
Σ Ai= Σ En y Δ=Σ Ai -T															
T=ΣΣ Ai / k =		T			22.5						W ≥ 0.5 agreement was reached W < 0.5 disagreement				
W= 12 Σ Δ ² / (m ² 2(k ³ -k)) =		W			0.78										
TERM		INPUT									Third round				
k = Quantity of attributes =		4													
m= Number of experts =		9													

Table C.2 Coefficient of Kendall (W) for each environmental protection attribute for each of the three rounds

No	Attributes	Experts									ΣA_i	Δ	Δ^2	Relevant	
		E1	E2	E3	E4	E5	E6	E7	E8	E9				yes	No
1	A01	1	1	2	3	2	2	1	3	3	18	0	0		x
2	A02	2	2	3	1	3	3	2	1	2	19	1	1		x
3	A03	3	3	1	2	1	1	3	2	1	17	-1	1	x	
ECUATION											54	$\Sigma \Delta^2$	2		
$\Sigma A_i = \Sigma E_n y \Delta = \Sigma A_i - T$															
$T = \Sigma \Sigma A_i / k =$		T			18						W ≥ 0.5 agreement was reached W < 0.5 disagreement				
$W = 12 \Sigma \Delta^2 / (m^2(k^3-k)) =$		W			0.01										
TERM		INPUT									First round				
k = Quantity of attributes =		3													
m = Number of experts =		9													

No	Attributes	Experts									ΣA_i	Δ	Δ^2	Relevant	
		E1	E2	E3	E4	E5	E6	E7	E8	E9				yes	No
1	A01	1	1	2	3	2	2	1	3	3	18	0	0	x	
2	A02	3	2	3	1	3	3	2	1	2	20	2	4		x
3	A03	2	3	1	2	1	1	3	2	1	16	-2	4	x	
ECUATION											54	$\Sigma \Delta^2$	8		
$\Sigma A_i = \Sigma E_n y \Delta = \Sigma A_i - T$															
$T = \Sigma \Sigma A_i / k =$		T			18						W ≥ 0.5 agreement was reached W < 0.5 disagreement				
$W = 12 \Sigma \Delta^2 / (m^2(k^3-k)) =$		W			0.05										
TERM		INPUT									Second round				
k = Quantity of attributes =		3													
m = Number of experts =		9													

No	Attributes	Experts									ΣA_i	Δ	Δ^2	Relevant	
		E1	E2	E3	E4	E5	E6	E7	E8	E9				yes	No
1	A01	1	1	2	3	2	2	1	3	3	18	0	0	x	
2	A02	3	2	3	1	3	3	2	1	2	20	2	4		x
3	A03	2	3	1	2	1	1	3	2	1	16	-2	4	x	
ECUATION											54	$\Sigma \Delta^2$	8		
$\Sigma A_i = \Sigma E_n y \Delta = \Sigma A_i - T$															
$T = \Sigma \Sigma A_i / k =$		T			18						W ≥ 0.5 agreement was reached W < 0.5 disagreement				
$W = 12 \Sigma \Delta^2 / (m^2(k^3-k)) =$		W			0.05										
TERM		INPUT									Third round				
k = Quantity of attributes =		3													
m = Number of experts =		9													

Table C.3 Coefficient of Kendall (W) for each social acceptability attribute for each of the three rounds

No	Attributes	Experts									ΣAi	Δ	Δ ²	Relevant	
		E1	E2	E3	E4	E5	E6	E7	E8	E9				yes	No
1	A01	3	1	3	2	2	1	3	2	1	18	0	0	x	
2	A02	1	2	2	3	1	2	2	1	2	16	-2	4		x
3	A03	2	3	1	1	3	3	1	3	3	20	2	4	x	
ECUATION											54	ΣΔ ²	8		
Σ Ai= Σ En y Δ=Σ Ai -T															
T=ΣΣ Ai / k =		T			18						W ≥ 0.5 agreement was reached W < 0.5 disagreement				
W= 12 Σ Δ ² / (m ² (k ³ -k)) =		W			0.05										
TERM		INPUT									First round				
k = Quantity of attributes =		3													
m= Number of experts =		9													

No	Attributes	Experts									ΣAi	Δ	Δ ²	Relevant	
		E1	E2	E3	E4	E5	E6	E7	E8	E9				yes	No
1	A01	3	1	3	2	2	1	3	1	1	17	-1	1	x	
2	A02	1	2	2	3	1	2	1	2	2	16	-2	4		x
3	A03	2	3	1	1	3	3	2	3	3	21	3	9	x	
ECUATION											54	ΣΔ ²	14		
Σ Ai= Σ En y Δ=Σ Ai -T															
T=ΣΣ Ai / k =		T			18						W ≥ 0.5 agreement was reached W < 0.5 disagreement				
W= 12 Σ Δ ² / (m ² (k ³ -k)) =		W			0.09										
TERM		INPUT									Second round				
k = Quantity of attributes =		3													
m= Number of experts =		9													

No	Attributes	Experts									ΣAi	Δ	Δ ²	Relevant	
		E1	E2	E3	E4	E5	E6	E7	E8	E9				yes	No
1	A01	3	1	3	2	2	2	1	1	1	16	-2	4	x	
2	A02	1	2	1	3	1	1	2	2	2	15	-3	9		x
3	A03	2	3	2	1	3	3	3	3	3	23	5	25	x	
ECUATION											54	ΣΔ ²	38		
Σ Ai= Σ En y Δ=Σ Ai -T															
T=ΣΣ Ai / k =		T			18						W ≥ 0.5 agreement was reached W < 0.5 disagreement				
W= 12 Σ Δ ² / (m ² (k ³ -k)) =		W			0.23										
TERM		INPUT									Third round				
k = Quantity of attributes =		3													
m= Number of experts =		9													