DECISION SUPPORT SYSTEM FOR
THE EVALUATION AND COMPARISON OF
CONCESSION PROJECT INVESTMENTS

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by

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DECLARATION

This work has not been previously submitted for a degree or diploma in any university. To the best of my knowledge and belief, the thesis contains no material previously published or written by another person except where due reference is made in the thesis itself.

Alison Kate McCowan

January 2004

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ABSTRACT

Governments of developed and developing countries alike are unable to fund the construction and maintenance of vital physical infrastructure such as roads, railways, water and wastewater treatment plants, and power plants. Thus, they are more and more turning to the private sector as a source of finance through procurement methods such as concession contracts. The most common form of concession contract is the Build-Operate-Transfer (BOT) contract, where a government (Principal) grants a private sector company (Promoter) a concession to build, finance, operate and maintain a facility and collect revenue over the concession period before finally transferring the facility, at no cost to the Principal, as a fully operational facility. Theoretically speaking, these projects present a win-win-win solution for the community as well as both private and public sector participants.

However, with the opportunity for private sector companies to earn higher returns comes greater risk. This is despite the fact that concession projects theoretically present a win-win-win solution to the problem of infrastructure provision. Unfortunately, this has not been the case in a number of countries including Australia. Private sector participants have admitted that there are problems that must be addressed to improve the process. Indeed they have attributed the underperformance of concession projects to the inability of both project Principals and Promoters to predict the impact of all financial and non-financial (risk) factors associated with concession project investments (CPIs) and to negotiate contracts to allow for these factors.

Non-financial project aspects, such as social, environmental, political, legal and market share factors, are deemed to be important; but these aspects would usually be considered to lie outside the normal appraisal process. To allow for the effects of such qualitative aspects, the majority of Principal or promoting organisations resort to estimating the necessary money contingencies without an appropriate quantification of the combined effects of financial and non-financial (risks and opportunities) factors.

In extreme cases, neglect of non-financial aspects can cause the failure of a project despite very favourable financial components; or can even cause the failure to go-ahead with a project that may have been of great non-financial benefit due to its projected ordinary returns. Hence, non-financial aspects need careful analysis and understanding so that they can be assessed and properly managed. It is imperative that feasibility studies allow the promoting organisation to include a combination of financial factors and non-financial factors related to the economic environment, project complexity, innovation, market share, competition, and the national significance of the project investment. While much research has already focused on the classification of CPI non-financial (risk) factors, and the identification of interdependencies between risk factors on international projects, no attempt has yet been made to quantify these risk interdependencies. Building upon the literature, this thesis proposes a generic CPI risk factor framework (RFF) including important interdependencies, which were verified and quantified using input provided by practitioners and researchers conversant with risk profiles of international and/or concession construction projects. Decision Support Systems (DSSs) are systems designed to assist in the decision making process by providing all necessary information to the analyst. There are a number of DSSs that have been developed over recent years for the evaluation of high-risk construction project investments, such as CPIs, which incorporate the analysis of both financial and non-financial (risk) aspects of the investment. However, although these DSSs have been useful to practitioners and researchers alike, they have not offered a satisfactory solution to the modelling problem and are all limited in their practical application for various reasons. Thus, the construction industry lacks a DSS that is capable of evaluating and comparing several CPI options, taking into consideration both financial and non-financial aspects of an investment, as well as including the uncertainties commonly encountered at the feasibility stage of a project, in an efficient and effective manner. These two criteria, efficiency and effectiveness, are integral to the usefulness and overall acceptance of the developed DSS in industry.

This thesis develops an effective and efficient DSS to evaluate and compare CPI opportunities at the feasibility stage. The novel DSS design is based upon a combination of: (1) the mathematical modelling technique and financial analysis model that captures the true degree of certainty surrounding the project; and (2) the decision making technique and RFF that most closely reproduces the complexity of CPI decisions. Overall, this thesis outlines the methodology followed in the development of the DSS – produced as a stand-alone software product – and demonstrates its capabilities through a verification and validation process using real-life CPI case studies.

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ACRONYMS

AHP	Analytical Hierarchy Process
ANP	Analytic Network Process
B/C	Benefit/Cost
B/CR	Benefit/(Cost x Risk)
BO/CR	(Benefit x Opportunity)/(Cost x Risk)
BOLT	Build-Own-Lease-Transfer
BOO	Build-Own-Operate
BOOST	Build-Own-Operate-Subsidize-Transfer
BOOT	Build-Own-Operate-Transfer
BOT	Build-Operate-Transfer
BTHSR	Bureau of Taiwan High Speed Rail
BTO	Build-Transfer-Operate
CASPAR	Computer Aided Simulation for Project Appraisal and Review
CIA	Cross Impact Analysis
COMFAR	COmputer Model for Feasibility Analysis and Reporting
CPI	Concession Project Investment
CSF	Critical Success Factor
DBFO	Design-Build-Finance-Operate
DBOT	Design-Build-Operate-Transfer
DSCR	Debt Service Coverage Ratio
DSS	Decision Support System
ECCO	Evaluate and Compare Concession Options
EMC	Electromechanical Cost
FBOOT	Finance-Build-Own-Operate-Transfer
HEPP	Hydroelectric Power Plant
HSR	High Speed Rail
ICRAM-1	International Risk Assessment Model
IRR	Internal Rate of Return
ISTEA	Intermodal Surface Transportation Efficiency Act
MCC	Modified Coefficient of Consensus
MCDM	Multi Criteria Decision Making
NN	Neural Networks
NPV	Net Present Value
NSW	New South Wales
NZ	New Zealand
O&M	Operations and Maintenance
O/R	Opportunity/Risk
PFI	Private Finance Initiative
PNG	Papua New Guinea
PPP	Public-Private Partnership
RFF	Risk Factor Framework
RIM	Risk Influence Matrix
THSRC	Taiwan High Speed Rail Corporation
UAE	United Arab Emirates
UK	United Kingdom
UNIDO	United Nations Industrial Development Organisation
US	United States
VaR	Value at Risk

VBA	Visual Basic for Applications
VCC	Ventana Coefficient of Consensus
VFM	Value For Money
WACC	Weighted Average Cost of Capital

CHAPTER 1

INTRODUCTION

1.1 MOTIVATION AND OVERVIEW

Rapid growth of the world's population and its continual dispersal due to technological advance in the late 20th century is creating a demand for the construction and maintenance of vital physical infrastructure, such as roads, railways, water and wastewater treatment plants, and power plants (Levy, 1996). Among other reasons, this rapid growth and the inability of governments of developing and developed countries alike to meet infrastructure needs has led to a resurgence of privately financed infrastructure projects, procured via concession contracts, in the 1980s.

Concession contracts can be broadly defined as contracts where the government (Principal) grants the private sector (Promoter) a licence or concession to deliver infrastructure services of a certain type for a set length of time. There are many variations of the concession contract, denoted by common acronyms, differing in one or more aspects of delivery. Some of these variations include:

BOOT:	Build-Own-Operate-Transfer
BOT:	Build-Operate-Transfer
BOO:	Build-Own-Operate
FBOOT:	Finance-Build-Own-Operate-Transfer

BOOST:	Build-Own-Operate-Subsidize-Transfer
DBOT:	Design-Build-Operate-Transfer
BTO:	Build-Transfer-Operate
BOLT:	Build-Own-Lease-Transfer

The term Build-Operate-Transfer (BOT) was first introduced in Turkey in the 1980s (Zhang and Kumaraswamy, 2001b) and may be defined as follows:

> *"a private party or Concessionaire retains a concession for a fixed period from a public party, called Principal (client), for the development and operation of a public facility. The development consists of the financing, design, and construction of the facility, managing and maintaining the facility adequately, and making it sufficiently profitable. The concessionaire secures return of investment by operating the facility and, during the concession period, the concessionaire acts as owner. At the end of the concession period, the concessionaire transfers the ownership of the facility free of liens to the principal at no cost."*
>
> (Menheere and Pollalis, 1996)

However, concession contracts are by no means a new concept. These contracts have been used as early as 1782 when the Perier brothers were granted a concession to distribute water in Paris, France (Walker and Smith, 1995). Throughout the 1800s concessions were granted for transportation infrastructure in Spain, Italy, France, Belgium and Germany. This included the famous Suez Canal (Levy, 1996), which was procured as a 99 year long, concession project and, later, the Panama Canal. During this period, the adoption of concession contracts spread as far as America, China and Japan.

From the late 1800s to the 1970s, most infrastructure projects were again being financed by the public sector, with less developed countries receiving support in the form of loans from organizations such as the World Bank and the International Monetary Fund. By the 1980's, governments were struggling to keep up with the rapidly growing need of society for additional infrastructure and the upgrading of existing infrastructure. It is believed that this growth, as well as the increased life expectancy of populations in developed countries, has been a catalyst for the resurgence of concession contracts over the last two decades (Walker and Smith, 1995).

From a Government's perspective, concession projects provide off balancesheet funding and bring an added advantage of innovation, and cost and resource efficiency through private sector involvement. The United Kingdom (UK) is a pioneer in the privatisation of public infrastructure with a number of successful projects through the Private Finance Initiative (PFI) program launched in 1992 (Akintoye et al., 2003). For example, the first Design-Build Finance-Operate (DBFO) roads in the UK realised cost savings of approximately 15%, and the UK Home Office's Immigration Casework information technology project was expected to achieve productivity improvements of at least 40% (Zhang and Kumaraswamy, 2001b).

Furthermore, concession projects offer private sector participants great opportunities to expand market share and earn high returns on their investments. For example, various Hong Kong tunnel projects expect returns on investment of between 15 and 18.5%, while other projects in Pakistan, Malaysia, California and Bangkok forecast returns between 16 and 21% (Kumaraswamy and Morris, 2002). These high returns are a result of the high degree of risk incurred by promoters. Finally, from the community's perspective, concession projects provide much needed infrastructure that otherwise may not have been built, allow for greater innovation and, rather than causing increases in rates or levies, are usually based on a user pays system.

Theoretically concession projects present a win-win-win solution for the community at large, and both private and public sector participants. For this reason, many governments around the world now require the option of private financing to be assessed as part of feasibility studies on all large public infrastructure projects. The UK launched its Private Finance Initiative (PFI) in 1992 and making it mandatory for all public capital works projects to explore private finance options in 1994 (Akintoye et al. 1998). In the year 2000, Five (5) percent of the UK construction sector's current annual turnover (£60billion) was accounted for by PFI projects, and this was set to increase (Hickman, 2000).

According to the Private Finance Panel (1995):

> *"The PFI has become one of the Government's main instruments for delivering higher quality and most cost effective public services…It is not simply about the financing of capital investment in services, but about exploiting the full range of private sector management, commercial and creative skills."*

The Green Book (Great Britain Treasury, 2003) provides guidance to other public sector bodies on how proposals should be appraised, before significant funds are committed – and how past and present activities should be evaluated. It is relevant to all project appraisals and evaluations, including conventional (publicly funded) projects and concession (privately funded) projects.

Also, in the United States (US), the Intermodal Surface Transportation Efficiency Act (ISTEA) was implemented by the federal government in 1991 to create a framework for public-private partnerships (PPPs) for toll road developments (Zhang and Kumaraswamy, 2001b). Numerous states have also adopted a concession approach to the rebuilding of inadequate infrastructure systems: airport, athletic arena, buildings, highways and bridges, prisons, railroad, water supply facilities and wastewater treatment plants (Price Waterhouse, 1990). This increase in US concession projects was prompted by insufficient public funding with only one third of the required funding for infrastructure being provided annually (Ock, 1998).

Many other governments around the world are also developing policies and strategies concerning the provision of infrastructure via concession contracts and private sector involvement. These include Australia, Canada, Ireland, Japan, Netherlands and many more. In Australia, a National PPP Council was established as an inter-governmental forum to discuss topics relating to Public Private Partnerships / Privately Financed Projects with an inaugural forum being held in May 2004. Many of the State governments in Australia have developed, or are in the process of developing, policies and guidance material to encourage a consistent application of the Value for Money framework and of the potential for private sector involvement in the delivery of major infrastructure projects and related services. The Value for Money framework sets out a process for rigorous assessment of the best available infrastructure delivery options through both the public and private sectors. In the case of concession projects, this assessment involves developing a detailed estimate of what it would cost to design, implement, operate and maintain the service over the contract period using public funding and then accepting or rejecting private sector bids based on this value (Akintoye et al., 1998). Guidance material provided by the various governments also usually includes supporting documents on Risk Management.

With the opportunity for private sector companies to earn higher returns comes greater risk. Although concession projects theoretically present a win-win-win solution to the problem of infrastructure provision, this has not been the case in a number of countries including Australia. Private sector participants generally look upon the concession project option favourably, however they have admitted that there are problems that must be addressed to improve the process (Akintoye et al., 2003). This underperformance of concession projects has been attributed to the inability of project sponsors and promoters to predict the impact of all financial and non-financial (risk) factors associated with CPIs and to negotiate contracts to allow for these factors (Halligan, 1997). CPIs that, financially speaking, should have been viable investments have either been delayed, terminated or are now running at a loss, due to non-financial factors affecting the project. Examples of such cases include: the development of a third terminal of Toronto Airport in 1985 which was terminated of a concession contract after changes were made in government composition (Walker and Smith, 1995); an Independent Power Project in India, where a change in State Government, during the construction phase, led to the review and subsequent repudiation of the first phase and the cancellation of the second phase of the project in 1995 (the project was later cleared for go ahead in 1996); and more recently, three BOT tunnels in Hong Kong, that have all been suffering low traffic volumes owing to competition from alternative routes (Zhang and Kumaraswamy, 2001a).

Companies looking to compete in these markets must select the CPIs which provide the greatest benefits, both financial and non-financial, in order to gain a competitive edge. It is imperative that whether benefits are purely financial or a combination of financial and non-financial gains, CPI options are compared as objectively as possible and feasibility studies incorporate risk analysis techniques, in conjunction with traditional economic analysis.

Unfortunately, non-financial project aspects, such as social, environmental, political, legal and market share factors, are deemed to be important; but these would usually be considered to lie outside the normal appraisal process for private sector companies (Lopez and Flavell, 1998). To allow for the effects of these qualitative aspects, the majority of companies resort to estimating the necessary money contingencies without an appropriate quantification of the combined effects of financial and non-financial (risks and opportunities) factors (Akintoye and Macleod, 1997). This is despite the fact that there are a myriad of risk analysis techniques for the appraisal of project investment opportunities, ranging from simple scoring or weighted sum methods to more sophisticated techniques, such as probabilistic simulation. This is supported by more recent investigations by Akintoye et al. (2003) that have identified the need for consistent risk assessment and management practices across the different organisations in a concession project consortium in the UK. One interviewee even stated, “I would like to see a reliable standard on how to deal with risk, because we have to invent our own criteria all the time. This is time consuming and very costly in terms of professional fees.”

In extreme cases, neglect of non-financial aspects can cause the failure of a project, despite very favourable financial components (Toakley, 1997), or even the failure to go-ahead with a project that may have been of great non-financial benefit, due to its projected ordinary returns. Hence, non-financial aspects need careful analysis and understanding so that they can be assessed and managed (Tweedale, 1993). A proper feasibility study should provide the company with the option to include factors related to the economic environment (boom or recession), project complexity, technical innovation, market share, service obligations, competition, national significance and other strategic aspects of the project investment.

Decision Support Systems (DSSs) are systems designed to assist in the decision making process by providing all necessary information to the analyst. There are a number of DSSs that have been developed over recent years for the evaluation of high-risk construction project investments, such as CPIs, which incorporate the analysis of both financial and non-financial (risk) aspects of the investment. However, it is proposed that although these DSSs have been useful to practitioners and researchers alike, they have not offered a satisfactory solution to the modelling problem and are all limited in their practical application for various reasons such as, being unable to include interdependencies between factors, and requiring too high a level of input definition at the feasibility stage of a project when this detailed information is yet unknown.

As mentioned earlier, many governments around the world have now developed their own policies and guidance material on CPIs (also known as Privately Financed Initiatives and Public Private Partnerships) outlining how to evaluate the feasibility of infrastructure project based on the concept of Value for Money. While this concept does take into consideration the impacts of non-financial factors on a project's feasibility, these guidelines adopt similar techniques to the above DSSs and are therefore also limited in their practical application.

Thus, due to the relative youth of this branch of research, the construction industry lacks a DSS that is capable of evaluating and comparing several CPI options, taking into consideration both financial and non-financial aspects of an investment, as well as including the uncertainties commonly encountered at the feasibility stage of a project, in the most efficient and effective manner. Effectiveness can be defined as the ability to reflect the true degree of complexity and certainty surrounding a real-life investment, whilst efficiency is the ability to fulfil all requirements using the least amount of the analyst's time and resources. These two criteria, efficiency and effectiveness, are integral to the usefulness and overall acceptance of the developed DSS in industry. A reported survey by Akintoye et al. (2003), supports the view that unless a DSS accurately captures the real-life investment characteristics, in the most resource and time efficient manner, construction companies will ultimately boycott its implementation. Other earlier surveys also broadly support this view (Pasquire, 1996, Akintoye and Macleod, 1997, Jackson et al., 1997). This research project was inspired by a perceived lack of such a DSS.

1.2 OBJECTIVES

The main goal of this research project was to develop an effective and efficient Decision Support System (DSS) for the construction industry to evaluate and compare concession project investment (CPI) opportunities at the feasibility stage. There are other opportunities that might be associated with CPIs, however these are project specific and highly dependent on the organisation involved and are therefore outside the scope of this thesis.

With this goal in mind, the following secondary objectives were identified for the research project to:

1. To undertake a critical literature review of all relevant topics, such as risks involved in concession project investments, investment appraisal techniques, risk assessment in the construction industry, requirements of a DSS, currently available DSSs and modelling techniques.

2. Select (or where necessary develop) the most effective, yet efficient, techniques in the following areas for implementation in the DSS conceptual design: mathematical modelling, CPI financial analysis, decision-making, and CPI risk factor frameworks (RFFs).

3. Design the DSS architecture based upon the best techniques selected in Step 2 and thus develop the conceptual DSS.

4. Obtain specific industry input via a pilot study to develop and verify the DSS generic CPI RFF, through the identification and quantification of all significant risk factor interdependencies.

5. Fully develop the conceptual DSS design of Step 4 as a computer software package ECCO (Evaluate and Compare Concession Options) with accompanying user manual and help files, to provide the construction industry with a practical, user-friendly, decision-making tool.

6. Obtain industry input, via reported national and international case studies, to verify and validate the DSS, as well as demonstrate its full capabilities.

Figure 1.1 presents the input, research activities and expected output of each stage of the research. The successful completion of these tasks has led to the realization of the research goal.

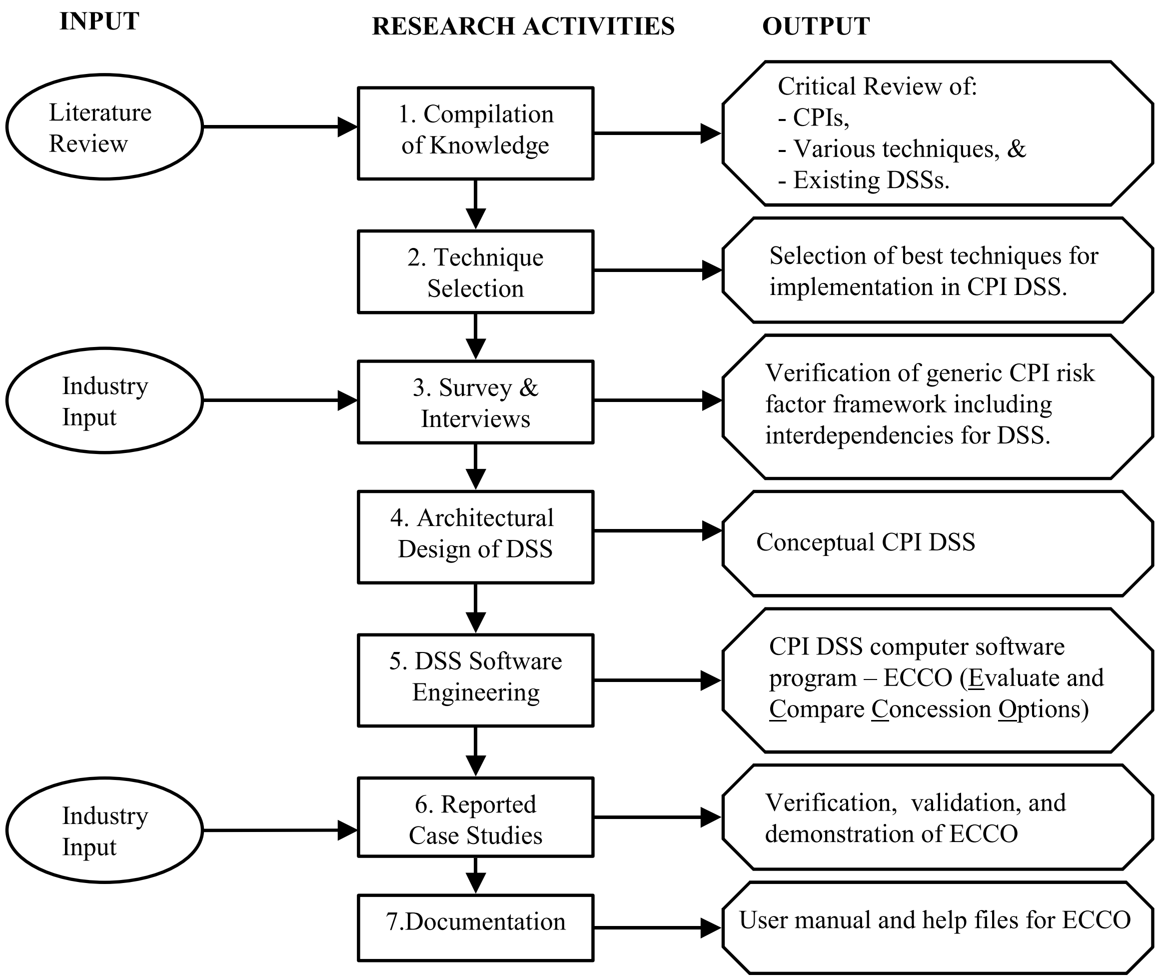


Figure 1.1 Input, Research Activities, and Expected Output

1.3 METHODOLOGY

The various research activities completed in pursuit of the above mentioned research objectives were divided into two main phases: Phase I - Literature Review and Analysis, and Phase II - Design and Implementation.

1.3.1 Phase I - Literature Review and Analysis

As a starting point for the research project it was necessary to first identify the needs of the construction industry in relation to evaluating and comparing concession project investment options. Thus an extensive review of all relevant literature was conducted in order to gain a full understanding of:

- Concession projects, including financing, contracts, risks, critical success factors and reported national/international case studies of successes and failures;
- Current practice feasibility studies in the construction industry;
- Key requirements of an efficient and effective CPI DSS; and
- DSSs currently available to the industry that could be used for the evaluation and comparison of CPI options.

In conducting the literature review, sources included relevant national and international literature, reported surveys and case studies. As a result of the above investigations, techniques in the following four areas were then critically compared with the aim of identifying the advantages and limitations of each as a CPI modelling tool:

1. Decision making techniques;
2. Mathematical modelling techniques;
3. Financial analysis models; and
4. Risk factor frameworks.

Although several of the techniques identified in the above review had not yet been specifically applied to the modelling of CPIs, all techniques were considered to be suitable for implementation in a CPI DSS, either in their present state, or with minor modifications.

In particular, the risk factor frameworks reviewed included some that were developed for the analysis of large scale, international projects. This decision was made on the assumption that there are strong synergies between the procurement process for large projects and the risks involved in CPIs. This assumption broadly holds true for the procurement element of these projects, with both being characterised by complex financial arrangements and organisational structures, and are exposed to a high country and market level risks which could significantly affect project viability. Also, many concession projects often fall into the category of international projects involving the coming together of organisations from more than one country.

1.3.2 Phase II – Design and Implementation

Technique Selection

Phase II formed the most important component of the research. The most efficient and effective techniques for the modelling of CPI options had to be selected from those critically compared as part of Phase I, before the architecture of the DSS could be designed. It was imperative that: (1) the mathematical modelling technique and financial analysis model selected capture the true degree of certainty surrounding the project; (2) the decision making technique and RFF selected were those that most closely reproduce the complexity of CPI decisions; and (3) the DSS as a whole successfully met all requirements identified in the literature review.

As a number of mathematical modelling and decision-making techniques included in the comparisons had not yet been specifically applied to the modelling of CPIs, the selection process for techniques in these two areas consisted of detailed numerical applications. From these comparisons the possibility theory and the Analytic Network Process (ANP) were chosen as the mathematical and decision–making techniques, respectively. The risk factor framework by Wang et al. (2002) was selected as the foundation for the DSS generic CPI RFF. This RFF was developed by Wang et al. (2002) for international projects, however due to the reasons set out in Section 1.3.1, and as it was the most advanced framework reported in literature, it has been selected for implementation in the DSS subject to the refinements discussed in Section 3.5.

Unfortunately the reported financial analysis models were not able to meet all DSS requirements. Thus a novel financial analysis model was developed for the DSS. Finally certain minor modifications were made to the selected techniques, in order to enhance their collective effectiveness and efficiency.

Architectural Design of DSS

Once the most suitable techniques had been selected and modified where required, the final CPI DSS architecture could be designed. The design consisted of three modules: Module One - Model Definition Module, Module Two - Model Evaluation and Ranking Module, and Module Three - Sensitivity Analysis Module. The purpose, structure and implementation of the three modules were determined, to a large degree, by the primary performance measure, ANP Project Rating method, selected as the basis for overall project rankings.

Module One of the DSS performs the function of creating individual project investment models including the definition of financial factors, non-financial factors, and the interdependencies between non-financial factors. A generic CPI RFF developed from pilot study results was also provided as an optional framework in this first module of the DSS. Individual project investment models were then evaluated, compared and ranked, according to their overall scores, using Module Two. This module performs both the financial and non-financial analysis of one to five CPI options, providing a total of fifteen performance measures (eleven financial, three non-financial and one combined), as well as the combined ranking of the projects. Thus the analyst is given a clearer picture of exactly how non-financial factors affect the overall viability of each project. The DSS design also caters for the examination of various CPI options' sensitivity to changes in any non-financial or financial factor via Module Three. Sensitivity analysis results can be particularly useful at the contract negotiations stage, and in forming a risk response plan if the project does in fact go ahead.

Pilot Study – Generic Risk Factor Framework Development & Verification

While much research has already focused on the classification of CPI non-financial (risks and opportunities) factors, and even the identification of interdependencies between these factors, no attempt has yet been made to quantify these interdependencies. Industry input was therefore required to establish and quantify the more critical interdependencies between non-financial factors. Due to time constraints, it was decided to focus purely on the development of a generic CPI RFF including significant interdependencies for implementation in the DSS via a pilot study comprising interviews and questionnaires.

Interviews were first conducted with industry participants from both managerial and design backgrounds in international construction projects. These interviews enabled the refinement of the questionnaire and identified the most critical interdependencies between factors. Due to a lack of rich local industry experience in concession projects and the large similarities in risk profiles of international and concession projects, the questionnaire targeted a small sample comprising two cluster samples: 1) industry participants having experience in international construction projects; and 2) international researchers who have recognized publication records in the area of concession projects. Responses from the questionnaire were then analysed and implemented as the DSS's generic CPI RFF available to the analyst in Module One.

Engineering of DSS Software

In order for the DSS to be of practical use to the industry, it was necessary to implement the DSS design as a standalone computer software program. This program was aptly named ECCO, Evaluate and Compare Concession Options. The main design considerations for the computer software were that it was capable of performing complex mathematical operations, whilst still maintaining a simplistic user-friendly interface. Thus, ECCO was developed as a dialog-based program in Visual C++, much like a commonly used wizard program. Visual C++ is an object-oriented language having advanced templates, comprehensive Microsoft Foundation Classes and low-level platform access, making it suitable for building mathematically powerful Windows applications.

Verification and Validation of DSS

Once the conceptual DSS had been fully developed as a computer software program, data gathered from reported national and international case studies were used to verify the individual components of ECCO, to validate ECCO as an overall system, to demonstrate its capabilities, and to identify its limitations. A combination of hypothetical and reported CPI case studies were used to verify individual components of the DSS, whilst the validation process employed three reported, real-life CPI case studies: a PPP highway project in

Canada, a high speed rail (HSR) project in Taiwan and a hydro-electric power plant (HEPP) project in Turkey. This variety of projects allowed for the full capabilities of ECCO to model any form of CPI at the feasibility stage in an efficient and effective manner.

Production of DSS Documentation

Finally help files including step-by-step instructions on how to use the program, sample project files and a user-friendly manual, were produced for ECCO to assist analysts in becoming familiar with the software. These extra resources detail the processes followed and assumptions made by ECCO.

Figure 1.2 presents a flow chart of the main phases of the research methodology outlined above.

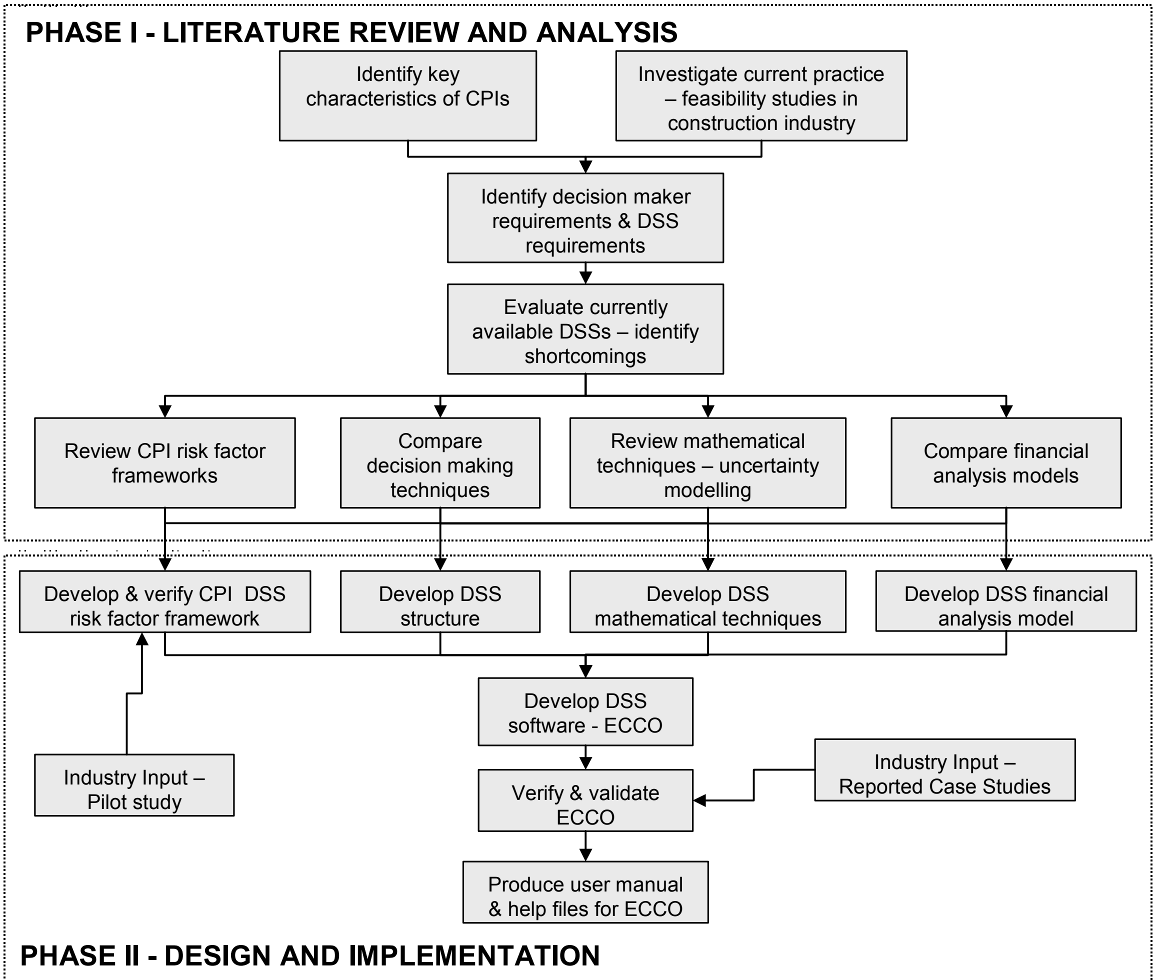


Figure 1.2 Methodology Flowchart

1.4 ORGANISATION OF THESIS

Following the introduction to the research project, in this chapter, Chapter 2 contains a review of the literature. This comprehensive review provides a foundation for my research, and gives an outline of the risks involved in CPIs, current practice investment appraisal and risk assessment in the construction industry and key requirements of a CPI DSS, as well as a critical comparison of currently available techniques, in the four areas of mathematical modelling, financial analysis, CPI risk factors and decision making, and the DSSs that implement them.

Chapter 3 presents the selection process of the most suitable mathematical modelling technique, financial analysis model, decision-making technique and RFF to be implemented collectively in the conceptual DSS. Both the mathematical modelling technique and decision-making technique were selected by numerical application, whereas the financial analysis model and RFF were developed and selected, respectively, based purely upon theoretical comparisons, as their application to the modelling of CPIs is well documented.

Chapter 4 describes in detail the DSS architectural design based upon the techniques selected in Chapter 3. This conceptual design of the DSS includes three modules: Module One - Model Definition Module, Module Two - Model Evaluation and Ranking Module, and Module Three - Sensitivity Analysis Module. Module One performs the function of creating individual CPI models, including the definition of financial factors, non-financial factors, and the interdependencies between non-financial factors. Module Two then analyses, compares and ranks individual projects according to their overall scores, whilst Module Three assesses the sensitivity of several projects to changes in non-financial or financial factors.

Chapter 5 focuses on the development and verification of the selected RFF and accompanying Risk Influence Matrix (RIM) via a pilot study involving industry interviews and a questionnaire. This chapter gives details of the pilot study objectives, development, implementation and application to the development of the generic CPI RFF for implementation in the DSS design.

Chapter 6 details the engineering of conceptual DSS as a computer software program, ECCO (Evaluate and Compare Concession Options), using the Visual C++ development environment. ECCO and its accompanying documentation were developed to ensure the system's time and resource efficiency.

In Chapter 7 the developed DSS is verified and validated using real-life CPI case studies of varying sizes, types and host country. Through this validation process the full capabilities and some minor limitations of ECCO are identified.

Finally, Chapter 8 outlines the three types of findings from the research, these being its conclusions, contributions and implications. This chapter also suggests a number of possible directions for future research. Additional relevant information and data are provided in the Appendices.

1.5 ACCOMPANYING CD-ROM

A CD-ROM containing the ECCO software, developed as part of the research, accompanies this thesis. A number of sample project data files are also included on the CD-ROM and a user manual is provided in Appendix E.

1.6 ORIGINAL CONTRIBUTIONS

The work presented in this thesis imparts the following original contributions to the field:

- Provides a critical review of existing techniques and systems available to the construction industry for the modelling of CPIs;
- Builds upon the eight aspects of a CPI that a DSS must cater for, as identified by Abdel-Aziz (2000), by proposing two additional aspects;
- Proposes a novel financial analysis model that best models the financial component of the CPI at the feasibility stage from the perspective of the construction industry;
- Proposes adaptations to the ANP technique to allow the DSS to more accurately reflect unique investment situations encountered on each individual project;
- Refines and extends Wang et al.'s (2002) RFF to develop a generic CPI RFF for the DSS; and

- Develops and implements an innovative DSS design as a computer software program using a unique combination of possibility theory, the ANP, a generic CPI RFF, and a novel financial analysis model, that is able to meet all 10 DSS requirements in an efficient and effective manner.

1.7 PUBLICATIONS RESULTING FROM RESEARCH

The following fully refereed publications have been produced as a result of the research presented in this thesis:

1.7.1 International Journal Publications

1. Mohamed, S. and McCowan, A.K. (2001), "Modelling project investment decisions under uncertainty using possibility theory." *International Journal of Project Management*, 19 (4), 231-241.
2. McCowan, A.K. and Mohamed, S. (2002), "A classification of decision support systems (DSSs) for the analysis and evaluation of concession project investments (CPIs)", *Journal of Financial Management of Property and Construction*, 7(2), 127-137.

1.7.2 International Conference Publications

1. McCowan, A. and Mohamed, S. (2002). "Modelling concession projects under uncertainty: a critical review." In *Proceedings of 1st International Conference on Construction in the 21st Century,* 25-26 April, Miami, USA, 79-86.

2. McCowan, A. and Mohamed, S. (2002). "Evaluation of Build-Operate-Transfer (BOT) Project Opportunities in developing countries." In *Proceedings of CIB W107*, 11-13 November, South Africa, 377-388.

3. McCowan, A. and Mohamed, S. (2003). "A comparison of risk analysis techniques in construction project management." In *Proceedings of 2nd International Conference on Innovation in Architecture, Engineering, and Construction*, 25-27 June, Loughborough, UK, 401-410.

4. McCowan, A. and Mohamed, S. (2004). "Evaluation and comparison of Concession Projects." Accepted for presentation at *CIB W107 Construction in Developing Economies,* 17-19 November, Bangkok, Thailand.

CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL REMARKS

As a starting point for the research project it was necessary to first identify the gaps in the literature in relation to evaluating and comparing CPI options. This involved a review of literature pertaining to:

- Concession projects including financing, contracts, risks, critical success factors and reported national/international case studies of successes and failures;
- Current practice of feasibility studies in the construction industry;
- Key requirements of an efficient and effective CPI DSS; and
- DSSs currently available to the industry that could be used for the evaluation and comparison of CPI options.

Secondly, once the gaps had been identified, it was necessary to critically review mathematical modelling techniques, CPI financial analysis models, Risk Factor Frameworks (RFFs) and decision-making methods, with the aim of identifying their respective advantages and limitations. This chapter presents a critical review of the literature resulting from the above investigations, which was then used as a basis for the selection of techniques for implementation in the DSS (see Chapter 4), and the conceptual DSS design detailed in Chapter 5.

2.2 RISKS IN CONCESSION PROJECT INVESTMENTS

Concession projects offer private sector participants great opportunities to expand market share and earn high returns on their investments. However, with these opportunities to earn greater returns, comes higher risk and uncertainty. Concession projects, much like large-scale international projects, involve complex financial arrangements and organisational structures, and can be significantly affected by country and market environments. In order for an appropriate risk response plan to be formulated, risk factors surrounding the project must be classified, identified and assessed. That is, risk factors must not only be identified, but their impact on the project must be quantified in some manner (i.e. assessed). This task is rendered even more difficult by the interdependencies that occur between risk factors, which can also significantly affect risk assessment results.

The process of classifying, identifying and assessing risk factors must form an important component of any CPI feasibility study. Recent research has focussed on the classification and identification of risk factors characteristic of CPIs and Critical Success Factors (CSFs) of these investments, however such research has not adequately addressed the assessment and quantification of risk factors (see Section 2.3.2). This section identifies, discusses and presents case studies of the effects of the more pertinent risk factors involved in CPIs.

2.2.1 Political Environment

The volatility of politics in a host country can often be the most significant risk factor in CPIs. Projects in developed and developing countries alike can be jeopardised by changes to government composition, new legislation and even civil wars and political coups. The following example of the termination of a concession contract due to changes in government composition was detailed in Walker and Smith (1995).

In 1985, the Canadian government decided to build a third terminal at the Toronto Airport. A concession type contract was chosen for this project. Due to the first Gulf War and global recession at the time of opening, passenger numbers were not as high as expected. Retailers and tenants at the airport were being charged at a higher rent and the per-passenger costs at this terminal rose to three times those at the other two terminals.

At the same time, a call was made by the Canadian transport minister to redevelop and expand terminals one and two, stating that airport capacity would soon be reached due to a passenger annual growth rate of 3%. The request for bids was put forth and the winning proposal was made by a firm whose main shareholder was a strong supporter of the Conservative Party ruling at the time. With only two weeks until the general elections, the contract was signed amidst great public and political opposition to the project. After elections, the new party in power reviewed the contract and claimed that, in the public's interest, it was terminated. This termination resulted in claims against the government by the promoters of US$23million for money already spent, plus an extra US$112million for forecast profits.

A similar event took place on an independent power project in India where a change in State Government (Maharastra), during the construction phase, led to the review and subsequent repudiation of the first phase and cancellation of the second phase of the project (Gupta and Sravat, 1998). Various petitions were filed in the High and Supreme courts which were overturned, forcing the promoter to initiate arbitration proceedings in London. The two parties finally entered into re-negotiations to revive the project, and the government cleared both phases for go ahead in 1996.

The above two examples demonstrate the extent to which the political environment of the host country of a project can affect its viability. However, federal or state elections are not the sole cause of political risk factors. In many countries today, local authorities are a law unto themselves and may uphold laws that contradict federal legislation. If these legislative differences are not detected at the feasibility stage, a project's profitability can be adversely affected by delays in construction approvals and even by project termination.

Walker and Smith (1995) suggest that promoters take four protection measures against political risks. Firstly, form an agreement with the host government to gain free reign over the project for a given time period. Regardless of such agreements, there is no guarantee that the government will not break the agreement amidst instability. Secondly, the consortium of investors should include various international firms. This will put pressure on the government, as expropriation of the facility will significantly lower the country's credit rating. Thirdly, insurance policies can be taken out through agencies such as the World Bank. The fourth protection measure is to involve the government financially in the project to cover against uninsurable risks.

2.2.2 Social Environment

The social environment surrounding a concession project can affect investment parameters such as material costs, labour costs, maintenance costs, overheads and revenues. A lack of local community support could result in significant delays or boycott of the project entirely (Levy, 1996). Yet, due to the international nature of concession projects, the promoter often has little knowledge of social conditions surrounding the project. Thus, the collection of information pertaining to the general public's perception of the project forms an integral part of a CPI feasibility study.

2.2.3 Source of Finance

A consortium of investing organizations, including Contractors, Investors, Lenders and Operators, is typically used to finance CPIs, as depicted by Figure 2.1. This provides contracting organisations with an opportunity to play a part in the consortium as an investor and/or a sponsor of the project. This new role assumes a higher degree of risk, but can also lead to greater returns than those from traditionally procured projects. Thus, the resurgence of concession projects has caused leading contracting organisations to diversify the range of services they provide, to form joint ventures between facilities management companies and large consultancy firms, and to form partnerships with funders.

Funding for a project must be obtained at an affordable price. The source of finance for a project will affect investment parameters, such as the working capital, fixed capital investment, the interest rate, insurance, tax and even overheads in the form of contract administration costs. In order to raise finances to fund a concession project, the promoter will consider a variety of financing options including: equity (e.g. common shares), mezzanine or quasi-equity financial instruments (e.g. preference shares, convertible preference shares, and redeemable preference shares, unsecured loan stock, convertible unsecured loan stock), and debt (e.g. commercial bank loans, publicly related bonds, export credit finance, debentures, multilateral agency loans) (Walker and Smith, 1995). Due to the high-risk nature of these projects, funding is usually limited or non-recourse, and high equity-debt ratio is favoured. However, according to Tiong (1990), the absence of a risk-taking capital market in developing countries limits project promoters to a low equity-debt ratio. This is contrasted to developed countries, in which high equity-debt ratios are commonly found.

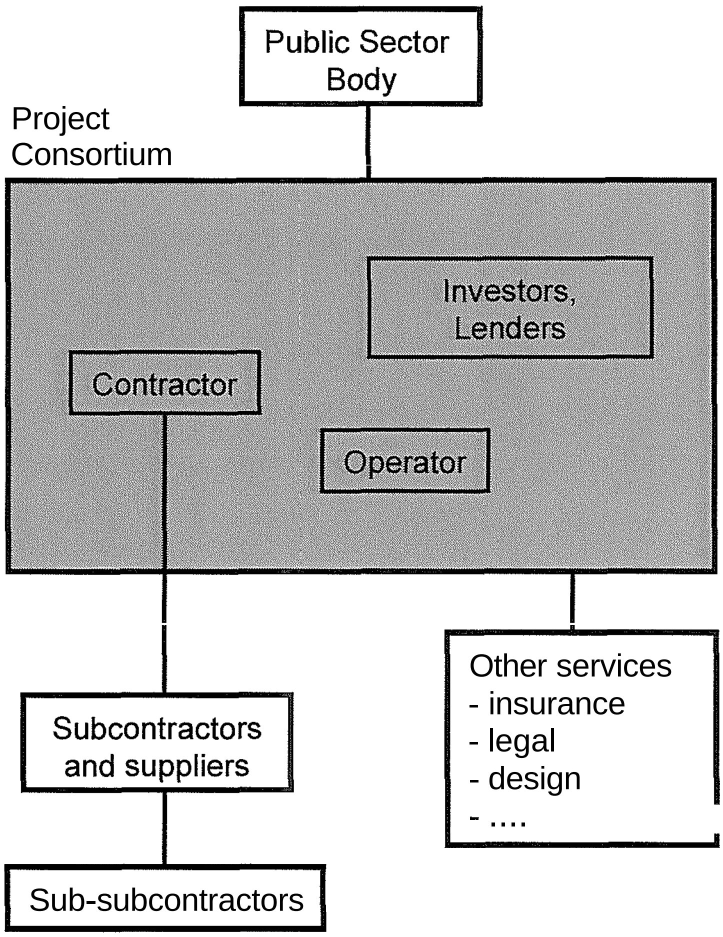


Figure 2.1 Potential Stakeholders in A Concession Scheme (Carmichael, 2000)

Financing structures for concession projects typically involves numerous source organisations, which can complicate administration practices. For example, consider the example of the Channel Tunnel project. This project originally involved 210 lending organisations alone with an overall finance debt-equity ratio of 80/20 (Smith, 1995). To allow for contingencies, the following financing structure was adopted.

Equity:

1. Banks and contractors: founder shareholders
2. Private institutions: 1st tranche
3. Public investors: 2nd tranche
4. Public investors: 3rd tranche
5. Public investors: 4th tranche

Debt:

1. Commercial Banks: main facility
2. Commercial Banks: standby facility

To raise the large amount of funds required, promoters must convince the lending organisations that the project is capable of generating profits and that repayments on loans will be made on time. For this purpose, guarantees of loans can be provided by the principal, the government or by multinational guarantee agencies. If the promoter fails to obtain a financial guarantee on loans, it automatically assumes the risk of the lenders taking over the project, due to an inability to make repayments on loans.

2.2.4 Organisational Arrangement

Expertise from a wide range of industries is required to construct, operate, maintain and finance the project. Thus the organisational structure of a concession project also comprises a large number of organisations. The various functions of the parties involved in a CPI include the principal, promoter, suppliers, lenders, investors, users, operators and constructors. Each of these parties may be composed of several companies forming a contractual agreement with at least one other party. On most concession projects an independent Project Company (project sponsor) is formed between these main parties, as shown in Figure *2.2.* The result is a highly complex organisational structure necessitating effective management.

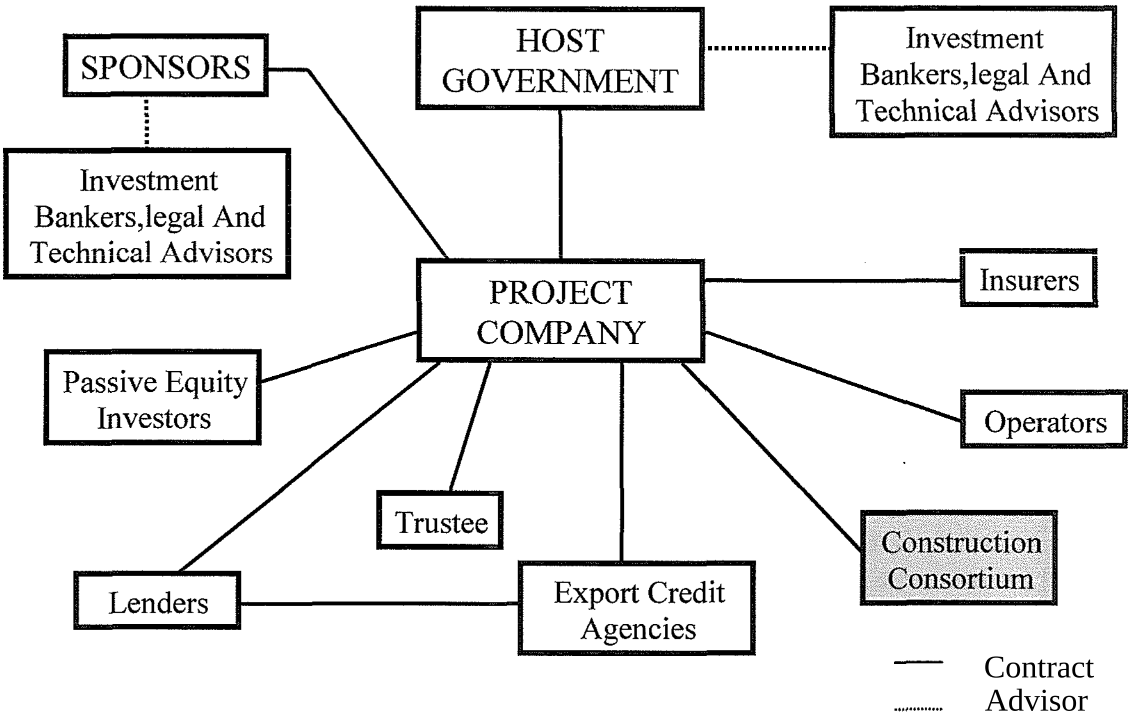


Figure 2.2 Typical BOT Project Contractual Arrangements (Walker & Smith, 1995)

According to Hickman (2000), the main contracts in a concession project follow three basic principles:

- The sponsor contracts the promoter (project company) to supply all services within the scope of the project (concession contract). The sponsor enters into a loan agreement (credit agreement) with external financiers. Financiers enter into a direct agreement (tripartite agreement) with the sponsor and promoter.

- The main contract between the project promoter and sponsor is called the concession agreement. A well-structured concession agreement will identify the risks involved and allocate them to the most relevant party to reduce their adverse affects on the project. Other principal contracts for these projects include: contracts governing the project company, collateral warranties, subcontracts with the design and build contractor and operating company, guarantees, direct agreements between banks and principal subcontractors, and agreements between subcontractors. It is important that these contracts are consistent with the three main contracts listed above and that risks are allocated to those most able to handle them.

- The administration of communications between parties must be such that no misinterpretation, misinformation or misunderstandings occur. Ideally, to minimise these problems, the main companies involved should be compatible in structure and policies. However, this is rarely the case and conflicts between and within organisations often arise, adversely affecting the project's profitability. Differences in management techniques and styles can cause conflict between companies, especially where specialist contractors are used who are unable to relate to other parties. Such conflicts could require mediation by an agreed panel. Also, due to the long-term nature of CPIs, the project teams or companies will often change, contractual arrangements must include mechanisms that manage the effects such changes.

The tripartite agreement between financiers, promoter and sponsor aims to protect concession holders from government default; governments from concession holder default; and financiers in the event of any default by regulating the termination and step in rights of government. The agreement typically provides for extended cure-periods, step-in rights for financiers and the suspension of termination rights while financiers are pursuing a cure.

2.2.5 Construction Delays and Cost Overruns

During the construction phase of a concession project, completion delays and unforeseen site conditions will almost inevitably occur. These risks are usually the responsibility of the promoter, who must provide completion guarantees and performance bonds to the principal. For example, the Sydney Harbour Tunnel Company paid a performance bond of A$23million that could be drawn upon in the case of a time overrun of 18months or more, or the failure to complete work. Effective planning by the promoter should include contingencies of time, monies or alternatives in order to allow for the following factors.

Design Changes

The possibility of such delays is particularly high in international concession projects, as it is difficult to fully assess the site conditions in terms of soil type, special, features of the site and time and space constraints prior to commencement of construction. The design and development is therefore based on incomplete knowledge and thus various assumptions must be made.

Each change in design that is required once construction has started, results in delays to the program of works and an increase in both the design and construction costs. If such changes cause a delay to the commissioning of the project, the interest paid on outstanding debts will rise, due to loss of revenues collected.

Climate

Poor climatic conditions can also cause delays to the program of works. Monsoons, drought, rain, snow, ice and even heat waves can reduce productivity on site. Thorough research into the local climate of the host country is required to assess the best time of year to start construction and what measures should be taken to minimise disruption due to poor weather conditions.

Material Supply

Difficulties with raw materials and equipment availabilities must also be overcome in certain projects located in remote areas. Contingencies for the transportation of materials and stand-by suppliers should be organised before work starts.

Productivity

Uncertainties pertaining to the productivity of the workforce and equipment used on site are particularly common in international projects. Productivity of the equipment depends on its age and efficiency; whether it was designed to perform the task it is used for and in said working conditions; whether it needs constant maintenance and repairs; and whether site access is sufficient. The most important factor is the ability and experience of its operator. The operator may not be familiar with the equipment and may require training, costing both time and money.

Technical Standards and Codes

Many concession projects are hosted by countries foreign to the promoting organisation. In such cases, the host country's technical standards and design codes applicable to the design and construction of the project may be difficult to acquire and understand. Where language differences exist, any translation of the codes may be inaccurate due to their technical nature.

Commissioning

If the finished work is not of a suitable quality then the commissioning will be delayed until it meets the required standards, costing the project lost revenue. This loss is incurred because the longer it takes to construct the facility, the less time there is out of the original concession period to operate the facility and actually generate revenue. Although commissioning delays can usually be avoided with careful planning and management, there still remains the uncertainty that there has been a misinterpretation of the users requirement and demands.

2.2.6 Operations and Maintenance (O&M)

At the commissioning stage, the cumulative cash flow has theoretically reached its lowest point. During the O&M phase, the project promoter must not only ensure that the facility generates sufficient revenue to pay off debts, cover O&M costs and make a reasonable profit, but must also comply to the relevant regulations, governance and service outcomes specified in the concession agreement. The capability of the promoter to do so heavily relies upon the processes adopted to maintain and operate the facility, the quality of the facility/equipment, training of operating personnel, and other market and revenue factors (see Section 2.2.7). It is integral to involve the operators at the design and commissioning stages to ensure that the facility can perform its required function and that all equipment have been correctly constructed and installed. If the promoter should default over the O&M phase, there is the risk that government parties and even financiers may exercise step-in rights.

2.2.7 Market and Revenue

During the O&M phase, the facility must generate sufficient revenue to pay off debts and make a reasonable profit. The quantity of revenue generated by the facility during the O&M phase can be affected by the following factors:

- Concession period;
- Productivity of equipment and personnel (as mentioned above);
- User charges;
- Foreign exchange rate fluctuations;
- Inflation;
- Tax;
- Concession payments;
- Recession;
- Relatively innovative market1 service/ product;
- Market demand change (quality, cost, function);
- Competitive facility;
- Social acceptance of the product1 service; and
- Availability of, or change in, price of materials/equipment.

Inflation and foreign exchange rates are the most prevalent risks that impact on the viability of an international concession project. The long-term nature of concession investments makes it difficult to predict changes in these economic factors. In order to protect the promoter from foreign exchange risks, the trend in developing countries is for the government to supply guarantees that loans will be paid in hard currency. The problem is not as common in developed countries because projects can usually be locally financed.

The host government may also choose to guarantee interest rates. One case where this was provided was a highway project in Malaysia where a guarantee to reimburse costs, due to an increase in interest rates of more than 20%, was made by the government (Tiong, 1990).

Tolls charged to users may be fixed or floating according to the concession contract. The principal usually sets the toll limits and the concession period. Tiong (1990) found that only in the Eurotunnel project, was the promoter given total freedom to set tariffs in his research of a total of six BOT projects.

Similar developments that compete for customers are also a concern for the project due to the long duration of the investment. The end-users have the right to use a less desirable facility, simply to save money. For example, three recent BOT tunnels in Hong Kong, the Tate's Cairn Tunnel, Country Park Section and the Western Harbour Crossing have all been suffering low traffic volumes owing to competition from alternative routes (Zhang and Kumaraswamy, 2001a). Thus, clauses are often included in the concession agreement for the principal to guarantee that sufficient revenue will be generated. For example, the Chinese government agreed to purchase a certain minimum amount of electricity, and to pay a fixed price per kilowatt-hour, from a power plant project in Shajiao. Tiong (1990) discovered this form of income guarantee was given by the government on three out of six BOT projects. Tiong also found that, in four cases, a concession from the government to toll-operate an existing facility was given to the promoter. In the case of the Dartford Bridge, the promoter actually bought the two existing crossing tunnels. The tolls generated from these tunnels were estimated to cover 40% of the total investment.

2.3 INVESTMENT APPRAISAL

Since large organisations are usually involved in several projects at a time that are all competing for valuable resources, a thorough evaluation of the feasibility of different project investments is critical to the selection, prioritisation and allocation of resources within the organisation. As part of this evaluation process, estimates of investment parameters are required for the calculation of cash flows and overall profit earning capability of the projects.

Although investment parameters differ from project to project, they may include: investment costs, labour costs, material costs, maintenance costs, taxes and insurance, quality costs, overheads, interest rates, period of investment and revenues. When estimating the values of such parameters for a prospective concession project, various risk factors will inevitably become apparent. These factors can totally distort predictions in an unknown way, making any decisions based on these predictions, highly suspect. Therefore, it is paramount for companies to be able to predict and compare all possible future financial outcomes, taking into account the inherent uncertainty associated with selected investment parameters, including construction, operation and maintenance costs, interest rates, inflation, depreciation, tax rate and operation life.

2.3.1 Uncertainty and Risk

Uncertainty can be defined as the chance occurrence of an event where the probability (chance) distribution is not known. The above definition of uncertainty only accounts for randomness, yet many times the type of uncertainty encountered in construction projects is epistemic (relating to the knowledge of things) rather than alearotic (depending on chance) (Williams, 1993). Thus, perhaps a better definition of uncertainty is that the outcome has a certain value, but it is yet unknown (Dong et al. 1987). The greatest degree of uncertainty about a project is encountered at the feasibility stage.

On the other hand, risk refers to the chance of a good/bad consequence, when probabilities can be attached to the outcome. Risks can be divided into three categories: known risks (e.g. variations in prices), known unknowns (either the probability of occurrence or likely effect is known), and unknown unknowns (e.g. force majeure) (Smith, 1999). Risks can be further divided into the categories of financial (quantitative) and non-financial (qualitative) risk factors (Smith, 1999). Ward and Chapman (2003) state that the term “risk” is incorrectly perceived as only a negative impact or things that might go wrong with the project, rather than both negative and positive (opportunity) impacts. Thus, they propose that a focus on uncertainty rather than risk management would enhance project management practises.

A number of authors agree with this, believing that uncertainty should be considered as separate from risk, whereas others believe that the terms are interchangeable and that the distinction between the two words is of little significance (Smith, 1999). In any case, formal risk analysis processes should take both risk and uncertainty into consideration. Edwards and Bowen (1998) define risk analysis as the systematic assessment of decision variables, which are subject to risk and uncertainty. They state that the risk analysis process comprises:

- The establishment of the chance of occurrence of good/bad events;
- The setting of assumptive bounds to associated uncertainties; and
- The measurement of the potential impact of risk event outcomes.

Unfortunately, it is evident that many construction companies prefer to concentrate on establishing the financial viability of a project through .feasibility studies, and that they fail to undertake any formal risk assessment process. Traditionally, Net Present Value (NPV), Internal-Rate-of-Return (IRR) and Payback Period investment appraisals have formed the major component of feasibility studies. These three (3) economic appraisal techniques are based on the time value of money formulae, Equation 2.1 and Equation 2.2.

$$P = \frac{F}{(1+i)^n}$$

Equation 2.1

$$P = \frac{A\left[(1+i)^n - 1\right]}{i(1+i)^n}$$

Equation 2.2

Where

P = Present Amount

F = Future Amount

A = Uniform Annual Amount

n = Number of Investment Periods

i = Interest Rate in Decimal Form.

The most commonly used of these techniques is the NPV, which discounts all future cash flow to its present day equivalent value using the minimum attractive rate of return (MARR) as the interest rate. The future cash flows can be either positive for cash inflow or negative for cash outflow. Once all future cash flows have been discounted, the sum of these amounts is called the NPV. That is:

$$NPV = \Sigma P$$

Equation 2.3

An NPV of zero (0) indicates a project that will break even, assuming all estimates are 100% correct. Similarly, a positive NPV represents a profitable project and a negative NPV represents an unprofitable project. Once the NPV has been calculated, the decision to proceed with the investment is subject to the company's acceptable profit level or "rate of return."

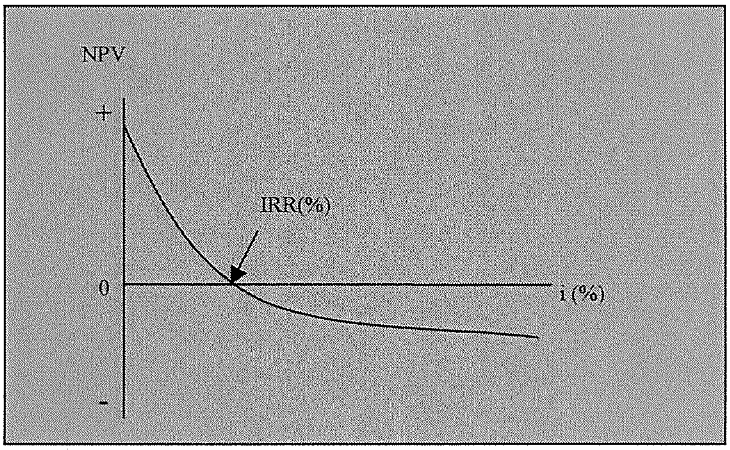


Figure 2.3 Diagrammatic Representation of the IRR Method

The IRR technique differs from the NPV in that it does not solve the time value of money formulas for the present day value, but rather for the interest rate that will cause the project to break even (see Figure 2.3). If this IRR is greater than the acceptable level of return for the company, considering all risks, then the investment is considered economically feasible. The Payback Period technique calculates the time in years for the project to reach the break-even point (see Figure 2.4). It is most useful in determining the project's liquidity or riskiness and is thus used in conjunction with either the NPV or IRR methods to calculate the project's profitability. The Payback Period would be of particular interest to investors in the project.

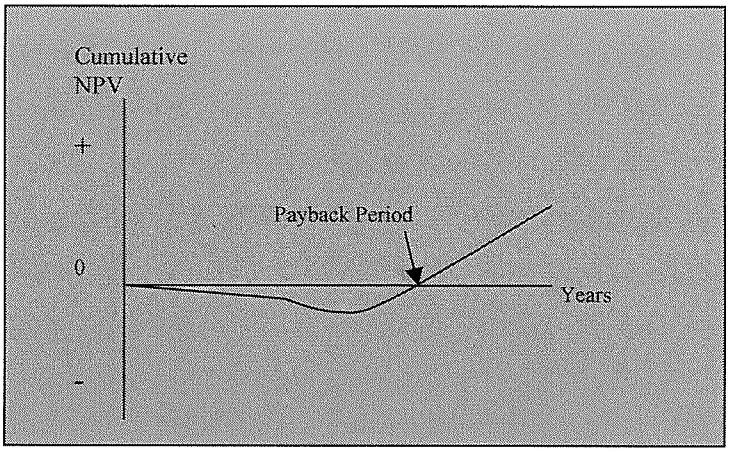


Figure 2.4 Diagrammatic Representation of the Payback Period

The reliability of the output from these appraisals depends upon the accuracy of the estimated, deterministic cash flow values (revenues and costs), their timing, and the discount rate used. In a perfect world, an analyst contemplating an economic decision would have access to precise deterministic values. Unfortunately, this ideal state does not exist when investing in a project where there is uncertainty about nearly every estimate that is entered into an economic model (Choobineh and Behrens, 1992). The value of each individual parameter is affected by a myriad of risks and uncertainties, which are often difficult to quantify, but could significantly impact on the outcome of the economic analysis. Uncertainty, emanating fi-om the project itself, or external factors, will always be present and needs to be accurately captured in the decision-making process (Dong and Shah, 1987).

In addition to the uncertainty inherent in estimates, the above techniques do not allow for the non-financial (qualitative) risk factors to be considered in assessing the investment option. Non-financial project aspects, such as social, environmental, political, legal and market share factors, are deemed to be important; but these would usually be considered to lie outside the normal appraisal process (Lopez and Flavell, 1998). Such aspects need careful analysis and understanding so that they can be managed (Tweedale, 1993). In extreme cases, neglect of these aspects can cause the failure of a project despite very favourable financial components (Toakley, 1997), or even the failure to go-ahead with a project that may have been of great non-financial benefit, due to its projected ordinary returns. For example, a dramatic change in government policy can substantially change project revenue to the extent that a once feasible project is rendered unprofitable. Therefore, it is recommended that the viability of a construction project should not be determined by monetary considerations alone. A proper feasibility study should also provide the organisation with the opportunity to include factors related to the economic environment (boom or recession), project complexity, technical innovation, market share, competition, national significance and other strategic aspects. To provide for the effects of these qualitative aspects, the majority of organisations resort to estimating the necessary money contingencies without an appropriate quantification of the combined effects of financial and non-financial (risks and opportunities) factors.

The success of a contracting company relies heavily upon its ability to select those project investment options of most benefit in both the short and long term. Whether these benefits are purely financial or a combination of financial and non-financial gains, investment options must be compared as objectively as possible. For this reason, CPI feasibility studies should incorporate risk analysis techniques in conjunction with traditional economic analysis.

It is equally important that feasibility studies are conducted in a time and resource efficient manner. Contractors have been known to commit considerable financial and human resources towards performing project appraisals and tendering for large infrastructure projects. For example, the EuroTunnel project promoters spent approximately $1 million US dollars on a feasibility study before the tender was even won (Smith, 1995). In fact, a survey by Akintoye and Dick (1996) found that 86% of UK contractors rated the risk of losing bidding costs as a major problem of privately financed projects. Again, in a more recent survey by Akintoye et al. (2003), high bidding costs were identified as a barrier to achieving best value in these projects. Also, leading construction companies have quoted the risk of losing tendering costs as the reason for pulling out of bids for certain types of Design-Build-Finance-Operate (DBFO) projects (Owen and Merna, 1997). Thus, it is important that contractors adopt the most efficient economic and risk analysis techniques available for the appraisal of CPIs.

2.3.2 Risk Assessment in Construction - Current Practice

There are a myriad of risk analysis tools and techniques available to the construction industry for the appraisal of CPI opportunities, ranging from simple scoring or weighted sum methods to more sophisticated techniques, such as probabilistic simulation. Although available techniques have been useful to practitioners and researchers alike, they have not offered a satisfactory solution to the risk analysis problem as a whole. This is evidenced by results from surveys conducted in a range of countries such as the US, the UK and Australia.

A survey (Yates and Sashegyi, 2001) of major Western Australian construction companies conducted in July 2001 revealed that 36% of respondents did not undertake formal risk assessment processes before awarding or tendering for a contract; 56% believed that risks were not allocated to the most able party; and 70% expected claims as a result of changes to risk allocation by parties to the contract.

Also in 1996, the New South Wales (NSW) Auditor-General conducted an audit of a number of concession projects and concluded that, although this form of procurement should result in savings of up to 20%, private sector's profits have often been based upon public losses (Halligan, 1997). It was postulated by the NSW Auditor-General that the failure of concession projects might be due to a lack of government experience in negotiating contracts leading to inefficient and ineffective risk allocation practices. Risks taken by the private sector should be proportional to the potential for future reward. If this is not the case, it is reasonable that companies will factor a risk premium into their bid price. It seems that the private sector's inability to identify and determine the cost of risks at the tendering stage has been a major contributing factor to the underperformance of concession projects in Australia.

It seems that US construction companies have similar difficulties in assessing risks when it comes to investing in higher risk, international projects. Even though the globalisation of the construction industry has created greater opportunities for companies to expand their market share abroad and earn higher returns, according to Engineering News Record (ENR, 1995-1998), only 19% of the top 400 US contractors seek and carry out international projects. Also, almost 15% of companies among the top 225 global contractors have sustained losses on their international projects (Han and Diekmann, 2001), despite the fact that international projects are generally more profitable than domestic projects. These statistics indicate a predominantly risk averse attitude in US contractors, and an inability to identify, assess, allocate and control risks on more complex projects such as international projects. Surely, an inability to effectively assess political, economic, cultural and legal conditions surrounding a project has significantly affected the US construction industry's willingness to invest in higher risk projects.

In the UK, the two primary requirements of a PFI project are: 1) Value For Money (VFM) for the private sector; and 2) Appropriate transfer of risk to private sector. According to Hornagold (1995), a VFM comparison can be made after all qualitative and quantitative assessments and adjustments have been made for risks involved and a risk transfer assessment completed. However, risk allocation has been a major source of problems, with the private sector feeling that they have been expected to shoulder too much risk (Owen and Merna, 1997).

This view is supported by results from two surveys of public and private organizations in the UK construction industry. A survey by Owen (1998) identified the critical success factor (CSF), "To ensure that adequate and accurate risk assessment is achieved with the responsibility of managing the said risks apportioned to the party most able to control them", as the only CSF to obtain a 100% agreement from participants (Owen, 1998).

The following personal comments on risks associated with PFI schemes were gathered from client, lender and contractor groups as part of a survey by Akintoye et al. (1998):

- Clients - "Risks associated with usage are very difficult to price" and again, "Risks must be apportioned to those best able to handle them";
- Lenders – "The government is putting too much risk transfer to the private sector"; and
- Contractors – "The biggest problem is in quantifying the value of risks."

According to a survey by Akintoye and Macleod (1997), techniques of risk analysis used in the UK construction industry include risk premium, risk adjustment discount rate, subjective probability, decision tree analysis, sensitivity analysis, Monte Carlo simulation and intuition. However, respondents said they seldom used Monte Carlo techniques due to the absence of good quality data from which probability calculations can be performed. A more recent investigation by Akintoye et al. (2003) identified inconsistent risk assessment and management across the different organisations in a consortium and less open communication with the client in regard to the pricing of risks as problems faced by the private sector in the UK. One interviewee even stated, "I would like to see a reliable standard on how to deal with risk, because we have to invent our own criteria all the time. This is time consuming and very costly in terms of professional fees."

A large number of international CPIs have experienced similar difficulties in quantifying and allocating the high degree of risk in China (Kurnaraswamy and Morris, 2002; Wang et al, 2000), Turkey (Ozdoganm and Birgonul, 2000), and India (Thomas et al., 2003; Gupta and Sravat, 1998).

These survey results support the premise that the construction industry currently lacks a decision support system (DSS) which is capable of effectively and efficiently evaluating CPI options, taking into consideration both financial and non-financial factors such as risks and opportunities.

2.4 BENEFITS OF A CPI DSS

The construction industry can only stand to benefit from the development of a comprehensive DSS. Whilst it is acknowledged that governments, lenders and investors (including promoters) all have different perspectives of the risks associated with CPI projects, the industry would definitely gain from employing a DSS that could deliver benefits such as:

- A set of economic performance measures that not only includes measures used by the construction industry, but also includes measures commonly used by financial institutions and governments to evaluate projects that could assist in negotiations with these parties;

- A streamlined project rating system, which takes into account the combined effect of finances, risk and uncertainty on the overall project attractiveness;
- Time and resource efficiencies due to the streamlined approach;
- Increased confidence that predictions are realistic;
- The facilitation of a Go/No-go decision through quantitative results;
- The clear identification of project risk factors that may have otherwise been overlooked;
- The identification of critical risk factors for input into the project's risk management plan via sensitivity analysis; and
- Analysis output values can be used in contractual negotiations between various project parties.

The four fundamental principles that facilitate best value in the UK's PFI approach are accountability, transparency, continuous improvement and ownership (DETR, 1999). A DSS would enable accountability and transparency between parties (government and financiers, lenders, investors) by providing a streamlined approach to the decision problem. This would create greater understanding between the parties, and aid in achieving a lower cost outcome, hence saving precious time and resources. It would also limit lengthy negotiations and reduce the likelihood of inconsistent risk assessment and lengthy negotiations, which are major barriers to CPIs for the private sector (Akintoye et al., 2003).

2.5 REQUIREMENTS OF A CPI DSS

To develop a DSS capable of realising the above-mentioned benefits, it was first necessary to clearly define the requirements of such a DSS. According to Abdel-Aziz (2000), a DSS should be capable of modelling the following eight generalised aspects of CPIs:

1. Various industries and evaluation methods;
2. Multiple project phases/sub-phases;
3. Cash flow characteristics;

4. Time dependent project variables;
5. Varied economic performance measures (e.g. Benefit-Cost Ratio, NPV, IRR);
6. Uncertainty;
7. Comparison of project alternatives/scenarios (incl. Sensitivity Analysis); and
8. Both detailed and generalised aspects of projects.

While the above list ensures that the DSS caters for the financial and organisational complexity of CPIs, and even the varying degree of certainty surrounding input values, it has become evident to the author, through extensive literature review, that there are two additional aspects that should be provided for by the optimum DSS. These are:

9. Important non-financial (risk and opportunity) factors; and
10. Interdependency of factors (both financial and non-financial).

Risk factors are numerous and interdependent in a real life CPI situation, rendering the task of developing a risk analysis model too complex for the human mind alone. According to Pouliquen (1970), isolating the individual uncertainties is preferable to limiting the disaggregation of variables, when solving the problem of dependencies between risk variables. This view is supported by Wang *et* al. (2002), who suggested that it is usually the unidentified risks that are most disastrous and catastrophic to a project. Unfortunately, we humans are limited in our ability to encompass and process the full range of information required for a holistic decision (Pender, 2001).

In fact, Han and Diekmann (2001b) conducted an experimental case study of go/no-go investment decisions on international construction projects. They concluded that the complexity of uncertain information and several biases influenced the decisions of both novice and industry participants when using intuition alone, and seemed to even confound them. Thus, it is imperative that a DSS assists the decision maker in forming a clear and realistic representation of the investment situation through the identification of individual non-financial factors and the significant interdependency of factors.

These latter requirements differ from requirement six in that requirement six takes into account the uncertainty surrounding the value of each and every financial and non-financial factor, whilst requirements nine and ten cater for the identification of actual non-financial factors (e.g. risk of changes in law) affecting the project and how they interact.

Several DSSs have been developed by others based upon various mathematical modelling techniques, financial analysis models, decision-making techniques and RFFs. However, as will be shown in the following sections, each DSS reviewed was limited in its ability to meet the above requirements. A DSS must be effective in modelling all ten aspects of a CPI, yet also be efficient in doing so. With this in mind, it is imperative that: (1) the mathematical modelling technique and financial analysis model employed by the DSS captures the true degree of certainty surrounding the project; and (2) the decision making technique and risk factor framework (RFF) used to structure the DSS most closely reproduces the complexity of CPI decisions. Sections 2.6 through to 2.9 discuss mathematical modelling techniques, financial analysis models, decision-making techniques and RFFs, respectively.

2.6 MATHEMATICAL MODELLING TECHNIQUES

According to Triantaphyllou (2000), most experts preach that the single most important step in solving any decision-making problem is to first correctly define the problem. Thus, it is important to use a mathematical modelling technique that will effectively reflect the true degree of uncertainty surrounding the input values into the CPI model, while not demanding an unreasonable amount of effort in data gathering.

There is three options when it comes to the mathematical modelling of financial input values: deterministic values, probability distributions or possibility distributions. Deterministic values should only be used when a value is 100% certain. For example, when the revenue generated by a toll road in the first year of operation is known to be exactly equal to $200,000. However, since the exact values of input data are highly uncertain at a project's feasibility stage, it would be inappropriate to use deterministic values to define input values in the DSS.

In the construction industry today, probability theory is the most widely accepted technique for modelling risk and uncertainty associated with estimates (Pender, 2001, Raz and Michael, 2001). One of the troublesome issues associated with probability theory is the utilisation of a probability measure to evaluate uncertainty (Akintoye et al., 1998). Much effort is needed in defining and developing each contributing input value's probability distribution using historical data in estimating relative frequencies (see Figure 2.5). Since each CPI is affected by different factors to varying degrees, accurate knowledge of relative frequencies cannot simply be assumed from another project, as would be possible in other industries, such as manufacturing, where events have a repetitive nature.

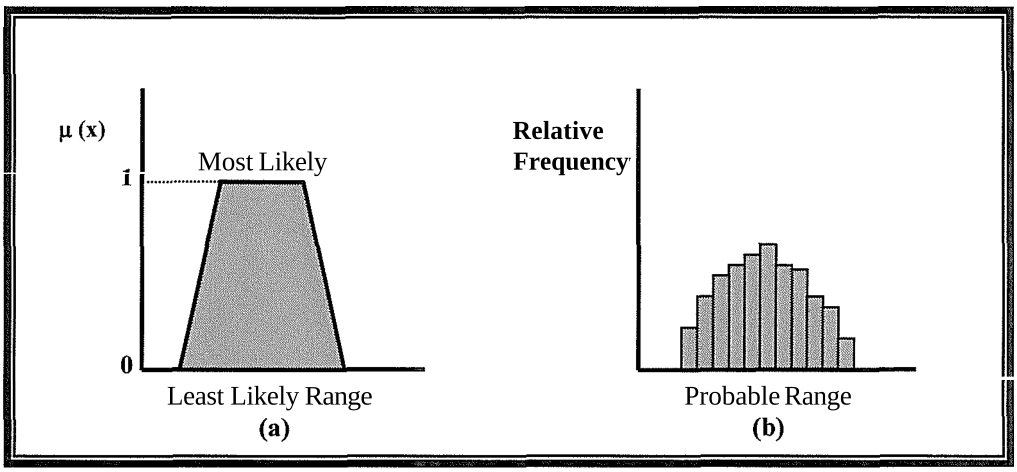


Figure 2.5 a) Possibility Distribution b) Probability Distribution

Most analysts take it for granted that uncertainty is a model associated with randomness (Behrens and Choobineh, 1989). According to Choobineh and Behrens (1992), while probability theory can be a powerful tool in the appropriate circumstances, many times the type of uncertainty encountered in construction projects does not fit the axiomatic basis of probability theory. They argue that uncertainty in these projects is usually caused by the inherent fuzziness of the parameter estimate, rather than randomness. Uncertainty involved in real risk situations is often epistemic (relating to the knowledge of things) rather than alearotic (depending on chance) (Williams, 1993). The use, advantages and disadvantages of probability for the purpose of investment appraisal are well documented (Gregory, 1988). Another limitation of using probability theory is that the influence of non-financial factors on concession project investments is often difficult to quantify. The lack of know-how in measuring strategic and intangible costs and benefits has resulted in current DSSs ignoring the contribution of these qualitative aspects to the overall economic analysis.

One way to alleviate the above shortcomings is to use the possibility theory, where the user needs only to determine a possible range, and perhaps even a most likely range, for each investment parameter, without the input of each factor's relative frequency. The possibility theory is an appropriate vehicle as it is based on the concept that all values within a certain range are possible, with the exact value being unknown. A range of values, or an interval, is assigned subjectively, but the individual values in the interval are not assigned a relative belief value. For example, in Figure 2.5, the trapezoidal possibility distribution can easily be defined using the linguistic variables, "most likely between" and "least likely between". Any value outside the least likely range has a possibility or a membership value ($\mu(x)$) of zero, that is, it is impossible for it to occur. Any value within the least likely range but outside of the most likely range has a membership value ranging somewhere between zero and one, and any value within the most likely range, has a membership value of one. Using possibility theory, values can be represented as crisp values, intervals, triangular, trapezoidal, or more rounded S, Z or bell-shaped distributions. For example, a triangular distribution is used to represent the price of a car in Figure 2.6 the price of the car will most likely be $10,000 but could be anywhere between $8,000 and $11,000.

In most cases, an expert may feel that a given parameter is within a certain range and may even have an intuitive 'feel' for the 'best' value within that range. However, seldom will the analyst have an empirical foundation for the estimate based on frequency of occurrence (Choobineh and Behrens, 1992). Mak (1995) argues that normative theories in probability are not as applicable in the construction industry as some may perceive, and considers possibility theory to be superior to probability theory in analysing problems where subjective judgements dominate the risk analysis process. This viewpoint is shared and supported also by others (Andersson, 1988).

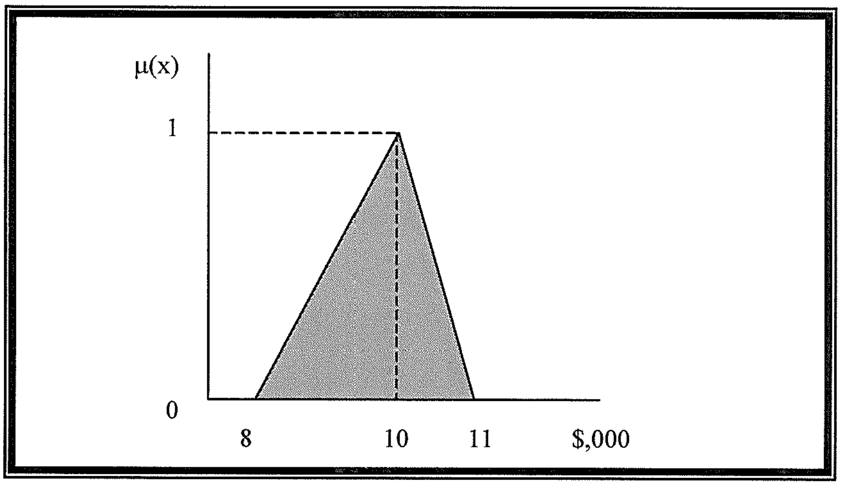


Figure 2.6 Triangular Possibility Distribution of Car Price

Wirba et al. (1996) also propose that possibility (fuzzy) theory is more efficient than conventional probability theory, reducing the number of steps involved in risk analysis from six to four as shown in Figure 2.7.

The possibility theory has been used successfully in a wide range of construction engineering fields, including: project resource scheduling and network analysis (Kutcha, 2001, Lorterapong and Moselhi, 1996; Zhang and Tam, 2003), financial analysis (Boussabaine and Elhag, 1999; Kumar et al., 2000; Lam and Runeson, 1999) contract selection and decision-making (Ng et al., 2002; Wong and So, 1995; Wang et al, 1996) and safety performance (Tam and Fung, 1996; Tam, et al. 2002).

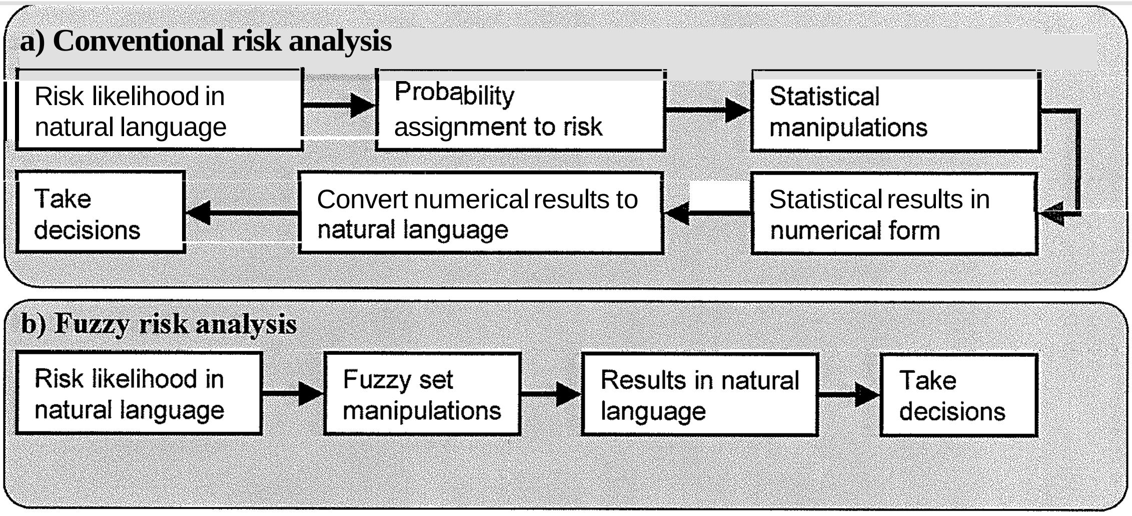


Figure 2.7 (a) Conventional and (b) Fuzzy Risk Analysis Process (Wirba et al., 1996)

2.7 CPI FINANCIAL ANALYSIS MODELS

A decision support system for the evaluation of a concession project investment must ultimately conduct an analysis of a project's financial viability. Each party to a project (i.e. government, lender, investor) evaluates the investment based upon different performance measures that are specific to their particular industry. According to Abdel-Aziz (2000), a DSS must cater for all industries, evaluation methods and performance measures, and also capture the complex financing structures, time dependent variables, and cash flow characteristics of multiple-phased concession projects to a level of detail that reflects the true degree of knowledge at the feasibility stage (See Requirements 1, 2, 3, 4, 5 and 8 in Section 2.5). It would be impossible to assess every available financial analysis model, thus the following discussion is limited to those models found in literature that were developed specifically for the evaluation of CPIs.

2.7.1 INFRISK Financial Model

Dailami et al. (1999) developed INFRISK, which is a computer based risk management approach to infrastructure project finance transactions that involve the private sector. According to Dailami et al. (1999), equity holders focus solely on the IRR, NPV and dividends of the project; creditors look to the loan payment capacity in terms of the Interest and Debt Service Coverage Ratios (DSCR); while Governments focus on the Social Welfare Function of the project. Thus, INFRISK caters for the calculation of these performance measures of a CPI investment via Equation 2.4 through to Equation 2.8.

$$NPV = \sum_{i=1}^{c} (-1) \frac{ESi + LSi + BSi}{(1+r)^{i}} + \sum_{i=1}^{0} \frac{NCFi}{(1+r)^{i+c}}$$

Equation 2.4

where:

r = Specified annual discount rate

c = Construction period (yrs)

o = Operating period (yrs)

ES_i = Equity allocation during i^{th} construction period

LS_i = Loan allocation during i^{th} construction period

BS_i = Bond allocation during i^{th} construction period

NCF_i = Net cash flow associated with project in i^{th} operating period

NCF = TOR – TOE – TAX + DEP (Depreciation)

TOR = Total Operating Revenue

TOE = Total Operating Expenses

$$\text{Interest Coverage} = \frac{\text{Earnings Before Interest and Taxes}}{\text{Interest Payment}}$$

Equation 2.5

$$DSCR = \frac{\text{Earnings Before Interest, Taxes, and Depreciation}}{\text{Interest} + \dfrac{\text{Principal Repayment}}{(I - \text{Tax Rate})}}$$

Equation 2.6

IRR = The closest rate to the discount rate at which *NPV = 0*. (However, the cash flows in *IRR* calculations use negative equity, and positive dividends.)

Equation 2.7

$$W = \lambda I - (1 + \lambda)(t)$$

Equation 2.8

where:

W = Social welfare function

$0 \leq \lambda < 1$ = Measure of welfare-loss from distortionary taxation

I = Project's investment size

t = Present value of net transfer of resources from government to private sector.

INFRISK's financial analysis model caters for cash flows to be entered in two currency units: local and US dollars. It allows for several different debt capital sources (loan, bond or letter of credit) and terms (amount, currency, maturity, repayment plan, disbursement plan, interest rate), as well as equity allocation schedules to be specified by the user. Construction costs, revenues and operations costs are entered as annual cash flows. INFRISK then calculates the above-mentioned performance measures for each year of the project, and checks that each measure does not fall below a predefined acceptable level.

2.7.2 BOT Financial Model (Bakatjan et al., 2003)

A similar financial model was developed by Bakatjan et al. (2003), as part of an attempt to determine the optimum equity level at the evaluation stage (immediately after the feasibility study) of a hydroelectric BOT power project in Turkey. This financial model adopts several assumptions, the more significant of which are:

- All loans are with the same term of equal instalments;
- Upfront and commitment fees are included in the committed loan amount;
- The grace period for the loan is equal to the construction duration as CPIs are usually non- or limited-recourse financed;
- There are no value added taxes, corporate, or income taxes, only withholding tax (most common to international lending); and

- There is complete depreciation of Total Project Cost (TPC) during operation period.

Bakatjan et al. (2003) calculate the project's NPV from the perspective of the equity holder according to Equation 2.9:

$$NPV = -\sum_{j=1}^{c} \frac{Ej}{(1+d)^{j-1}} + \sum_{i=1}^{m} \frac{NCAi}{(1+d)^{i+c}}$$

Equation 2.9

where:

E_i = Equity drawing in i^{th} year of construction

c = construction period

E = e (equity fraction) * TPC

$TPC = BC$ (Base Cost) + EDC (Escalation During Construction) + IDC (Interest During Construction)

d = discount rate

m = concession period

NCA_i = Net Cash Available in the i^{th} year of operation

= $PBIT_i$ (Profit Before Interest and Tax) – TAX_i + DEP_i (Depreciation) – D_i (annual Debt Instalment) in the i^{th} year of operation

Looking at Equation 2.9 it was evident that no costs or revenues were discounted for the end of the final year of construction. That is, the first part of the formula assumes cash flows occur at the start of the year, whereas the second part of the formula assumes cash flows take place at the end of the year. Thus, the equation sums cash flows up until the start of year c (or end of year c-1), and the second part sums cash flows starting from the end of year c+1, effectively skipping the end of year c. Upon confirmation from an accounting and finance expert, the formula was adjusted as per Equation 2.10.

$$NPV = -\sum_{j=l}^{c} \frac{Ej}{(1+d)^{j}} + \sum_{i=1}^{m} \frac{NCAi}{(1+d)^{i+c}}$$

Equation 2.10

The Debt Service Coverage Ratio (DSCR) is then calculated from the perspective of lenders according to Equation 2.11:

$$DSCR = \frac{PBIT_i + DEPi - TAX_i}{D_i}$$

Equation 2.11

2.7.3 Other CPI Financial Models

Abdel-Aziz (2000) developed a generalised economic model as part of an overall decision support system that is discussed further in Section 2.9.1. The economic model of the DSS consists of four main components: financing, revenue, capital expenditure and operations and maintenance. Each of these components is defined using a different set of properties and methods. For example, capital expenditures are connected to individual work packages and can be represented using a variety of functions (aggregated, semi-detailed and detailed), which allow the expenditure to change over time, in accordance with changes in other properties of the work package. Thus, similar to Microsoft Project software, the model links cash flows to individual project network activities. The performance measures calculated by the model include:

- Life Cycle Cost (LCC);
- Benefit Cost Ratio (B/C);
- NPV;
- IRR;
- Loan-Life Coverage Ratio (LLCR);
- Debt Service Coverage Ratio (DSCR); and
- Construction Completion Time.

Chang and Chen (2001) also developed a financial model for a BOT high-speed rail project in Taiwan. The model evaluates the payback period from the three perspectives of overall cash flows (promoter), equity (stockholders) and dividends (stockholders). It also calculates the DSCR from the perspective of lenders.

The popularity of real options analysis or option pricing technique, as a means of accounting for uncertainty, has grown considerably over the last five years in the construction industry. Ho (2001) recently developed a real options based model for the financial evaluation of BOT projects. This analysis technique values the option to defer, expand, contract or abandon an asset (project). Also known as the "Strategic NPV", real options analysis calculates all possible changes to the project's NPV through out its life cycle due to risk and uncertainty associated with its stock value. Thus, the base financial analysis technique of Ho's (2001) real options model is the NPV. The effectiveness of the real options as an overall DSS decision-making framework is discussed further in Section 2.9.2.

2.7.4 Comparison of CPI Financial Analysis Models

It is important that the financial analysis model of the DSS caters for all participants to a CPI, including equity holders, creditors and government. A comparison summary of the various performance measures employed by the financial analysis models discussed above is presented as Table 2.1.

All models use the NPV technique as the main method to evaluate a CPI's financial viability from the perspective of equity holders (including the promoter), with the exception of Chang and Chen's (2001) model. The NPV model developed by Bakatjan et al. (2003) closely reflects the degree of detail in input definition of financial parameters available to analysts at the feasibility stage. Both the INFRISK and Abdel-Aziz NPV models would be more appropriate for the contract negotiations phase, once a project's feasibility has been established. The INFRISK model requires too great an amount of detail in defining individual sets of terms and properties of debt and equity financing terms, and taxes, while Abdel-Aziz' economic model links cash flows to individual project network activities.

Chang and Chen (2001) adopt the payback period from three different perspectives in order to assess a project's viability from the perspective of lenders, equity holders and promoter.

The payback period is not a measure of a project's profitability but of its liquidity or riskiness. It indicates how long an investment can be recovered. Unfortunately, the payback period has been found to be limited in its practical application as it ignores the time value of money and all cash flows that occur after the payback period. Also, there is little theoretical base for the acceptable payback period set by a company (Taylor and Wamuziri, 2002). Thus it can give misleading results when used in isolation from other financial analysis techniques.

Both the INFRISK and financial analysis model, developed by Abdel-Aziz (2000), also calculate the Internal Rate of Return (IRR) of the investment from the perspective of equity holders. However, the IRR has been criticised as a financial analysis technique because it assumes that cash flows are reinvested at the IRR, rather than at the true cost of capital (DeGarmo et al., 1993). Therefore the IRR will not be used in isolation for the DSS design.

The most widely used performance measure for the evaluation of a project's financial viability, from the perspective of creditors, is the Debt Service Coverage Ratio (DSCR). This measure was calculated as part of all financial analysis models discussed above, with the exception of the real options analysis model developed by Ho (2001).

Only two of the models reviewed cater for the evaluation of a project from the government's perspective. INFRISK adopts a government willingness equation, which requires the estimation of the parameter λ, a measure of welfare-loss from distortionary taxation. Abdel Aziz's (2000) model calculates a Benefit/Cost (B/C) Ratio. Historically, the B/C ratio has been widely used to assess large-scale public projects and has also been used by the private sector (Degarmo et al., 1993) since most infrastructure projects traditionally procured by public sector, have multiple benefits, which cannot be measured in financial terms. The B/C ratio is the ratio of the equivalent worth of benefits to the equivalent worth of costs in present worth values. The B/C Ratio was selected for implementation in the developed DSS.

Table 2.1 Comparison of CPI Financial Analysis Model Performance Measures

MODEL	PERFORMANCE MEASURES		
	Equity Holder	**Creditors**	**Government**
INFRISK	NPV IRR Dividends	Interest Coverage Ratio DSCR	Social Welfare Function
Bakatjan et al. (2003)	NPV	DSCR	
Abdel-Aziz (2000)	NPV Life Cycle Cost IRR Const. completion	Loan-Life Coverage Ratio DSCR	Benefit/Cost Ratio (B/C)
Chang and Chen (2001)	Payback period	DSCR	
Ho (2001)	NPV		

2.8 DECISION MAKING TECHNIQUES

A DSS must be able to incorporate both financial and non-financial aspects of a CPI. Financial analysis models and mathematical modelling techniques have been critically compared as to their ability to model the financial aspects of a CPI. It is now necessary to select a decision-making technique that can be used to model the non-financial (risk and opportunity) factors that will identify important non-financial factors and their interdependencies (see DSS requirements 9 and 10 in Section 2.5).

There are a myriad of decision-making techniques available that have been fully developed into DSSs. Due to the large number of DSSs available, the following sections will focus only on those considered to be most suitable for the specific task of evaluating and comparing CPI options. Some of these DSSs may have already been used specifically for the evaluation of CPI options, whilst others may not.

2.9 CURRENTLY AVAILABLE DSSs

As presented in Figure 2.8, the DSSs can be divided into three main categories according to the decision-making technique used. The aim of this section is to highlight the advantages and the shortcomings of these systems, rather than to provide a detailed description of their respective methodologies. Table 2.2, at the end of this section, presents a summary of the advantages and limitations of each system in regard to its practical application to the evaluation and comparison of CPI options.

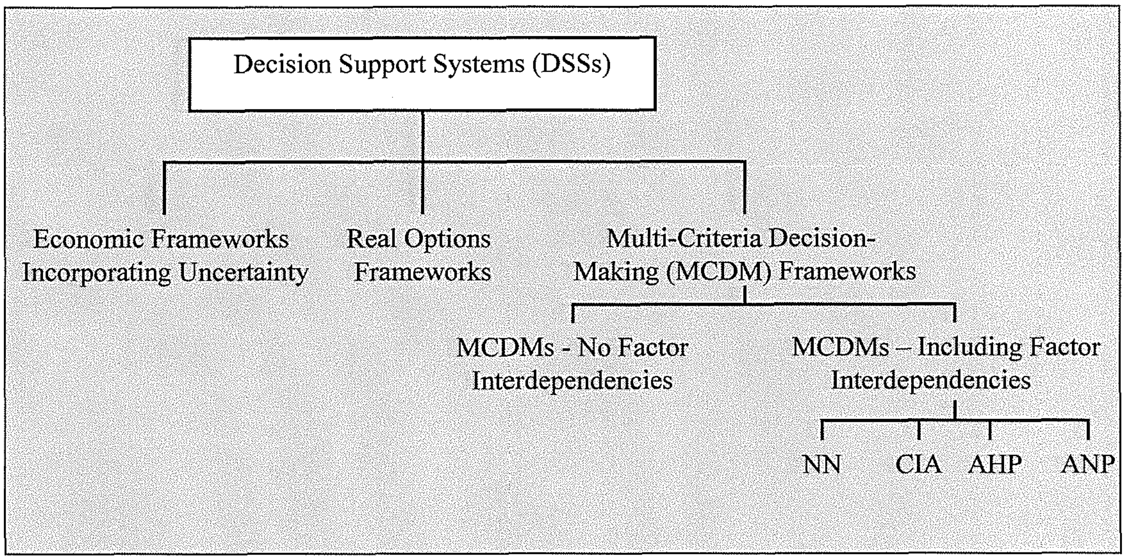


Figure 2.8 A Classification of Available DSSs for the Analysis of CPIs

2.9.1 Economic Framework Incorporating Uncertainty

DSSs, such as UNIDO's COMFAR III, CASPAR (Merna and von Storch, 2000), NPV-At-Risk (Ye and Tiong, 2000), @RISK, Value At Risk (Dowd, 1998), the World Bank's INFRISK (Dailami et al., 1999), and the Four Moment Framework (Abdel-Aziz, 2000), are all fully developed computer software packages that perform both probability and sensitivity analyses on economic parameters in order to predict an expected envelope of values for selected economic performance measures of projects.

The advantage of the above DSSs is that the results are quantitative in the form of an expected envelope of values for selected economic performance measures, thus facilitating a definite go/no-go decision. Although only the latter two systems were developed specifically for the analysis of privately financed infrastructure projects, all can be adapted to perform this function. These systems facilitate a definite go/no-go decision through their quantitative results, yet are limited in one or more of the following ways:

- There is no allowance for interdependency of risk factors;

- Individual non-financial factors causing uncertainty distributions in forecasts are not formally identified;
- A high level input definition is required (probability distribution parameters); and
- The complexity of calculations that renders the system prone to crashing when simulating realistic investment situations.

COMFAR 111

The third generation program, COMFAR III (Computer Model for Feasibility Analysis and Reporting), was released by the United Nations Industrial Development Organisation (UNIDO) in 1995, twelve years after the project was first released. COMFAR III provides financial/economic statements and calculations of economic performance measures for investment projects.

Indeed COMFAR III have extensive financial modelling capabilities, providing for up to twenty different currencies, several sources of funding (eg. loans, equity), and separating costs into two phases, construction and production. The program also includes a Sensitivity Analysis module, which assesses the effects of variable uncertainties on the calculated NPV. However, according to Abdel-Aziz (2000), the COMFAR III program lacks three important functions, which are essential for functionality and generality: a network structure, a spectrum of calculation methods for estimating, and a probabilistic risk analysis on the variables of the model.

CASPAR

CASPAR (Computer Aided Simulation for Project Appraisal and Review) was developed by the Centre for Research in the Management of Projects, at the University of Manchester Institute of Science and Technology (UMIST) in 1989. This software program models the time and cost aspects of both engineering and operation phases of a project using a network based structure. The Channel Tunnel project and several other BOT projects have used CASPAR in the appraisal stage.

CASPAR implements separate programs for cost and time analyses. Activity costs can be assigned as lump sums at a specific time or spread uniformly over the duration of an activity to any one of a maximum of seven cost centres (e.g. production, administration and marketing). A maximum of twenty risk variables can be introduced to the analysis defined as a percentage risk change in a number of cost, duration or resource elements. The maximum range and most suitable probability distribution are assigned to each risk variable. The program also performs sensitivity analysis and presents analysis results in terms of several key financial indicators.

According to Abdel-Aziz (2000), limitations of CASPAR include its inability to cater for:

- Interaction of cost and time programs;
- Varied calculation methods for different phases and cost centres;
- Definition of probability distributions; and
- Variation in the degree of influence of a risk variable on different elements within that particular variable (same percentage change is made to all elements).

According to the author, CASPAR is also limited in the following ways:

- Inability to model risk variables that are unquantifiable in terms of time, cost, or resources; and
- Lack of interdependency between risk variables.

@RISK, NPV-at-Risk and Value-at-Risk (VaR)

@RISK, NPV-at-Risk, and VaR are all software programs that account for risk by assigning suitable probability distributions to cash flows and financial parameters of the economic model. Results are expressed as a percentage chance that a firm could lose no more than a certain amount of money over a set time period. In particular, the @RISK Decision Tools Suite of software provides an integrated set of risk analysis and decision analysis tools for Excel that combine various analytical methods (e.g. Monte Carlo, decision trees, influence diagrams) and can be applied to a range of different problems.

These systems have the advantage that they are generic in nature, are quite flexible and allow for the modelling of risk interdependencies through linear correlations. However these systems are computationally intensive requiring a high degree of input definition and statistical data. Also, VaR would require significant modifications to be suitable for construction industry use, as it was originally developed for financial institutions.

INFRISK

INFRISK (Dailami et al., 1999) is a computer based DSS developed by the Economic Development Institute of the World Bank, for the analysis of infrastructure project finance transactions that involve the private sector. Indeed INFRISK concentrates on ensuring a project's economic feasibility, by analysing its exposure market, credit and performance risks. It does this by generating probability distributions (uniform, normal, beta and log-normal) for key decision variables using Monte Carlo simulation. The INFRISK process is presented as Figure 2.9.

Limitations of this system include: (1) individual risk factors are not identified; and (2) a high level of input definition is required to generate probability distributions. Also, this model is highly detailed, allowing for several different debt capital sources (loan, bond or letter of credit) and terms (amount, currency, maturity, repayment plan, disbursement plan and interest rate), as well as equity allocation schedules to be specified by the user. However, this degree of detail in financing arrangements would be yet unknown at the feasibility stage. Therefore, INFRISK would be more applicable to the contract negotiations stage, rather than the feasibility stage.

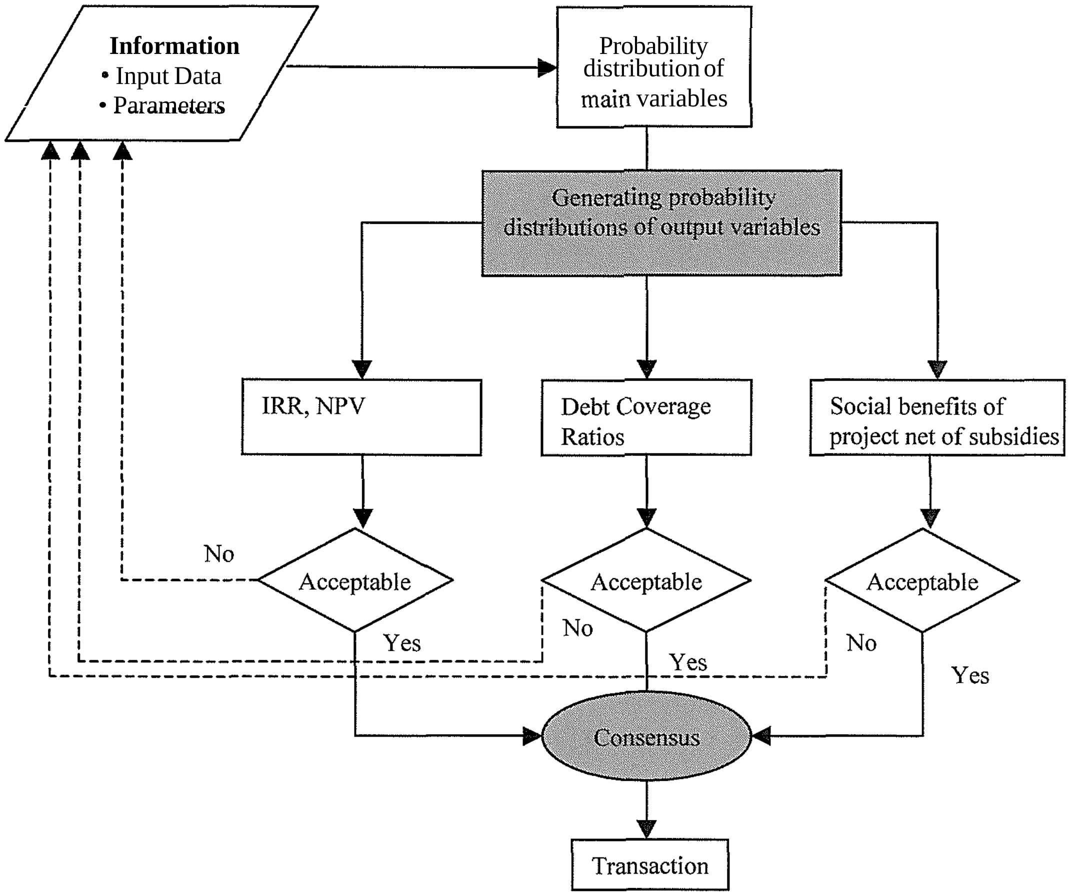


Figure 2.9 Flowchart Diagram of INFRISK (Dailami et al., 1999)

Four Moment Framework

As part of his PhD research, Abdel-Aziz (2000) developed a DSS for the analysis and evaluation of capital investment projects in construction, based upon a probabilistic, Four Moment Framework technique. The four moments technique is an approximate method of characterizing a probability distribution using four parameters or "moments" of a data set. The first moment of the distribution is the mean value (μ); the second is the variance (σ^2); the third is the skewness; and the fourth is the kurtosis (peakiness) of the probability distribution. These are called moments because they are calculated by exponentiating the data to different levels (moments). There are an infinite number of moments of any data set, but the first four go along way in characterizing the distribution.

Figure 2.10 presents the three components of this system. Abdel-Aziz's DSS comprises a generalised economic model that caters for both the detailed and generalised aspects of a capital investment, and a risk analysis framework that assigns probability distributions to variables within the economic model by use of the distribution's defining four moments.

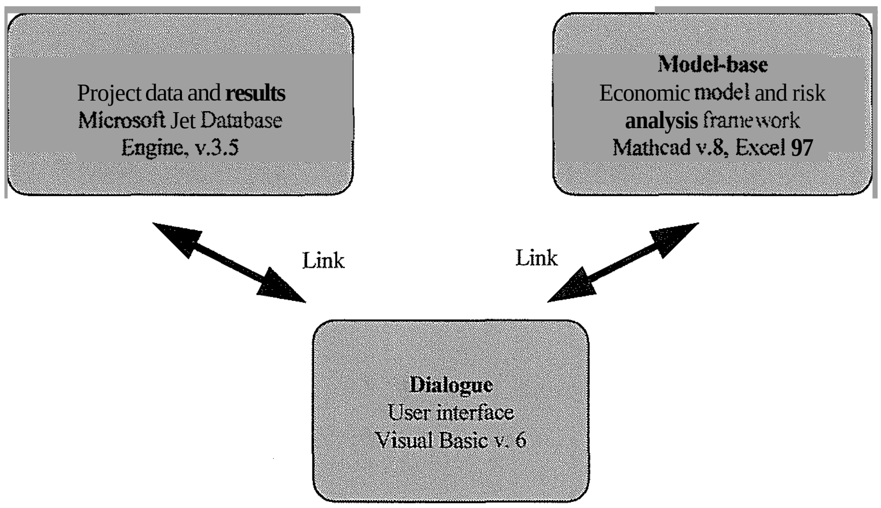


Figure 2.10 Components of Four Moments Framework (Abdel-Aziz, 2000)

Unfortunately, most decision makers in construction would not have the specialist knowledge of probability theory required to estimate the four parameters of a probability distributions for such a framework. Other limitations include: individual risk factors are not identified; correlations between variables are not catered for; the system is unable to compare several different types of projects (e.g. road, rail and power); and the software has substantial overhead due to the use of multiple software.

2.9.2 Real Options Frameworks

Attempts have also been made to develop DSSs for CPIs based upon the real options analysis (Ho, 2001; Ho and Lui, 2002; Park and Herath, 2000). As previously mentioned in Section 2.7.3, real options analysis is also known as the Strategic NPV, as it calculates all possible changes to the project's NPV throughout its life cycle, due to risk and uncertainty associated with its stock value. Ho and Lui (2002) applied the reverse binomial pyramid model to the evaluation of BOT investments using the two risk variables construction costs (K), and net operating cash flows (V). This model first calculates the present value of the two risk variables and, after each time increment, four branches emanate representing the four possible price movements after this time, as shown in Figure 2.11.

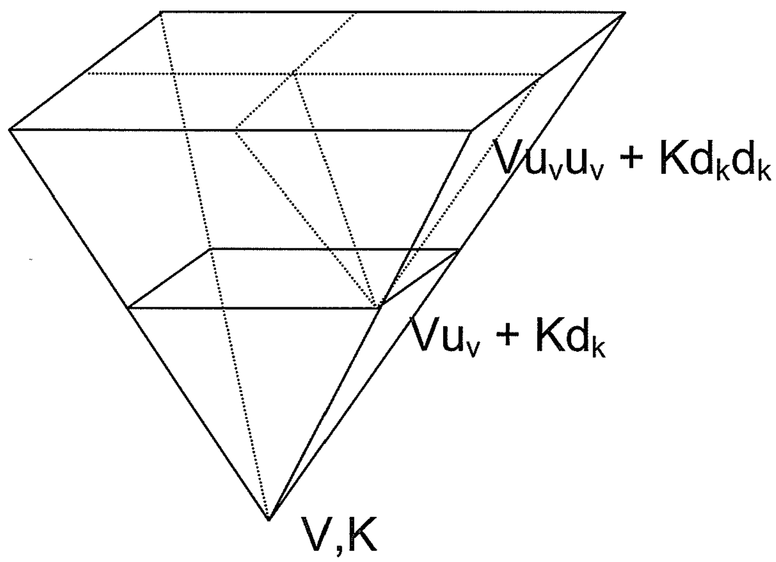


Figure 2.11 Two Step Binomial Pyramid (Ho and Liu, 2002)

Each risk variable "jumps" up by a certain percentage, u, or down by a certain percentage d = 1/*u*, with the probability q and 1-*q* respectively. The values of *u* and d depend on the risk free rate of return (determined by government long term bond), rate of return shortfall (analogous to stock dividend yield) and project value volatility, which are all determined from historical data, implication, estimation or simulation. For example, Ho (2001) derived the project value volatility from five (5) years of historical data (1995-2000). Ho makes several assumptions in the estimation of values that could significantly affect the real option value of the project. The volatility of K, correlation of K to market values, and the correlation of V and K are all assumed values. Thus, the Real Options approach is limited by the requirement of quantifying non-financial factors into monetary value probability distribution parameters, such as mean (μ) and variance (σ^2) (Ho, 2001), and the need to estimate various dynamic and static variables of the model. Also, the Real Options model developed by Ho (2001) assumes that risks caused by legal, economic, political environment and host country credit rating are ruled out, thus the analysis only focuses on construction, operating and financial risks.

Finally, Park and Herath (2000) believe that the Real Options approach integrates traditional capital budgeting with strategic (long range) planning by capturing the flexibility to defer, abandon, alter or start up and shut down a capital investment project. However, the public sector is the responsible party for determining local infrastructure development plans and individual project schedules, according to community needs (Arndt, 2000). Thus, when bidding for a concession project, companies have no real option to defer the investment. For the above reasons, it would seem that the Real Options approach is neither an effective nor efficient basis for the accurate and realistic modelling of a CPI option.

2.9.3 Multi-Criteria Decision Making (MCDM) Frameworks

Frameworks Not Including Factor Interdependencies

In essence, the decision to invest in a concession project is a multi-criteria decision problem. Multi-Criteria Analysis (Choobineh, 1990; Wirba et al, 1996; Wong, 2000), Weighted Sum Model, Weighted Product Model, and Multi-Attribute Utility Analysis (Accorsi et al, 1999; Duarte 2001; Pongpeng and Liston, 2003; Yeh et al., 1999) are all multi-criteria decision making (MCDM) frameworks that could be applied to the CPI modelling problem. Unfortunately, these frameworks fail to account for the interdependencies that exist between risk factors. In real life project situations, factor interdependencies can significantly affect the overall feasibility of an investment. Therefore, these frameworks would not accurately reflect the investment situation.

Frameworks Including Factor Interdependencies

There are a few other frameworks that fall into this category that do actually attempt to capture the interdependency of both financial and non-financial factors in the investment model. Neural Networks, Cross Impact Analysis, the AHP, the ICRAM-1 model and the ANP, are briefly described below.

<u>Neural Networks</u>

Lam et al. (2001) attempted to capture the interaction of variables, through extensive "training" of a developed Neural Network model using historical data sets from similar projects. An illustration of a Neural Network is presented as Figure 2.12. In fact, Lam et al. (2001) used 85 sets of input and output data to train a fuzzy neural network for contractor prequalification, in order to obtain meaningful results.

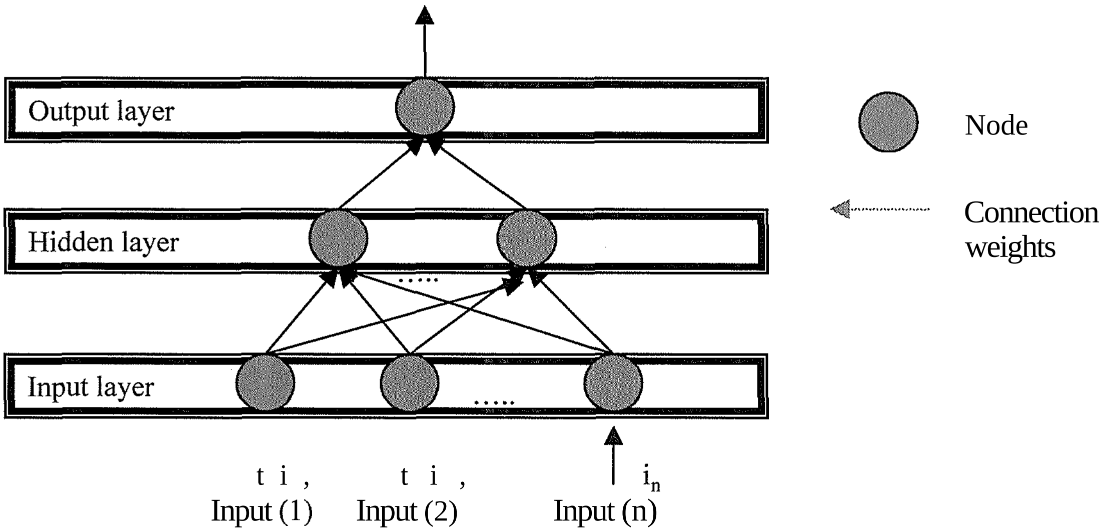


Figure 2.12 A Neural Network With Three Layers (Al-Tabtabai and Alex, 2000)

The Neural Network technique could equally be applied to the modelling of CPIs, assuming the decision maker has access to a large historical database of input and output values. In this case, the input layer would consist of project financial and non-financial factors, and the output layer would represent the overall project feasibility. However, this technique would be difficult to implement, due to the absence of CPI data sets, owing to the one-off nature of construction projects. Furthermore, in the event that such data sets did exist, this technique would involve a considerable amount of time and resources.

Cross Impact Analysis (CIA)

CIA is a decision-making technique that attempts to capture the cross impact, or interdependencies, between variables that exist in real life decision-making problems. The general notion of this technique was first introduced by Helmer and Gordon (Gordon and Hayward, 1968) and has been adapted and extended by others (Alarcon and Ashley, 1996). As shown in Figure 2.13, a CIA model closely resembles a brainstorm structure. It has been applied to the modelling of political, economic and technological conditions on project cost

(Han and Diekmann, 2001b), and it has also been used in the appraisal of BOT highway projects in conjunction with a probabilistic financial analysis model (Ock, 1998). The CIA employs the following scale to define the degree of impact of one variable on another:

Sli + /- (slight impact)
Mod +/- (moderate impact)
Sig + /- (significant impact)

Negative values are used where an increase in one causes a decrease in the other, or *vice* versa. CIA models the impact of the variable interactions on predefined, "prior" probabilities of events, using Monte Carlo simulation. The main limitation of the CIA framework is that the variables in the model only affect the shape of the estimated project cost probability distribution, not its lower and upper bounds. In other words, the analyst must estimate the bounds of the final project cost distribution incorporating the effects of the variables prior to defining the variables and their interactions. Also, frameworks that employ a brainstorm structure, such as the CIA, can be confusing when modelling complex decision problems (Saaty, 2001).

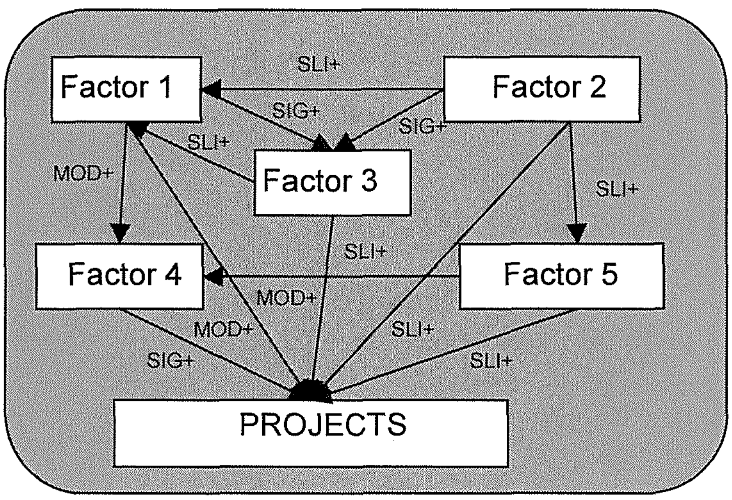


Figure 2.13 Illustrative CIA DSS Framework

Analytical Hierarchy Process (AHP)

The Analytical Hierarchy Process (AHP) was developed in the early 1970s as a general theory of measurement that derives ratio scales from paired comparisons in multilevel hierarchic structures (Saaty, 2001). These comparisons can be based either upon actual measurements (tangible risk factors) or a fundamental scale of relative strengths of preferences (intangible risk factors). The fundamental scale ranges from 1 (equal importance) to 9 (extremely more important), and uses reciprocals (e.g. 1/9) to represent where dominance is in reverse. A fairly basic decision problem would involve a three level hierarchy of Goal, Criteria and Alternatives, where the links between levels represent the relative priorities of the criteria with respect to the set goal, and the preference of the alternatives with respect to each criterion (see Figure 2.14). Others have applied the Analytic Hierarchy Process (AHP) to the assessment of construction risk (Paek et al, 1992; Tah and Carr, 2000) and performance measurement (Suwignjo et al., 2000).

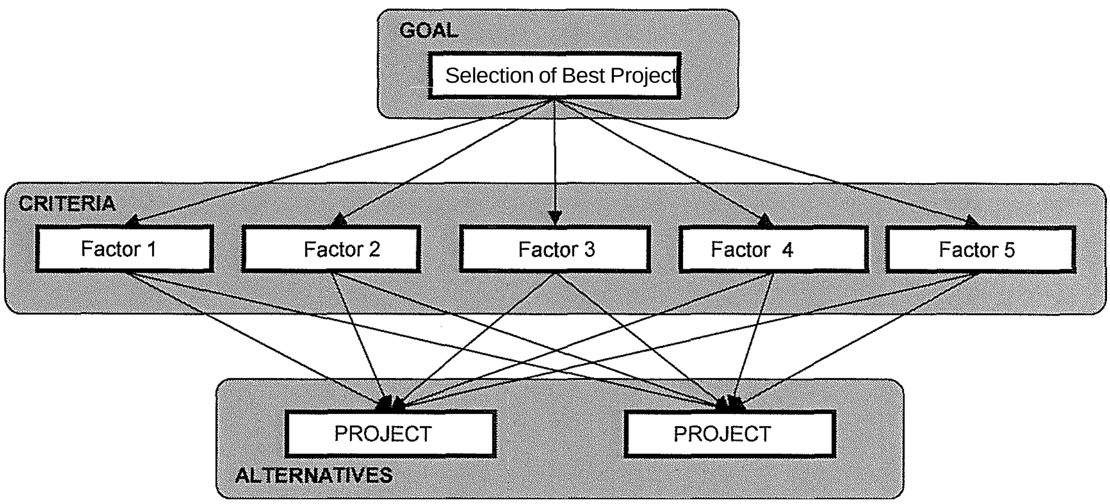


Figure 2.14 Illustrative AHP Hierarchy With Three Levels

ICRAM-1

A fundamental assumption of the AHP is that all elements (factors) and criteria within the structure are independent of each other. For example, the relationship between the risk of a change of political direction and a change in environmental regulations cannot be modelled by the AHP. This limitation of the AHP was addressed by Hastak and Shaked (2000) in the ICRAM-1 model.

The ICRAM-1 model is a variation of the AHP that allows a specific lower level sub-criterion to be directly affected by an overall upper level criterion (see Figure 2.15). For example, the overall political environment could affect a sub-criterion of the future market volume. However, a specific sub-criterion of the political environment cannot affect a specific sub-criterion of another criteria, such as market potential.

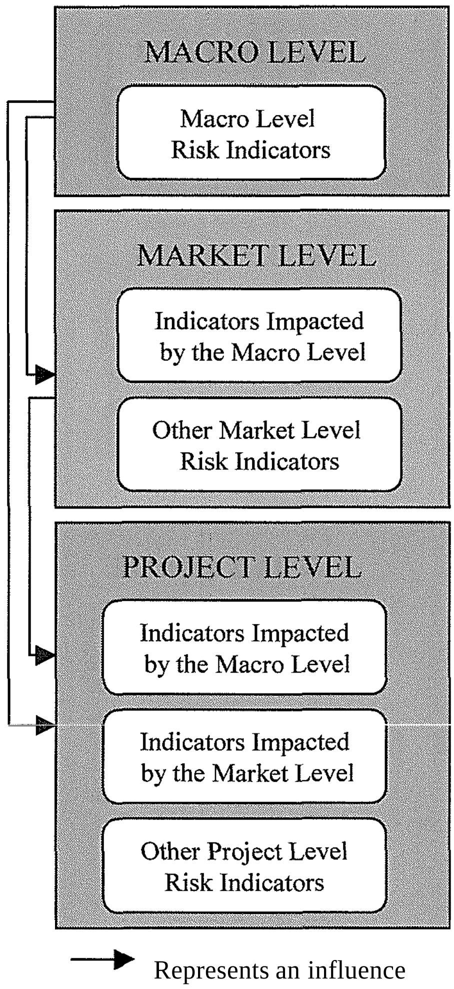
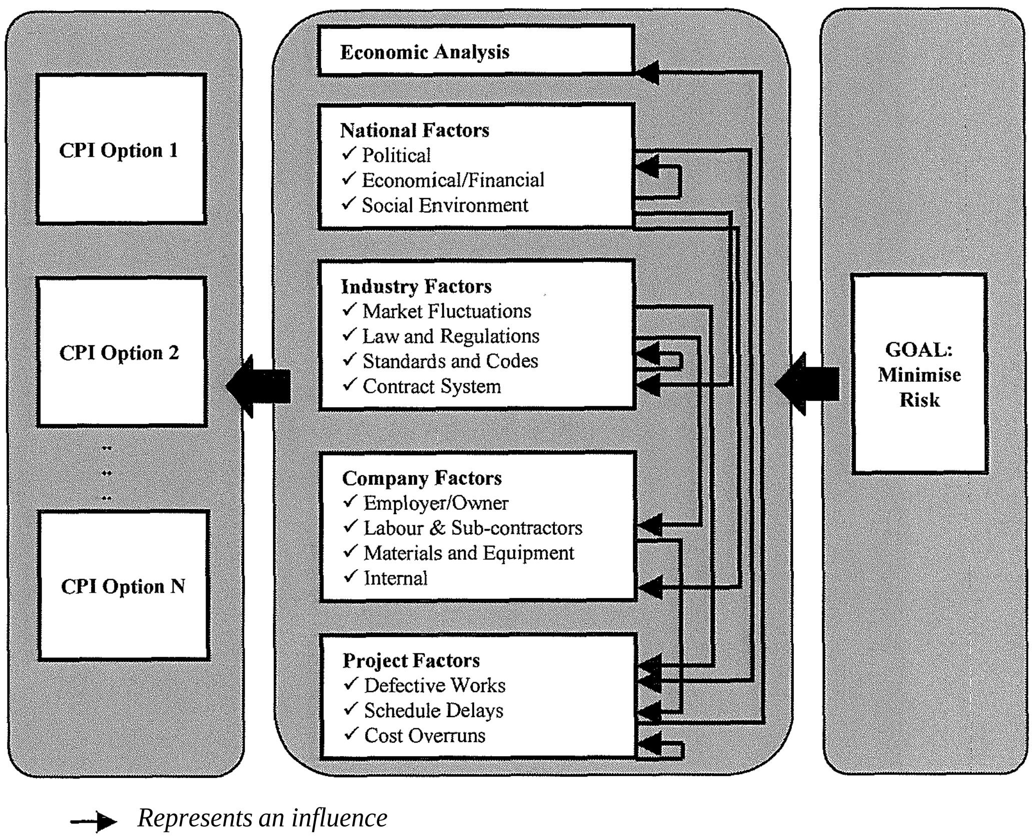


Figure 2.15 Structuring of Criteria in ICRAM-1 (Hastak and Shaked, 2000)

<u>Analytic Network Process (ANP)</u>

Similar to CIA, the Analytical Network Process (ANP) was developed in order to cater for the dependence of individual elements, both within and in-between criteria (Saaty, 2001). The ANP is a variation of the AHP that looks more like a network than a hierarchy, thus making it an ideal technique for modelling risk on concession projects (see Figure 2.16).

The ANP employs the same fundamental scale of comparison as the AHP in order to generate relative priorities of criteria with respect to the goal, and the preference of different alternatives, with respect to criteria. However, it adds a third dimension to the decision problem by allowing for any element (e.g. goal, criteria, alternative) to influence any other element within the network.



N.B. All arrows are not shown to maintain legibility of the diagram.

Figure 2.16 Typical ANP Framework Adapted From Zhi's (1995) Risk Identification Hierarchy

Not only is the ANP capable of modelling non-financial factors, it also provides for the combined (financial and non-financial) evaluation of projects through the use of the ANP project rating method (see Figure 2.17). This method combines the use of a financial B/C ratio performance measure, with an equivalent non-financial performance measure, the Opportunity/Risk (O/R) ratio.

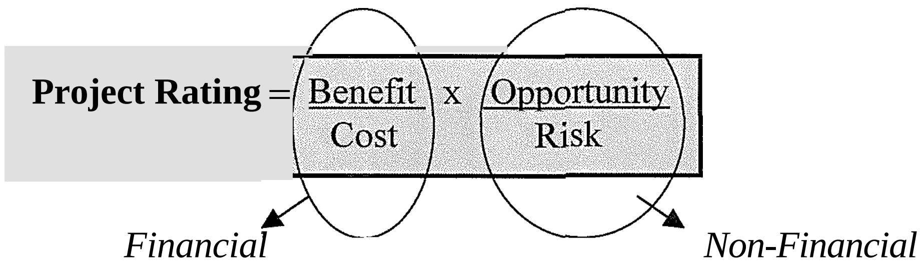


Figure 2.17 ANP Project Rating Method (Saaty, 2001)

Project ratings developed using this method provide a holistic evaluation of the projects, which can then be used to rank the various CPI options. The ANP method overcomes difficulties encountered when combining financial and non-financial values into one aggregated project rating such as:

- The ratio of Benefit to Cost and Opportunity to Risk eliminates the need for a common unit (financial vs. non-financial) or scale of comparison ($1billion vs. $1Obillion).
- A series of linguistic pairwise comparisons overcome the difficulty of subjectively assigning importance weightings to the non-financial factors.
- This technique facilitates the inclusion of both positively (opportunities) and negatively (risks) impacting non-financial factors in a logical and well-structured manner.
- Results are similar to the Benefit/Cost Ratio already used by most public sector departments to evaluate project feasibility and could therefore be presented as part of a bid proposal.

Although this technique requires more effort for input definition, it is not a difficult task and can often lead to the discovery of new elements and the clarification of the decision problem (Saaty, 2001). In fact, the amount of user input and complexity of mathematical calculations could be greatly reduced by simply giving the analyst the option of assigning dependencies between elements (factors), only where required. To date, no evidence has been found of this framework being applied to the modelling of CPIs, although it has been applied to information system project selection (Lee and Kim, 2000), and logistics and supply chain management systems (Meade and Sarkis, 1998).

2.9.4 Summary

Several currently available DSSs were objectively compared according to their ability to incorporate important non-financial (risk and opportunity) factors (DSS Requirement 9) and the interdependencies between non-financial factors (DSS Requirement 10) in an efficient and effective manner. A summary of the advantages and limitations of these DSSs is presented as Table 2.2.

From the above critical review of currently available DSSs, the three, most appropriate decision making techniques (employed by the DSSs) for the modelling of CPIs, were selected for further comparisons. Section 3.4 critically compares the AHP, ANP and CIA techniques by way of a numerical example, and makes a final selection of the decision-making technique for implementation in the DSS design.

Table 2.1 Summary of Currently Available DSS Advantages and Limitations

DSS Classification	**Economic Frameworks Incl. Uncertainty**	**Real Options Frameworks**	**MCDMs – No Factor Interdependencies**	**Neural Networks**	**CIA**	**AHP & ICRAM-1**	**ANP**
Advantages	✓Accurate CPI financial model ✓ Quantitative results facilitating a Go/No-go decision	✓Considers both financial & non-financial aspects	✓ Specific identification of non-financial (risk) factors ✓ Considers both financial & non-financial aspects according to relative importance	✓Simulated approach	✓ Specific identification of non-financial (risk) factors ✓ Considers financial & non-financial aspects ✓ Simulated approach ✓ Allows interdependency between ANY factors	✓Easy to determine factor weights via pairwise comparisons ✓Simplistic, hierarchical structure	✓Same as AHP, plus Ability to reflect real-life complexities ✓Allows inter-dependencies between ANY factors
Limitations	✗ No interdependency of factors ✗ Individual non-financial risk factors causing uncertainty distributions in forecasts are not formally identified ✗ A high level input definition is required (probability distributions) ✗ Some of these systems are prone to crashing when simulating realistic investment situations	✗ A high level input definition is required (probability distribution parameters) ✗ Value of non-financial factors must be converted into dollar values ✗ No inter-dependency of factors ✗ Bid must be placed by set date – no option to delay in real-life	✗ No allowance for the inter-dependency of factors ✗ Some have not yet been used to model the holistic investment decision (i.e. financial & non-financial) ✗ Difficulty in assigning factor weights	✗ A high level input definition is required ✗ Large quantities of historical data required ✗ Inter-dependency determined by training of network using historical data	✗ Confusing brainstorm structure ✗ Input of final project cost distribution required ✗ Relative frequency distributions must be defined for factors ✗ Limited scale (-3 to +3) for interdependency	✗ No inter-dependencies between factors.	

2.10 RISK FACTOR FRAMEWORKS

One of the ten requirements of a CPI DSS (listed in Section 2.5) is the identification of important non-financial (risk and opportunity) factors (DSS Requirement 9) and their interdependencies (DSS Requirement 10). Although contributing non-financial factors vary from project to project, it is vital that the DSS assists the analyst by providing the option of using a generic CPI risk factor framework (RFF). This RFF must closely reflect the complexities of a real-life CPI in a time and resource efficient manner. Thus it was necessary to critically review available literature in order to select a RFF for implementation in the DSS.

Research publications in construction and project risk can be traced back as early as the 1960s. Since this time, a myriad of risk factor categorisations or frameworks have been developed in an attempt to identify the unique risks facing the construction industry by way of case studies, literature reviews, questionnaire or survey results. In fact, Edwards and Bowen (1998) reviewed a total of over 280 authoritative English language publications between 1960 and 1997 to develop a comprehensive risk categorisation for general construction projects. As discussed in Section 2.2, concession projects are higher risk investments owing to the unique set of risks encountered on these types of projects. Also, the risks faced by investors in concession projects can be greatly likened to those faced by investors in international projects. For this reason, the research dissertation will focus on those RFFs developed by others specific to either CPIs or international construction projects.

Salzmann and Mohamed (1999) conducted a review of RFFs and critical success factor (CSF) frameworks specific to international BOOT projects. The review compared and identified the limitations of a number of existing frameworks (Tiong, 1990; Tiong et al., 1992; Walker and Smith, 1995; Tam, 1995; David and Fernando, 1995; Keong et al., 1997; Tiong and Alum, 1997; Ma et al., 1998; Kerf et al., 1998; Zhi, 1995) and concluded that:

1. None were able to provide a comprehensive listing of BOOT project risks,

2. No attempt had been made to explain the interactions that exist between the factors.

In response to these findings, Salzmann and Mohamed (1999) developed two comprehensive risk frameworks for BOOT projects, one for the development phase of a project, and one for the operations phase. Each framework was divided into four Superfactors: 1) Project Management/Organisation; 2) Country; 3) Investors; and 4) Project. Each of these Superfactors was then subdivided into Subfactors, which were then subsequently divided into specific risks. For example, under the "Investor" Superfactor, the "Financial" Subfactor consisted of: government guarantees, insurance, dividend payment and operation expense risks.

More recent literature reveals the following RFFs used in the modelling of concession and international projects:

1. Akintoye et al. (2001) – List of 26 risks in PFI schemes resulting from literature review;
2. Arndt (2000) – 12 areas of risk divided into three (3) phases (development, operational, transfer) of private provision of infrastructure. This framework was developed as a result of literature review, case studies and experience;
3. Hastak and Shaked (2000) – 73 risks between a three (3) level (macro or country, market, project) hierarchy divided into various categories for international projects. The framework was developed as a compilation of an extensive literature review and considers factor interaction of higher levels (as an aggregate) on individual lower level factors;
4. Han and Diekmann (2001a) – 33 risks in five (5) categories (political, economic, cultural/legal, technological/construction, other) for international projects resulting from literature review;
5. Ozdoganrn and Birgonul (2000) – 37 Critical Success Factors (CSFs) in four (4) categories (financial and commercial, political and legal, technical, social) for BOT in developing countries developed specifically for a hydropower plant project case study;

6. Qiao et al. (2001) - 27 CSFs in six (6) phases (preliminary qualification evaluation, tendering, concession award, construction, operation, transfer) for Chinese BOT projects;
7. Thomas et al. (2003) – Eight (8) very critical risk factors specifically for Indian BOT road projects;
8. Wang et al. (2000) – 50 risks in six (6) categories (political, construction, operating, market and revenue, financial, legal) for BOT projects resulting from literature review and interviews;
9. Wang et al. (2002) – Refinement of Hastak and Shaked's (2000) framework to 27 most critical risks via survey. Also identifies interaction of individual factors of higher levels on individual factors of lower levels; and
10. Zayed and Chang (2002) – Eight (8) main risk areas (political, financial, revenue and market, promoting, procurement, development, construction/completion, operating) for BOT projects.

The dual objective of effectiveness and efficiency must be considered when comparing the various RFFs for implementation in the DSS. When considering efficiency, frameworks with a large number of factors can seem too detailed and cumbersome (Ozdoganm and Birgonul, 2000; Wang et al., 2000; Hastak and Shaked, 2000). These models have failed to discount the less critical risk factors making them too large and thus unattractive to the analyst. Also, frameworks that categorise risks according to the project phases (Arndt, 2000; Qiao et al., 2001; Salzmann and Mohamed, 1999) tend to have an overlapping of risk factors from one phase into another. For example, in Arndt's (2000) framework, "Legislation" and "Policy" risk falls into both the development and operational phases. Thus, risk factors must be evaluated more than once, creating inefficiency.

When considering effectiveness in reflecting the real life CPI situation, it is evident that, although the above frameworks contain similar listings of risk factors, some more generalised frameworks, such as that by Zayed and Chang (2002), make it difficult for the analyst to evaluate risk by failing to be specific in identifying risk factors. Other frameworks, such as the listing of 26 risks developed by Akintoye et al. (2001), are not structured or grouped, also making it difficult for the analyst, whilst others have been developed for specific types of BOT projects (Thomas et al., 2003; Ozdoganm and Birgonul, 2000; Wang et al. 2000) and would not be effective in providing a generic CPI model.

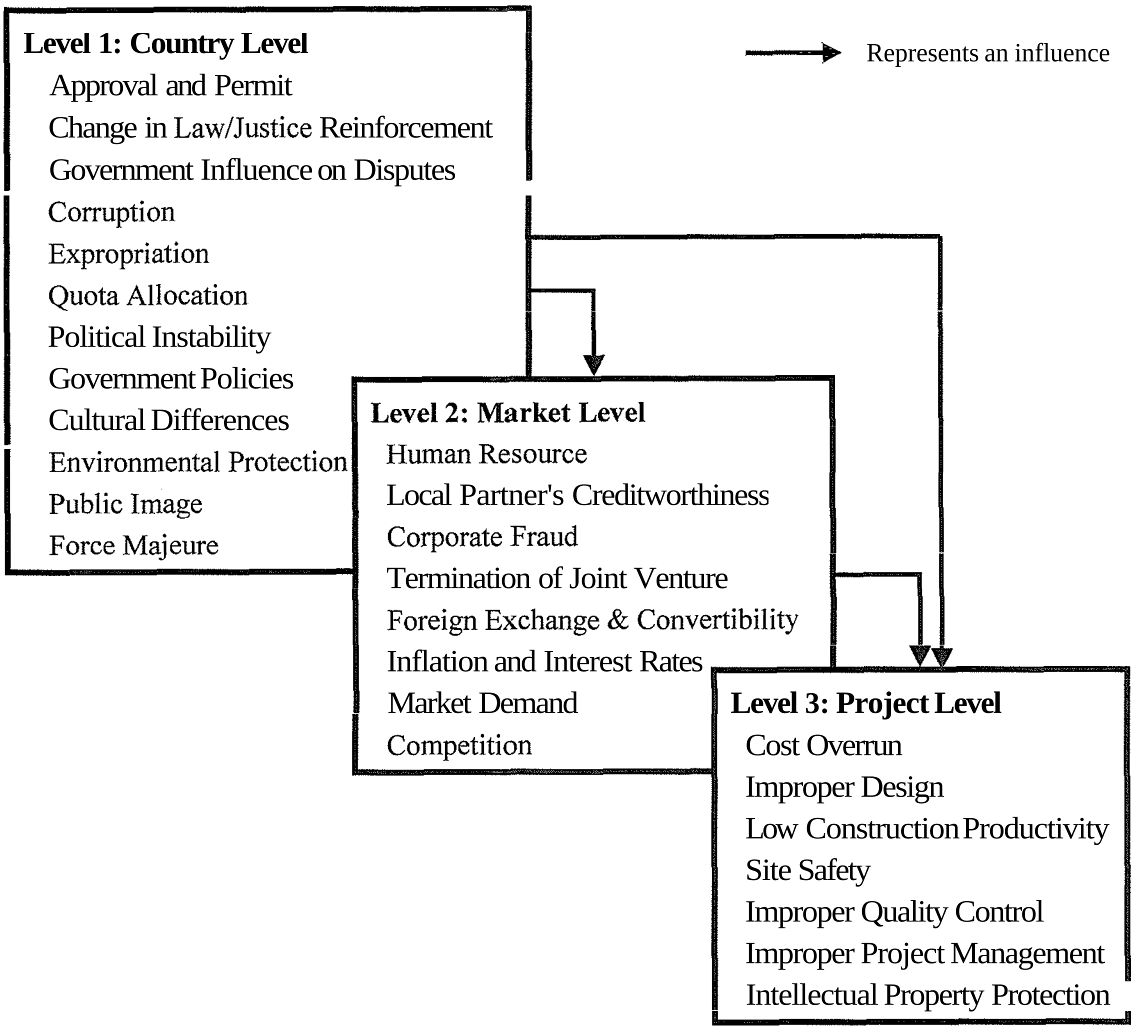


Figure 2.18 Refined Risk Factor Framework (Wang et al., 2002)

To most closely represent the real life CPI situation, the framework must cater for the interaction between factors. ICRAM-1, the three-level (project, market, country) RFF by Hastak and Shaked (2000) identifies interactions of aggregated higher levels on individual lower level factors (e.g. the overall macro risk level influences the "bidding volume index" factor in market level) on international projects. Wang et al. (2002) further refined this framework from a framework of 73 comprehensive to 27 most critical risk factors using input from industry. In its refined form (Wang et al., 2002), interactions between individual higher-level factors and individual lower level factors are identified in a risk influence matrix (RIM). Thus, the refined RFF by Wang et al. (2002), presented as Figure 2.18, is not only efficient, containing only the more critical risk factors; it is also effective, reflecting the real life interactions between risk factors on a CPI in a logical manner for the analyst.

CHAPTER 3

TECHNIQUE SELECTION

3.1 GENERAL

The primary objective of this research dissertation was to develop an effective and efficient DSS for the evaluation and comparison of various CPI opportunities in construction. Before the DSS Architecture could be designed, it was necessary to select the most suitable techniques for the evaluation of CPI options from those critically reviewed in Chapter 2. It was imperative that: (1) the mathematical modelling technique and financial analysis model selected captured the true degree of certainty surrounding the project; and (2) the decision making technique and risk factor framework selected were those that most closely reproduce the complexity of CPI decisions. More specifically, the chosen techniques, when used in conjunction with each other needed to meet all ten DSS requirements (as outlined in Section 2.5) in an efficient and effective manner. This chapter outlines the selection process followed in each of the four areas: mathematical modelling techniques, financial analysis models, decision-making techniques and risk factor frameworks.

3.2 SELECTION OF MATHEMATICAL MODELING TECHNIQUE

The mathematical modelling technique selected for implementation in the DSS needed to be able to model uncertainty surrounding the CPI (DSS Requirement 5). Possibility theory was selected as a more appropriate modelling tool than the traditional deterministic and probability theories. Possibility theory accurately reflects the true degree of certainty at the project appraisal stage making it an effective modelling tool. It is also time and resource efficient, not requiring large amounts of historical data to develop possibility distributions. With this technique, financial factors can be represented as crisp (single) values, intervals, triangular, trapezoidal, or even more rounded distributions using linguistic definitions, such as "most likely between…" and "least likely between…"

A pilot project was undertaken by the author (see Section 3.2.1) to investigate the implementation of possibility theory to modelling the combined affects of financial and non-financial factors of a CPI option using a simple Weighted Sum Method framework. It should be noted that due to the key focus of this pilot project being on the suitability of possibility theory to the modelling of CPIs, the pilot DSS does not employ the most suitable financial analysis model, risk factor framework and decision making model as these had not yet been decided upon (see following sections). Hence the pilot DSS's ability to effectively and efficiently model a CPI is limited by the use of the Weighted Sum Method to calculate the resultant aggregated non-financial factor possibility distribution and the assigning of the relative importance of non-financial factors to financial factors. As economic decision-making often requires the relative ranking of alternatives under consideration (Moselhi and Deb, 1993), it was decided to allow the DSS to prioritise available options. A number of programming languages were considered to develop the DSS as a computer software program. However, it was decided that a combination of the Visual Basic for Applications (VBA) and the widely used Microsoft Excel software would be both adequate and user friendly.

3.2.1 Pilot DSS Methodology and Model Input

The pilot DSS allows the user to perform the following tasks (see Figure 3.1):

- *Identify the number of financial factors applicable to the project under investigation.* The user can identify up to 150 factors including the following:
  - Financial factors (prior to operation) such as design, material, labour and construction costs;

- o Financial factors (annual payments during operation) such as revenue, loan repayment, and operation and maintenance costs; and
- o Financial factors (lump sum payments during operation) such as replacement costs.

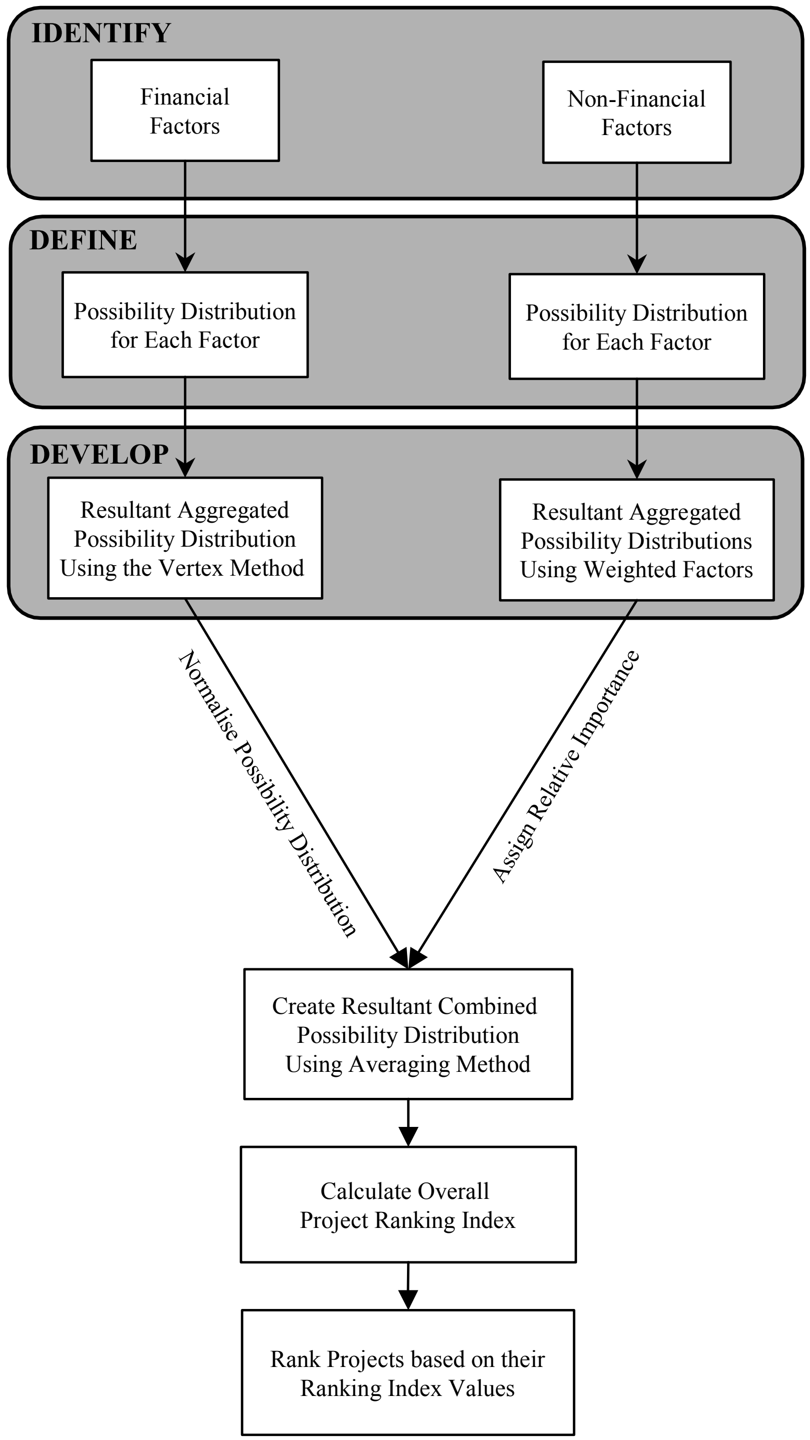


Figure 3.1 The Pilot DSS Process Flowchart (Mohamed & McCowan, 2001)

- *Define the selected financial factors as possibility distributions.* This step allows users to define the appropriate possibility distribution for each factor in dollar values. For the purpose of modelling, it is assumed that each factor will be entered into the model in any one of the following four forms (see Figure 3.2):
  1. A single deterministic value (with 100% certainty; e.g. design cost is a lump sum of $100,000);
  2. A closed interval (defined by an equally likely range; e.g. design cost is somewhere between $80,000 and $130,000);
  3. A triangular distribution (defined by a most likely value; e.g. design cost is about $100,000, with a lower and upper least likely values of $80,000 and $130,000, respectively); and
  4. A trapezoidal distribution (defined by a most likely range; e.g. design cost is most likely in the range of $100,000–$120,000 with a lower and upper least likely values of $80,000 and $130,000, respectively).

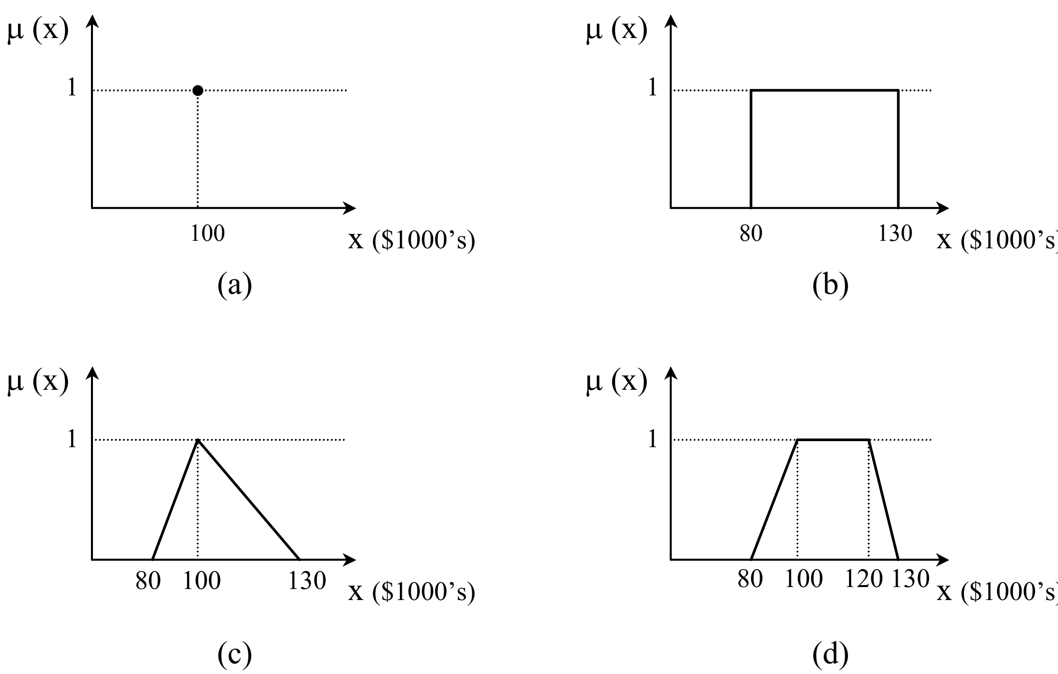


Figure 3.2 Analyst's Perception of Design Cost: (a) Single Value; (b) Closed Interval; (c) Triangular Distribution; (d) Trapezoidal Distribution

- *Develop the resultant financial distribution.* Applying the conventional time-cost-of-money principle, the net present value (NPV) for all financial factors can be calculated (see Figure 3.3). To facilitate the arithmetic manipulation (addition and multiplication) of the possibility distributions, the vertex method (Dong et al., 1987) has been utilized (see Appendix A). Also, the following four assumptions were made:

1. Financial factors (prior to operation) take place in Year (0). That is, the length of the construction period is minimal compared to the period of investment (operation);
2. Financial factors (during operation) are of constant annual value (+ve cash in-flow and -ve cash out-flow) throughout the period of investment;
3. Financial factors (lump sum payments during operation) are discounted back to Year (0); and
4. Cash flow discount and tax rates can be represented by any of the above four forms of possibility distribution.

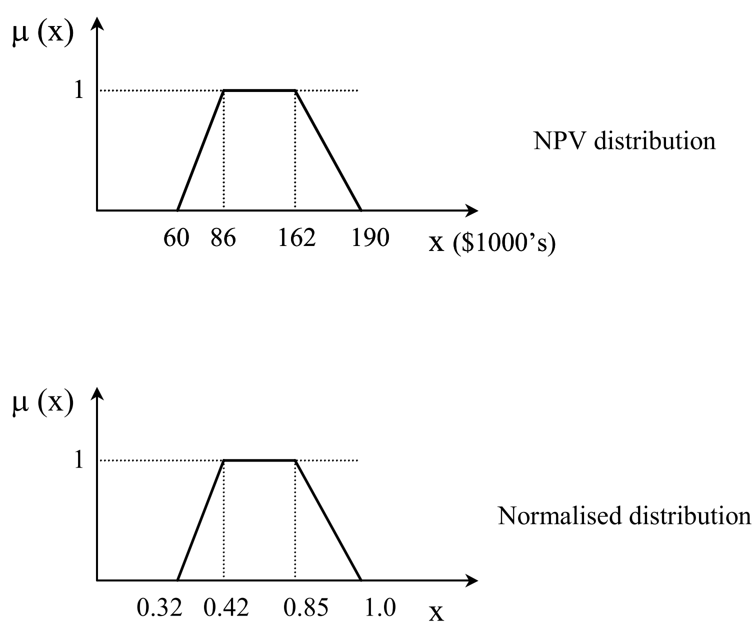


Figure 3.3 Resultant NPV Possibility and Its Normalised Distribution

Figure 3.3 shows a hypothetical output of this stage; i.e. a resultant possibility distribution representing a hypothetical project's NPV. The NPV distribution is defined by a most likely range of $86,000-$162,000 and a lower and upper limit of $60,000 and $190,000, respectively.

- *Identify the number of non-financial factors applicable to the project under investigation.* These non-financial factors may include political, environmental, social, technological and strategic aspects of the project, as well as that of the organisation.

- *Define the selected non-financial factors as possibility distributions.* Due to the qualitative nature of these factors, users need to reflect the level of satisfaction for each factor on an interval scale from zero (0) to one (1), with 1.0 indicating a maximum positive project or organisation outcome for this particular factor. For example, if the project is 100% compatible with the organisation's strategy, a score of 1.0 may be used. Scores will be entered into the model in a similar manner as with financial factors, the user can use any of the following distributions:

    1. A single deterministic value (with 100% certainty; e.g. project compatibility with the organisation's strategy is 0.8);
    2. A closed interval (defined by an equally likely range; e.g. project compatibility with the organisation's strategy is somewhere between 0.7 and 1.0);
    3. A triangular distribution (defined by a most likely value; e.g. project compatibility with the organisation's strategy is about 0.8 with a lower and upper least likely values of 0.6 and 1.0, respectively); and
    4. A trapezoidal distribution (defined by a most likely range; e.g. the most likely range for project compatibility with the organisation's strategy is 0.8-0.9 with a lower and upper least likely values of 0.6 and 1.0, respectively).

- *Develop the resultant non-financial distribution*. As it is highly unlikely for selected non-financial factors to have the same importance, weights of importance need to be utilized. The assessment of a weight for each factor is an important decision for the analyst to make in view of the investment opportunity at hand. The analyst must decide which factors are most important; weights are then assigned according to the relative importance of factors. A recommended method for eliciting criteria weights is the analytic hierarchy process method, which is a hierarchical scaling method proposed by Saaty (1980). In the proposed method herein, the weight of importance varies between 0 and 1.0, with 0 indicating no importance and 1.0 indicating a very high importance. Each possibility distribution is multiplied by respective importance weights and the resultant project non-financial distribution values are simply equal to the sum of the weighted factor values, divided by the sum of weighting values. This is otherwise known in its various forms as the fuzzy weighted averaging method (Bojadziev and Bojadziev, 1996; Dong and Wong, 1987; Smith, 1995) (see Appendix A). This technique seeks to find the 'average' of two or more possibility distributions by modifying their shape through fuzzy arithmetic.

- *Create the combined 'aggregate' project distribution*. In this step, both the financial and non-financial distributions are combined using the fuzzy weighted averaging method. Prior to combining both distributions, however, the user needs to assign a relative importance level among them. For example, if both distributions were of equal importance, then each distribution is multiplied by 0.50. This step is crucial in highlighting the contribution of the non-financial factors to the overall attractiveness of the investment option. As both distributions (range values) differ in magnitude and unit, the financial distribution values must first be modified. According to Schmucker (1984), 'normalisation' is a common modification process that involves dividing each value of the financial distribution by the largest value so the range is between zero (0) and one (1) (see Figure 3.3). The normalised distribution is then combined to the non-financial distribution to form one resultant 'aggregate' distribution representing the overall possibility distribution for the project, which may or may not resemble its predecessors (Kaufmann and Gupta, 1985). This distribution, in turn, can be compared to other developed projects' distributions facilitating their ranking as explained in the following step.

- *Calculate the overall project ranking.* This step allows the decision-maker to select the most appropriate investment option. For each option, a ranking index is developed reflecting its overall possibility distribution. The ranking index method used by Choobineh and Li (1993) (see Appendix A) was selected above other ranking procedures (Smith, 1995; Tseng and Klein, 1989) to perform the final task of ranking the various project investment options. This method was considered the most rational, involving less complicated computations for the case in which distributions fell within a set range (0-1).

The program output includes the resultant financial and non-financial distributions as well as the overall distribution for each investment option. Up to five (5) options could be ranked according to their overall possibility distributions, with an output of a tabular summary of financial, non-financial and combined ranking index values of the projects.

3.2.2 Numerical Application 1

Moselhi and Deb (1993) presented a method for selecting a project under risk. Their method uses multi-objective decision criteria through the probability based multi-attribute utility theory and takes into account the uncertainties associated with each individual objective. In this section, the numerical example detailed in Moselhi and Deb (1993) is used to demonstrate the applicability of the possibility-based method proposed above by comparing its prediction with that of its probability-based counterpart. In Moselhi and Deb's (1993) numerical example, a government department was to select one of three proposed projects for development, based upon five (5) set factors (or criteria) including one (1) financial factor (X_1), and four (4) non-financial factors (X_2– X_5) (see Table 3.1).

The base data given for X_1, in Table 3.1, is that of the predicted cash flows for projects A, B and C with each project having an economic life of 25 years. For utility matrix generation, Moselhi and Deb (1993) employed Equation 3.1 and Equation 3.2 to utilise the cash flow data and then determine both the expected E(NPV) and associated standard deviation σ(NPV) for each project.

$$E(NPV_i) = \sum_{t=0}^{n} \frac{E(C_{ti})}{(1+I_f)^t}$$

Equation 3.1

Where $E(C_{ti})$ is the expected net cash flow for project i in period t, I_f is a risk-free interest rate, and n is the economic life.

$$\sigma(NPV_i) = \sum_{t=0}^{n} \frac{\sigma(C_{ti})}{(1+I_f)^t}$$

Equation 3.2

Table 3.1 Base Data for Projects A and B (Moselhi and Deb, 1993)

Objective	Project	Period (years)	Minimum (Optimistic)	Maximum (Pessimistic)	Likely (Most likely)
X_1 Net Cash Flow \$(10)[6]	A	0	-0.875	-1.15	-1.0
		1-25	0.46	0.35	0.40
	B	0	-1.7142	-2.285	-2.0
		1-25	0.9	0.60	0.70
	C	0	-2.25	-3.90	-3.00
		1-25	1.0431	0.727	0.9458
X_2 No. new jobs created	A		145	120	130
	B		175	145	160
	C		300	180	200
X_3 No. minority employees	A		18	10	15
	B		11	7	10
	C		22	15	18
X_4 No. new staff on team	A		2	6	4
	B		4	9	6
	C		7	10	8
X_5 Prestige of agency	A		5.5	4.5	5.0
	B		7.5	6.0	7.0
	C		3.5	2.5	3.0

The verification of the methodology presented in the previous section required cash flows to be represented by triangular distributions similar to those shown in Figure 3.2c. The reason for choosing triangular distributions was to simply utilise all given data in the original numerical example. The relative importance of the sum total of the non-financial factors was taken to be 0.60 to reflect the weighting of net cash flow assumed by Moselhi and Deb (1993). Additionally, the interest rate was assumed to be a risk- free, single rate of 9.0% and the least likely range of results was defined as being within three (3) standard deviations of the mean. Table 3.2 contains a comparison of the NPV (financial) results obtained by the proposed methodology to those gained by the utility method (Moselhi and Deb, 1993). From this table, it is evident that the expected values of projects A, B and C are in a good agreement (± 4.0%).

Table 3.2 Summary of Financial Results Using Possibility vs. The Utility Method

Project	Model	Expected Value($)	Deviation (%)
A	Possibility	2,929,000	- 0.1
	Utility	2,933,000	
B	Possibility	4,876,000	- 3.0
	Utility	5,040,000 *	
C	Possibility	6,292,000	+ 4.0
	Utility	6,058,000	

The formulae for calculating E(NPV) given in Moselhi and Deb (1993) were used to verify the tabulated result for project B. The above correctly calculated value actually differs from that presented in Moselhi and Deb (1993).

As for the E(NPV), the mean and standard deviation of every variable is determined from the base data for optimistic, pessimistic and most likely values presented in the example. The standard deviation around the mean represents the level of risk or uncertainty associated with that variable. The base data for the variables X_2 to X_5 are presented in Table 3.1. The resulting characteristic values for each variable were then used as program input to determine the project expected utilities (Moselhi and Deb, 1993). Once a full analysis of the entire data set was completed, it was found that the combined project ranking index values were 0.73, 0.63 and 0.5 for projects C, B and A, respectively. These results are in complete agreement with the project ranking order given by Moselhi and Deb using the utility method.

3.2.3 Numerical Application 2

The objective of the developed program was to model and rank a number of concession investment options through the application of possibility theory. Its effectiveness at meeting this objective was tested using two projects of similar nature, which are referred to as Project A and Project B. The two projects (A and B) had different concession (operation) periods of 30 and 24 years, respectively. Both projects were affected by different risk factors. Project A was surrounded by low political and moderate financial risks; it was to be entirely funded by a consortium of national banks; and there was also little chance that a competitive facility would be built nearby due to the environmental sensitivity of the region. Careful consideration also had to be given to factors such as disturbance of the environment, especially the local tourism industry, and the risk in adopting an innovative construction. The cash flow discount rate was assumed to be in the range of 6.0 - 8.0% (closed interval) (see Figure 3.2b). Table 3.3 and Table 3.4 show a summary of the financial and non-financial factors considered for Project A. It should be noted that the net annual revenue accounts for both gross revenue and costs.

Table 3.3 Project A: Financial Input and Output

		Defining possibility distribution values			
Financial Factor	**Year**	**a**	**b**	**c**	**d**
Discount rate (%)	1-30	6.0	6.0	8.0	8.0
Estimated construction cost (M$)	0	- 260	- 250	- 250	- 240
Net annual revenue (M$)	1-30	40	42	42	44
Resulting NPV (M$)		**60.6**	**86.4**	**161.2**	**190.6**
Normalised NPV value		**0.32**	**0.45**	**0.85**	**1.00**

Table 3.4 Project A: Non-Financial Input and Output

		Defining possibility distribution values			
Non-financial Factor	**Weighting**	**a**	**b**	**c**	**d**
Political	0.40	0.90	0.95	0.95	1.00
Environmental	0.75	0.50	0.60	0.70	0.75
Social	0.85	0.80	0.80	0.95	0.95
Technological	0.80	0.25	0.50	0.50	0.70
Financial	0.50	0.40	0.40	0.60	0.60
Non-financial distribution value		**0.55**	**0.64**	**0.73**	**0.80**

Table 3.5 Project B: Financial Input and Output

		Defining possibility distribution values			
Financial Factor	**Year**	**a**	**b**	**c**	**d**
Discount rate (%)	1-24	8.0	9.0	9.0	10.0
Estimated construction cost (M$)	0	- 300	- 280	- 280	- 250
Net annual revenue (M$)	1-24	51	51	53	53
Resulting NPV (M$)		**9.13**	**54.9**	**67.5**	**133.8**
Normalised NPV value		**0.07**	**0.41**	**0.50**	**1.00**

Table 3.6 Project B Non-Financial Input and Output

		Defining possibility distribution values			
Non-financial Factor	**Weighting**	**a**	**b**	**c**	**d**
Political	1.00	0.20	0.50	0.50	0.80
Environmental	0.40	0.80	0.80	0.90	0.90
Organisational	0.85	0.40	0.50	0.50	0.60
Competition	0.80	0.50	0.50	0.70	0.70
Market Share	0.90	0.80	0.90	0.95	1.00
Financial	0.90	0.70	0.70	0.80	0.80
Non-financial distribution value		**0.53**	**0.63**	**0.71**	**0.79**

Project B was to be located in another country with a relatively unstable political environment. Additionally, the promoting organisation was required to form a contractual arrangement with the host country. The difference in political uncertainty is reflected in Table 3.4 and Table 3.6, whereby Project B assigns a higher weighting and uncertainty to the political risk factor. Other risks to the project included working with local contractors, the effects of high inflation and also the high possibility of competitive facilities being constructed. However, the project could potentially reap great benefits for the promoting organisation in the form of increasing future market share in this particular country. The final financial possibility distribution for Project B shows more uncertainty than Project A. The cash flow discount rate was assumed to be in the range of 8.0 - 10.0% with 9% being the most likely value (triangular distribution) (see Figure 3.2c). Table 3.5 and Table 3.6 show a summary of financial and non-financial factors considered for Project B. For both projects, a tax rate of 36.0% was assumed and the relative importance of non-financial factors was set at 0.35, implying a 0.65 contribution of financial factors.

The computed overall combined project distributions for Project A and B were [0.41, 0.52, 0.81, 0.93] and [0.22, 0.41, 0.48, 0.93], respectively. Figure 3.4 contains a representative diagram of the two project's overall possibility distributions. The ranking index for Project A was higher than its counterpart for B (see calculations in Appendix A), therefore, Project A represents the better investment option.

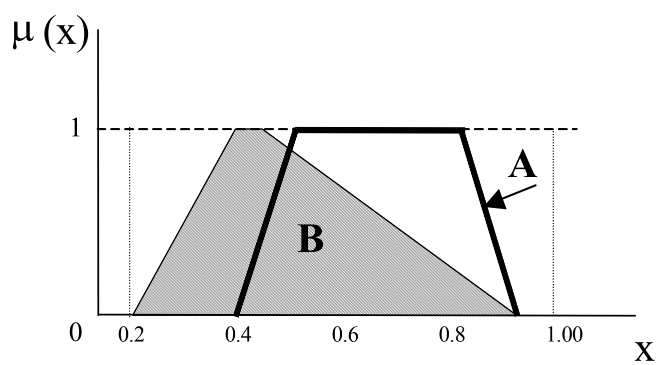


Figure 3.4 The Overall 'Combined' Possibility Distributions for Project A and B

3.2.4 Summary

A pilot DSS program was designed to conduct an evaluation of each CPI option and to provide an overall ranking of these options using the possibility theory. Two numerical examples were modelled using the DSS: the first as a comparison to the probability-based utility method (Moselhi and Deb, 1993), and the second to demonstrate the successful application of the program to rank two concession projects. From the first numerical example, the possibility theory appears to offer an even less calculative intensive method than the probability theory whilst still providing accurate and transparent results. Whilst from the second numerical example it was found that the developed pilot DSS program provided an accurate and convenient methodology for comparing different project alternatives.

The possibility theory was selected as the most suitable technique for implementation in the DSS as it is able to accurately model the true uncertainty (DSS Requirement 5) surrounding both financial and non-financial factors.

3.3 SELECTION OF FINANCIAL ANALYSIS MODEL

It was important that the financial analysis model of the DSS calculated the specific performance measures of investments used by the three main parties to the project (investors or equity holders, lenders and government)(DSS Requirements 1 and 4). It also needed to incorporate the multiple project phases of a CPI (DSS Requirement 2), the time dependency of financial factors (DSS Requirement 3), varied cash flow characteristics (DSS Requirement 7), and both the generalized and detailed aspects of the project (DSS Requirement 8).

Comparisons, detailed in Section 2.7.4, found the NPV model developed by Bakatjan et al. (2003), to be a generic financial model which closely reflects the degree of detail in input definition available to analysts at the feasibility stage, that would allow for both generalised and detailed aspects of the project to be modelled. It also accounts for the time dependency of factors (e.g. via inflation, discounting) and the multiple phases of a CPI by dividing the concession period into two sub-phases: a construction period and an operations period. Finally, varied cash flow characteristics, such as one-off, annual, or even annually increasing payments, could easily be incorporated into this model at the data input definition stage.

Unfortunately, Bakatjan et al.'s (2003) financial model, along with the other financial analysis models reviewed, was found to be limited in its effectiveness as it did not provide a sufficient selection of performance measures. In fact, this model only calculated the equity holder's NPV, and annual DSCR for lenders, failing to cater for the government's perspective. Also, certain irregularities were identified in the formulae presented in the paper.

It was therefore decided not to implement any of the reviewed models in their entirety. Adjustments were made to the formulae of Bakatjan et al.'s model, which was then adopted as a basis for the DSS's financial analysis model. However, the model was then expanded to ensure it included a comprehensive set of performance measures (i.e. DSS Requirements 1 and 4). Adjustments to the formulae were verified by a finance and accounting expert who also gave advise as to which financial performance measures are most important to each party involved and how they should be calculated. The following expansions were made to the financial model.

Equity holders, investors or promoters are the primary end users of the DSS and use a variety of performance measures to evaluate project investments. For this reason, the cumulative cash flows, payback period and NPV, as well as their IRR and B/C ratio, were all provided from the equity holder's perspective. Lenders are provided with the annual DSCR as detailed in Bakatjan et al. (2003). The DSCR was found to be the most widely used performance measure for lenders, in addition to the equity holder's payback period. Therefore, no further performance measures were added to cater for lenders' needs. The B/C ratio is historically the most widely used financial performance measure by the public sector, as it considers both the dollar value of (quantifiable) benefits to the community, and the cost incurred by the government for a project investment. Thus, the government party is provided with a B/C ratio for the overall project (not including financing considerations), as well as the overall project cumulative cash flows (non-discounted), payback period (non-discounted) and NPV.

The following comprehensive set of financial performance measures was selected for implementation in the DSS:

Equity Holder (includes financing considerations)
Total project cost NPV ($)
Equity holder cumulative cash flows (non-discounted) ($)
Equity holder payback period (yr)
Equity holder NPV ($)
Equity holder Benefit/Cost ratio
Equity holder IRR (%)

Lender
Debt Service Coverage Ratios (DSCR)

Government (Overall Project) (not including financing considerations)
Project cumulative cash flows (non-discounted) ($)
Project payback period (yr)
Overall project NPV ($)
Overall project Benefit/Cost ratio

Details of the formula used by the DSS to calculate these performance measures are presented in Chapter 4 of this research dissertation.

3.4 SELECTION OF DECISION MAKING TECHNIQUE - DSS STRUCTURE

A great deal of effort was concentrated on selecting the optimal decision making technique for modelling non-financial aspects of a CPI. In Chapter 2, several decision-making techniques were objectively compared according to their ability to incorporate important non-financial (risk and opportunity) factors (DSS Requirement 9) and the interdependencies between non-financial factors (DSS Requirement 10) in an efficient and effective manner. Three techniques, thought to be most appropriate for the modelling of CPIs, the AHP, ANP and CIA, were selected for further comparisons by way of the following numerical example.

3.4.1 Numerical Example

The following numerical example demonstrates the practical application of the three techniques, namely the AHP, CIA and ANP, to the modelling of risk on two construction projects, A and B. For the purpose of this example, the analysis is limited to the following five (5) non-financial factors commonly encountered on construction projects: (1) Financing, (2) Social, (3) Political, (4) Technological and (5) Environmental. All attempts have been made to ensure consistency of input values throughout the three analysis cases. For the purpose of this example, financial factors have not been included in comparisons.

Analysis Case 1 - AHP

Figure 3.5 presents the decision structure used for the first case of analysis. The hierarchy consists of three levels: Goal, Criteria (non-financial factors) and Alternatives (project). Pairwise comparisons (scale of 1-9), used to determine the relative priorities of the five criteria, and the preference of Project B over Project A with respect to each of the five non-financial factors, are presented as Table 3.7 and Table 3.8, respectively.

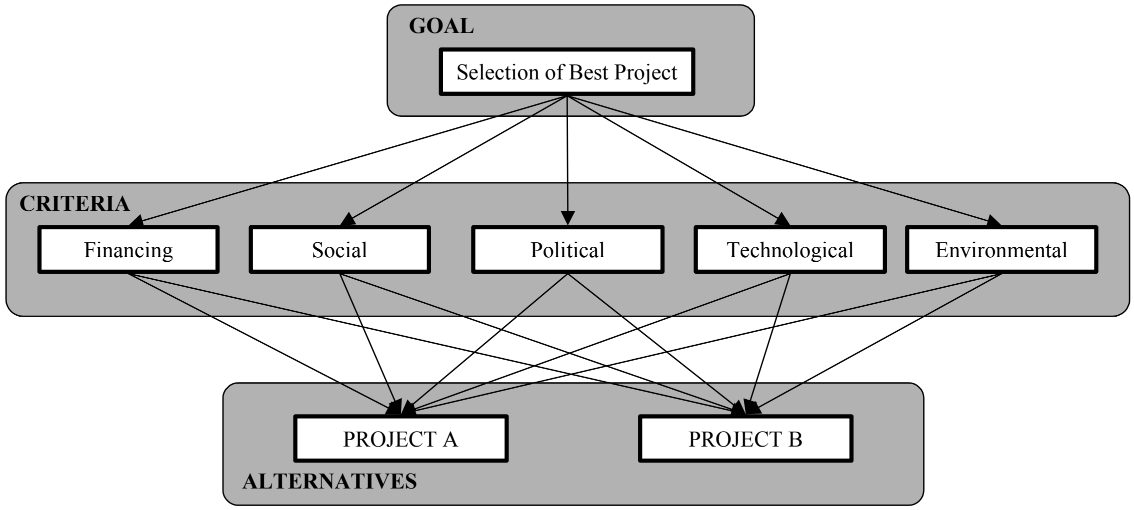


Figure 3.5 Decision Problem Structure for Case 1 - AHP

Table 3.7 Pairwise Comparison Matrix and Resulting Normalised Priorities for Level 1 - Criteria wrt Goal (Selection of Best Project)

	Financing	**Social**	**Political**	**Technological**	**Environmental**	***Priority Vector***
Financing	1	5	3	7	6	0.502
Social	1/5	1	1/3	5	3	0.140
Political	1/3	3	1	6	3	0.243
Technological	1/7	1/5	1/6	1	1/3	0.039
Environmental	1/6	1/3	1/3	3	1	0.076

Table 3.8 Level 2 Comparisons -Projects wrt Criteria

WRT CRITERIA…	Preference Of Project B over Project A
Financing	6
Social	7
Political	1/8
Technological	1
Environmental	1/5

PROJECT A	0.39
PROJECT B	0.61

The Super Decisions software, available on the Internet (Creative Decisions Foundation, 2003) was used to run the analysis. The following results were obtained: 0.39 for Project A and 0.61 for Project B. Thus, Project B was found to be less risky than Project A.

Analysis Case 2 - CIA

Figure 3.6 presents the risk analysis problem structured using the CIA technique. This technique employs a brainstorm structure and allows for interdependencies between variables. For the purpose of this example, a simple "Good"/ "Bad" rating system was adopted. However more complex, probability curves could also be used. The data input comprised prior probabilities of risk variables (Table 3.9) and the level of interaction between variables. Both the prior probabilities and the levels of interaction of factors on the Projects were kept in line with the preference values and priorities used in the AHP model, respectively. In a real life analysis, the values for Project B would be defined independently of Project A. However, to maintain consistency throughout the analysis cases, values in Table 3.9 were simply reversed for Project B (e.g. Prior P_B: Event 11=0.857, Event 12=0.143). It was assumed that the final project outcome on both Project A and B was 50% good: 50% bad prior to the impacts of risk. Final results after 200 Monte Carlo iterations (using MATLAB) again found Project B to be less risky, with a 34.4% probability of a "Good" outcome on Project A, compared to 66% on Project B.

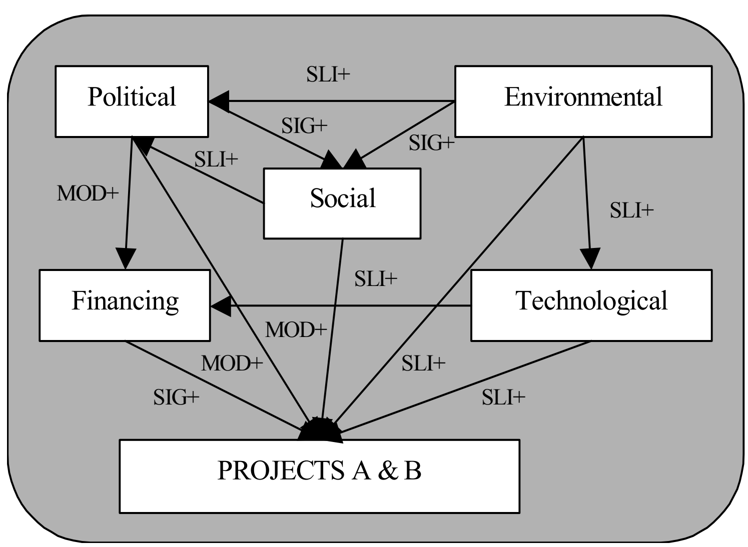


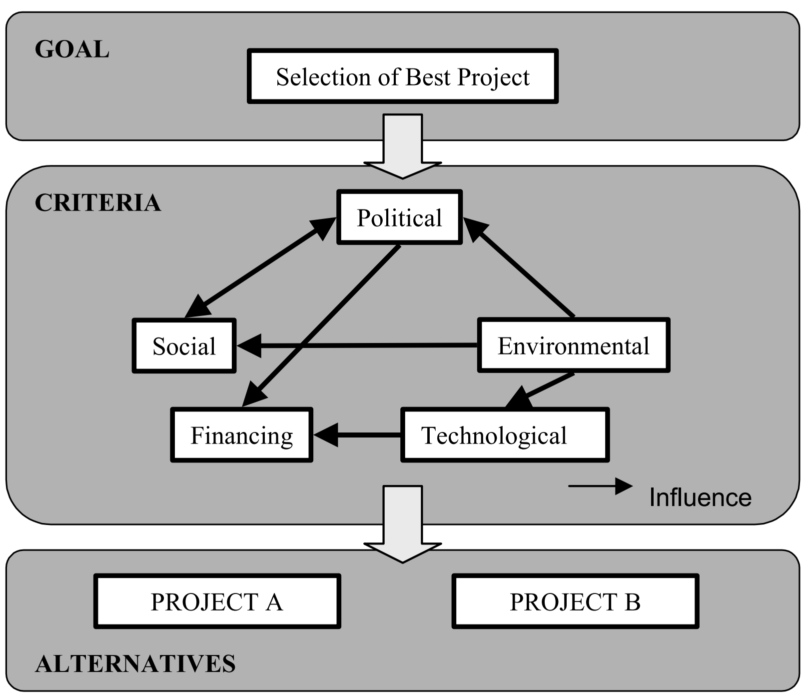
Figure 3.6 Decision Problem Structure for Case 2 – CIA

Table 3.9 Input for the CIA model Project A

Variable	Event	Event Name	Prior Probability
Financing	11	Good	0.143
	12	Bad	0.857
Social	21	Good	0.125
	22	Bad	0.875
Political	31	Good	0.889
	32	Bad	0.111
Technological	41	Good	0.500
	42	Bad	0.500
Environmental	51	Good	0.833
	52	Bad	0.167
Project A	A1	Good	0.500
	A2	Bad	0.500

Analysis Case 3 – ANP

For this analysis case, the AHP structure used in Case 1 was simply modified to include the factor interdependencies shown in Figure 3.7.



N.B. Not all arrows are shown in order to maintain legibility of the diagram.

Figure 3.7 Decision Problem Structure for Case 3 – ANP

A Super Decisions model was built using data input that was as consistent with Cases 1 and 2 analyses as possible. Data from Table 3.7 and Table 3.8 was entered into the model along with additional pairwise comparison matrices of factor interactions. These additional pairwise comparisons were kept in line with interactions in the CIA model, resulting in some fractional values, as seen in Table 3.10. The final results for this analysis case were: Project A - 0.56, and Project B - 0.44. These results differ greatly from the results gained in Case 1, and actually represents a reversal of project preference, from Project B to A.

Table 3.10 Pairwise Comparisons of Non-Financial Factors wrt Financing

	Political	**Technological**
Political	1	1.5
Technological	0.67	1

Critical Comparison

The effectiveness of a decision making technique relates to its:

1. Ability to model the decision environment accurately, including both the identification of individual non-financial factors and also the interdependencies that exist between these factors on real-life projects; and
2. Accuracy in capturing the decision maker's preferences through use of meaningful scales/values for the definition of input data.

Both the CIA and ANP techniques meet the first requirement of effectiveness mentioned above. Yet, whilst the AHP does cater for the identification of individual non-financial factors, it does not allow for interdependencies between these factors to be included in the model. Thus, the AHP fails to meet the first criteria of effectiveness. When comparing the results of the AHP and ANP cases, it is evident that the inclusion of real-life interdependencies in the model can significantly affect analysis results, and can actually cause a reversal in the preference of two projects, as it did in the above numerical example.

When considering the second criteria of effectiveness, both the AHP and ANP use a common 1-9 scale (where 1 represents equal importance and 9 represents extreme importance) for the definition of input values, whereas CIA employs a three-point scale (slight, moderate, significant) for the definition of impact values, in conjunction with percentage based probabilities for the definition of prior probabilities. It was found that the three-point scale limits the user in distinguishing between the degree of impact of individual factors, causing a loss of accuracy in the CIA model. Also, the prior probabilities are more difficult to define, as they require too high a degree of certainty for input values, which simply does not exist on real life construction projects.

For the purpose of this example, an efficiency rating has been calculated for the three techniques based upon the ratio of the number of decisions required by the decision maker to the number of interactions (or links) between variables in the models used in the numerical example. Table 3.11 presents the efficiency ratings of all three techniques applied to the above numerical example.

Table 3.11 Comparison of Technique Efficiency

Analysis Case	**No. Decisions Req'd**	**No. Interactions**	**Efficiency Rating (Decisions/Interactions)**
1 – AHP	15	15	1
2 – CIA	12 + 12 = 24	12	2
3 – ANP	15 + 3 = 18	22	0.82

These results show that the ANP technique was most efficient for this particular example, having a rating of less than one; the AHP technique was the second most efficient, having a rating equal to 1; and the CIA technique was the most inefficient, having a rating of 2. However, it must be noted that these ratings would change for each individual model being analysed, according to the number of non-financial factors, projects and interactions. Therefore, it is important that only the more significant non-financial factors and interactions are included in the model.

The CIA technique, in particular, also has a significant drawback that it requires a large number of decisions to define variable prior probabilities on each project, which only increases as the level of definition increases. For example, if we replaced the very simplistic "Good"/ "Bad" definition system with a "Good"/ "Average"/ "Bad" system an extra six (6) decisions per project would be required. Some even suggest that probability curves should be used to gain accurate results from the CIA, which would require an even greater amount of effort in gathering input data.

3.4.2 Final Selection of Decision Making Technique

The Analytical Network Process (ANP), developed by Saaty (1996), was selected as the optimal decision making technique owing to its ability to accurately reflect the complexities and interdependencies of different non-financial factors encountered on real-life concession projects (DSS requirements 9 and 10). To date, no evidence has been found of this framework being applied to the modelling of CPI decisions.

As a final check, the sensitivity of the ANP to changes in various aspects of the structuring of interdependencies was investigated, as follows:

1. *Location of interdependencies:* Modifying the location of interdependencies between factors by removing just one interdependency (from Environmental to Political) meant that the final ratings of the projects became 0.514 to 0.486. Whilst removing an extra interdependency between Environmental and Social resulted in a reversal of project ratings to 0.49:0.51.
2. *Direction of interdependencies*: By changing the direction of only one interdependency (between Environmental and Social), Project A received a rating of 0.493 and Project B 0.507.
3. *Magnitude of interdependencies*: By making random, moderate changes to the magnitude of interdependencies in the above mentioned ANP network, the ratings of the projects changed moderately to 0.521 for Project A and 0.479 for Project B.
4. *Cycling between risk factors*: Removing the interdependency of Political on Social eliminated the cycling between Social and Political factors in the model. This resulted in the smallest change of all - 0.557 for Project A and 0.442 for Project B. Whilst making Social's influence on Political equal to that of

Political on Social (i.e. SIG +) produced a reversal in project rankings to 0.474:0.526.

It can be seen from the above investigations that the ANP model is sensitive to the four aspects of the structuring of interdependencies to varying degrees. It is also evident from these results that it is impossible to conclude whether the ANP technique is more sensitive to one particular aspect of interdependency structuring than another. However, all results were as expected, and the variation in results for each investigation could be easily justified by looking at the relative priorities of the factors, and the preference of the projects with respect to each criteria. It should also be mentioned that the adoption of a different scale of comparison could also affect results to a lesser degree.

Not only is the ANP capable of modelling non-financial factors, it also provides for the calculation of an overall project rating based upon both financial and non-financial aspects of a project, as presented in Figure 3.8.

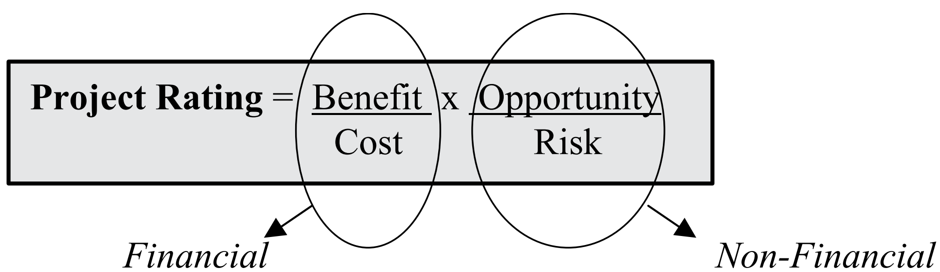


Figure 3.8 Saaty's (2001) ANP Project Rating Method

The ANP rating system overcomes difficulties encountered when combining financial and non-financial values into one aggregated project rating, such as:

- The ratio of Benefit to Cost and Opportunity to Risk eliminates the need for a common unit ($$ vs. no units) or scale of comparison ($1billion vs. $10billion);
- A series of linguistic pairwise comparisons overcomes the difficulty of subjectively assigning importance weightings to the non-financial factors;

- This technique facilitates the inclusion of both positively (Opportunities) and negatively (Risks) impacting non-financial factors in a logical and well-structured manner; and
- Results are similar to the Benefit/Cost Ratio already used by most public sector departments to evaluate project feasibility and could therefore be presented as part of a bid proposal.

For these reasons, the ANP was selected as the technique not only for the structuring of non-financial aspects (risk and opportunity factor frameworks) of a CPI option, but also as the primary performance measure from which the DSS would derive project rankings.

3.5 SELECTION OF CPI RISK FACTOR FRAMEWORK

As the resurgence of CPIs is still relatively recent (over the last two decades), the level of understanding on these types of projects and the risks involved is still limited. Thus, it was decided that a generic CPI risk factor framework should be provided for analysts as part of the final DSS design, which could be amended or even discarded at the will of the analyst. This framework would need to identify not only the more important risk factors, but also the interdependencies that exist between these factors (DSS Requirements 9 and 10).

The refined framework by Wang et al. (2002), which builds upon research conducted by Hastak and Shaked (2000), has been selected as a basis for the DSS's generic RFF as it was found to be the most advanced framework in the literature review (see Chapter 2). Although this research focused primarily on international project risk, it has been adopted as a basis for the following work on concession projects. As mentioned in Section 1.3.1, this decision was taken on the assumption that concession projects face much the same risks as international projects, due to similarities in complexity of financial arrangements and organisational structure, and the ability of the country and market environment to significantly affect project viability. This framework is not only efficient, containing only the most critical risk factors, but it is also effective, reflecting the real life interactions between risk factors on a CPI in a logical manner for the analyst.

One limitation of Wang et al.'s (2002) framework is that it contains a total of 27 risk factors, which could still be considered too cumbersome, bearing in mind that all significant factor interactions must also be considered. The research dissertation has therefore refined the framework to include only the four most critical risk factors at each level of the investment (see Table 3.12). This resulted in the inclusion of those risk factors having a criticality index very close to and greater than the 3rd quartile value calculated by Wang et al. (2002), for their respective levels. It should be noted that all of the risk factors included in the reduced framework received a criticality rating above "4-critical".

Table 3.12 Most Critical Risk Factors As Previously Identified By Wang et al.(2002)

COUNTRY LEVEL	**C1**	Approval and Permit – Delay or refusal
	C2	Change in Law / Justice Reinforcement –Inconsistency in application
	C3	Corruption
	C4	Political Instability
MARKET LEVEL	**M1**	Local Partner's Creditworthiness- Financial soundness & staff reliability
	M2	Corporate Fraud - Problems with ethics and governance
	M3	Termination of Joint Venture/Agreement with Local Partner
	M4	Inflation & Interest Rates – Immature local economic & banking systems
PROJECT LEVEL	**P1**	Cost Overrun
	P2	Improper Design – Incompatibility with local conditions
	P3	Improper Quality Control - By local partner
	P4	Improper Project Management –Inappropriate structure, planning, management

From survey results, Wang et al. (2002) were also able to develop the risk influence matrix (see Table 3.13). This risk influence matrix identifies which individual higher level factors (e.g. country) influence individual lower level factors (e.g. project). However, it is believed that other influences exist between same level factors and possibly even from lower level factors on higher level factors.

Table 3.13 Adapted Risk Influence Matrix Based On Wang et al., 2002

	C1	C2	C3	C4	M1	M2	M3	M4
M1			✓	✓				
M2		✓	✓	✓				
M3		✓	✓	✓				
M4			✓	✓				
P1	✓	✓		✓	✓	✓	✓	✓
P2		✓						
P3		✓	✓					
P4		✓	✓					

N.B. " ✓ " Represents an existing interaction.

Thus, a pilot study (see Chapter 5) was also conducted as part of this research dissertation in an attempt to:

1. Verify the risk factor framework and original RIM developed by Wang et al. (2002);
2. Adapt the RIM by identifying all significant factor interactions, including those previously identified by Wang et al. (2002); and
3. Quantify all identified factor interactions in the adapted RIM.

Using the results from this pilot study, Wang et al.'s (2002) RFF, in conjunction with the adapted RIM developed, were selected for implementation in the DSS.

Table 3.14 Selected Techniques and DSS Requirements for Which They Cater

Technique Area	***Technique Selected***	***DSS Requirement (see Section 2.5)***
Mathematical Modelling	Possibility Theory	5, 6
Financial Analysis Model	Bakatjan et al.'s (2003) model – with adjustments and expansions	1, 2, 3, 4, 6, 7, 8
Decision Making Technique	Analytic Network Process (ANP)	6, 9, 10
Risk Factor Framework	Wang et al.'s (2002) framework – with adaptations	6, 9, 10

3.6 SUMMARY

This chapter outlined the selection process followed in each of the four technique areas, mathematical modelling, financial analysis, decision-making, and risk factor frameworks, for implementation in the DSS design. It was imperative that: (1) the mathematical modelling technique and financial analysis model chosen capture the true degree of certainty surrounding the project; and (2) the selected decision making technique and risk factor framework were those that most closely reproduce the complexity of CPI decisions. More specifically, they needed to be efficient in doing so. Table 3.14 summarises how the selected techniques combine to meet nine (9) out of ten (10) DSS requirements identified in the literature review. (DSS Requirement 6, comparison of several project alternatives and scenarios, is facilitated by all techniques selected, and also by the third module of the DSS architecture presented in Chapter 4).

CHAPTER 4

DSS ARCHITECTURE

4.1 GENERAL

The primary objective of this research dissertation was to develop an effective and efficient DSS for the evaluation and comparison of various concession project investment opportunities in construction. Ten (10) aspects of a CPI have been identified as key aspects that must be accounted for by the DSS (see Section 2.5). The design requirements for the DSS therefore became to cater for the above 10 aspects of a CPI decision problem, in the most efficient and effective manner. The next step in the development process was to select the best techniques in the areas of mathematical modelling, financial analysis modelling, decision-making and risk factor frameworks for implementation in the DSS, keeping these requirements in mind (see Chapter 3). Finally, based upon the selected techniques and the identified design requirements of the DSS, the system's architecture could be designed in detail. This chapter outlines the final architecture of the DSS.

4.2 OVERALL DSS ARCHITECTURE

As depicted in the flowchart of Figure 4.1, the DSS architecture comprises three basic modules: 1) Model Definition; 2) Model Evaluation and Ranking; and 3) Sensitivity Analysis. The Model Definition module of the DSS performs the function of creating individual project investment models, including the definition of financial factors, non-financial factors and the interdependencies between non-financial factors. Individual project investment models can then be evaluated, compared and ranked, according to their overall scores using the Model Evaluation and Ranking Module. The DSS design also caters for the determination of the criticality of selected factors (non-financial or financial) on various project investment options via the Sensitivity Analysis Module.

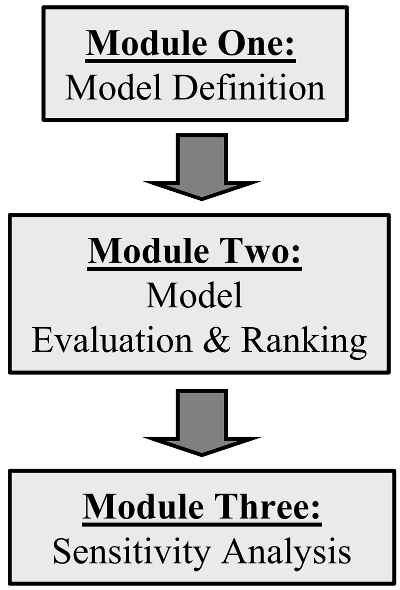


Figure 4.1 Flowchart of DSS Modules

The purpose, structure and implementation of the three modules were determined to a large degree by the primary performance measure selected for the overall CPI rankings as explained below. Additional secondary performance measures, such as NPV, payback period, annual DSCR and risk ratings have also been included in the DSS design to ensure that measures commonly used by all parties involved in these investments were incorporated (DSS Requirement 1).

The DSS's primary performance measure needed to allow for both financial and non-financial aspects of the project to be taken into consideration in overall CPI rankings. The ANP Project Rating method (Figure 3.8) was selected as the most suitable technique for this purpose (see Chapter 3). As shown in Figure3.8, this rating method extends the traditional financial B/C ratio, to incorporate non-financial factors via an Opportunity/Risk ratio (O/R). Thus, the CPI Rating calculated by the DSS provides a holistic evaluation of the CPI option's feasibility. Where opportunities or risks are not included in a CPI model, the DSS simply ranks the projects based on adaptations of the above method, as shown in

Figure 4.2 and Figure 4.3. Alternatively, in the case of a purely financial comparison of projects, the project's B/C ratio is used for ranking.

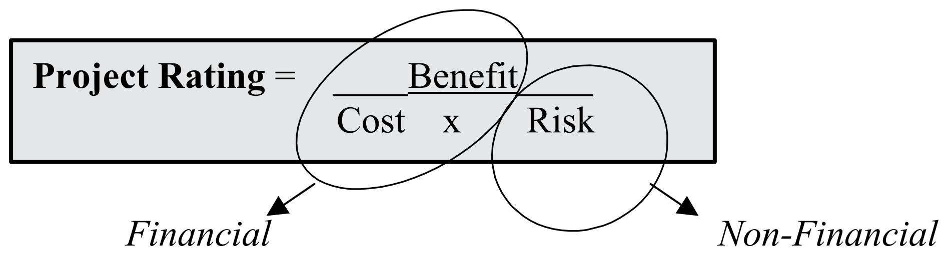


Figure 4.2 First Adaptation of ANP Project Rating Method

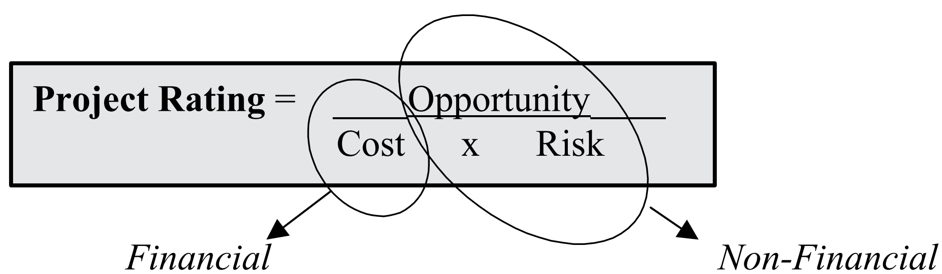


Figure 4.3 Second Adaptation of ANP Project Rating Method

The following sections describe the purpose, structure and implementation of the DSS' three modules resulting from the selection of the ANP Project Rating as the primary performance measure.

4.3 MODULE ONE – MODEL DEFINITION

The purpose of the Model Definition Module is to provide a structured framework for the development of individual CPI models. Thus, Module One performs the task of input definition for analysis that takes place in Modules Two and Three. In keeping with the ANP Project Rating method, the structure of the Model Definition Module is divided into two independent components: financial and non-financial.

4.3.1 Financial Component

The financial component of Module One is structured according to Bakatjan et al.'s (2003) two-phase financial analysis model. Using this model, financial cost and revenue factors are divided into the two project phases: Construction and Operation. Analysts must provide information on the following financial factors to this Module in order to define the financial component of the CPI model:

- *Construction*
  Construction costs ($, yr)

- *Operation*
  Operation and Maintenance (OM) costs ($, yr)
  Revenue streams ($, yr)

- *Financial Parameters*
  Concession period, incl. construction period (yr)
  Construction period (yr)
  Equity fraction (%)
  Discount rate (%)
  Escalation rate (%)
  Tax rate (%)
  Loan interest rate (%)
  Grace period on loan (yr)
  Loan repayment period (yr)

The above financial factors of the project investment model are defined using one of the following possibility distribution types, thus enabling the DSS to meet DSS Requirement 6 (uncertainty):

- Single value,
- Interval,
- Triangular, or
- Trapezoidal.

There is also flexibility in the model for construction costs, O&M costs and revenue streams to be defined in any of the following methods:

- One-off payments taking place in a certain year,
- Annual payments over a set period, or
- Annually increasing payments over a set period.

By adopting the above generic methods for the definition of the financial component of Module One, the DSS design is able to meet DSS Requirements 1, 2, 3, 4, 5, 6, 7 and 8. Module One's financial component includes evaluation methods used by the three main various parties involved in CPIs, the distinction of multiple (i.e. two) project phases/sub-phases, differing cash flow characteristics, the time dependency of variables, and both detailed and generalised definition of project variables, as they would exist at the feasibility stage. Uncertainty is also accounted for by the module, through the use of possibility distributions in the definition of all financial factors.

4.3.2 Non-Financial Component

Using the ANP Project Rating method as a basis for the structuring of the CPI's non-financial component, the non-financial factors must be divided into two separate ANP frameworks of opportunities and risks. Typically, when using the ANP, several projects are analysed according to the same risk/opportunity factors in the one framework. However, since the risks and opportunities faced by one project may not necessarily be the same as another project, it was required that individual risk and opportunity frameworks be developed for each project being evaluated.

Thus, the implementation of the ANP technique had to be modified in two ways in order to allow for analysts to be able to define a unique set of risk/opportunity factors for each project, where required. Firstly, the risk and opportunity frameworks of each project had to be separated from other projects. Secondly, to obtain meaningful results, a dummy project was required in each of the resulting frameworks. This second modification is explained further in Section 4.4.2.

Figure 4.4 demonstrates the structure of the risk framework developed for each individual project. The opportunities framework structure for each project is identical to the risk framework shown, except for having a goal to "Maximise Opportunities". Please note, that for each project, the criteria (factors) on the second level will most likely be different. In this figure, all arrows represent a direction of influence. The arrows do not identify specific interdependencies between two factors, but rather the fact that one or more interdependencies exist between or within the clusters.

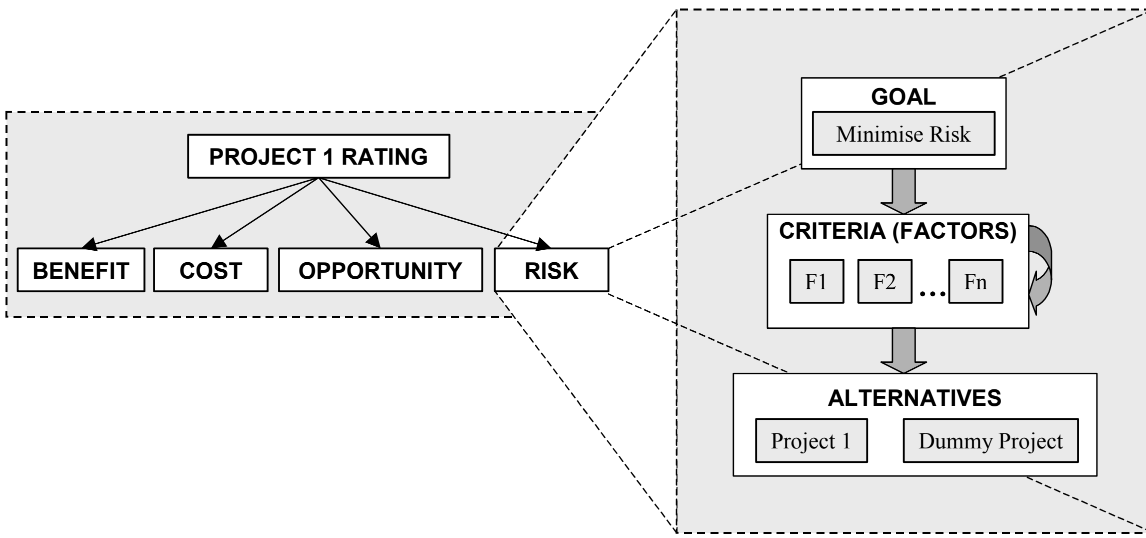


Figure 4.4 Typical Risk Factor Framework

There are three common ordinal scales used in attitudinal research, a 1-5 scale, 1-7 scale and a 1-9 scale. The 1-7 scale was adopted in the non-financial component of Module One as the 1-5 scale is considered inadequate for multi-variate analysis, and the 1-9 scale typically used in the AHP and ANP were considered too cumbersome for analysts of CPIs due to the great deal of uncertainty surrounding these projects. Figure 4.5 presents the 1-7 scale that was employed in the DSS design for the definition of non-financial factor importance, likelihood, and any interdependencies between non-financial factors (2, 4, and 6 can also be used as intermediate values on the scale).

Figure 4.5 The 1-7 Scale for Non-Financial Factors

Thus, the following information must be provided for the non-financial component of each model:

- *Risks*
  Factor name
  Importance (1-7)
  Likelihood (1-7)
  Interdependencies (1-7)

- *Opportunities*
  Factor name
  Importance (1-7)
  Likelihood (1-7)
  Interdependencies (1-7)

For the purpose of the DSS, importance has been defined as the degree of impact on the project should a particular factor occur, likelihood as the possibility of a factor actually occurring/impacting upon the project and interdependency as the existence of an influence of one factor on another (e.g. Political Instability risk may influence Approvals and Permit risk).

The non-financial component of Module One also provides the adapted Wang et al. (2002) risk factor framework to the analyst as a generic RFF that can either be used in addition to other identified risk factors, or simply on its own. However, the analyst remains responsible for the quantification of each factor's importance and likelihood, as these will change from project to project. If the generic RFF is included in the model, the DSS will also provide a generic set of interdependencies identified and quantified through the pilot study results. (Details of this pilot study are presented in Chapter 5). Table 3.12 provides a summary of the risk factors included in the generic RFF.

It can be seen that the non-financial component of Module One caters for DSS Requirements 9 and 10 by allowing for: 1) the identification of important non-financial factors contributing to uncertainties (both positively and negatively impacting); 2) the interdependency of non-financial factors (both financial and non-financial); and 3) the uncertainty associated with the importance, likelihood and interdependencies of these factors by use of a 1-7 linguistic scale.

4.3.3 Summary

Module One's purpose is to provide a structured framework for the development of individual Concession Project Investment models that will be used as input for Modules Two and Three. The module is divided into two separate components, financial and non-financial, in keeping with the data requirements of the primary performance measure, the ANP method. Collectively, the two components cater for DSS Requirements 1, 2, 3, 6, 7, 8, 9, and 10. Figure 4.6 presents a summary flowchart of the Model Definition Module.

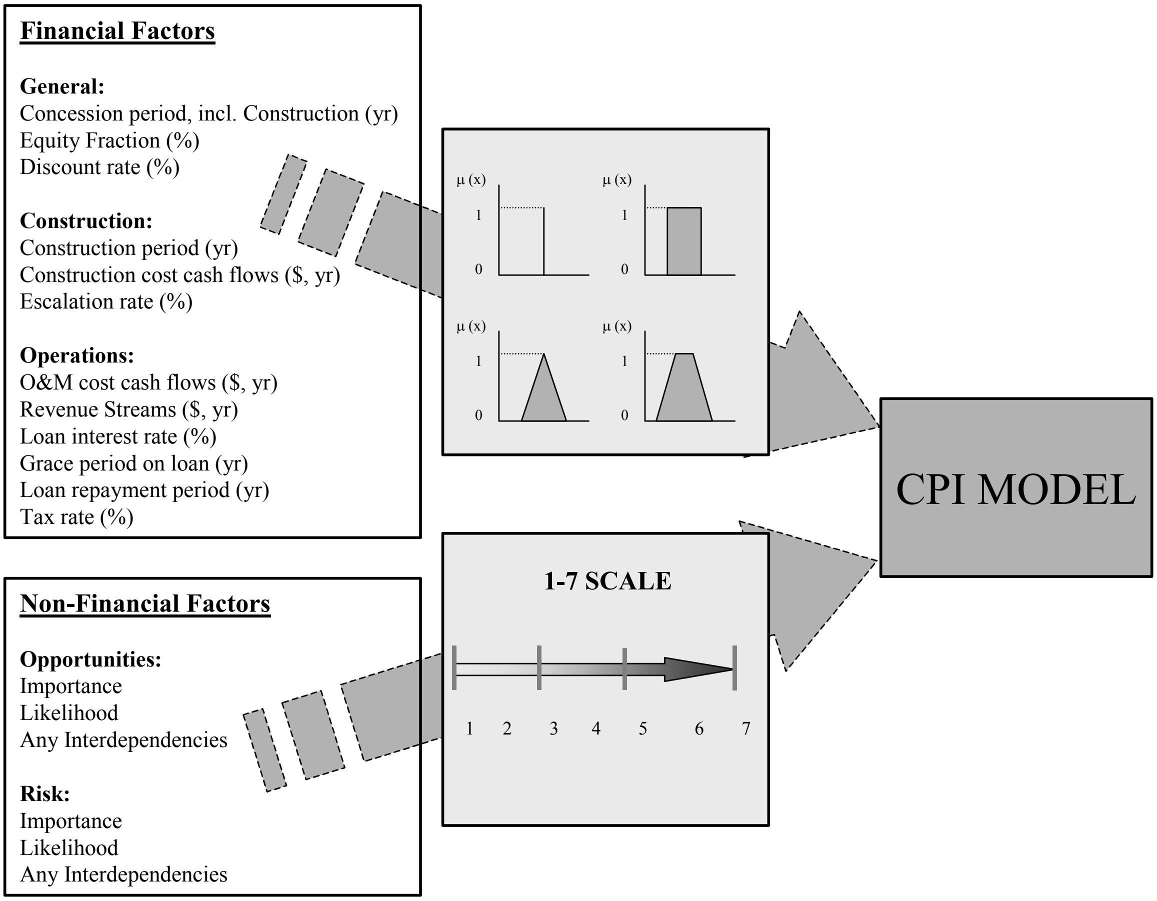


Figure 4.6 Model Definition Module Flowchart

4.4 MODULE TWO –MODEL EVALUATION AND RANKING

Module Two of the DSS architecture is the Model Evaluation and Ranking module. The purpose of this module is twofold: 1) to evaluate between one and five CPIs at a time, and 2) to rank the options based upon their primary performance measure value. The module calculates the following performance measures:

- **Primary Performance Measure**
  BO/CR (or adapted BCR) – ANP Project Rating

- **Secondary Performance Measures**
  Financial
  Equity Holder (includes financing considerations)
  Total project cost NPV ($)

Equity holder cumulative cash flows (non-discounted) ($)
Equity holder payback period (yr)
Equity holder NPV ($)
Equity holder B/C ratio
Equity holder IRR (%)

Lender
Debt Service Coverage Ratios (DSCR)

Government (Overall Project) (not including financing considerations)
Project cumulative cash flows (non-discounted) ($)
Project payback period (yr)
Overall project NPV ($)
Overall project B/C ratio

Non-Financial
Opportunity Rating (0-1)
Risk Rating (0-1)
Opportunity/ Risk Ratio (O/R)

The integration of the four selected techniques, within the confines of the ten DSS design requirements, way facilitated by minor refinements to their implementation within the module. These refinements, and the resulting financial and non-financial analysis carried out by Module Two, are detailed below.

4.4.1 Financial Formulae

All financial formulae were refined to incorporate uncertainty by means of possibility distributions. All variables in the formulae, with the exception of year values such as construction period, concession period and repayment period, were represented by possibility distributions. Thus it was necessary to incorporate the vertex method in calculations. However, with all possibility distribution types selected being composed of straight lines (i.e. single value, interval, triangular and trapezoidal), two α-cuts at $\alpha = 0$ and

$\alpha = 1$ were sufficient to define the resulting distribution (See Appendix A). Calculations were carried out iteratively for each alpha cut, with the maximum and minimum values being taken as the outer bounds of the resulting performance measure distributions.

The procedure followed by Module Two to evaluate the above listed financial performance measures for each project was divided into two parts: construction period and operations period. An assumption was made, that construction costs, revenue streams and OM costs could be grouped in these iterative, vertex method calculations. The financial analysis model was further modified by separating calculations into costs and benefits to obtain suitable results for inclusion in ANP ratings.

Construction Period

Module Two performs financial calculations throughout the construction period in the following manner.

All construction cost distributions are first read from a CPI project data file created in Module One, into annual cash flow distributions (A_j) for each year (j) of the construction period (c). From these distributions, non-discounted, cumulative cash flow distributions from the perspective of the equity holders *(EQUITYFLOWyr)* and the overall project *(PROJECTFLOWyr)* are calculated using Equation 4.1 (adapted from Bakatjan et al., 2003) and Equation 4.2. The Total Project Cost (*TPC*) including financing considerations is then calculated as per Equation 4.3 (adapted from Bakatjan et al., 2003), along with its net present value (*TPCNPV*) using Equation 4.4. The NPV of costs incurred by equity holders *(ECOSTNPV)* and the overall project *(PCOSTNPV)* are also calculated for use in NPV, B/C ratio and IRR calculations using Equation 4.5 (adapted from Bakatjan et al., 2003), Equation 4.6 and Equation 4.7.

It should be noted that since it is assumed that the grace period (G) will be at least equal to or greater than the construction period, the financial analysis of loans is not required throughout this period.

$$EQUITYFLOW_{yr} = -e \cdot \sum_{j=1}^{yr}\left[e \cdot A_j \prod_{k=0}^{j}(1+\theta_k)^{j-1} + (1-e)A_j(1+r)^{G-j+1}\prod_{k=0}^{j}(1+\theta_k)^{j-1}\right]$$

Equation 4.1

$$PROJECTFLOW_{yr} = -\sum_{j=1}^{yr}\left[A_j \prod_{k=0}^{j}(1+\theta_k)^{j-1}\right]$$

Equation 4.2

$$TPC = \frac{-EQUITYFLOW_C}{e}$$

Equation 4.3

$$TPCNPV = \sum_{j=1}^{c}\frac{\left[e \cdot A_j \prod_{k=0}^{j}(1+\theta_k)^{j-1} + (1-e) \cdot A_j \cdot (1+r)^{G-j+1}\prod_{k=0}^{j}(1+\theta_k)^{j-1}\right]}{(1+d)^j}$$

Equation 4.4

$$ECOSTNPV = e \cdot TPCNPV$$

Equation 4.5

$$PCOSTNPV = \sum_{j=1}^{c}\frac{A_j \prod_{k=0}^{j}(1+\theta_k)^{j-1}}{(1+WACC)^j}$$

Equation 4.6

$$WACC = d \cdot e + (1-e) \cdot r \cdot (1-t)$$

Equation 4.7

where:

$WACC$ = Weighted Average Cost of Capital

e = Equity fraction as a decimal

d = Discount rate as a decimal

c = Construction period in years

yr = Year of construction

θ = Escalation rate as a decimal

r = Interest rate as a decimal

t = Tax rate as a decimal.

Operations Period

The annual, equal debt instalment (*DI*) and annual straight-line depreciation (*DEP*) are then calculated from the *TPC* value using Equation 4.8 and Equation 4.9 (Bakatjan et al., 2003).

$$DI = (1-e)\cdot TPC \cdot \frac{r(1+r)^N}{(1+r)^N - 1}$$

Equation 4.8

$$DEP = \frac{TPC}{m}$$

Equation 4.9

where:

N = Debt repayment period in years

m = Operations period in years.

Throughout the operations period, Module Two reads the OM cost and revenue stream distributions into annual cash flow distributions, R_i and OM_i, which it then uses to calculate the non-discounted cumulative cash flows from the perspective of the equity holder (*EQUITYFLOW*) and the overall project (*PROJECTFLOW*) according to Equation 4.10 and Equation 4.11, respectively. The net revenue NPV is also calculated from both the equity holder's (*EREVNPV*) and overall project's (*PREVNPV*) perspective using Equation 4.12 and Equation 4.13. The overall project and equity holder B/C ratio *(PROJECTBC* and *EQUITYBC)* and overall NPV *(PROJECT NPV* and *EQUITYNPV)* performance measures are then calculated from these values according to Equation 4.14 to Equation 4.18. Equation 4.14 and Equation 4.17 were adapted from formulae reported in Bakatjan et al.

(2003). When using these formulae, it is important to note that the value of *DI* becomes zero, once the repayment period *N,* is completed.

$$EQFLOW_{yr} = -TPC + \sum_{i=1}^{yr}(1-t)(R_i - OM_i) + t\left[DI \times (1-(1+r)^{-(N-i+1)}) + DEP\right] - DI$$

Equation 4.10

$$PROJECTFLOW_{yr} = -TPC + \sum_{i=1}^{yr}(1-t)(R_i - OM_i) + t \cdot DEP$$

Equation 4.11

$$EREVNPV = \sum_{i=1}^{m}\frac{(1-t)(R_i - OM_i) + t\left[DI \times (1-(1+r)^{-(N-i+1)}) + DEP\right] - DI}{(1+d)^{i+c}}$$

Equation 4.12

$$PREVNPV = \sum_{i=1}^{m}\frac{(1-t)(R_i - OM_i) + t \cdot DEP}{(1+WACC)^{i+c}}$$

Equation 4.13

$$DSCR_i = \frac{(1-t)(R_i - OM_i) + t\left[DI \times (1-(1+r)^{-(N-i+1)}) + DEP\right]}{DI}$$

Equation 4.14

$$EQUITYBC = \frac{EREVNPV}{ECOSTNPV}$$

Equation 4.15

$$PROJECTBC = \frac{PREVNPV}{PCOSTNPV}$$

Equation 4.16

$$EQUITYNPV = -ECOSTNPV + EREVNPV$$

Equation 4.17

$$PROJECTNPV = -PCOSTNPV + PREVNPV$$

Equation 4.18

The remaining performance measures to be calculated by Module Two are the payback periods (*EQUITYPAYBACK* and *PROJECTPAYBACK*), and equity holder's IRR (*EQUITYIRR*). The equity holder and overall project payback periods are calculated as the year in which the respective non-discounted cumulative cash flows (*EQUITYFLOW* and *PROJECTFLOW*) pass from negative to positive (i.e. through zero). The equity holder's IRR is calculated by iteratively calculating the equity holder's NPV (*EQUITYNPV*) for varying discount rates. The IRR is equal to the discount rate at which the NPV changes from a negative to positive value (i.e. through zero).

The performance measures are then converted into their equivalent single values in order to ensure the user friendliness of the results. This conversion is achieved using Equation 4.19, which calculates the Centre of Gravity of the distribution in the *x*-direction (C_x), used to represent the equivalent single value of a distribution as shown in Figure 4.7.

$$C_x = \frac{2ac + a^2 + cb + ab + b^2}{3(a+b)}$$

Equation 4.19

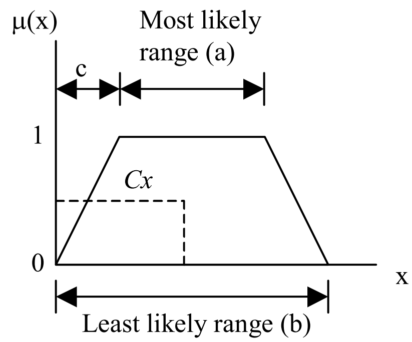


Figure 4.7 Possibility Distribution Centre of Gravity (Cx)

4.4.2 Non-Financial Formulae

The ANP technique was used to develop the overall risk and opportunity ratings of each CPI evaluated. However, as mentioned earlier, the implementation of this technique had to be modified in order to allow for analysts to be able to define a unique set of risk/opportunity factors for each project, where required. This means that, instead of creating one risk and one opportunities framework including all projects being analysed, Module Two must create separate ANP frameworks for the Risks and Opportunities of each individual project. To obtain meaningful results, the module must also introduce a Dummy project representing a "most risky" and "best opportunity" case project, respectively, to each of the frameworks, as a means of providing comparisons. In other words, each Dummy project is assigned a "likelihood" rating of 7 for all risk/opportunity factors contained in the framework. Test runs were performed using the SuperDecisions software to ensure that this technique of developing separate frameworks for individual CPIs using Dummy projects would give the same results as the original ANP method. The necessity of a Dummy project can be best explained by a description of the mathematical operations carried out by the Module.

Module Two represents each ANP framework as a supermatrix of the form shown in Figure 4.8. In this figure, W is a column stochastic matrix; W_{21} is a column vector of the priorities (i.e. factor importance) of Criteria with respect to the Goal (to minimise risk/ maximise opportunities); W_{32} is the matrix of column eigenvectors of Alternatives with respect to each Criterion (i.e. factor likelihood); and W_{22} is a matrix of column eigenvectors of interdependence amongst Criteria (factors). Hence, Module Two develops numerous of these supermatrices, from the importance, likelihood, and interdependencies of factors defined in Module One.

$$W = \begin{array}{r} \\ Goal\ (G) \\ Criteria\ (C) \\ Alternatives\ (A) \end{array} \begin{array}{c} \begin{array}{ccc} G & C & A \end{array} \\ \begin{pmatrix} 0 & 0 & 0 \\ W_{21} & W_{22} & 0 \\ 0 & W_{32} & I \end{pmatrix} \end{array}$$

Figure 4.8 Matrix Representation of Each Risk/Opportunity Framework

According to Saaty (2001), the synthesis of all interactions among the elements of W, a column stochastic matrix, is given by W^{∞} shown in Figure 4.9. The solution of W^{∞}, or the impact of the goal on the ranking of the alternative CPIs is given by the (3,1) entry of W^{∞}, $W_{32}(I-W_{22})^{-1}W_{21}$ (Saaty, 2001).

$$W^{\infty} = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ W_{32}(I-W_{22})^{-1}W_{21} & W_{32}(I-W_{22})^{-1} & I \end{pmatrix}$$

Figure 4.9 Matrix Representation of W^{∞}

The reason for including a Dummy project in each supermatrix, is that entry (3,1) of W^{∞} (the solution of the supermatrix), is, in fact, a stochastic column matrix. This means that each column of the matrix sums to 1. In other words, if only one project was being evaluated in the framework, the project would automatically receive a maximum rating of 1. The Dummy project representing the worst/best case scenario is therefore introduced and assigned a maximum likelihood value of 7 for each criterion in matrix W_{32}, for the sole purpose of providing a comparison for the project being analysed. Each supermatrix developed is then raised to powers until the element values of the matrix change by less than 0.0001 with each iteration. The Risk and Opportunity ratings for the projects are then calculated by dividing its own rating by the Dummy Project's rating (representing worst/best case scenario) both taken from the (3,1) entry of each supermatrix. Thus, Risk and Opportunity ratings between 0 and 1 are obtained, where 0 represents no risk/opportunity, and 1 represents maximum risk/opportunity (worst/best case scenarios).

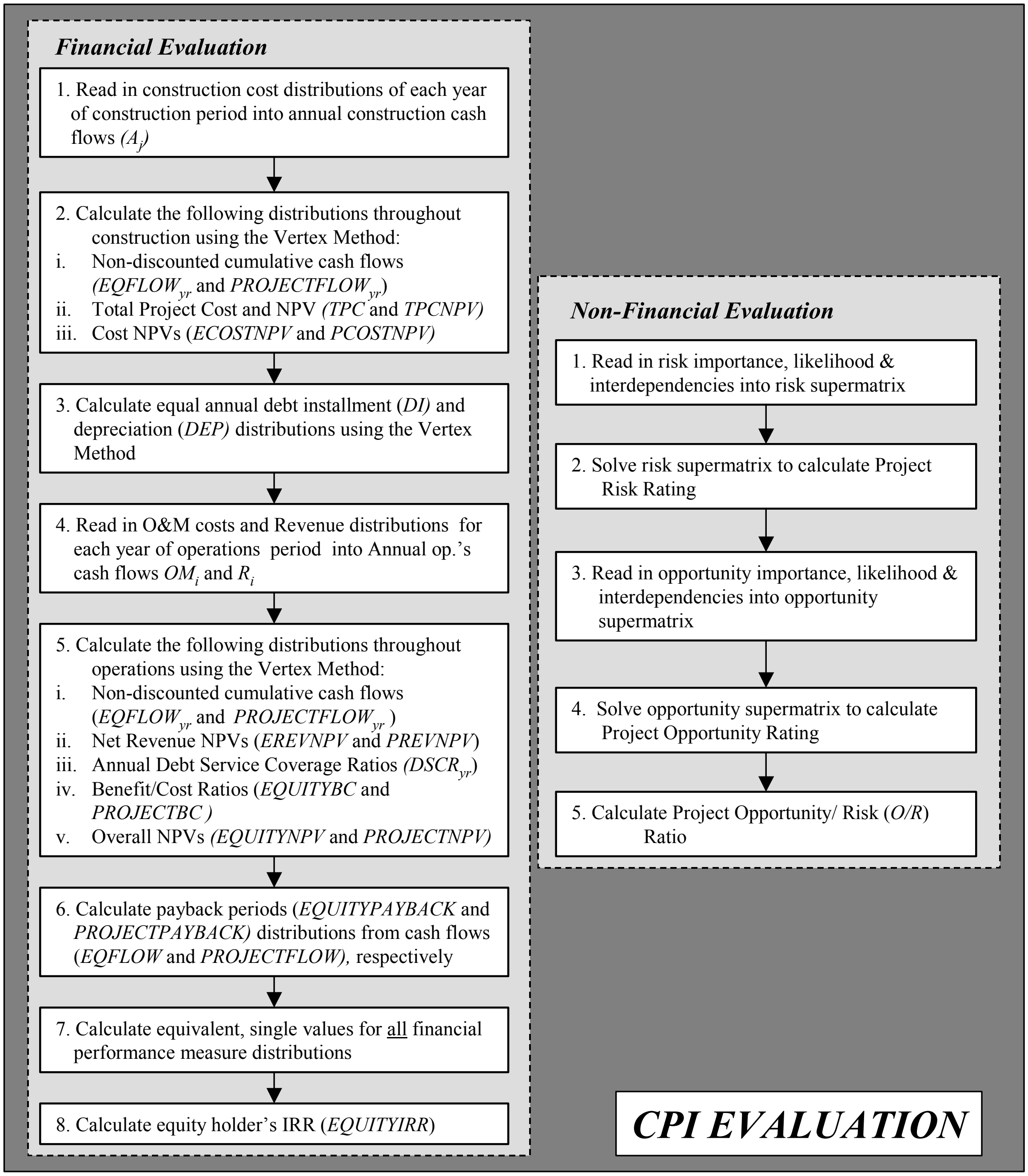


Figure 4.10 CPI Evaluation Methodology

4.4.3 Summary

A summary flowchart of the overall structure of Module Two is presented as Figure 4.11, whilst Figure 4.10 summarises the methodology followed by the module to evaluate the financial and non-financial aspects of a set of projects. The culmination of this Module is the ranking of the projects according to their BO/CR ratings (or adapted B/CR ratings). The BO/CR rating is simply calculated from the product of the project's B/C ratio and the O/R ratio from the financial and non-financial evaluations of the projects, respectively. Finally, the Module presents all results in both tabular and graphical form.

Module Two essentially employs the selected financial model, mathematical modelling technique, decision making technique, and the risk factor framework to evaluate and rank the models defined using Module One of the DSS. Thus Module Two, in conjunction with Module One, successfully enables the DSS design to achieve design requirements 1, 2, 3, 5, 7, and 8. In addition, Module Two caters for design requirement 4, by evaluating a number of varied performance measures that would be of interest to the main parties of a CPI (equity holders, creditors and government).

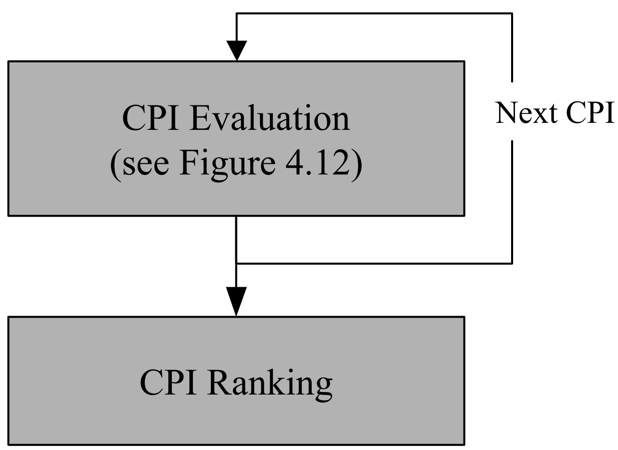


Figure 4.11 Module Two Flowchart

4.5 MODULE THREE – SENSITIVITY ANALYSIS

The purpose of the Sensitivity Analysis Module is to assist the analyst in comparing the sensitivity of selected projects to changes in any single factor (financial or non-financial) common to all the projects selected. It is not the purpose of this module to perform Scenario Analysis. Scenario Analysis can be performed simply by editing existing models in Module One, to create different project scenarios, and then evaluating and comparing the models using Module Two. Thus, the three modules collectively satisfy design requirement 6.

The Sensitivity Analysis Module is designed as a third module to the DSS that can only be accessed via Module Two. Analysts can select the models to be analysed from the list of models evaluated as part of Module Two (i.e. not all projects have to be included in the sensitivity analysis). Thus, the module caters for the analysis and comparison of between one to five projects at a time. The module only analyses factors common to all models selected, and can only analyse one factor at a time. Analysts must therefore input the following data:

- Project(s) to be analysed;
- Factor to be analysed (either financial or non-financial); and
- Range of the analysis.

The range of analysis is defined differently for financial and non-financial factors:

- Financial - If a financial factor, such as the interest rate or a cash flow, is being analysed, the range is defined as being between a negative %age of the original factor's value, and a positive percentage of the original factor's value.
- Non-Financial - If a non-financial factor is analysed, the module automatically analyses for the entire range of likelihood values (1 to 7) for the selected factor.

Module Three then uses the above input from the analyst to run the sensitivity analysis. Module Three calls Module Two to evaluate each project repetitively, according to the changes in the selected factor, throughout the defined range. Results are presented both in tabular and graphical form, and again differ according to the type of factor selected. If a financial factor has been selected, the results will be of % change in selected factor vs. % change in equity holder's NPV (*EQUITYNPV*). If a non-financial factor has been selected, results will be of the above set changes to that factor, vs. % change in the project's risk/opportunity rating as appropriate.

A summary flowchart of the processes followed by Module Three to perform sensitivity analysis on a set of projects is included as Figure 4.12.

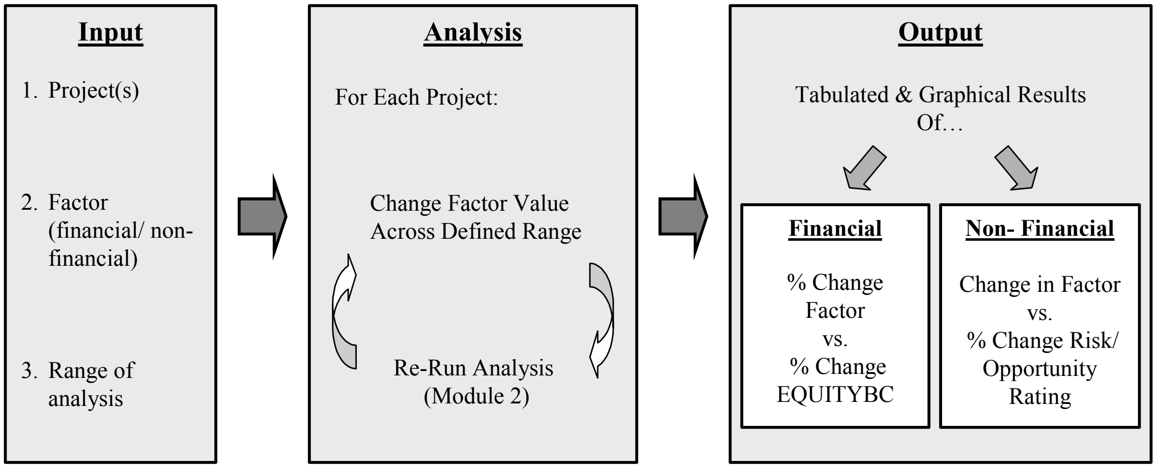


Figure 4.12 Module Three Flowchart

4.6 SUMMARY

The DSS architecture, consisting of the Model Definition Module, Model Evaluation and Ranking Module, and Sensitivity Analysis Module has been detailed in this chapter. The purpose, structure and implementation of these three modules were predominantly determined by the selection of the ANP Rating method as the primary performance measure for the DSS. However, these were also substantially affected by the mathematical modelling, financial analysis modelling, and decision-making techniques, as well as the risk factor framework selected for implementation in the final design.

The key objective of this research dissertation was to develop an effective and efficient DSS that would cater for all ten requirements identified in the literature review. Table 4.1 outlines how each of these ten design requirements have been met by the final DSS design.

Table 4.1 How DSS Requirements are met by DSS Design

Design Requirement	***Module***
1. Various industries and evaluation methods	1 & 2
2. Multiple project phases/sub-phases;	1&2
3. Cash flow characteristics	1 & 2
4. Time dependent project variables	1 & 2
5. Varied economic performance measures (e.g. Benefit-Cost Ratio, NPV, IRR)	2
6. Uncertainty	1 & 2
7. Comparison of project alternatives/scenarios (incl. Sensitivity Analysis)	1, 2 & 3
8. Cash flow characteristics	1 & 2
8. Both detailed and generalised aspects of projects	1 & 2
9. Important non-financial (risk and opportunity) factors	1 & 2
10. Interdependency of factors (both financial and non-financial)	1 & 2

CHAPTER 5

PILOT STUDY

5.1 GENERAL

The three main requirements of the DSS with regard to modelling the non-financial side of a concession project, are to cater for: 1) Uncertainty; 2) The identification of the most critical non-financial factors contributing to uncertainties (risks and opportunities); and 3) The identification of interdependencies that exist between these factors. It is important to reiterate at this point, that, although opportunities are allowed for by the DSS design, it was outside the scope of this research dissertation to develop a generic CPI opportunities factor framework. For this reason Chapter 5 focuses purely on the development and verification of the DSS's generic risk factor framework (RFF). The first two of the three above-mentioned requirements have already been fulfilled in the DSS design, while the third has only been partially fulfilled, as explained below.

The first requirement of catering for uncertainty was met through the adoption of a 7-point linguistic scale for the definition of risk factor importance, likelihood and interdependencies (see Section 4.3.2). The second requirement was addressed in Chapter 3, where the risk factor framework developed by Wang et al. (2002) was reduced into a framework of 12 risk factors (4 most critical factors on project, market, and country level), and was implemented as the DSS's generic RFF in Chapter 4.

The third requirement was only partially addressed in Chapter 3, through the selection and adaptation of the Risk Influence Matrix (RIM) developed by Wang et al. (2002). The original RIM identifies interdependencies of individual lower-level risk factors on individual higher-level risk factors. However, it is believed that other significant interdependencies exist between same-level factors and possibly even of higher-level factors on lower-level factors. For example, the country level risk, “Political Instability”, could well be influenced by the market level risk, “Inflation and Interest Rates”. Further, the original RIM makes no attempt to quantify the identified interdependencies. Thus, the adapted RIM, described in Chapter 3, only partially addresses this 3rd non-financial modelling requirement. Thus, it was deemed necessary to collect additional data to verify, adapt and quantify the interdependencies contained in the RIM for application as part of the DSS’s generic RFF.

There are many methods of collecting data. Survey research is one frequently used method in management research spheres, which enables questions to be asked directly through interviews (telephone or face-to-face), questionnaires and case studies (Fellows and Liu, 1997). This method is time and resource efficient when the researcher knows exactly what is required and how to measure it (Sekeran, 1992). Thus, survey research was selected as the data collection method for the pilot study.

This chapter outlines the objectives, methodology, results and analysis of the questionnaire conducted as part of this research dissertation.

5.2 OBJECTIVES

The objectives of the questionnaire were three fold:

1. To verify the risk factor framework and original RIM developed by Wang et al. (2002);
2. To adapt the RIM by identifying all significant factor interactions, including those previously identified by Wang et al. (2002); and
3. To quantify all identified factor interactions in the adapted RIM.

5.3 PILOT STUDY – DEVELOPMENT

5.3.1 Sampling

Sampling Criteria

Cluster sampling was selected as the method of data collection for the pilot study. Cluster sampling involves three steps: 1) dividing the population into clusters; 2) obtaining a simple random sample of the clusters; and 3) using all members of the clusters as the sample (Weiss, 1995). This method is suitable when populations are widely scattered and resources are limited. However, it should be noted that if the clusters did not reflect the population, this method would not be suitable.

The key criterion for sampling was an individual's adequate experience on, or demonstrated knowledge of, CPI or international concession projects. Thus, the population was divided into two clusters from which samples were taken: 1) Industry, and 2) CPI Researchers.

Due to the limited extent of concession project experience in industry, and the similarities in risk profiles of international and concession projects, the industry sub-sample was selected according to the criteria of international project experience. To a lesser extent, the selection was also based upon achieving a spread of participants playing a variety of roles on international projects, i.e. consultants, contractors and investors. Respondents in this sub-sample were specifically asked to complete the questionnaire based on their knowledge of international projects.

There are a good number of researchers worldwide who actively research and publish in the area of concession projects. As such, the second sub-sample was selected according to the researcher's demonstrated knowledge of concession projects by way of published papers and texts.

A two-tailed t-test was performed on results from the two sub-samples at the 0.05 significance level and found the means to be statistically different on only one of a total 50 interdependencies quantified. Thus, it was seen reasonable to combine the two sub-samples into the one sample, thereafter called the sample (see Figure 5.1). Although it was obvious from the pilot study results that there were differences in opinion between consultants, contractors and investors, the sample size of these groups was not large enough to be able to determine any statistical differences between responses (e.g. only one financial investing company was sampled).

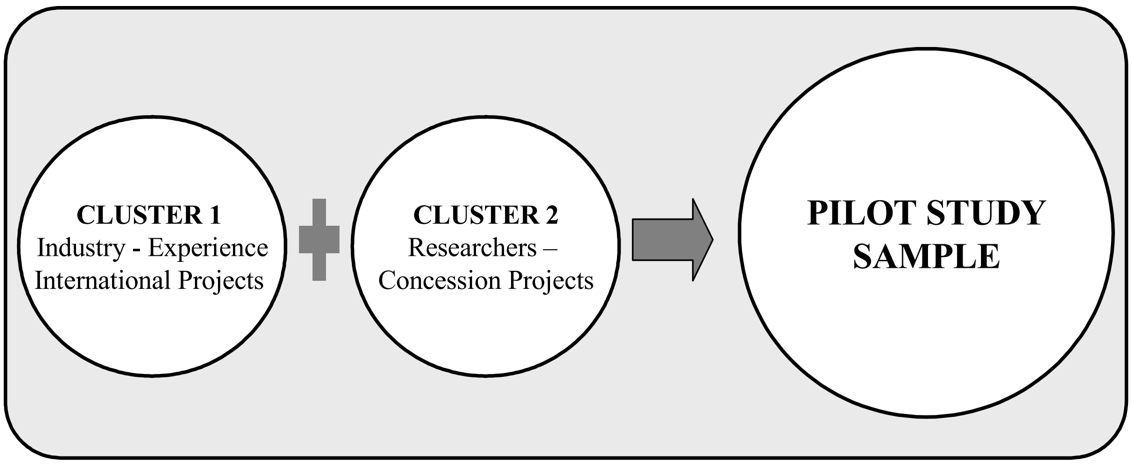


Figure 5.1 Pilot study sampling

Preliminary Interviews

Before the questionnaire was disseminated, pilot interviews were conducted with four industry participants in order to verify assumptions made in developing the adapted RIM contained in the questionnaire, and to ensure its suitability and user friendliness. These four (4) participants were well experienced in both the design and project management of international projects. Independent interviews of between one, and one and half hours were conducted with each participant and covered information pertaining to the participant's experience in international projects (E.g. number of international projects worked on, project host countries, types of projects, role/capacity), the overall user friendliness of proposed survey design and a review of the adapted RIM. This lead to the refinement of the adapted RIM through opening and closing of various cells according to the recommendations given by participants. More details of the refinements resulting from these preliminary interviews are provided in Section 5.3.3.

Final Sample

The final sample group for the questionnaire consisted of:

- 21 industry participants from consulting, contracting and financing backgrounds, with experience in international projects in the following countries: UK, Europe, Canada, USA, Australia, NZ, New Caledonia, PNG, Philippines, Japan, China, Hong Kong, Malaysia, Singapore, Indonesia, Thailand, India, Vietnam, Brunei, Pakistan, Sri Lanka, UAE, Sudan, Egypt, Mauritius and South Africa; and

- 15 researchers with considerable knowledge of concession projects in the USA, Canada, China, Hong Kong, Singapore, Taiwan, Thailand, Turkey, Australia and the UK.

Industry participants provided first-hand experience on high risk, international projects from a consulting, contracting and financing perspective, while researchers contributed their wide exposure to concession projects around the world. Based on this high level of experience and expert knowledge, we can assume that their opinion reasonably represents the larger population.

5.3.2 Questionnaire Design

A questionnaire is a pre-formulated, written set of questions to which respondents record their answers, usually within rather closely defined alternatives. Two separate questionnaire designs, entitled “International Project Risk Interaction” and “Concession Project Risk Interaction”, were developed for the industry and researchers sub-samples, respectively. The two questionnaires were purposefully similar. Both were limited to a two page length, in an attempt to minimise completion time and increase response rates. The first page of each questionnaire contained the following:

- Brief background on research topic;
- Tabulated listing and description of the 12 most critical risk factors, as identified by Wang et al., 2002 (Table 1); and

- Instructions on how to fill out the questionnaire (including an example).

The response sheet (page 2) of the questionnaire was designed to contain all required response information for ease of return by fax or email. This page was divided into three sections: 1) Contact details, 2) Scale of influence (Figure 5.2), and 3) Adapted RIM.

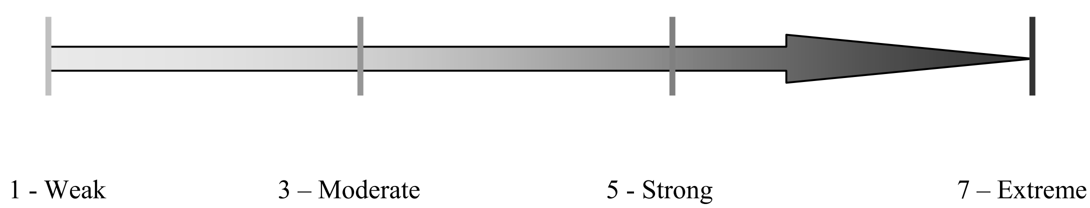


Figure 5.2 Scale of Influence (2, 4, 6 can also be used)

Different contact details were requested of the respective sub-samples and were used to create a profile of the respondents' risk perception, i.e. level of experience on international projects or in concession project research. The same adapted RIM was included in both questionnaires in the hope that the results gained from the two sub-samples would be comparable and thus provides verification that the risks faced on concession projects are much the same as those encountered on international projects. If this were the case, it would be reasonable to culminate results from the two sub-samples into the one sample thereafter.

The preliminary version of the adapted RIM, shown as Table 5.1, was developed based upon interdependencies identified by Wang et al. (2002), and various other interdependencies considered significant by the author through the literature review. All cells in the matrix where no significant interdependency existed, were shaded; while cells where interdependencies could possibly exist, were left blank. These blank cells were to be filled with a linguistic rating of influence from the 1-7 scale, shown as Figure 5.2. The selection of this scale is justified in Chapter 4.

It was decided to use a direct data entry method to quantify influences rather than pairwise comparisons, due to the significantly lower number of decisions required by this method. For example, in this particular application: a simple ANP structured risk factor framework, containing two projects, one goal ("To minimise risk"), and 12 criteria, not including any interdependencies, would require 78 pairwise comparisons compared to just 36 direct data entries. This is more than double the number of decisions required by direct data entry.

Table 5.1 Adapted Risk Influence Matrix - Preliminary Version

Direction of Influence	C1- Approval and Permit	C2- Change in Law / Justice Reinforcement	C3 - Corruption	C4 - Political Instability	M1 - Local Partner's Creditworthiness	M2 - Corporate Fraud	M3 - Termination of Joint Venture	M4 - Inflation and Interest Rates	P1 - Cost Overrun	P2 - Improper Design	P3 - Improper Quality Control	P4- Improper Project Management
C1 - Approval and Permit												
C2 - Change in Law / Justice Reinforcement												
C3 – Corruption												
C4 - Political Instability												
M1 - Local Partner's Creditworthiness												
M2 - Corporate Fraud												
M3 - Termination of Joint Venture												
M4 - Inflation and Interest Rates												
P1 - Cost Overrun												
P2 - Improper Design												
P3 - Improper Quality Control												
P4 - Improper Project Management												

N.B. Please leave blank where you feel that no influence exists.

5.3.3 Interviews: Refinement of Questionnaire Design and Adapted RIM

Interviews with four industry participants were first conducted in order to ensure the suitability, validity and user friendliness of the international risk questionnaire. These interviews resulted in the following modifications to both questionnaires:

- More detailed description of risk factors in Table 1;
- Re-wording of example on how to fill in the questionnaire;
- The addition of a "0" and "?" rating to distinguish between the case where the respondent believes there is no influence ("0") and where they are unsure or feel unqualified to answer ("?");
- The lighter shading of shaded cells to allow respondents to place a value in any shaded cell which they believed represented a significant influence;
- The addition of a comments section at the bottom of the response sheet;
- The opening of a number of cells; and
- The shading of some other cells.

The refined versions of the adapted RIM were included in the two questionnaires presented as Table 5.2 and Appendices B and C, respectively.

Table 5.2 Adapted Risk Influence Matrix - Refined Version

Direction of Influence	C1- Approval and Permit	C2- Change in Law / Justice Reinforcement	C3 - Corruption	C4 - Political Instability	M1 - Local Partner's Creditworthiness	M2 - Corporate Fraud	M3 - Termination of Joint Venture	M4 - Inflation and Interest Rates	P1 - Cost Overrun	P2 - Improper Design	P3 - Improper Quality Control	P4- Improper Project Management
C1 - Approval and Permit												
C2 - Change in Law / Justice Reinforcement												
C3 – Corruption												
C4 - Political Instability												
M1 - Local Partner's Creditworthiness												
M2 - Corporate Fraud												
M3 - Termination of Joint Venture												
M4 - Inflation and Interest Rates												
P1 - Cost Overrun												
P2 - Improper Design												
P3 - Improper Quality Control												
P4 - Improper Project Management												

N.B. Please place a "?" where unable to answer, or write in shaded boxes where appropriate.

5.4 PILOT STUDY – IMPLEMENTATION

5.4.1 Questionnaire Dissemination & Collation of Responses

Questionnaires were sent to the researchers sub-sample via email, while questionnaires for the industry sub-sample were distributed via preliminary telephone interviews, followed by the emailing or faxing of the questionnaires. A total of 15 responses were received from industry and 10 from researchers, giving an overall response rate of 69.4%. All responses were received by fax or email. Table 5.3 summarises the distribution and feedback received from the questionnaire.

Table 5.3 Questionnaire Response Summary

	Sub-Sample Industry	***Sub-Sample Researchers***	***Total Population***
No. Sent	21	15	36
No. Received	15	10	25
Response Rate	***71.4 %***	***66.7 %***	***69.4 %***

5.4.2 Data Analysis

Following the receipt of the questionnaires, the adapted RIM was further refined for application as the DSS generic RFF through basic statistical analysis. It is worth mentioning that the main objective of data analysis is to verify the proposed risk factor framework and quantify all identified factor interactions, rather than conducting a rigorous statistical analysis. The data analysis procedure is detailed in the following sections and summarised in Figure 5.3.

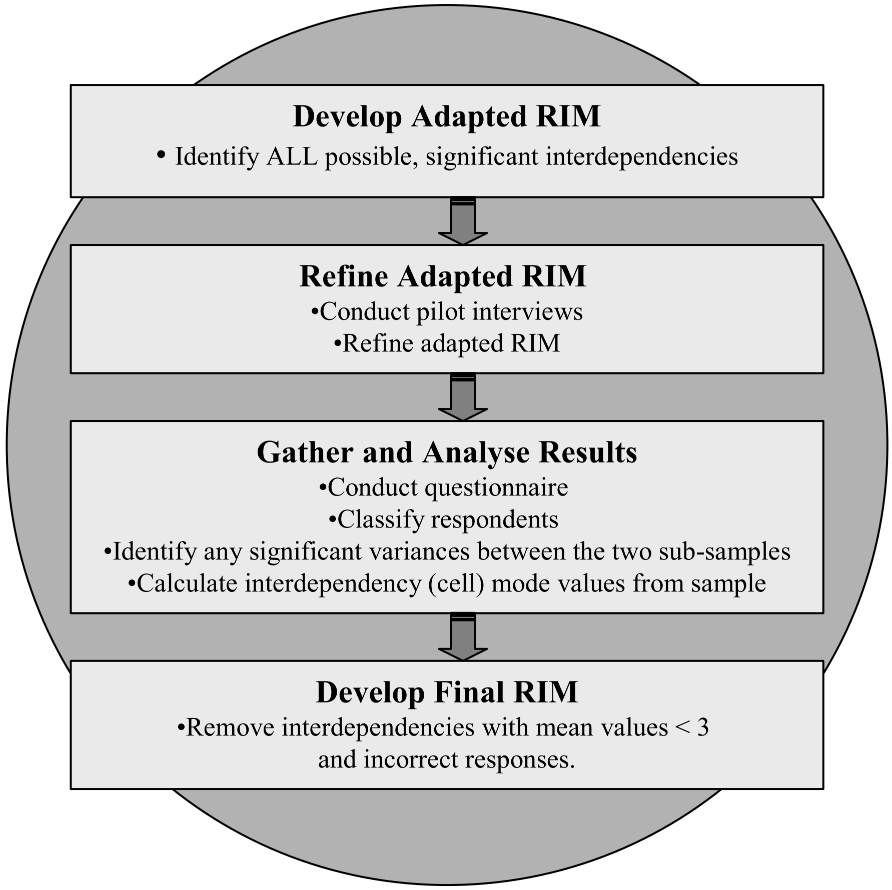


Figure 5.3 Data Analysis Procedure

Classification of Respondents

Industry Sub-Sample – International Project Experience

A total of fifteen responses were received from the industry sub-sample. As shown in Figure 5.4, the roles of the respondents on international projects were classified into three categories: consultant (60%), contractor (33%) and investor (7%). The responses received indicated a difference in perspective between these three categories of respondents. However, due to the small sample size of each category, the statistical significance of differences could not be determined. As expected, the investor was most concerned about the effects of project and market level factors on factors such as cost overrun, interest and inflation rates, and the termination of the joint venture; whereas consultants weighted highly any impact upon project level factors; and contractors concentrated on country level and market level factors, such as change in law, and termination of joint venture.

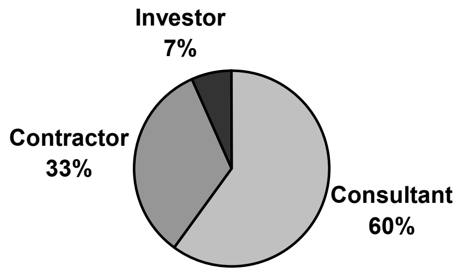


Figure 5.4 Respondent Role Profile

The variance in perspective can easily be explained by the differing roles and responsibilities of the respondents. Investors are primarily concerned with the expected return on their investment and any factors, which could impact upon these financial returns. Consultants are usually involved with the design of the project. Thus, any risks impacting upon project level factors would be important to the respondents of this category. Finally, the contractors are typically part of the project consortium. They carry greater responsibility, and hence greater risk, than do the consultants. Contractors are therefore concerned about all factors impacting upon the long-term viability of the project (e.g. country level and market level environment). This is supported by the following comment from one respondent:

> *"The influences are different depending on whether one is looking at the design or construction end of the industry. Country and market level factors affect the construction end while project level issues are felt greater at the design end."*

The respondents' level of experience on international construction projects was grouped into four categories: Group 1 represented respondents with experience on less than 5 international projects; Group 2 on 5 to 10 projects; Group 3 on 10-20 projects; and Group 4 represented respondents with experience on more than 20 international projects. Over 40% of respondents had experience on only 0 to 5 international projects, with the average experience of respondents being 8.75 projects. The profile of the respondents in regard to their experience on international projects is presented in Figure 5.5.

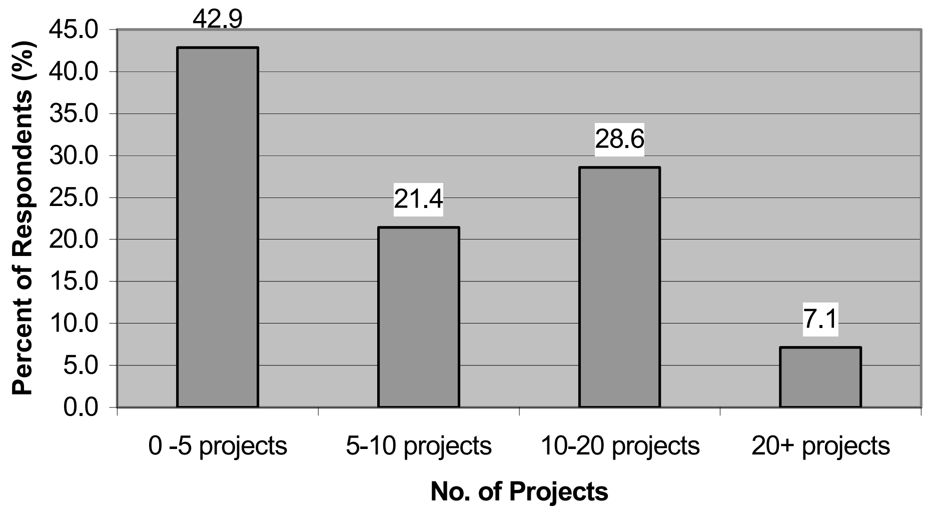


Figure 5.5 Respondent's International Project Experience Profile

Respondents were also asked to detail the host countries of projects they had been involved in. It was found that the experience of this sub-sample spanned across a large (23) and vast range of countries worldwide. Table 5.4 presents the respondent profile in terms of project host country. Seven out of the fifteen respondents were employed by companies that have been involved in international Public Private Partnerships (PPPs). This PPP involvement spread across a variety of project types (i.e. road, rail, airports, power plants, water and wastewater) and countries (i.e. UK, US, Canada, Australia, Egypt, Sudan, Pakistan, Asia, Hong Kong, and Europe).

Table 5.4 Frequency of Responses by Project Host Country

Country	Frequency of Responses*
Australia	2
New Caledonia	1
Indonesia	5
Philippines	1
New Zealand	2
Hong Kong	1
Singapore	3
UK	2
Ireland	1
Papua New Guinea (PNG)	1
China	4
United Arab Emirates (UAE)	2
South Africa	1
Mauritius	1
USA	2
India	3
Egypt	2
Malaysia	3
Thailand	1
Vietnam	2
Sri Lanka	1
Canada	1
Germany	1

** A respondent may have experience in several countries.*

Researchers Sub-Sample – Concession Project Experience

A total of ten responses were received from researchers of varying levels of knowledge of concession projects (see Figure 5.6). Respondents were asked to give details as to the types of concession projects they had researched (e.g. road, rail, water). Figure 5.6 presents a profile of the respondents' knowledge of concession projects according to the types of projects researched. It is evident from this profile that the respondents had most knowledge on road and power plant projects.

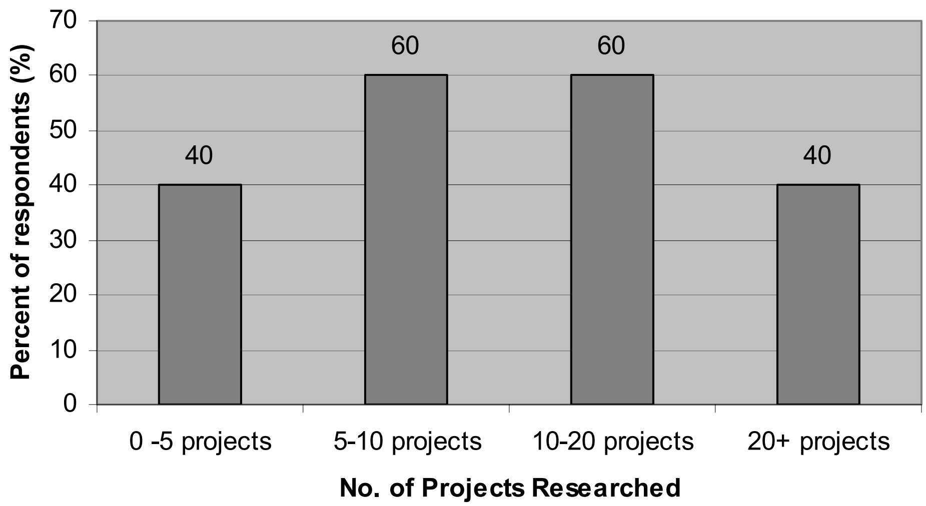


Figure 5.6 Respondents' Concession Knowledge Profile

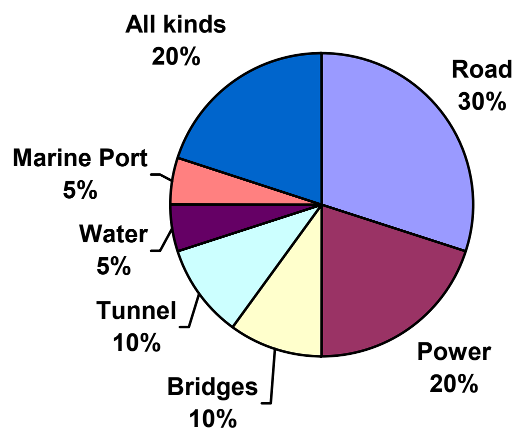


Figure 5.7 Respondent Profile by Project Type

The respondents from this 2nd sub-sample had researched projects hosted by a wide range of countries (see Table 5.5). It is evident from Figure 5.8 that more than half of the respondents (55.6%) focussed their research on concession projects in Asia, heralding a keen interest in concession contracts as a means of providing infrastructure in this region, predominantly consisting of developing countries.

Table 5.5 Respondents' Knowledge of Concession Projects by Host Country

Country	No. Researchers
USA	4
Canada	4
Turkey	1
Australia	1
Mexico	1
Caribbean	1
Asia	3
China	4
Hong Kong	3
Taiwan	1
Malaysia	1
Thailand	1
Philippines	1
Indonesia	1

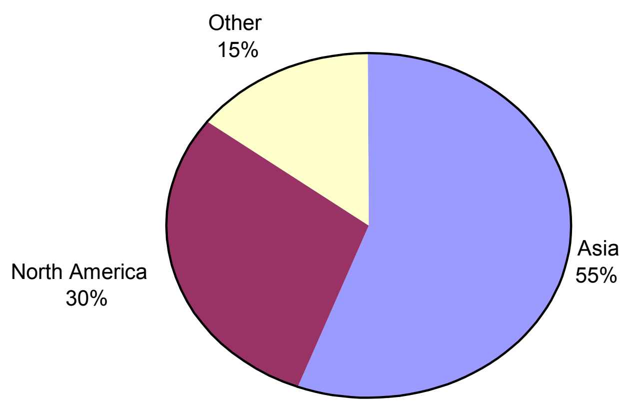


Figure 5.8 Respondent Profile by Project Host Country/Region

Comparison of Industry vs. Researcher Sub-Samples

When comparing the level of experience of the two sub-samples, it can be seen that the researchers had knowledge of a greater number of projects than did the industry respondents. This could be attributed to the difference in level of involvement on the projects (i.e. observing vs. participating). However, the two sub-samples had experience/knowledge of a similar profile of host countries and types of projects.

5.4.3 Development of Final Risk Influence Matrix

According to Weiss (1995, p102), the mean is the most commonly used measure of central tendency. Thus, once all responses had been collated, the mean values of each of the 50 interdependencies were calculated for each sub-sample. This was also in accordance with a fuzzy based approach to collaborative decision making developed by Yang et al. (2001), which used a weighted mean average of expert opinions (in this case, all respondents' opinions were weighted equally). As mentioned earlier, these mean values of the two sub-samples were then compared using the non-pooled t-test (two-tailed) as recommended by Weiss (1995), to test for statistically significant differences between the means of the two sub-samples at the 0.05 significance level (see Appendix D). This test found only one (Political Instability's influence on Inflation and Interest Rates) out of 50 mean values to be statistically different, thus validating the assumption that the two sub-samples could be combined together to form the one sample from which mean interdependency values could be taken. These results also support the assumption that the risk profiles of large scale international projects and concession projects are similar, particularly with regard to the interdependencies that exist between risk factors.

All mean interdependency values less than 3 (moderate) were then removed from the adapted RIM as they represented influences with less than moderate strength, and would not have a significant affect on results. Hence, the following cells in the matrix became shaded:

- Column C2, Rows M2, P2, P3 and P4;
- Column C3, Row M4; and
- Column M4, Row P2.

Each mean interdependency value was then rounded to the nearest integer value and entered into the final version of the adapted RIM (see Table 5.6). A few respondents suggested that other factors should have been included in the matrix, specifically: Market

Demand Fluctuation, Currency Fluctuation and Construction Delays. However, these risk factors were previously included in Wang et al.'s (2002) RFF, but were not ranked amongst the top four (4) most critical factors on their respective levels (project, market, or country). Thus, the factors were not included in the final version of the matrix due to a lack of supporting evidence.

Table 5.6 Final Risk Influence Matrix

Direction of Influence	C1- Approval and Permit	C2- Change in Law / Justice Reinforcement	C3 - Corruption	C4 - Political Instability	M1 - Local Partner's Creditworthiness	M2 - Corporate Fraud	M3 - Termination of Joint Venture	M4 - Inflation and Interest Rates	P1 - Cost Overrun	P2 - Improper Design	P3 - Improper Quality Control	P4- Improper Project Management
C1 - Approval and Permit		4	5	5								
C2 - Change in Law / Justice Reinforcement			3	5								
C3 – Corruption	4			5								
C4 - Political Instability		4						4				
M1 - Local Partner's Creditworthiness			3	4		4			3			
M2 - Corporate Fraud			4	3	3							
M3 - Termination of Joint Venture	4	4	3	4	5	5		3	5			
M4 - Inflation and Interest Rates				5								
P1 - Cost Overrun	4	4		4	3	4	4	5		5	5	5
P2 - Improper Design						3					3	4
P3 - Improper Quality Control			4			4						5
P4 - Improper Project Management			3			4						

5.5 APPLICATION

The objectives of this pilot study were to verify, adapt and quantify the adapted RIM, as in its original state it only partially addressed the DSS's third non-financial requirement (identifying the interdependencies that exist between factors). The intended application of the final RIM was to structure the DSS's generic RFF by identifying and quantifying the interdependencies between risk factors.

Group Decision Making in Practice

Complex decision problems, such as the decision to invest in a concession project, involve selecting the best solution from a set of alternatives based on its ability to satisfy a number of quantitative and qualitative criteria. In most cases, the decision maker is not able to effectively assess all criteria on all options and must seek advice from various experts.

As shown by the pilot study results above, there will typically be some degree of variability in these expert opinions, as different people, coming from different situations, will have different perceptions of the importance and severity of the different criteria, especially when the criteria are subjective. The Delphi Method is a widely used formal structured approach to group decision making which seeks an eventual consensus of a panel of expert opinions through several rounds of intensive questionnaires with controlled feedback to respondents between rounds (Dalkey and Helmer, 1963). Formal group decision-making techniques such as the Delphi Method could be implemented by decision makers to generate risk and opportunity factor importance, likelihood, and interdependency values for input into the DSS. A review of 27 Delphi Method studies by Rowe and Wright (1999) found that the accuracy of opinions tends to increase with Delphi rounds and hence the Delphi method outperforms statistical groups as well as unstructured interacting groups. However, the difficulty with this and other iterative group decision-making techniques is in deciding when to terminate consultation, and what values to select from the various opinions provided.

In most cases, the decision maker will terminate discussions when sufficient consensus is achieved. Lang (1998) found that it may take anywhere between two and ten rounds of discussion to reach a reasonable consensus. Consensus can be measured objectively using: range measures such as the interdecile or interquartile ranges; deviation measures such as variance, standard deviation, coefficient of variation; the Gini coefficient; or using any other measures developed from these such as the Ventana Coefficient of Consensus (VCC), or the Modified Coefficient of Consensus (MCC). The reader is referred to Deer and Fan

(2002) for a more detailed description of these measures. Deer and Fan's (2002) paper also contains a numerical example comparing various objective measures of consensus to the subjective assessment of 10 decision makers, voting on a five point scale. This found that the standard deviation, coefficient of variation, Gini coefficient, VCC and MCC all compare well to the judgement of human decision makers, with the MCC achieving the closest. However, when consensus does not seem possible, the decision maker may terminate discussions when respondents are no longer changing their opinions and a stable state in responses has been reached.

Once discussions have been terminated, the decision maker must then decide which values to select from the sometimes, divergent opinions of respondents. Most commonly, weightings will be applied to the various opinions of respondents before calculating the mode, median or arithmetic mean values such as in Yang et al. (2001). Rowe and Wright (1999) found the median and mean were most commonly used as the response value in their review of 27 Delphi studies.

5.6 SUMMARY

The identification of interdependencies that exist between factors (DSS Requirement 10) was only partially addressed in Chapter 3, through the selection and adaptation of the Risk Influence Matrix (RIM) developed by Wang et al. (2002). It was therefore deemed necessary to conduct a pilot study to verify, adapt and quantify the interdependencies contained in the RIM for application as part of the DSS's generic RFF. Survey research was selected as the data collection method for the pilot study. This chapter has looked at the objectives, methodology, results and analysis of the questionnaire conducted as part of this research dissertation.

Figure 5.9 provides a summary flowchart of the development, implementation and application of the pilot study conducted.

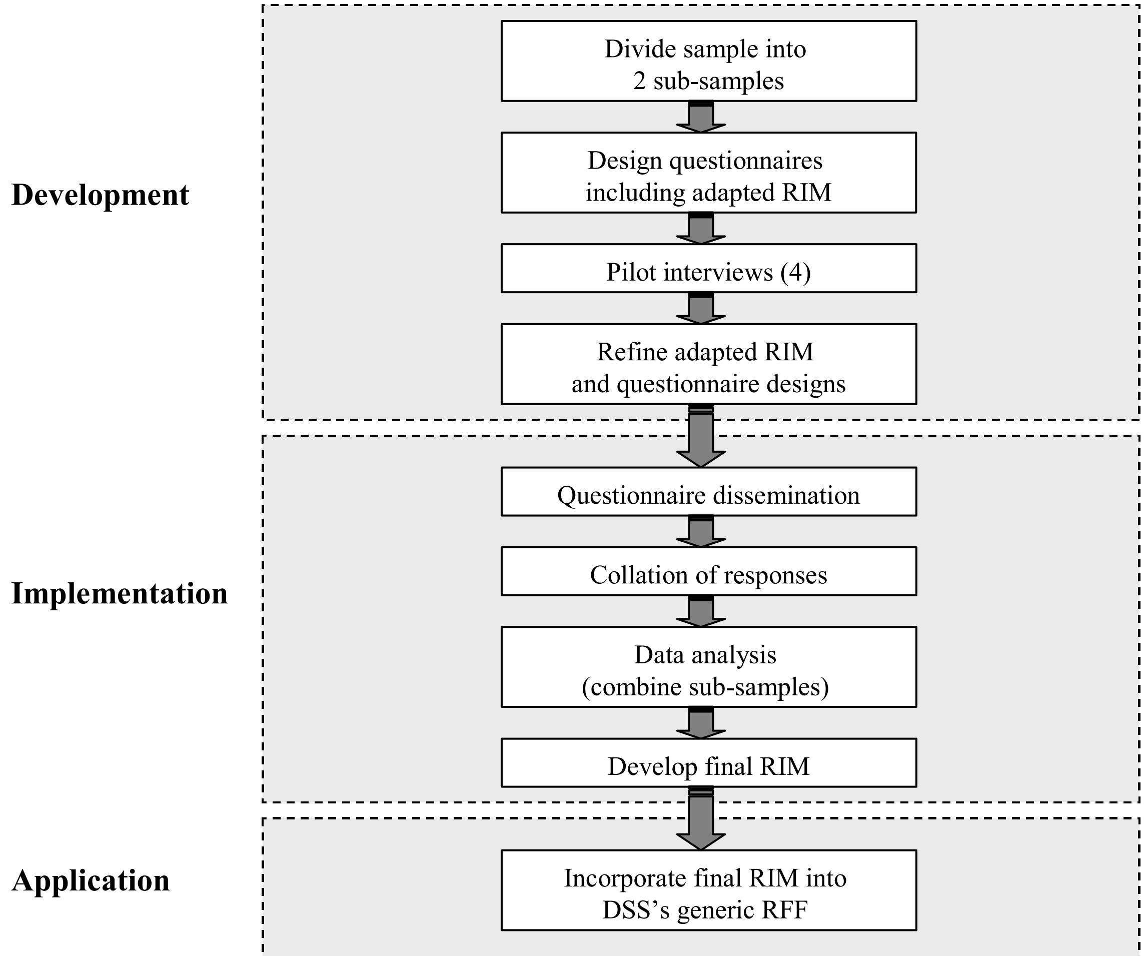


Figure 5.9 Questionnaire Process Flowchart

CHAPTER 6

DSS SOFTWARE ENGINEERING

6.1 GENERAL

The primary goal of this research dissertation was to develop an effective and efficient DSS for the evaluation and comparison of various CPI opportunities. Chapter 4 outlines the conceptual DSS architecture resulting from extensive literature review and comparisons of selected techniques. For this conceptual design to be of practical use to industry, it was imperative that it be fully implemented as a stand-alone computer software package. Thus, the ECCO (Evaluate and Compare Concession Options) software was developed, along with accompanying user manual, help topics and sample CPI models, to assist analysts in becoming familiar with the software. This chapter looks at how the three modules of the DSS architecture have been implemented in the DSS software program, ECCO.

6.2 DESIGN OVERVIEW

Visual C++ was selected as the development environment for ECCO as it is an object-oriented language having advanced templates, comprehensive Microsoft Foundation Classes and low-level platform access, making it suitable for building mathematically powerful Windows applications. According to Abdel-Aziz (2000), developing systems with Visual C++ reduces the overhead (computer memory and processing control) that comes with the use of multiple software.

In order to ensure its user friendliness, ECCO was developed as a dialog-based application, much like a commonly used wizard program. ECCO's opening dialog provides access to the first two modules, Model Definition, and Evaluation and Ranking via the Project Data and Analysis buttons, respectively (see Figure 6.1). The third module, Sensitivity Analysis, is accessed from within the Evaluation and Ranking Module. Each of the three modules caters for the creation of tab-delimited output files that can be opened in Notepad, Microsoft Word or Microsoft Excel for further analysis or printing.

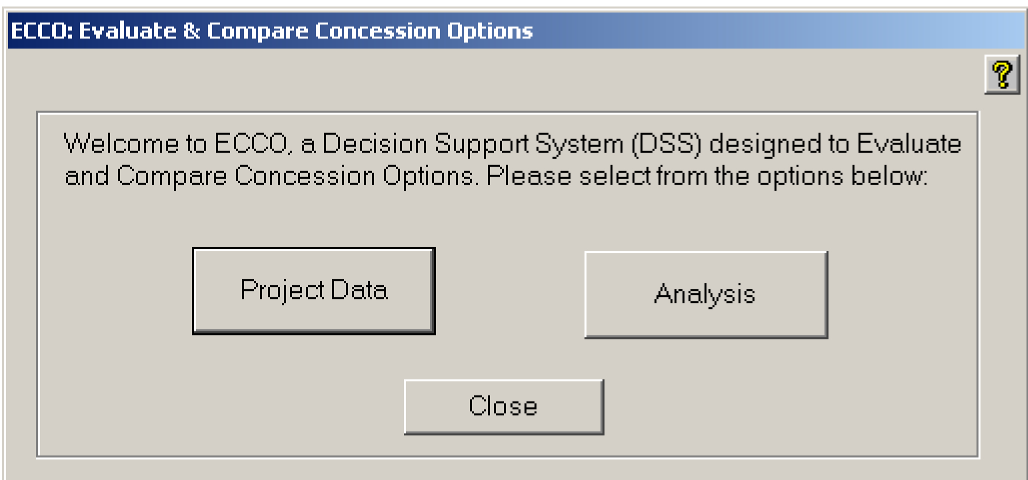


Figure 6.1 The Main ECCO Dialog

The following sections discuss in detail the design and processes followed by ECCO in realization of the conceptual DSS design.

6.3 MODULE ONE – MODEL DEFINITION MODULE

This first module of the DSS is implemented in ECCO as a 5-step data input process accessed via the "Project Data" button on the main ECCO dialog. ECCO provides the option to either edit an existing project data file, or create a new project. The Project Data dialog, shown in Figure 6.2, is then displayed. This dialog contains general information pertaining to the CPI including; project name, description, total project duration (yr), construction period (yr) and source file location; it also provides access to the five steps of the model definition process. These steps are: Step 1: Parameters ($); Step 2: Benefits ($); Step 3: Costs ($); Step 4: Risks; and Step 5: Opportunities.

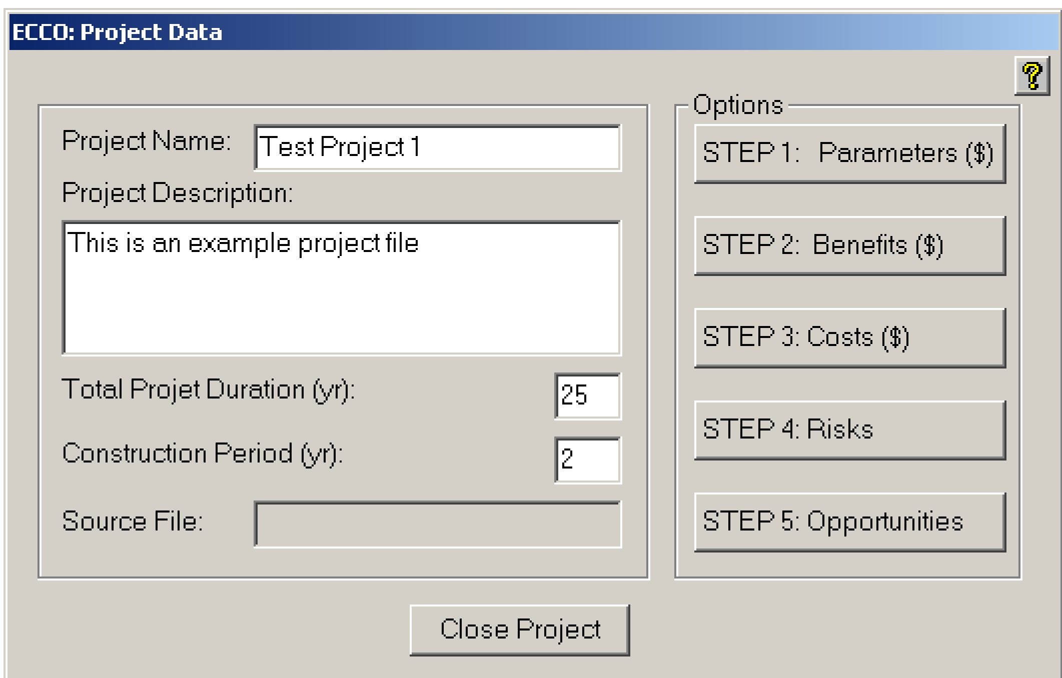


Figure 6.2 Project Data Dialog

If the analyst wishes to edit an existing file, ECCO first invokes the common Open "Source File" dialog (see Figure 6.3), from which it opens the selected model and reads the data into the relevant dialog boxes. The analyst can exit the module at any time by returning to the

Project Data Dialog and clicking on the Close Project button, at which time he/she can either save the developed model as a tab-delimited text file or discard it.

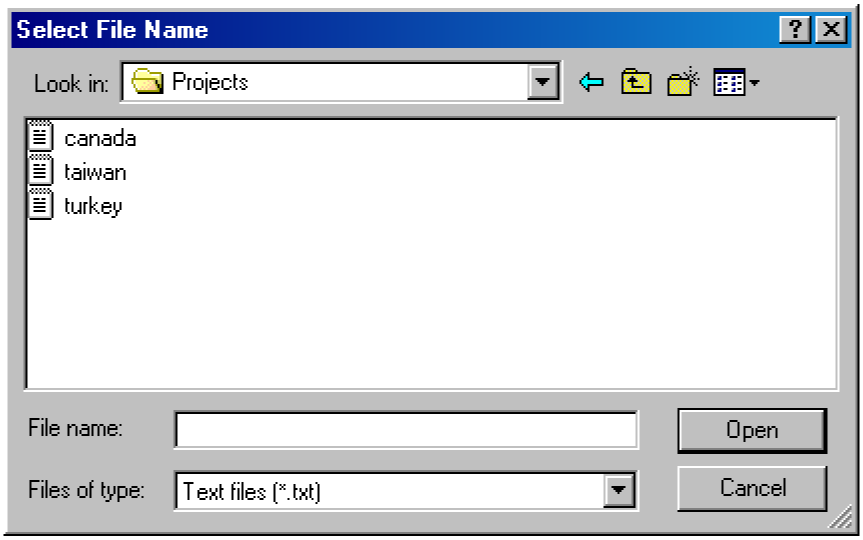


Figure 6.3 Open "Source File" Dialog

6.3.1 Step 1: Parameters

Step 1 in the model definition process is to define all required financial parameters listed on the Financial Parameters dialog shown as Figure 6.4.

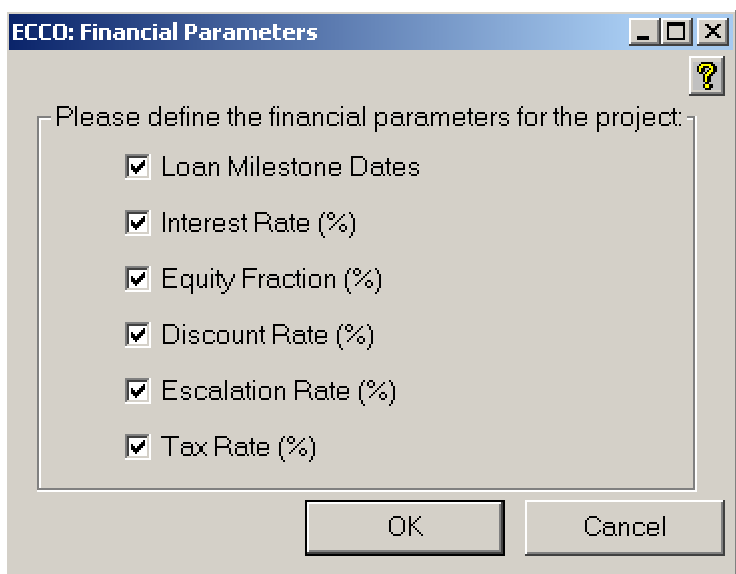


Figure 6.4 Financial Parameters Dialog

The first parameters to be defined are the loan milestone dates. These include both the loan grace period (assumed to be at least equal to the construction period) and the loan repayment period in years (see Figure 6.5). The default settings for the loan grace and operations period are the construction period and the operations period, respectively. Once values have been edited, the analyst is returned to the Financial Parameters dialog. However, as with all module one dialogs, ECCO will show an error message if the values entered in these boxes are not appropriate (e.g. if the grace period and loan repayment period sum to greater than the total project duration).

Figure 6.5 Loan Milestone Dates Dialog

The remaining financial parameters to be defined include the loan interest rate, equity fraction, discount rate, escalation rate and tax rate. These parameters are defined as % values via individual dialogs, identical in design to the Interest Rate dialog (see Figure 6.6). As shown in Figure 6.6 the parameters may be defined as any of the four possibility distribution types, namely, the single value, interval, triangular, or trapezoidal distributions by clicking on the appropriate option. Once appropriate values of least likely and most likely range have been entered into the four cells at the bottom of the dialog, ECCO then returns the analyst to the Financial Parameters dialog for input of the remaining parameters.

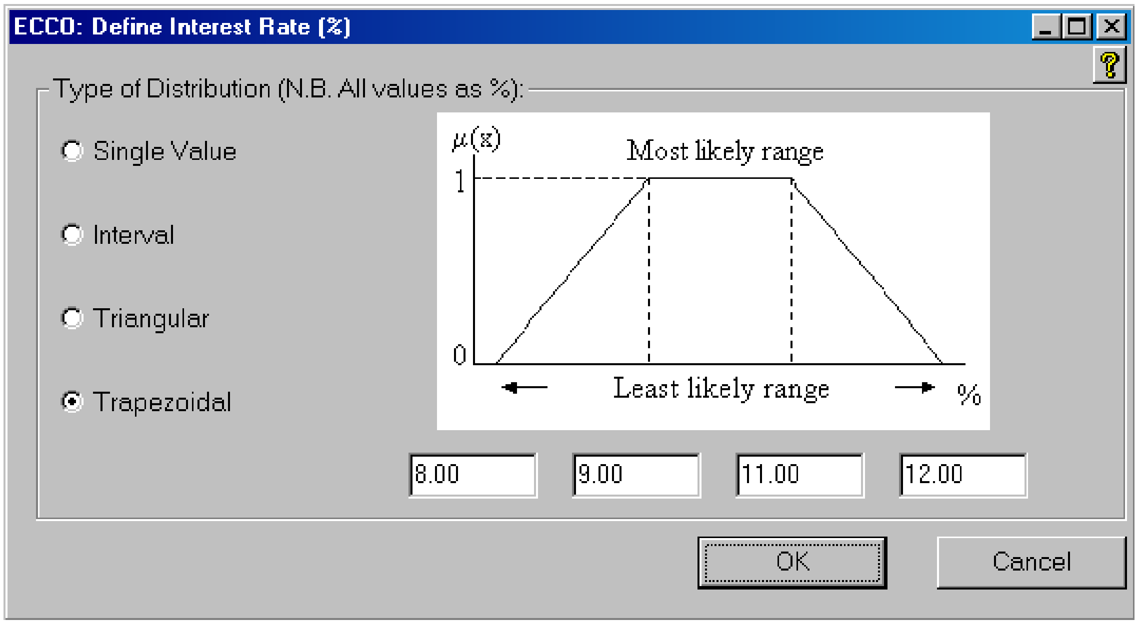


Figure 6.6 Financial Parameters Definition Dialog

6.3.2 Step 2: Benefits ($)

Step 2 of the model definition process involves defining all financial benefits of the project (i.e. any forecast revenue streams of the project, such as toll charges). It is assumed by the program that revenue cannot be generated by the project until the facility has been fully constructed. Thus, ECCO will not allow the entering of start or finish year values less than the construction period, or greater than the total project duration.

Revenue streams are entered into the model via the Revenue dialog, shown as Figure 6.7. The table on this dialog cannot be edited directly. It can only be edited using the Define Financial Data dialog (see Figure 6.8), which is accessed via the Edit Stream, Add Stream and Remove Stream buttons. The Define Financial Data dialog allows the analyst to enter a description of the revenue stream, the timing of the stream and the value of the stream as one of the four distribution types. Streams may be in the form of a one-off payment in a specific year of the project's life, a set of annual payments over a period, or annually increasing/decreasing payments over a set period. This latter option is suitable for when demand is forecast to increase, or unit prices are expected to decrease over time.

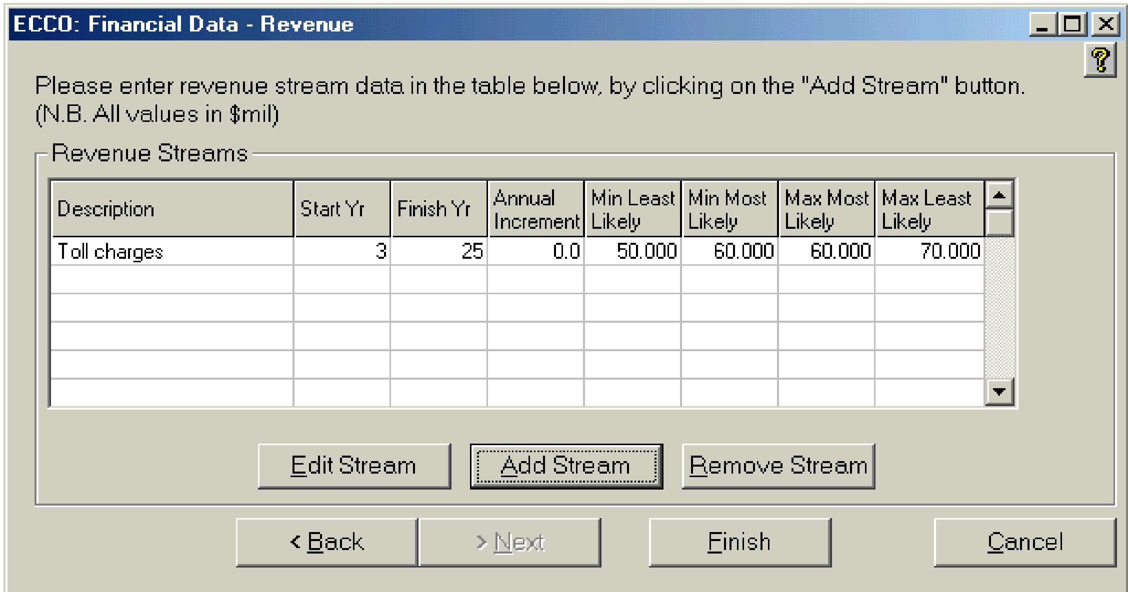


Figure 6.7 Revenue Dialog

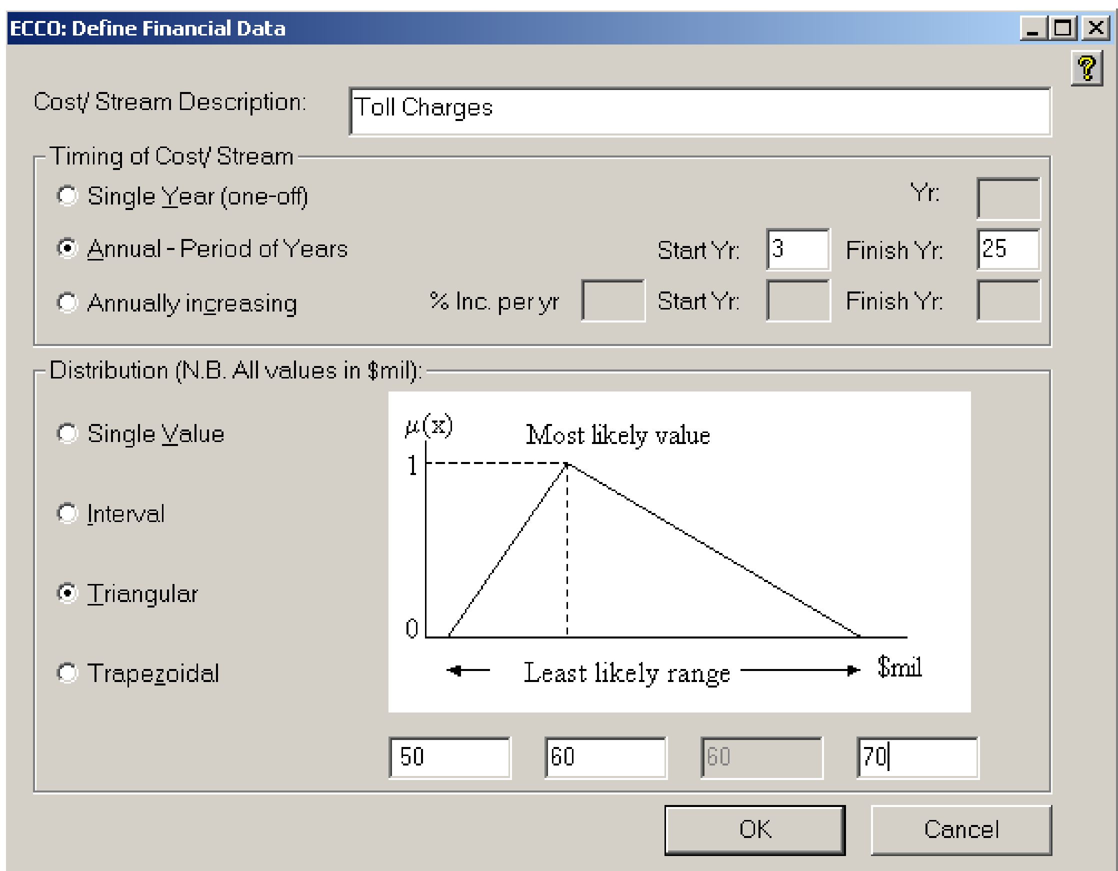


Figure 6.8 Define Financial Data Dialog

6.3.3 Step 3: Costs ($)

All construction costs and Operations and Maintenance (O&M) costs are entered into the model in this third step. Costs are entered in the same manner as Step 2, using the Construction Costs dialog followed by the Operations Costs dialog, which are identical to the Revenue dialog. Again, the tables on these dialogs can only be edited via the Define Financial Data dialog.

6.3.4 Step 4: Risks

Any risk factors (negatively impacting non-financial factors) surrounding the project investment are entered into the model in Step 4. The Risk Data (1) Dialog, shown in Figure 6.9, is used to enter the name, importance weighting) and likelihood values of each risk factor. Dropdown lists of the 7-point linguistic rating scale are provided for the definition of importance and likelihood values.

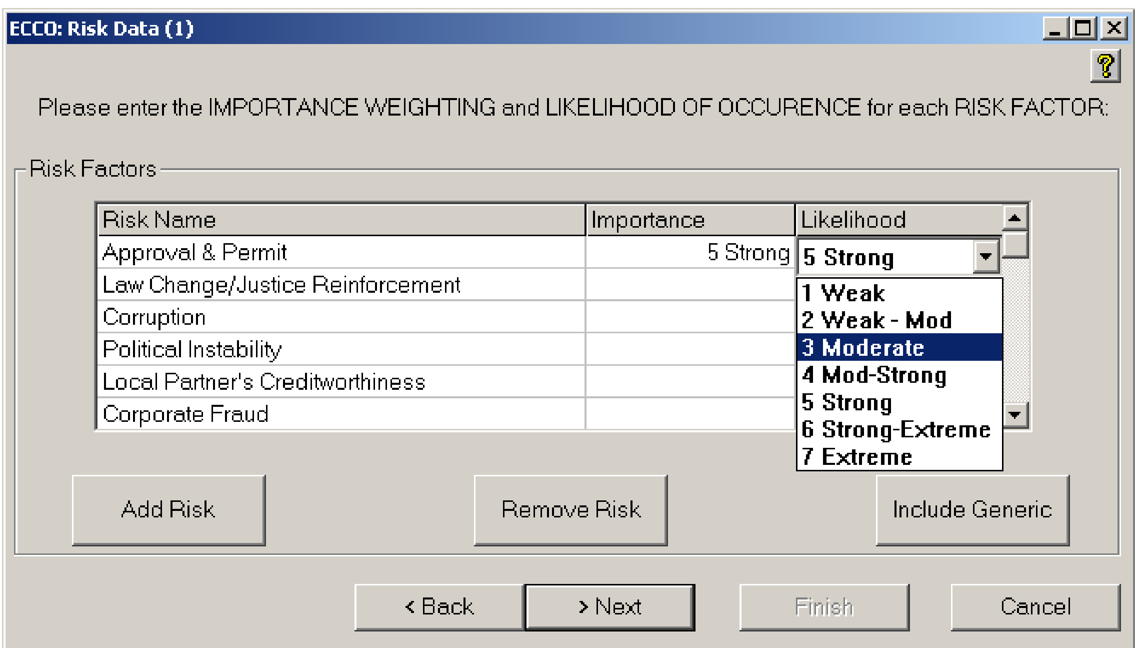


Figure 6.9 Risk Data (1) Dialog

The analyst is then taken to the Risk Data (2) dialog (see Figure 6.10), where any interdependencies between risk factors can be defined. As shown in Figure 6.9, dropdown lists of the risk factors entered in the Risk Data (1) dialog are provided in the Influenced

Risk and Influencing Risk columns, as well as the 7-point linguistic rating scale in the Strength of Influence column.

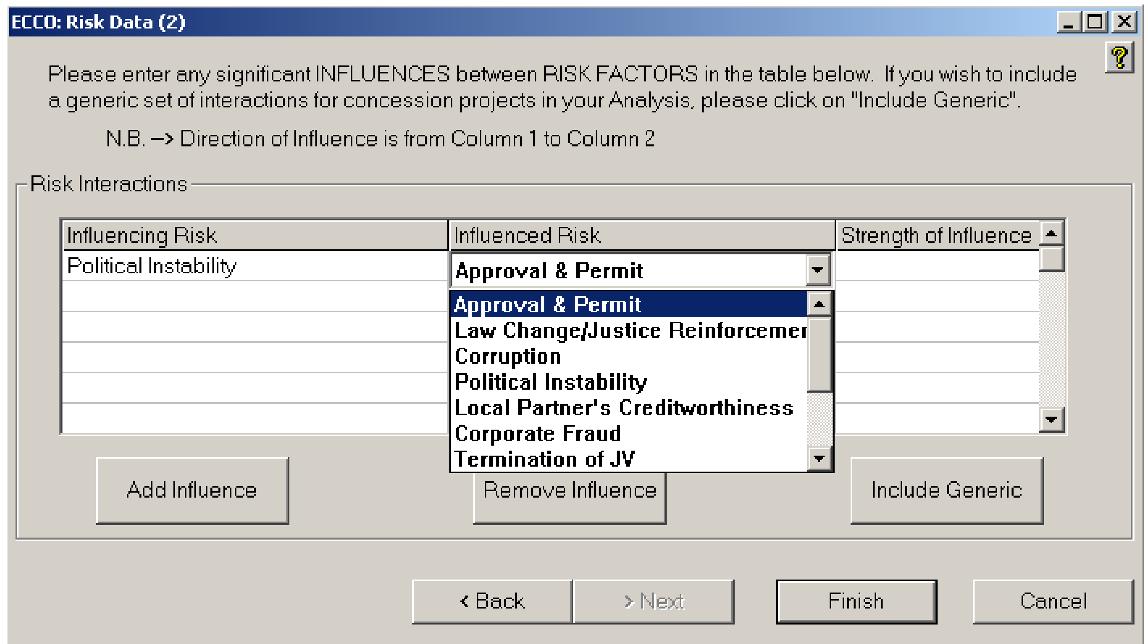


Figure 6.10 Risk Data (2) Dialog

ECCO also provides for the inclusion of the 12 most critical risk factors to concession project investments, and also the interdependencies between these generic factors identified and quantified by the literature review and subsequent pilot study of this research dissertation. These risk factors can be included by simply clicking on the Include Generic button on the relevant Risk Data dialog; ECCO will automatically enter the risk factors and their interdependencies into the tables.

6.3.5 Step 5: Opportunities

All opportunity factors (positively impacting non-financial factors) of the project investment are entered into the model in this fifth and final step of the model definition process. Opportunity factors are entered in the same manner as risk factors, using the Opportunities Data (1) and Opportunities Data (2) dialogs. However, since it was not within the scope of this research dissertation to identify key opportunities created by concession project investments, a generic set of opportunity factors is not provided by the program.

6.4 MODULE TWO – EVALUATION AND RANKING MODULE

The second module of the conceptual DSS design was implemented in the ECCO program and can be accessed via the Analysis button on the main ECCO dialog. ECCO allows the analyst to evaluate and rank between one and five project investment models at one time (see Figure 6.11). It analyses these projects by opening their respective tab-delimited text files entered by the analyst in the Analysis (2) dialog (see Figure 6.12). Note, ECCO also provides for a purely Non-Financial Analysis of projects, via the "Non-Financial Analysis Only" checkbox at the bottom of this dialog.

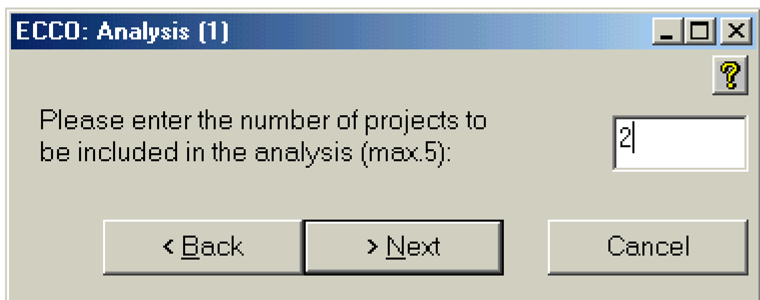


Figure 6.11 Analysis (1) Dialog

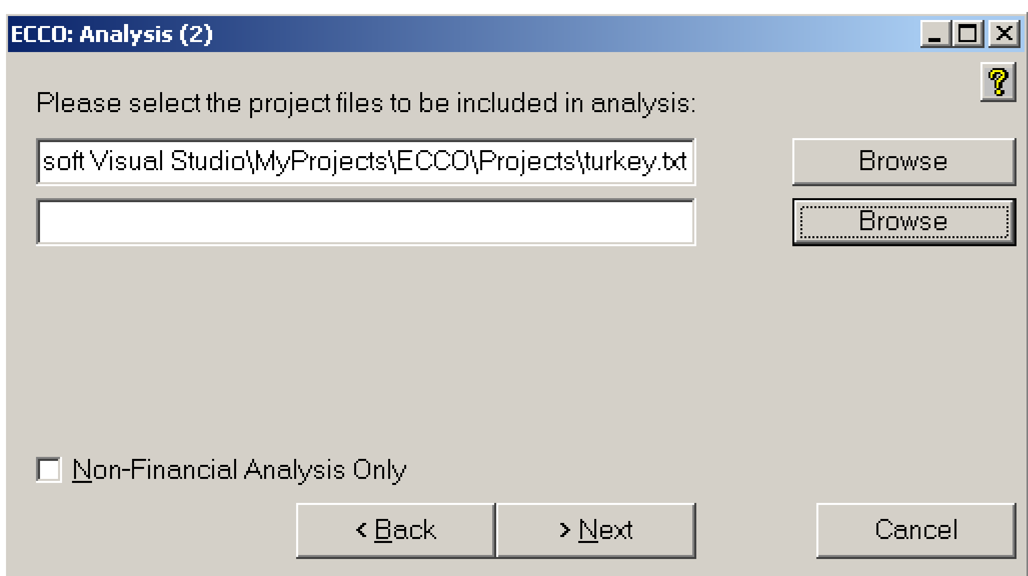


Figure 6.12 Analysis (2) Dialog

From the data contained in the project data files, ECCO evaluates each of the selected project models and compares them on the basis of their ANP Project Rating (or adapted rating). This analysis is conducted in accordance with the process flowchart and methodology presented as Figures 4.11 and 4.12. Results of the analysis are then displayed in both tabulated and graphical form on the Analysis Results dialog (see Figure 6.13).

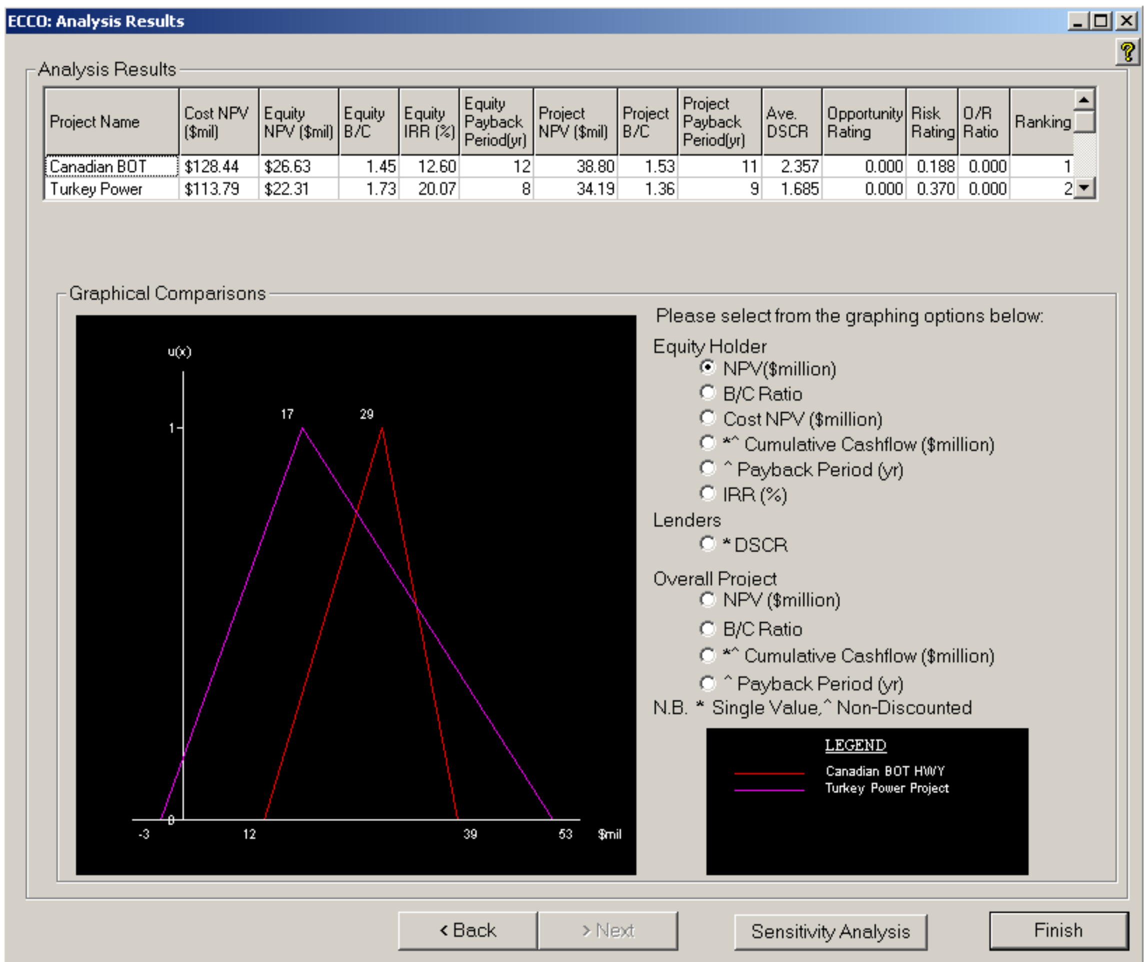


Figure 6.13 Analysis Results Dialog

Tabulated results are presented in order of project preference as equivalent single values (C_x) of the calculated performance measures, and include:

- Project name
- Cost NPV ($mil)

- Equity holder's NPV ($mil)
- Equity holder's B/C ratio
- Equity holder's IRR (%)
- Equity holder's payback period (yr)
- Overall project NPV ($mil)
- Overall project B/C ratio
- Overall project payback period (yr)
- Average DSCR
- Opportunity rating
- Risk rating
- O/R Ratio
- Ranking

Graphical comparisons of the projects performance measures are also displayed on this dialog. All performance measures listed below, except cumulative cash flows and annual DSCR values, are displayed as possibility distributions, whilst cumulative cash flows and DSCRs are presented as non-discounted, annual equivalent single values (C_x).

- Equity holder's NPV ($mil)
- Equity holder's B/C ratio
- Cost NPV ($mil)
- Equity holder's cumulative cash flows ($mil)
- Equity holder's payback period (yr)
- Equity holder's IRR (%)
- Annual DSCRs
- Overall project NPV ($mil)
- Overall project B/C ratio
- Project cumulative cash flows ($mil)
- Overall project payback period (yr)

The Analysis Results dialog also provides access to the Sensitivity Analysis module via the Sensitivity Analysis button. Alternatively, if no sensitivity analysis is required, the analyst can return to the main ECCO dialog by clicking on the Finish button, at which point they will be given the option to save the analysis results as a tab delimited text file.

6.5 MODULE THREE – SENSITIVITY ANALYSIS MODULE

The sensitivity analysis module of the conceptual DSS design has been fully implemented as part of ECCO and can be accessed via the Sensitivity Analysis button at the bottom of the Analysis Results dialog (see Figure 6.13). The sensitivity analysis can therefore only be conducted on projects previously selected for evaluation in module two, although not all projects evaluated must be included. Upon opening the Sensitivity Analysis (1) dialog (see Figure 6.14), ECCO provides a list of the projects available for analysis in the left-hand list box of Step 1. Projects are selected for analysis by using the left and right arrow buttons to move them into the right-hand list box.

Once the projects have been selected, ECCO generates a list of financial and non-financial factors common to ALL projects selected, including additional options to analyse all construction costs, all O&M costs or all revenue costs, in the list box of Step 2. The analyst then selects ONE of these factors (Step 2), and enters a range for analysis (Step 3) according to the type of factor being analysed as follows:

- Financial factors (e.g. interest rate, cash flows) - the range is defined as being between a negative % and positive % of its original value; and
- Non-financial factors - the module automatically conducts analysis for the entire range of likelihood values (1 to 7) for the selected factor.

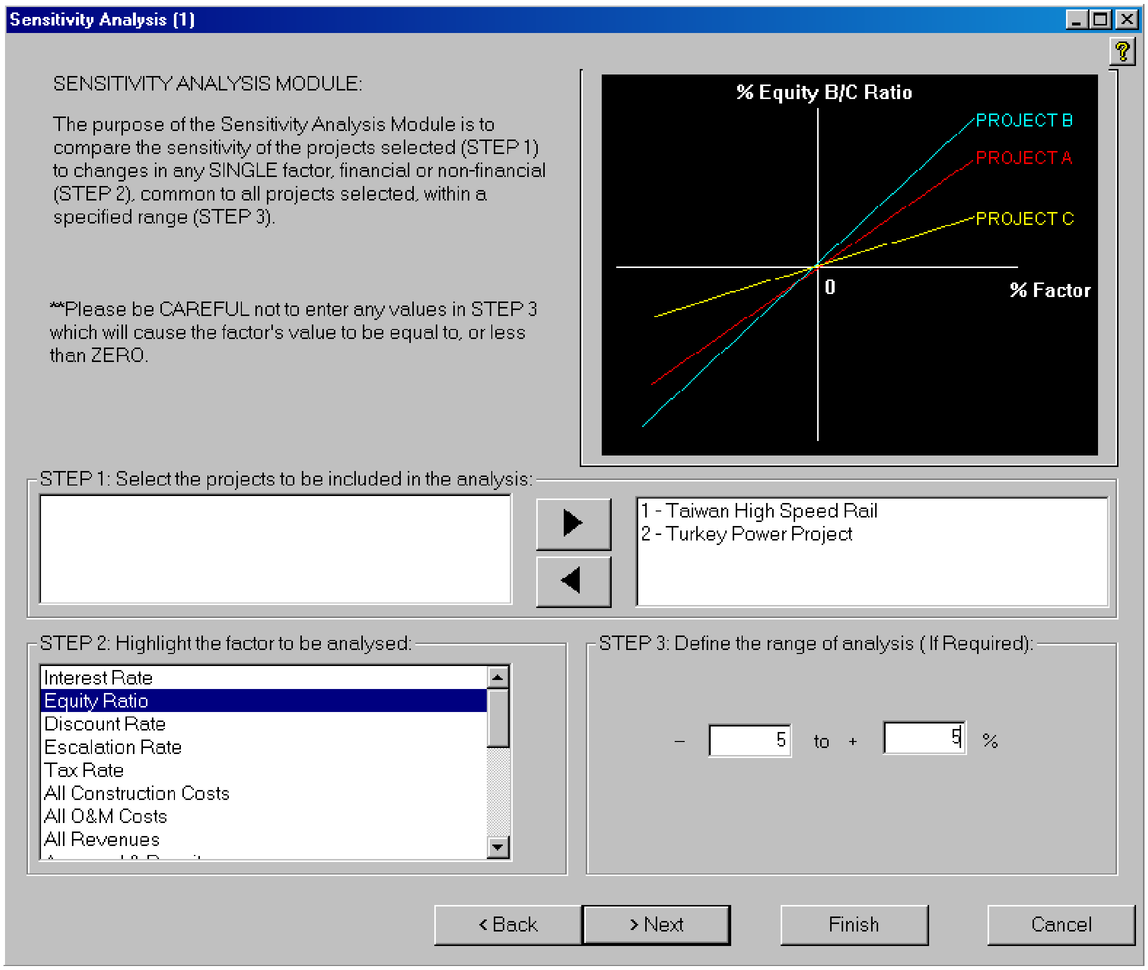
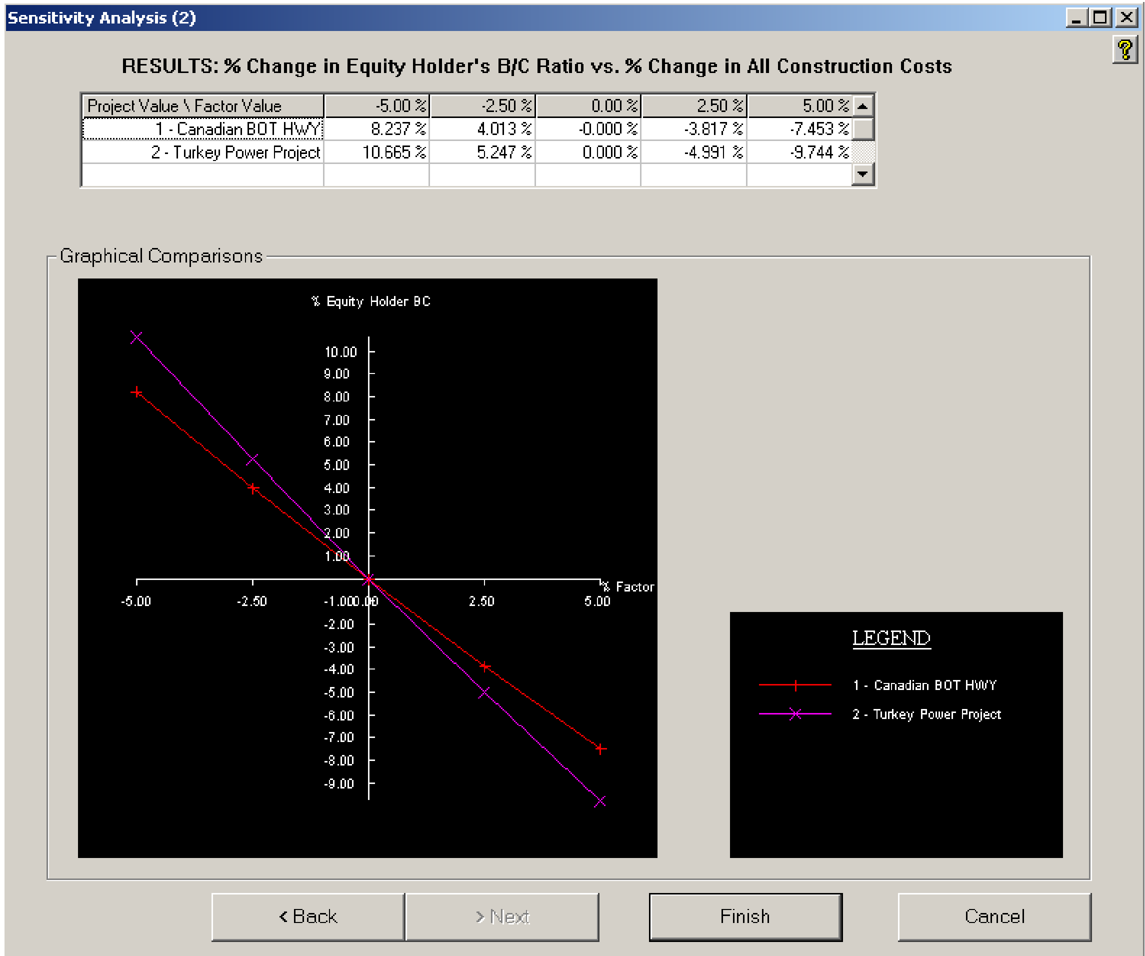


Figure 6.14 Sensitivity Analysis (1) Dialog

ECCO uses the above data to call the sensitivity analysis function, which simply runs the Module Two analyses repetitively for a changing value for the selected factor (across the defined range). In the case of financial factors, five different values, across the defined range, are used. In the case of non-financial factors, seven different values are used. Sensitivity analysis results are presented in both tabulated and graphical form on the Sensitivity Analysis (2) dialog, shown in Figure 6.15 and Figure 6.16.



Project Value \ Factor Value	-5.00 %	-2.50 %	0.00 %	2.50 %	5.00 %
1 - Canadian BOT HWY	8.237 %	4.013 %	-0.000 %	-3.817 %	-7.453 %
2 - Turkey Power Project	10.665 %	5.247 %	0.000 %	-4.991 %	-9.744 %

Figure 6.15 Sensitivity Analysis (2) Dialog –Financial Factor

As depicted in Figure 4.13, different performance measures are used to depict the sensitivity of the projects to a certain factor, depending on the type of factor analysed. If a financial factor has been analysed (see Figure 6.15), the results will be of the % change in the selected factor vs. the % change in the equity holder's B/C ratio (*EQUITYBC*). Whereas if a non-financial factor has been selected, the results will be of the factor's likelihood value vs. the % change in the project's risk or opportunity rating as appropriate (see Figure 6.16). These performance measures were selected because they form part of the primary performance measure, the overall project rating. The analyst can save then sensitivity analysis results to a tab-delimited text file and return to the Analysis Results dialog by clicking on the Finish button.

It is again important to note that it is not the purpose of this module to perform Scenario Analysis. Scenario Analysis can be performed simply by editing existing CPI models to create the different project scenarios using Module One, and then evaluating and comparing the models using Module Two. The thrust of the Sensitivity Analysis Module is to evaluate and compare the sensitivity of several projects to changes in a certain factor, be it financial or non-financial.

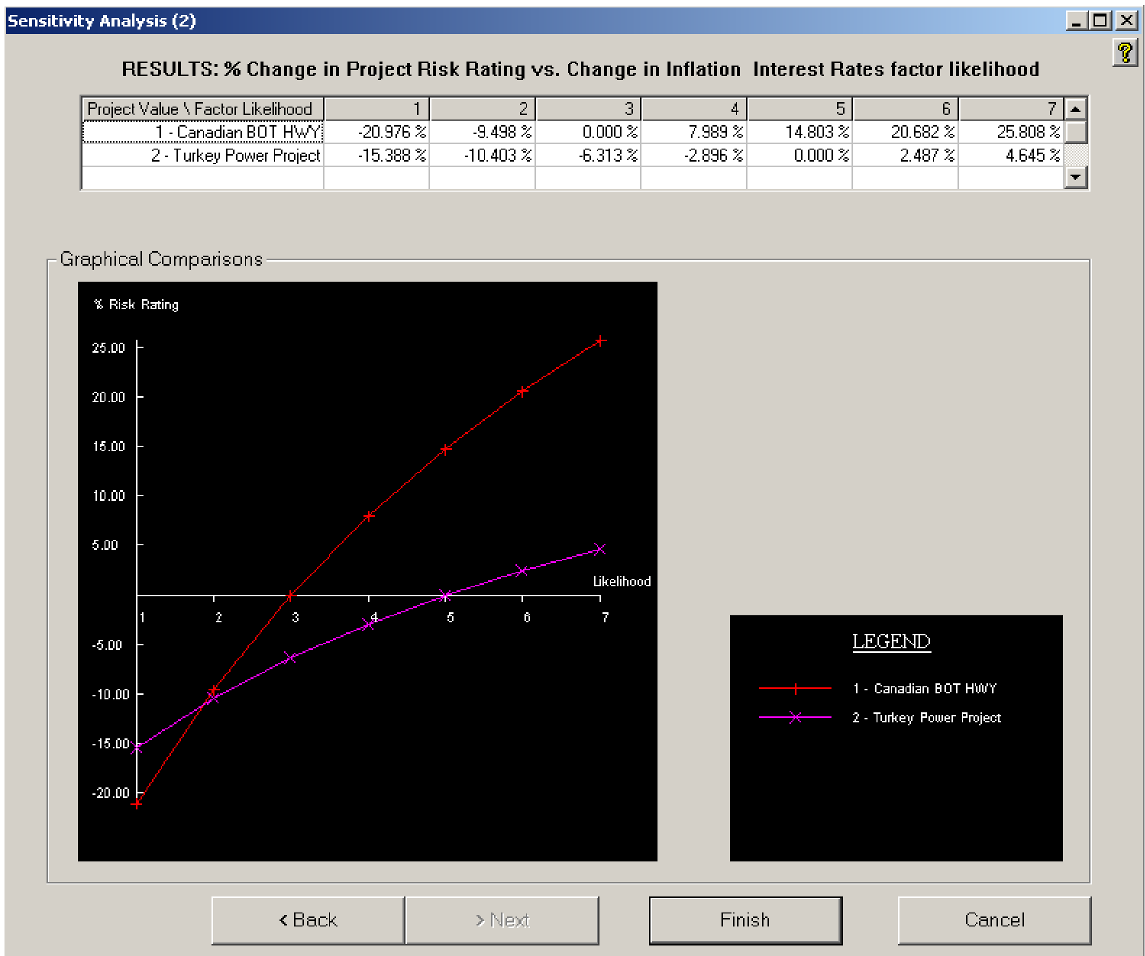


Figure 6.16 Sensitivity Analysis (2) Dialog – Non-Financial Factor

6.6 HELP SECTION AND USER MANUAL

In order to ensure users have an adequate understanding of the processes followed by ECCO and how to best use it to develop, evaluate and compare CPI options, a user manual and various help topics were produced for the software.

ECCO's user manual (see Appendix E) provides all necessary background knowledge as well as a step-by-step tutorial on how to develop, evaluate and analyse the sensitivity of a CPI model using the program. Features of the manual include:

- Introduction to ECCO;
- Overview of DSS design;
- Step-by-step instructions on how to use all three modules of the program;
- Sample CPI model files.

ECCO's help section is context sensitive. Double clicking on any of the Help buttons found at the top of each dialog box, or pressing the F1 key, opens the program's help section to a dialog specific page. The help section includes all topics covered in the user manual.

6.7 SUMMARY

For the conceptual DSS design of Chapter 4 to be of practical use to industry (i.e. time and resource efficient), it was imperative that it be fully developed as a stand-alone computer software package. This chapter has looked at how the three modules of the DSS design software were implemented in ECCO and the accompanying user manual, help topics and sample CPI models to ensure maximum user friendliness of the software.

CHAPTER 7

DSS SOFTWARE VALIDATION

7.1 GENERAL

For convenience, and to facilitate a more proactive validation process, a brief summary of the foundation underpinning the DSS development has been provided below.

The underperformance of concession projects has been attributed to the inability of project sponsors and promoters to predict the impact of all financial and non-financial (risk and opportunity) factors associated with CPIs and negotiate contracts to allow for these factors (Halligan, 1997). Available DSSs are limited in their capacity to incorporate both financial and non-financial aspects of an investment, as well as the uncertainties commonly encountered at the feasibility stage of a project in the most efficient and effective manner.

This research was inspired by the perceived lack of a DSS that is efficient and effective in evaluating and comparing CPI opportunities at the feasibility stage, taking into consideration both financial (benefit and cost) and non-financial (opportunity and risk) factors, for the construction industry. The main objective of the research was, therefore, to develop such a DSS. After conducting extensive literature review of CPI characteristics, current practice feasibility studies, and decision maker requirements, ten requirements were identified that the DSS must cater for in an efficient and effective manner (see Section 2.5).

With these ten requirements in mind, the most appropriate techniques in the areas of mathematical modelling, financial analysis modelling, decision-making, and risk factor frameworks were selected for implementation in the DSS (see Chapter 3). Possibility theory and probability theory were compared on the basis of capability and practicality in modelling the uncertainty in CPIs at the feasibility stage. As a result, possibility theory was found to be the most suitable mathematical modelling technique for this particular purpose. The financial analysis models found in literature either did not provide adequate project performance measures, or required too much detail in defining parameters, loans, and project scheduling. Thus, a novel financial analysis model was derived comprising a total of 11 secondary financial performance measures encompassing measures commonly used by the various parties for implementation in the DSS. This model was designed to be largely generic to suit the level of data definition available at the feasibility stage. Finally, the refined RFF developed by Wang et al. (2002) was selected as the basis for the DSS generic RFF as it was found to be the most advanced framework reported in the literature. Although this framework was originally developed for international projects, it was chosen based upon the broad assumption that the concession projects face much the same risks as large-scale international projects due to similarities in the complexity of financial arrangements and organisational structure, and the ability of country and market environments to significantly affect project viability.

A pilot study was also conducted to verify and adapt the selected RFF with accompanying RIM, and also quantified all interactions of the adapted RIM. From the results of this pilot study, the final RIM was developed for implementation in the DSS generic RFF.

Based upon the selected techniques, the conceptual DSS architecture was developed which met all ten identified requirements (see Chapter 4). The DSS design comprised three separate modules for model definition, model evaluation and ranking and sensitivity analysis. The purpose, structure and implementation of these modules was largely determined by the primary performance measure selected as the basis for overall rankings of the projects, being the ANP project rating method. This rating method extends the traditional financial B/C ratio to incorporate non-financial factors via the inclusion of an

O/R ratio, hence providing a holistic evaluation of the CPI options. A combination of the developed financial analysis model and possibility theory was used to define the financial component of the modules, whilst the ANP was again applied to the modelling of the non-financial component (risks and opportunities). However, it was adapted to allow for each project to have its own individual risk factor framework. A generic CPI RFF was developed as an option when using the DSS. This RFF contains the four (4) most critical risk factors identified by Wang et al. (2002) at the country, market and project levels, as well as the quantified interdependencies between these factors, as identified by the pilot study.

For the conceptual design of the DSS to be of practical use to industry, it was imperative that it be fully implemented as a stand-alone computer software program capable of interacting with standard software used by analysts. Hence, the ECCO (Evaluate and Compare Concession Options) software was developed using the Visual C++ development environment as a dialog-based application, not unlike a commonly used wizard program, including a user manual; help files and example project files. ECCO is structured according to the three modules of the DSS architecture with each of the three modules catering for the creation of tab-delimited output files that can be opened in Microsoft Excel© or Microsoft Word© for further editing, analysis or printing.

7.2 Need for DSS Verification and Validation

The main purpose of Chapter 7 was to validate and verify the developed software program, ECCO. According to Howe (2003), verification is defined as the process of determining whether or not the products of a given phase in the life-cycle of the development process fulfil a set of established requirements; whereas validation is defined as the stage in the software life-cycle at the end of the development process where software is evaluated to ensure that it complies with the requirements. Any software can only be verified and validated in terms of its intended purpose. The intended purpose of ECCO is to provide an effective and efficient system for the evaluation and comparison of various CPI opportunities by meeting all ten requirements identified.

The validation and verification test objectives were threefold:

1. Verify that each individual component of ECCO's three modules fulfil their set of established requirements;
2. Validate that ECCO, as an overall system, complies with all ten requirements identified, and truly does provide an effective and efficient system for the evaluation and comparison of various CPI options; and
3. Demonstrate the capabilities, and identify the limitations of the developed ECCO software.

The following sections detail the verification processes carried out for each individual component of the three modules, as well as the validation of the final product, through application of ECCO to the modelling, evaluation, comparison and sensitivity analysis of three, real-life BOT case study projects. The capabilities and limitations of ECCO identified in these processes are also discussed and summarised at the end of the chapter.

7.3 VERIFICATION

7.3.1 Financial Analysis Model

ECCO's Financial Analysis Model was verified by independently assessing the accuracy of: 1) the financial formulae themselves; and 2) the adaptation of these formulae to the possibility theory.

The accuracy of financial formulae calculated by ECCO were first verified by comparing the program's analysis results to those reported by Bakatjan et al. (2003), for a real-life Build-Operate-Transfer (BOT) hydroelectric power plant (HEPP) project in Turkey. Since the formulae adopted in ECCO differed from those used by Bakatjan et al. (2003), an Excel spreadsheet of the modified formulae was also created as an independent comparison. For more details about the differences in the formulae see Section 3.3.

The CPI model developed for this BOT HEPP project was composed purely of single value (deterministic) distributions. The objective of the source paper was to determine the optimal capital structure (equity level) for this project at the evaluation stage, through application of a simplified model, which combined the use of a financial model together with a linear programming model to maximise equity holder returns. Assumptions made by Bakatjan et al. (2003), which have been adopted in the CPI model, include:

- Construction period of 4 years, followed by a fixed operations period of 20 years from which revenues are generated;
- Grace period is equal to the construction period (4 years), due to the nonrecourse or limited recourse nature of the project;
- All investment costs and revenues are in US dollars;
- Upfront and commitment fees are included in the loan amount.
- Land expropriation cost is included in the base cost;
- Equity fraction is equal to 31.69%, which is the optimum determined by Bakatjan et al.'s model;
- Forecast escalation rate is 4.1% (equal to US Consumer Price Index change rate);
- Loan repayment period is set at 10 years with an interest rate of 10%;
- Revenues are equal to the product of the annual unit price of electricity (U_i) and the net annual energy production (P_i). $R_i = U_iP_i$;
- Unit price of electricity is a declining function throughout the loan repayment period, and a constant value after maturity;
- Operations and Maintenance (O&M) costs are approx. 3% of the Electromechanical Cost (EMC) of the project;
- Withholding tax of 11% including surcharge is the only tax that applies to the project; and
- Discount rate is equal to 12% (US bond yield in 2000 - 9%, plus 3% risk premium).

The cash flows during construction are pre-estimated with the total base cost of the project being US$132.565 million. This base cost includes all civil works, electromechanical, connection works, engineering, insurance, expropriation and working capital costs, and was distributed over the 4 years as follows:

- Year 1 – $ 16,570,000 (12.5%)
- Year 2 – $ 36,455,000 (27.5%)
- Year 3 – $ 39,770,000 (30%)
- Year 4 – $ 39,770,000 (30%)

Revenue and O&M costs throughout the operations period are presented below as Table 7.1.

Table 7.1 Revenue and O&M Costs (US$,000) (Bakatjan et al., 2003)

Year	1	2	3	4	5	6	7	8	9	10	11-20
Revenue	36,684	34,850	33,109	31,454	29,879	28,386	26,965	25,618	24,336	23,118	9,106
O&M cost	790	790	790	790	790	790	790	790	790	790	790

Table 7.2 presents a comparison of analysis results. The equity holder's NPV calculated by ECCO represented a 6.9% difference from those calculated by Bakatjan et al.'s (2003) financial model, while the average DSCR value represented only a 0.5% difference. The variation in the NPV results could be attributed to the difference in formulae used to model the particular performance measures (modifications made to Bakatjan et al.'s (2003) formulae in the DSS are detailed in Section 3.3). Also, the IRR determined by ECCO was within the range calculated by Bakatjan et al.'s (2003) two models (0.74-0.94). All calculations were programmed into an Excel© spreadsheet as a final check of the financial models accuracy. As can be seen in Table 7.3, these results were found to replicate those calculated by ECCO. Other performance measures were calculated by ECCO for the project, but have not been included in the tabulated comparison due to the absence of data with which to compare them. The ECCO project data file, analysis results file and the Excel spreadsheet used in these comparisons are attached as Appendix F.

Table 7.2 Comparison of Financial Analysis Results for Turkey BOT HEPP Project

Performance Measure	ECCO	Bakatjan et al. (2003)	Excel© Spreadsheet
Equity Holder's NPV ($USmil)	7.27	7.81 (financial model) - 7.89 (linear programming)	7.27
IRR (%)	14.85	14.74 (financial model) - 14.94 (linear programming)	14.85
Average DSCR	1.48	1.47	1.48

Secondly, to ensure that the possibility theory had been applied correctly to the financial formulae within Module Two, and perform a mathematical check of ECCO results, a MATLAB© program was written incorporating the formulae detailed in Section 4.4.1 and then used to calculate all financial performance measures mentioned in Section 4.4 for a simplistic (hypothetical) CPI model. This CPI model contained sufficient financial data in order to test all aspects of ECCO's financial model (i.e. at least one construction cost, O&M cost, and revenue stream; varied distribution types; and a range of cash flow characteristic), which was also analysed by ECCO. Results from MATLAB were found to replicate those calculated by ECCO for the given model. The ECCO project data file used in comparisons is provided as Appendix G, while a comparison of single equivalent value results (to 3 decimal places) is presented below as Table 7.3.

Table 7.3 Comparison of Financial Analysis Results – Single Equivalent Values

PERFORMANCE MEASURE	MATLAB	ECCO
Project Cost NPV ($mil)	198.561	198.484
Equity Holder NPV ($mil)	271.791	271.791
Equity Holder B/C Ratio	8.321	8.321
Equity Holder Payback Period (yr)	3	3
Overall Project NPV ($mil)	298.747	298.747
Overall Project B/C Ratio	2.722	2.722
Overall Project Payback Period (yr)	3	3
DSCR – year 1	2.823	2.823
DSCR – year 2	3.700	3.700
DSCR – Ave	3.262	3.262
IRR (%)	Out of Range	Out of Range

7.3.2 Non-Financial Model

The non-financial model included as part of ECCO was verified by comparing results from the analysis of two, purely non-financial, fictitious CPI models using ECCO, to those from the ANP based, Super Decisions© software. It was necessary to adopt the same risk network for both projects to be able to make comparisons with the Super Decisions© software. This was due to the adaptations made to the technique in ECCO where a dummy project was introduced for the analysis of each individual project to allow different projects to be affected by different risk factor networks. Therefore, risk factors affecting the two projects had to be the same, of equal importance, and affected by the same interdependencies, whilst the degree to which these risks (likelihood values) affected each of the projects could be varied.

The ECCO project data files for the two models (Test1 and Test2) and images of the Super Decisions model are provided as Appendix H. It should be noted that, due to the manner in which ECCO allows for the projects to be analysed individually, and by different risk networks, the raw output of ECCO had to be interpreted so that the two results sets could be compared using common terms. Table 7.4 presents a comparison of analysis results from the two software programs using common terms, consequently verifying the non-financial model of ECCO (difference of between 0.3% and 0.4% for each value is minimal when considering accuracy of input data).

Table 7.4 Comparison of results: ECCO vs. Super Decisions©

PROJECT	ECCO (EQUIVALENT) RISK RATING	SUPER DECISIONS© RISK RATING	% DIFFERENCE
Test1	0.556	0.558	0.29%
Test2	0.444	0.442	0.37%

7.3.3 Sensitivity Analysis

It was necessary to ensure that Module Three was accurate in modelling changes to both financial and non-financial factors in up to five (5) projects at a time.

Financial Factors

The purely financial project data file used earlier in Section 7.3.1 was chosen for analysis in ECCO. Module Three was entered via the Analysis Results Dialog, where the “Equity Fraction” financial factor was selected for analysis in the range of –5 to +5 % change in value. The sensitivity of the project to a change in value of a financial factor was calculated in terms of the resulting change in equity holder B/C ratio. For this particular analysis case, the equity holder’s B/C ratio varied from + 4.492 % to – 4.064 % of its value, as shown in Figure 7.1.

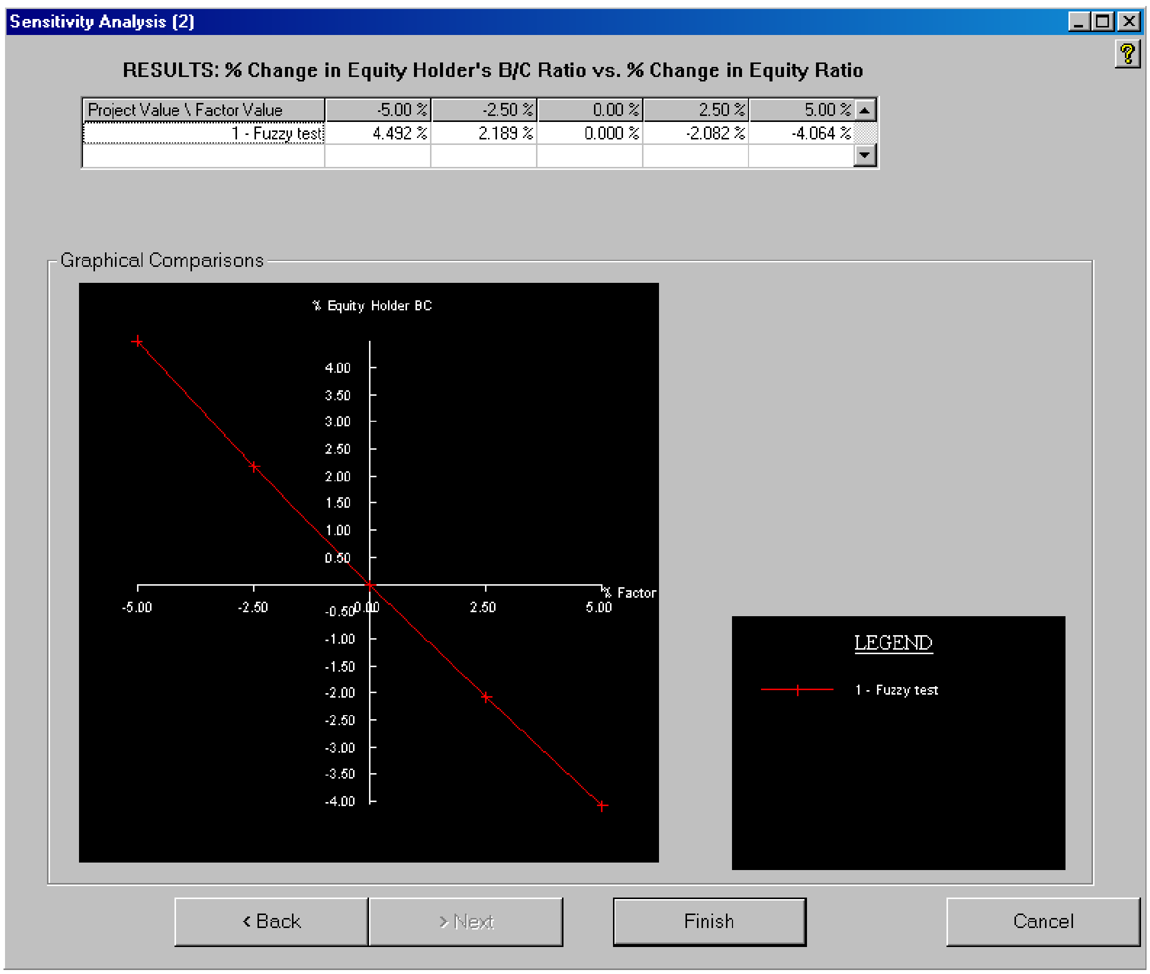


Figure 7.1 Sensitivity Analysis (2) Dialog –Financial Verification

These results were compared with results gained by manually changing the equity fraction distribution in the MATLAB file previously developed in Section 7.3.1. As can be seen from the comparisons in Table 7.5, the two programs concurred, thus verifying the accuracy of Module Three in modelling changes to financial factors. Finally, it was verified that the module was capable of analysing five (5) projects at a time by running a financial and non-financial sensitivity analysis of five (5) project data files.

Table 7.5 Comparison of Sensitivity Analysis Results

% CHANGE IN EQUITY FRACTION	MATLAB - % CHANGE IN EQUITY HOLDER B/C RATIO	ECCO - % CHANGE IN EQUITY HOLDER B/C RATIO
-5%	4.492	4.492
-2.5%	2.188	2.189
0%	0.0	0.0
+2.5%	-2.083	-2.082
+5%	-4.064	-4.064

Non-Financial

Verification of the module's ability to evaluate the effects of changes in non-financial factors was achieved by comparing analysis results for a simple risk factor framework using ECCO to those using the Super Decisions© software. As shown in Figure 7.2, the risk factor "Financing" was selected from the CPI model (detailed in Section 7.3.2) for analysis. ECCO then iteratively calculated the percent change in the project's risk rating caused by a change in the likelihood value of the "Financing" risk factor from 1(weak) to 7 (extreme). The % change was calculated relative to the original project rating corresponding to the original input likelihood value for the selected risk factor, which in this particular case, happened to be four.

The Super Decisions© results were then generated by creating six new model files as a variation to the original model developed as part of the verification of the non-financial model itself. These six new models differed solely in likelihood value for the risk factor "Financing" and, together with the original model, represented the full range of likelihood values for the factor from one to seven.

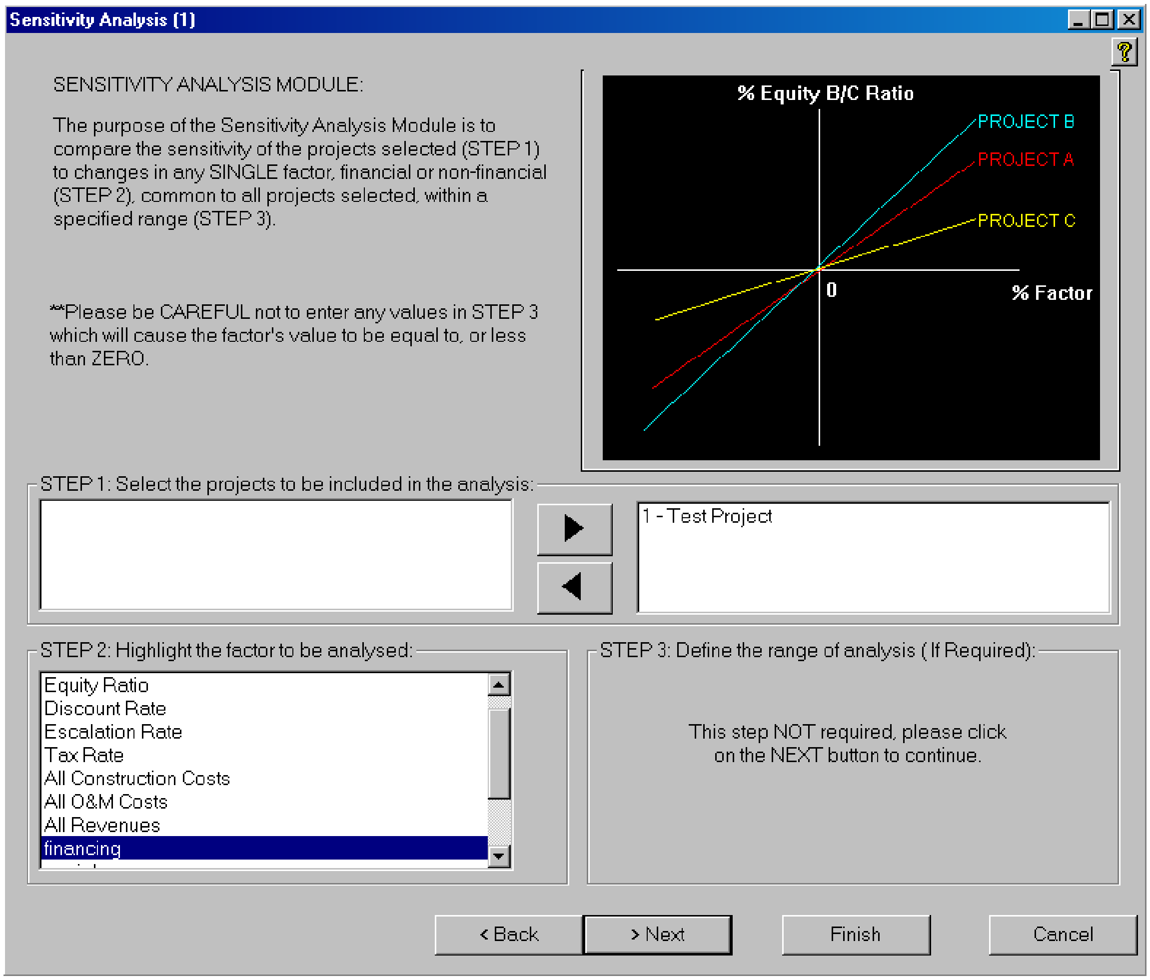


Figure 7.2 Sensitivity Analysis (2) Dialog – Non-Financial Verification

Results from both software were finally collated, interpreted and compared using common terms. As shown in Table 7.6, the differences in results from the two software are minimal, having an average value of 0.11% and a maximum value of 0.32%. These differences can be traced to the introduction of a dummy project in ECCO for the analysis of each project, thus allowing individual projects to be affected by different risk factor networks.

Table 7.6 Comparison of Results – ECCO vs. SuperDecisions©

"FINANCING" LIKELIHOOD VALUE	SUPERDECISIONS©			ECCO	DIFFERENCE (%)
	RISK RATING	(EQUIVALENT) RISK RATING	% CHANGE FROM ORIGINAL	% CHANGE FROM ORIGINAL	
1	0.278	0.386	-19.26	-18.94	0.32
2	0.297	0.422	-11.75	-11.52	0.23
3	0.311	0.452	-5.44	-5.29	0.15
4	0.323	0.478	0.0	0.0	0.0
5	0.333	0.500	4.52	4.56	0.04
6	0.342	0.519	8.52	8.52	0.0
7	0.349	0.536	12.04	12.00	0.04

7.4 VALIDATION - CASE STUDY SELECTION CRITERIA

The literature contains numerous case studies of concession projects. A set of criteria was developed to ensure that the case studies selected would be effective in validating and demonstrating the full capabilities of ECCO. These criteria included:

- Real-life project;
- Data availability (both financial and non-financial);
- Various scales of project (e.g. $100 million vs. $1 billion);
- Different types of concession projects (road, rail, power plants, schools);
- Diverse range of host countries (developed and developing);
- Varied concession periods (e.g. 20years vs. 50years); and
- Reported financial/ non-financial analysis results, or performance of project to date.

The required financial data included: construction period, concession period, equity fraction, loan grace period, repayment period, discount rate, escalation rate, interest rate, tax rate, construction costs including year incurred, O&M costs including year incurred and revenue streams including year received. The required non-financial factor data were dependent upon which of the following modelling options was adopted:

1. Use reported information to generate a new RFF for the project (need critical risk identification, description of likelihood and importance of risks and possibly how the risks interact); or
2. Implement the generic RFF from the pilot study (only need likelihood and importance of risks).

Each case study was assessed against the above set of criteria. However, since the majority of case studies focussed purely on the non-financial aspect of the project (i.e. risks and critical success factors) or on the financial aspect, none provided all the required data. It was therefore decided to select the three case study projects listed below, where the majority of all necessary financial data was available.

1. Case Study One - Build-Operate-Transfer (BOT) hydroelectric power plant (HEPP) project in Turkey, documented in Bakatjan et al. (2003).
2. Case Study Two - BOT High Speed Rail (HSR) Project in Taiwan, reported by Chang and Chen (2001).
3. Case Study Three - Closely reflects actual data from a 45km, 4-lane highway PPP project in Eastern Canada contained in Abdel-Aziz (2000).

These projects were real-life projects of varied scale, type and concession period, and were hosted by a range of developing to developed countries. Informative descriptions of the projects were provided along with almost all required financial data; financial analysis results (performance measures) were reported. Thus, the case studies met all criteria excluding one – the provision of non-financial data. This problem was overcome by taking Option (2) for the modelling of non-financial factors (i.e. adopt the generic RFF). The authors of the source papers were located, and were requested by email, to supply the importance and likelihood ratings of the generic 12 risk factors as applicable to their projects. All authors complied with this request.

It must be noted, that due to the absence of suitable data, the validation process has been limited to: 1) the validation of ECCO's financial component; 2) its application to transport and power plant CPIs; and 3) a demonstration of ECCO's capabilities and limitations.

Sections 7.5 through to 7.7 provide descriptions of CPI model development for Case Study One, Two, and Three, respectively. Whilst analysis results are presented in Section 7.8 and sensitivity analysis results in Section 7.9.

7.5 VALIDATION - CASE STUDY ONE

7.5.1 General

The first case study project selected to validate and demonstrate the capabilities of ECCO is a real-life, Build-Operate-Transfer (BOT) hydroelectric power plant (HEPP) project in Turkey, documented in Bakatjan et al. (2003). The objective of this source paper was to determine the optimal capital structure (equity level) for the BOT HEPP project at the evaluation stage, through the application of a simplified model, which combined the use of a financial model together with a linear programming model to maximise equity holder returns.

All necessary information pertaining to financial factors on the project were provided in the source paper. However, due to the purely financial nature of the paper, details of the non-financial factors surrounding the project were not given. Additionally, for confidentiality reasons, the project's location and name were not specified. Thus, in order to demonstrate the full capabilities of ECCO in combining financial with non-financial factors surrounding a project, the generic risk factor framework (including interdependencies) was adopted as the project's risk factor network, while opportunities were simply omitted from the model. The paper's author, upon request, kindly provided additional non-financial information required for the development of the CPI model.

7.5.2 CPI Model Development

Financial Factors

Two separate CPI models were developed for this first case study using: 1) deterministic financial data, the generic RFF, and no interdependencies between risk factors; and 2) possibility distributions of financial data and the inclusion of interdependencies between the risk factors in the generic RFF. Section 7.3.1 presents the details of the deterministic financial model developed for the project.

In order to demonstrate the full capabilities of ECCO in modelling the uncertainty surrounding financial factors, a 2nd CPI model was developed for this project by transforming each of the above financial factors into triangular possibility distribution. The minimum and maximum least likely values of each triangle were derived using information provided in the source paper. For example, construction costs composed of civil works and EMC works; additional costs included a 10% contingency for all civil works and 5% for EMC works. Therefore, the values given were taken to be the maximum least likely values of the yearly construction costs. The most likely and minimum least likely values were then calculated by deducting the included contingencies to get their original values, and further discounting these original values by contingencies (according to their cost type), respectively.

Also, annual O&M costs were calculated as being 3% of the total EMC cost (which included a 5% contingency), in the source paper. However, the paper stated that O&M costs were usually 3-4% of the EMC cost. Therefore, an interval distribution of 0.03 to 0.04 was multiplied by the developed triangular EMC cost distribution described above to obtain the annual O&M cost distribution. Finally, revenues were calculated using the formulae provided in the source paper using input of: depreciation distributions coming from ECCO's preliminary analysis of construction period cash flows; the annual O&M cost distribution`, and annual energy production rates provided in the source paper. Finally, financial parameters such as interest rate, were transformed into distributions having a most likely value equal to its stated value (provided above), and a least likely range considered to be reasonable for that particular parameter, as demonstrated in Figure 7.3. Full details of the second CPI model developed for Case Study One are summarised below as Table 7.7 and also in the Project Data File generated by ECCO (see Appendix I).

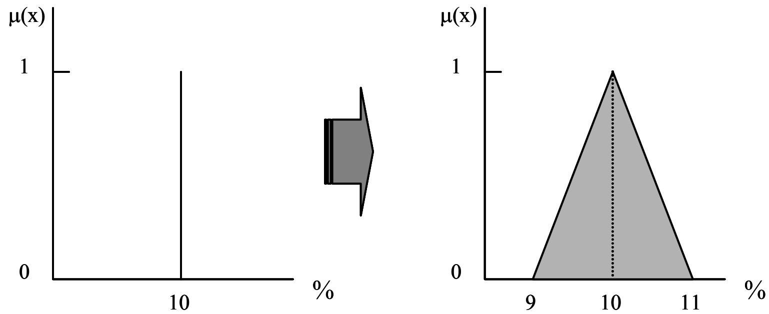


Figure 7.3 Transformation of Interest Rate (%) into Possibility Distribution

Table 7.7 Financial Factor Possibility Distributions (US$,000) – Case Study One

Financial Factor	Min. Least Likely	Most Likely	Max. Least Likely
Equity Fraction (%)	28	31.69	35
Escalation Rate (%)	3.5	4.1	4.5
Interest Rate (%) – Loan rate	9	10	11
Discount Rate (%) – Average	9	12	12.5
Tax Rate (%)	11	11	11
Construction Cost – Year 1	13,843	15,206	16,571
Construction Cost – Year 2	30,454	33,455	36,455
Construction Cost – Year 3	33,223	36,496	39,770
Construction Cost – Year 4	33,223	36,496	39,770
Revenue - Year 1 (of Operations)	35,168	37,411 – 37,723	39,826
Revenue - Year 2 (of Operations)	33,410	35,540 – 35,837	37,835
Revenue - Year 3 (of Operations)	31,739	33,763 - 34,045	35,943
Revenue - Year 4 (of Operations)	30,152	32,075 - 32,343	34,146
Revenue - Year 5 (of Operations)	28,645	30,471 - 30,726	32,439
Revenue - Year 6 (of Operations)	27,213	28,948 - 29,190	30,817
Revenue - Year 7 (of Operations)	25,852	27,500 - 27,730	29,276
Revenue - Year 8 (of Operations)	24,559	26,125 - 26,344	27,812
Revenue - Year 9 (of Operations)	23,331	24,819 - 25,026	26,422
Revenue - Year 10 (of Operations)	22,165	23,578 - 23,775	25,101
Annual Revenue – Years 11-20 (of Operations)	6,590	8,278 - 8,529	10,328
Annual O&M Costs –Years 1-20 (of Operations)	715	752-1,003	1,053

Non-Financial Factors

As mentioned earlier, due to an absence of non-financial data for this case study the generic RFF was adopted as the Risk Factor Network for the project, and opportunities created by the project were not taken into consideration. Therefore, the only additional information required was the importance and likelihood ratings (on a scale of 1-7) of each of the 12 risk factors of the generic RFF, which the first source author, Bakatjan, kindly provided, upon request. Table 7.8 presents the ratings given to each of the risk factors. It is interesting to note that the risk factor rated as most important to the project investment was "M3 - Termination of Joint Venture" with a rating of "7- extreme importance", however it was only believed to be "3 - moderately likely" to affect the project. The explanation that could be offered herein is that, although the risk of "Termination of Joint Venture" was considered extremely important to the project, having an extreme impact on the project should it happen, it was only considered moderately likely to actually occur on the project.

Table 7.8 Risk Factor Ratings – Case Study One

RISK FACTOR	IMPORTANCE	LIKELIHOOD
C1 - Approval and Permit	2	2
C2 – Change in Law / Justice Reinforcement	5	3
C3 – Corruption	2	2
C4 - Political Instability	5	3
M1 - Local Partner's Creditworthiness	3	1
M2 - Corporate Fraud	2	1
M3 - Termination of Joint Venture	7	3
M4 - Inflation and Interest Rates	5	5
P1 - Cost Overrun	5	3
P2 - Improper Design	5	2
P3 - Improper Quality Control	3	3
P4 - Improper Project Management	5	2

N.B. Scale is from 1 (weak) to 7 (extreme). 0 represents no importance/likelihood.

The most likely risk factor to affect the project was "M4 - Inflation and Interest Rates" ("strong likelihood"), which was also rated as "strongly important" to the project. Several other factors were considered strongly important, but not very likely to affect the project investment.

The above risk factor framework was applied to both CPI models developed for Case Study One. However, to better illustrate the importance of including factor interdependencies, interdependencies were excluded from the first project data file, and included in the second (i.e. the generic set of interdependencies from the pilot study).

7.6 VALIDATION - CASE STUDY TWO

7.6.1 General

The second case study project chosen to validate ECCO was a BOT High Speed Rail (HSR) Project in Taiwan. This BOT HSR project is the largest rail project in the world, estimated to cost US$14 billion. Stretching between the capital Taipei and the city, Kaohsuing (350km), the train will reduce the current travel time of 10 hours to just 90 minutes. Design challenges for the project include length of the tunnels, viaducts, bridges and the crossing of several earthquake fault lines. The Taiwan High Speed Rail Corporation (THSRC), formed by five local companies, is the sponsor of the project, and was granted a concession period of 30 years following a 14-year design/build period starting in 1990.

The main source of information on this project was a published paper by Chang and Chen (2001). The objective of this particular paper was to present the financial model used by the Bureau of Taiwan High Speed Rail (BTHSR) to evaluate the viability and develop the best-case scenario for BOT projects at the financial planning stage. The model evaluates the project from the three perspectives of overall cash flows, equity and dividends. It provides output of total net cash flows, cumulative total net cash flows, debt-coverage ratio, a check index, and payback period for each case scenario analysed.

In their paper, Chang and Chen (2001) present five representative scenarios for the HSR project. Most financial data required to develop the CPI model in ECCO was specified in the paper, however details of annual revenues and O&M costs throughout the operations period and information pertaining to non-financial factors surrounding the project had to be sought from the authors, who kindly obliged.

7.6.2 CPI Model Development

Financial Factors

As in the first case study, two separate project data files were developed for the Taiwan project using deterministic and uncertain financial data, respectively. Financial factors provided by Chang and Chen (2001) were based upon rates in Taiwan, and have been summarized below, and in Table 7.9. They are also attached in Appendix J (spreadsheet of revenue and O&M costs). Note that although the project started in 1990, the project sponsor did not incur any construction costs until 1995.

- Equity fraction = 30%
- Escalation rate = 3.5%
- Interest rate = 9%
- Discount rate = 13.5 % (Based on 30% at return on equity rate of 24% and 70% at 9% loan interest rate.)
- Business income tax rate = 25%

Table 7.9 Project Sponsor Construction Costs ($US million) – Case Study Two

Year	1995	1996	1997	1998	1999	2000	2001	2002	2003
Cost	1	23	126	496	1,347	2,248	2,204	1,951	1,042

No information was given pertaining to the assumptions made in estimating these values (e.g. Whether contingencies were included). Thus in developing the second CPI model including uncertainty, values were transformed into triangular possibility distributions having a most likely value equal to its stated value (provided above), and a least likely range considered to be reasonable for that particular factor (maximum $\pm$10%). The resulting financial factors input into the BOT HSR model are detailed in the project data file generated by ECCO in Appendix J.

Non-Financial Factors

Similar to the first case study project, it was necessary to adopt the generic RFF as the risk factor network for the project, and opportunities were simply omitted from the model, due to a lack of information pertaining to non-financial factors in the paper. Also, in keeping with Case Study One, interdependencies were excluded from the first model, while they were included in the second CPI model. The generic interdependencies as determined by the pilot study were used for this purpose.

Table 7.10 presents the importance and likelihood ratings for each of the non-financial factors kindly provided by the main source author. In general, the importance ratings supplied were of a higher magnitude (ranging from 4 to 6), whilst the likelihood ratings were fairly moderated (ranging only between 1 and 4). In other words, although the risk factors were considered strongly important to the success of the project investment, they were not considered likely to affect the project. The most highly rated risk factors for this case study consisted of project level risk factors (P1-P4), closely followed by the market level factor, M4, Inflation and Interest Rates, and the country level factor, C3, Corruption.

Table 7.10 Risk Factor Ratings – Case Study Two

RISK FACTOR	IMPORTANCE	LIKELIHOOD
C1 - Approval and Permit	6	2
C2 – Change in Law / Justice Reinforcement	4	1
C3 – Corruption	4	4
C4 - Political Instability	4	2
M1 - Local Partner's Creditworthiness	5	3
M2 - Corporate Fraud	5	3
M3 - Termination of Joint Venture	5	2
M4 - Inflation and Interest Rates	5	4
P1 - Cost Overrun	6	4
P2 - Improper Design	6	3
P3 - Improper Quality Control	6	4
P4 - Improper Project Management	6	4

N.B. Scale is from 1 (weak) to 7 (extreme). 0 represents no importance/likelihood.

7.7 VALIDATION - CASE STUDY THREE

7.7.1 General

The third and final case study project selected to further validate ECCO and demonstrate its modelling capabilities, is a case study contained by Abdel-Aziz (2000), the data of which closely reflects actual data acquired from a 45km, 4-lane highway (hwy) project in Eastern Canada delivered by PPP. Abdel-Aziz (2000) also used this case study to validate a DSS for the analysis and evaluation of capital investment projects. For further information on the design of this DSS, the reader is advised to read the Literature Review, Chapter 2.

For confidentiality reasons, the project's location and name were not specified in the source document. All necessary information pertaining to financial factors on the project was provided. However, due to the fact that the risk analysis framework assigns probability distributions to variables within the economic model by use of a distribution's defining four moments, the individual risk factors themselves are not identified. Thus, in order to demonstrate ECCO's full capabilities in combining both financial and non-financial aspects of a project, the generic RFF was adopted as the project's risk factor network, while opportunities were simply omitted from the model. Risk factor interdependencies for the project were taken from the source author's response to the pilot study questionnaire, while factor likelihood and importance ratings were also provided upon further request.

7.7.2 CPI Model Development

Financial Factors

The financial data adapted from Abdel-Aziz (2000), and used as input for the development of the Canadian Hwy project model, is listed below and summarised in Table 7.11. Since ECCO's financial model does not cater specifically for escalation in revenues and O&M costs, Excel© was used to generate annual operations, maintenance and revenue data, including the relevant inflations as input into the model. Also, government contributions made during the construction period were simply deducted from the road construction costs due to ECCO's inability to allow for revenue to be generated throughout the construction period.

- Construction period of 2yrs
- Operations period of 30yrs, thus, total project duration of 32years
- Discount rate of 8.25%
- Equity fraction of 47.41% (value of bonds/capital cost of project)
- Interest rate of 10.63% (Weighted average of bond coupons)
- Grace period of 9 years (Weighted average of bond coupons)
- Repayment period of 23years
- Escalation rate of 2.35% (Applies to all construction and operations costs)
- Inflation of revenues in a sinusoidal pattern, starting at 2.35% with an annual increase of 0.05%, amplitude 0.3% and cycle length of 10years.
- Inflation of all maintenance costs at 1.5% per year and 0.04% annual increase.
- Government Contributions of $19.333million in Year 1, $9.667million in Year 2, and $26million in Year 3.
- Tax rate 0% - not specified in source, hence assumed to already taken into account in cost data.

Table 7.11 Annual Cost and Revenue Data – Case Study Three

FINANCIAL FACTOR	VALUE ($million)
Design Cost – Year 1	13
Road Construction – Year 1	31.358 – 19.333 (govt contribution) =12.025
Road Structure – Year 1	6.472
Road Construction – Year 2	53.392 – 9.667 (govt contribution) = 43.725
Road Structure – Year 2	8.778
Annual Operations Costs	2.259
Annual Maintenance Costs	0.65
Major Maintenance – Year 12	11.3
Major Maintenance – Year 22	11.3
Major Maintenance – Year 32	11.3
Annual Revenues in Operations	7.777158
Annual increase in Revenues	0.393529 /yr
Government Contribution – Year 3 of project	26

A second CPI model for the project was also generated to include uncertainty in financial factors. This second model was developed using data given in the source dissertation pertaining to uncertainty in inflation rates of toll growth and maintenance, in major maintenance costs, and in certain construction costs. The latter uncertainty was calculated as a percentage of the specific construction cost and applied to all construction costs in the model. Finally, the equity fraction was adjusted according to the distribution of the construction costs (i.e. deterministic value of debt / value of construction cost possibility distribution = equity fraction possibility distribution), and the interest rate distribution was assumed to range from the minimum coupon value to the maximum, with a most likely value of the weighted average coupon value. For more information on financial factors included in both CPI models for the Canadian Hwy, the reader is referred to the project data files attached as Appendix K.

Non-Financial Factors

As in Case Studies One and Two, it was necessary to adopt the generic RFF for the project, and opportunities were simply omitted from the model, due to a lack of information pertaining to non-financial factors in the source dissertation. Table 7.12 presents the importance and likelihood ratings for each of the non-financial factors kindly provided by the source author, whilst Table 7.13 provides all interdependencies included in the project's risk factor framework in the form of an RIM. Again these were included in the model including uncertainty and excluded from the deterministic model.

Table 7.12 Risk Factor Ratings – Case Study Three

RISK FACTOR	IMPORTANCE	LIKELIHOOD
C1 - Approval and Permit	5	5
C2 - Change in Law / Justice Reinforcement	5	1
C3 – Corruption	5	0
C4 - Political Instability	5	0
M1 - Local Partner's Creditworthiness	3	1
M2 - Corporate Fraud	3	1
M3 - Termination of Joint Venture	3	1
M4 - Inflation and Interest Rates	5	3
P1 - Cost Overrun	5	4
P2 - Improper Design	5	1
P3 - Improper Quality Control	3	3
P4 - Improper Project Management	5	3

N.B. Scale is from 1 (weak) to 7 (extreme). 0 represents no importance/likelihood.

Table 7.13 Risk Influence Matrix (RIM) for Case Study Three

Direction of Influence	C1 - Approval and Permit	C2- Change in Law / Justice Reinforcement	C3 – Corruption	C4 - Political Instability	M1 - Local Partner's Creditworthiness	M2 - Corporate Fraud	M3 - Termination of Joint Venture	M4 - Inflation and Interest Rates	P1 - Cost Overrun	P2 - Improper Design	P3 - Improper Quality Control	P4- Improper Project Management
C1 - Approval and Permit		3	7	5								
C2 - Change in Law / Justice Reinforcement			3	5								
C3 – Corruption				5								
C4 - Political Instability								3				
M1 - Local Partner's Creditworthiness			1	1		5			5			
M2 - Corporate Fraud			3	1								
M3 - Termination of Joint Venture		3	1	3	3	5			5			
M4 - Inflation and Interest Rates			3	7								
P1 - Cost Overrun	3	3		1	1	1		5		5	3	5
P2 - Improper Design		1				1					1	
P3 - Improper Quality Control		1	1			1						3
P4 - Improper Project Management		1	1			3						

7.8 VALIDATION - ECCO ANALYSIS RESULTS

Once all six project data files had been created for the three case study projects, a total of four analysis runs were conducted:

1. Case Study One – Model 1 vs. Model 2;
2. Case Study Two – Model 1 vs. Model 2;
3. Case Study Three - Model 1 vs. Model 2; and
4. Case Study One (Model 2) vs. Case Study Two (Model 2) vs. Case Study Three (Model 2)

Table 7.14, Table 7.15, and Table 7.16 present results from the first three analysis runs.

Table 7.14 Comparison of Analysis Results – Case Study One**

PERFORMANCE MEASURE	MODEL ONE	MODEL TWO+	
		Distribution	Equivalent Value*
Construction Cost NPV ($mil)	122.12	{98.72, 112.07,112.07, 133.66}	114.82
Equity Holder NPV ($mil)	7.27	{-6.38, 15.48, 17.63, 56.11}	22.00
Equity Holder B/C Ratio	1.188	{0.830, 1.436, 1.497, 2.858}	1.714
Equity Holder IRR (%)	15.0	{9.80, 18.80, 19.60, 30.00}	19.66
Equity Holder Payback Period (yr)	8	{6, 7, 8, 10}	8
Overall Project NPV ($mil)	20.20	{3.81, 28.75, 31.42, 67.88}	33.85
Overall Project B/C Ratio	1.184	{1.035, 1.285, 1.312, 1.718}	1.35
Project Payback Period (yr)	9	{8, 9, 9, 10}	9
Average Annual DSCR	1.477	1.675	1.675
Project Risk Rating	0.373	0.370	0.370
Project Ranking (using B/CR Rating)	2	1	1

* See Equation 4.19 and Figure 4.8.

** Table 7.2 shows actual figures obtained by Bakatjan et al. (2003).

+ Uncertainty in financial data and risk factor interdependencies are included.

Table 7.15 Comparison of Analysis Results – Case Study Two

PERFORMANCE MEASURE	MODEL ONE	MODEL TWO+	
		Distribution	Equivalent Value*
Construction Cost NPV ($mil)	3935	{3353, 3935.3, 4817.8}	4035
Equity Holder NPV ($mil)	-794	{-1376.3, -792.2, -144.8}	-771
Equity Holder B/C Ratio	0.328	{-0.07, 0.33, 0.86}	0.373
Equity Holder IRR (%)	9.2	{6.8, 9.2, 11.8}	9.3
Equity Holder Payback Period (yr)	30	{28, 30, 33}	31
Overall Project NPV ($mil)	207	{-1136.3, 209.6, 2041.2}	371
Overall Project B/C Ratio	1.041	{0.79, 1.04, 1.08}	1.078
Project Payback Period (yr)	25	{24, 25, 27}	26
Average Annual DSCR	0.907	0.928	0.928
Project Risk Rating	0.433	0.408	0.408
Project Ranking (using B/CR Rating)	2	1	1

* See Equation 4.19 and Figure 4.8.

+ Uncertainty in financial data and risk factor interdependencies are included.

Table 7.16 Comparison of Analysis Results – Case Study Three

PERFORMANCE MEASURE	MODEL ONE	MODEL TWO+	
		Distribution	Equivalent Value*
Construction Cost NPV ($mil)	127.633	{117.7,126.4,141.24}	128.439
Equity Holder NPV ($mil)	27.872	{9.41, 28.7, 39.4}	25.82
Equity Holder B/C Ratio	1.461	{1.151, 1.472, 1.681}	1.435
Equity Holder IRR (%)	12.60	{10.0, 12.8, 14.6}	12.47
Equity Holder Payback Period (yr)	9	{8, 9, 17}	12
Overall Project NPV ($mil)	39.494	{26.4, 40.1, 48.2}	38.23
Overall Project B/C Ratio	1.537	{1.346, 1.547, 1.688}	1.527
Project Payback Period (yr)	11	{10, 10, 11}	11
Average Annual DSCR	2.597	2.334	2.334
Project Risk Rating	0.243	0.188	0.188
Project Ranking (using B/CR Rating)	1	2	2

* See Equation 4.19 and Figure 4.8.

+ Uncertainty in financial data and risk factor interdependencies are included.

The analysis results from these first three analysis runs show that the inclusion of the generic interdependencies in the RFF accounted for only moderate decreases in the project risk ratings of Case Study One from 0.373 to 0.370 (0.8%), and Case Study Two from 0.433 to 0.408 (5.77%), but caused a significant decrease in the project risk rating of Case Study Three from 0.243 to 0.188 (22.63%). As discussed in Chapter 3, the ANP method is sensitive to four aspects of the structuring of interdependencies in the RFF: 1) location of interdependencies; 2) direction of interdependencies; 3) magnitude of interdependencies; and 4) cycling between risk factors. Thus, the significant variation in project ratings of Case Study Three can easily be attributed to the high number of low likelihood values (0 and 1) assigned to the risk factors, the greater range in interdependence values in the RIM (see Table 7.13) and the dependence of more likely factors on less likely factors. To illustrate the latter of these explanations, consider the risk factor, “Inflation and Interest Rates”, which is moderately likely to occur, strongly important to the project, but is highly dependent on “Corruption” and “Political Instability” risk factors, which have both been assigned likelihood values of zero (0). These low likelihood values of the influencing factors, actually act to reduce the overall project risk rating.

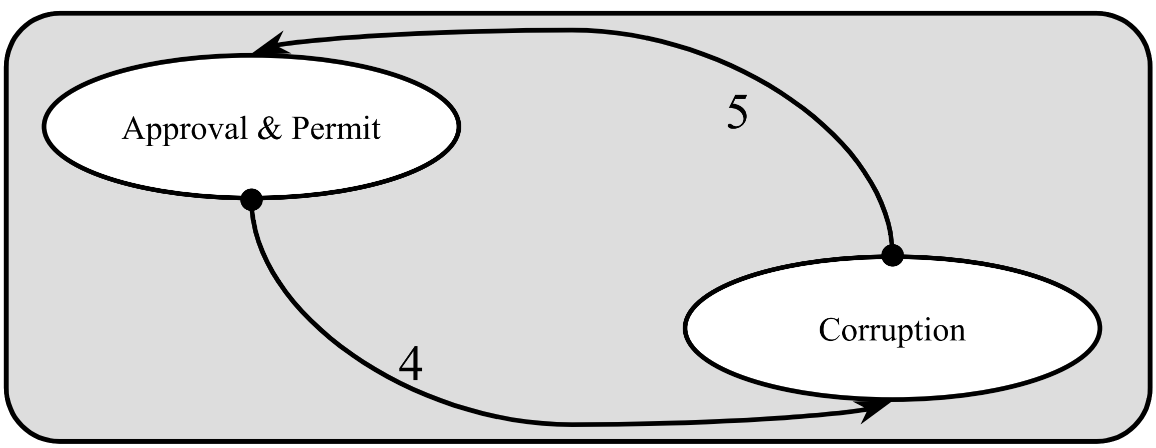


Figure 7.4 Cycling Between Approval & Permit and Corruption Risk Factors

The moderate variations in project risk ratings for the first two case studies can partly be attributed to the highly moderated values in the final RIM (only ranging between 3 and 5) caused by the averaging of the pilot study respondents risk perceptions. The final RIM for the generic RFF also included six (6) cycling pairs of risk factors, which could have reduced the impact of interdependencies (see Figure 7.4). Unfortunately, since all these aspects of the structuring of interdependencies were determined by industry via the pilot study, it was not possible to make any alterations to the final RIM included in the case studies.

These three analysis runs demonstrate the advantage of using possibility distributions to represent the uncertainty in financial data. With deterministic data a single value answer is given for each performance measure; the possibility distributions allow for a single, equivalent value to be calculated for comparisons, but also provides final distributions for each, indicating the least likely range and most likely. For example, the use of possibility distributions in Case Study One to accurately reflect the uncertainty in financial estimates, rather than exploring a worst-case scenario, allowed a greater understanding of all possible outcomes for the project. For example, the equity holder NPV was found to range from -$6.38million to $56.11million, with a most likely value of $15.48 to $17.63million and an equivalent single value of $22.00million. This result is compared to a deterministic value of $7.27 million (see Table 7.14 and Figure 7.5).

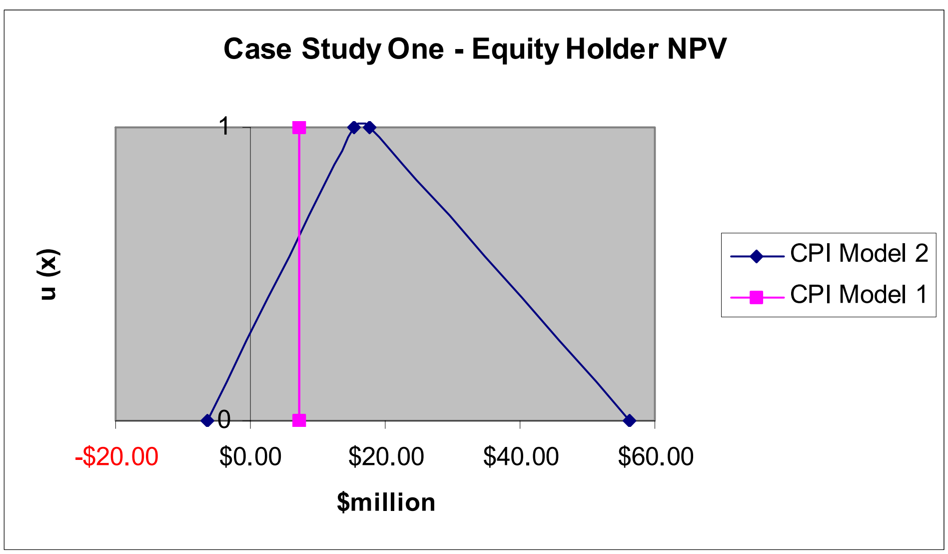


Figure 7.5 Graphical Comparison of Case Study One Models Results

The accuracy of Module Two calculations has been verified earlier in this chapter through use of the deterministic CPI model for Case Study One. However, it should be noted that results from the deterministic models for Case Studies Two and Three also compared reasonably to those stated in their respective source papers, despite various differences between ECCO's financial analysis model and those described in the papers. Chang and Chen (2001) calculated an overall project payback period of nine (9) years from completion of construction, and 13-14 years for equity holders; compared to 11 years and 15 years respectively calculated by ECCO. Both the overall project and equity cumulative cash flow graphs presented in the paper resembled those produced by ECCO, despite Case Study Three's CPI model being developed using a combination of data from crude and semi-detailed models. However, the overall investment cost NPV was reported to be $116million, IRR as 13.9%, and aggregated B/C ratio of 1.543 compared to $128million, 12.47%, and 1.527 (overall project) calculated by ECCO, respectively. From the cumulative cash flow graph provided in the source paper, the payback period was taken as approximately 10 years, compared to ECCO's values of nine (9) years for equity holders and 11 years for the overall project.

With ECCO's accuracy being verified, the fourth analysis run was crucial in demonstrating the full capabilities of ECCO to evaluate and compare up to five CPI options. This final analysis run consisted of the CPI model including uncertainty for each of the three case study CPIs. The three projects were of varying type and scale, and were hosted by a range of different countries. ECCO successfully analysed and compared on a common basis, a Taiwanese high-speed rail project, a Turkish power plant project and a Canadian highway project, for which construction costs differed from approximately $4 billion to $120 million, and non-financial factors had a unique impact upon the investment. Thus this fourth analysis run demonstrates ECCO's ability to evaluate and compare any set of CPI options, no matter how different the projects are.

The results for the evaluation and comparison of the three projects are presented as Table 7.17, Figure 7.6, Figure 7.7, and are also attached as Appendix L. ECCO ranked the projects in the following order according to their B/CR rating due to the absence of Opportunity Ratings data: 1) Case Study Three – Canadian BOT Hwy (7.633); 2) Case Study One - Turkey HEPP Project (4.630); and 3) Case Study Two - Taiwan HSR (0.915).

Table 7.17 Analysis Results for Final Analysis Run - Equivalent Single Values

	Case Study One	*Case Study Two*	*Case Study Three*
Construction Cost NPV ($mil)	114.82	4035.37	128.439
Equity holder NPV ($mil)	22.00	-771.13	25.82
Equity holder B/C	1.714	0.373	1.435
Equity holder Payback Period (yr)	8	31	12
Equity holder IRR (%)	19.66	9.27	12.47
Overall project NPV ($mil)	33.85	371.49	38.23
Overall project B/C	1.35	1.078	1.527
Project Payback Period (yr)	9	26	11
Average Annual DSCR	1.675	0.928	2.334
Project Opportunity Rating (0-1)	0	0	0
Project Risk Rating (0-1)	0.370	0.408	0.188
Project O/R Ratio	Not Available	Not Available	Not Available
Project B/CR Rating	4.630	0.915	7.633
Project BO/CR Rating	Not Available	Not Available	Not Available
PROJECT RANKING	***2***	***3***	***1***

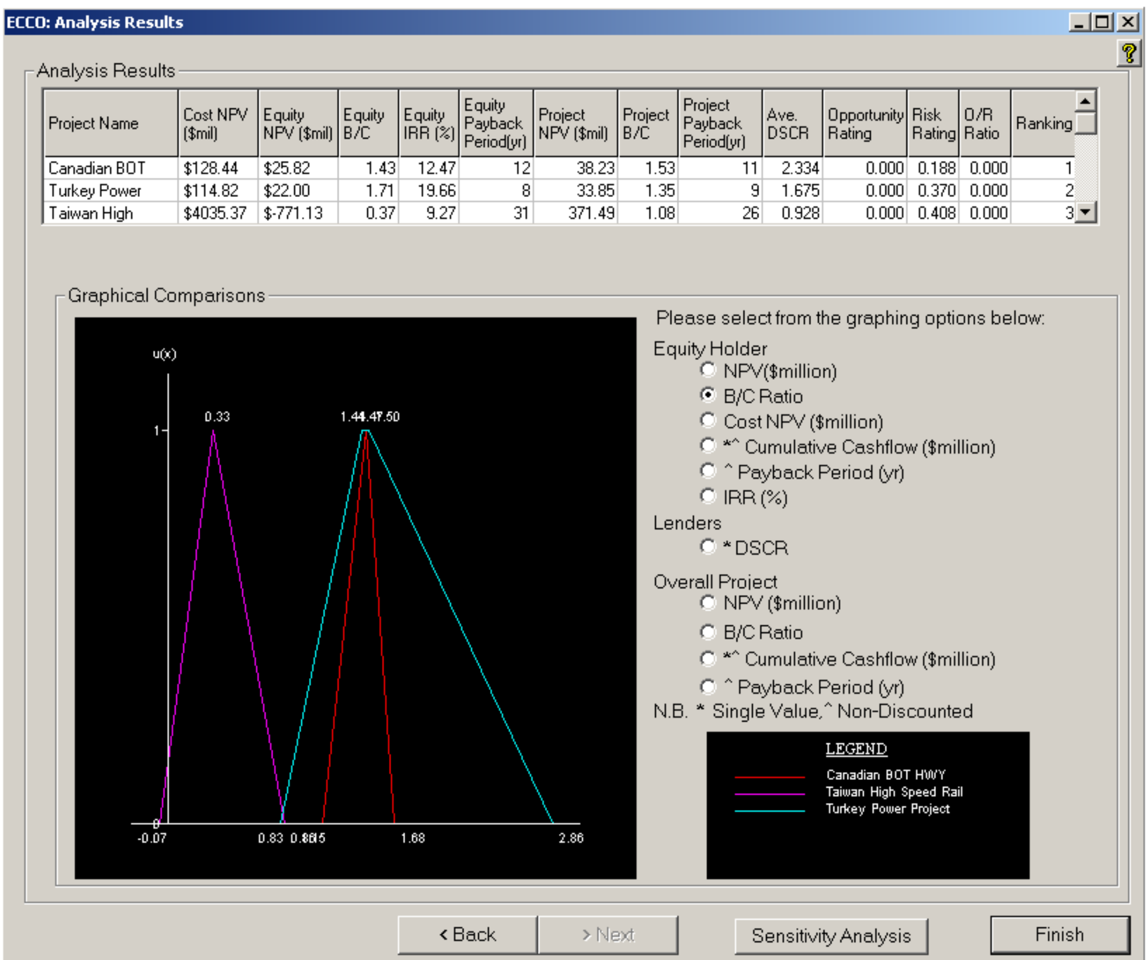
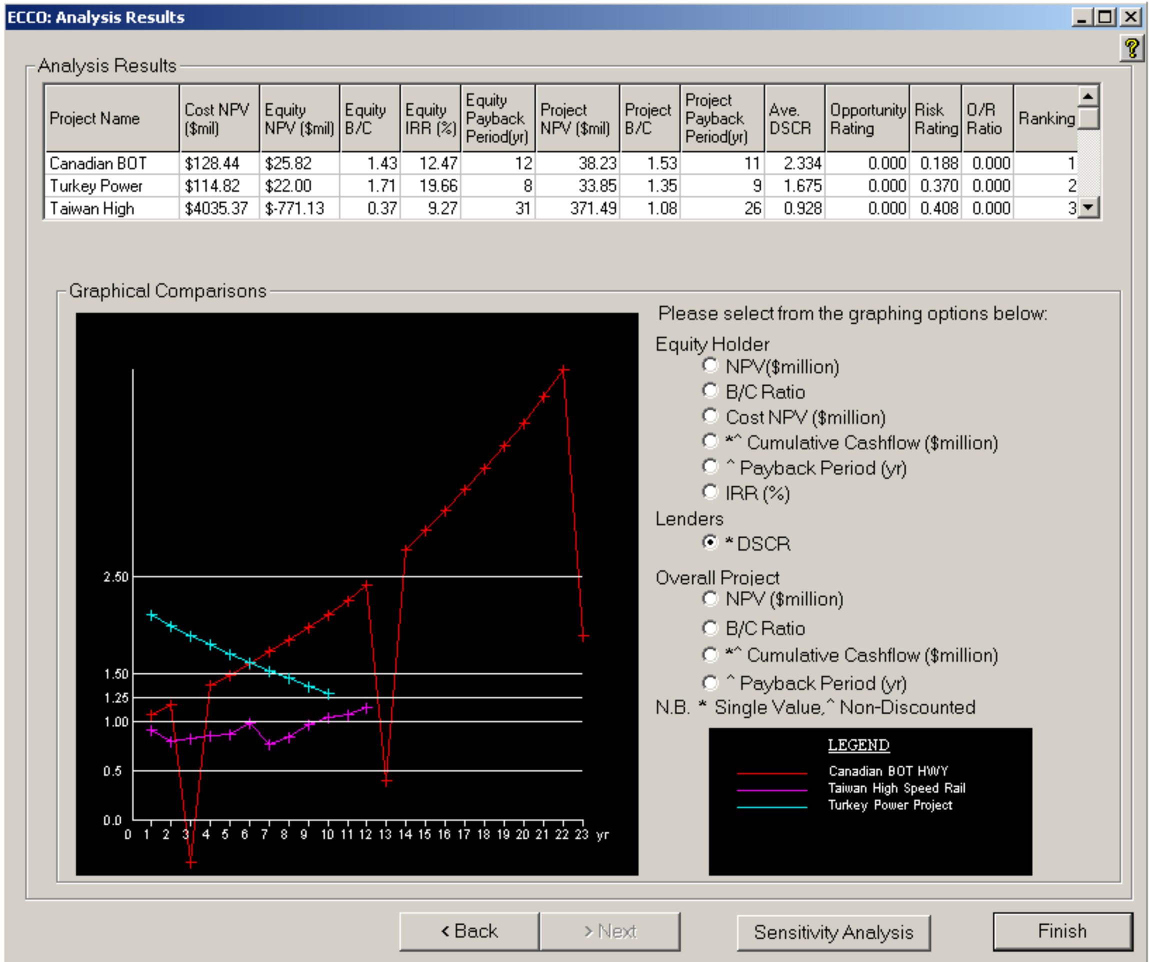


Figure 7.6 Fourth Analysis Run Results – Equity Holder B/C Ratio Distributions

From the equity holder's perspective, looking at the financial feasibility of the projects, the Taiwanese project is least feasible with a negative NPV and a B/C ratio well under one. Therefore, although Taiwan is by far the largest project, unless measures are taken to increase revenues, decrease taxes or reduce interest payments, this project would be infeasible for equity investors, given the data provided. This demonstrates that ECCO facilitates a Go/No-go decision through quantitative results.

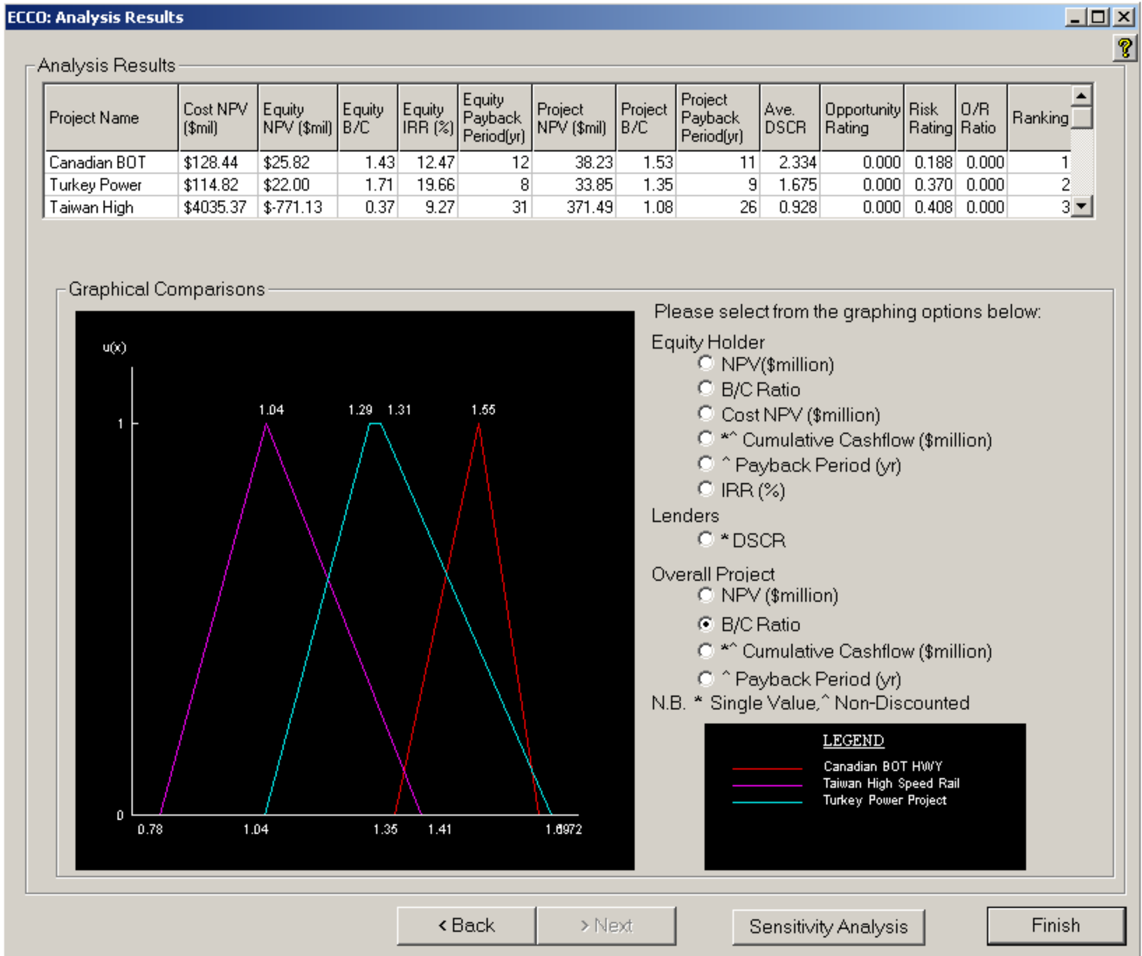
The Turkey HEPP project has a lower NPV than the Canadian BOT Hwy project ($22.00million vs. $25.82million), yet a greater B/C ratio (1.714 vs. 1.435) and IRR (19.66% vs. 12.47%). In other words, a greater percentage return is likely for the least capital outlay. Hence financially speaking Turkey would be considered the better investment. However, looking now at the two projects' non-financial aspects, Turkey has been evaluated as a more risky investment (project risk rating of 0.370 vs. 0.188). This acts to reduce the B/CR rating, so much so that the ranking of the two projects is reversed, and the Canadian BOT Hwy would be considered the better investment on the basis of both financial and non-financial aspects (7.633 vs. 4.630). ECCO, therefore, provides a streamlined project rating system that takes into account the combined effect of finances, risk and uncertainty on the overall project attractiveness.



Project Name	Cost NPV ($mil)	Equity NPV ($mil)	Equity B/C	Equity IRR (%)	Equity Payback Period(yr)	Project NPV ($mil)	Project B/C	Project Payback Period(yr)	Ave. DSCR	Opportunity Rating	Risk Rating	O/R Ratio	Ranking
Canadian BOT	$128.44	$25.82	1.43	12.47	12	38.23	1.53	11	2.334	0.000	0.188	0.000	1
Turkey Power	$114.82	$22.00	1.71	19.66	8	33.85	1.35	9	1.675	0.000	0.370	0.000	2
Taiwan High	$4035.37	$-771.13	0.37	9.27	31	371.49	1.08	26	0.928	0.000	0.408	0.000	3

Figure 7.7 Fourth Analysis Run Results – Annual DSCR Values

From the debtor's perspective, the annual Debt Service Coverage Ratio (DSCR) should be at least equal to one for the project to be considered feasible. In other words, the net revenue must be able to meet the debt instalment due on loans throughout the repayment period. Looking at Figure 7.7 it is evident that lenders would consider the Canadian Hwy project and Turkey HEPP project feasible, whilst the Taiwan HSR project would be considered infeasible with a DSCR less than one for most of the repayment period. The three spikes in the Canadian projects DSCR graph are caused by the major maintenance required every 10 years of operations. Apart from these spikes however, the Canadian project has a DSCR greater than one at all times, with an average value of 2.334. The Turkey project is most able to service its debt consistently, having a minimum DSCR value of 1.293 and an average value of 1.675.



Project Name	Cost NPV ($mil)	Equity NPV ($mil)	Equity B/C	Equity IRR (%)	Equity Payback Period(yr)	Project NPV ($mil)	Project B/C	Project Payback Period(yr)	Ave. DSCR	Opportunity Rating	Risk Rating	O/R Ratio	Ranking
Canadian BOT	$128.44	$25.82	1.43	12.47	12	38.23	1.53	11	2.334	0.000	0.188	0.000	1
Turkey Power	$114.82	$22.00	1.71	19.66	8	33.85	1.35	9	1.675	0.000	0.370	0.000	2
Taiwan High	$4035.37	$-771.13	0.37	9.27	31	371.49	1.08	26	0.928	0.000	0.408	0.000	3

Figure 7.8 Fourth Analysis Run Results – Overall Project B/C Ratio

From an overall project perspective, excluding financing concerns would produce a slightly different ranking of the three projects (see Figure 7.8). According to the overall single equivalent B/C ratios, the Canadian Hwy project would be ranked first (1.53), followed by the Turkey HEPP project (1.35), and then the Taiwan HSR project (1.08). A more careful investigation of the distributions reveals that the maximum least likely overall B/C ratio for the Turkish project is, in fact, slightly greater than that of the Canadian project (1.72 vs. 1.69). However, the Turkish project's single equivalent value is reduced by the large spread of its distribution {1.04, 1.29, 1.31, 1.72} compared to that of the Canadian project {1.35, 1.55, 1.69}. Thus, greater uncertainty in the Turkish project's B/C ratio has decreased its attractiveness and ranking amongst the projects. ECCO's ability to reflect the effects of uncertainty on the overall project attractiveness, and consequently increase the decision-makers confidence that predictions are realistic, is just one of the many benefits it delivers.

It can be also be seen from the results, that the Taiwan HSR project may possibly become feasible if its financing arrangements could be optimised, since its overall project B/C ratio (excluding financing considerations, such as debt instalments) is greater than one. These analysis results could be used in contractual negotiations between the various project parties; demonstrating another benefit of the developed DSS.

Although government parties would obviously not need to evaluate projects in three different countries, ECCO would be useful in the following ways:

- Overall project performance measures could be used as a bargaining tool in negotiation with interested parties;

- It could also be adapted for use by government parties to examine the feasibility of different options for public infrastructure provision. For example, evaluating the best option between building a bridge, building a tunnel or providing a ferry service across a river.

The above validation results give evidence that: 1) the inclusion of non-financial aspects in the CPI model can considerably influence the CPI's overall feasibility; 2) the inclusion of generic interdependencies in the risk factor framework does impact upon the CPI's risk rating; 3) the inclusion of uncertainty in financial factors in the project model can significantly affect results; and 4) the use of possibility distributions to accurately reflect the uncertainty in financial estimates gives a greater understanding of all possible outcomes for the project.

7.9 VALIDATION - ECCO SENSITIVITY ANALYSIS

Sensitivity Analysis was conducted on the three case study projects evaluated in the fourth analysis run. The independent effects of both a financial (equity fraction) and non-financial ("Cost Overrun") factor were explored for the projects.

Sensitivity analysis results for both these analysis cases are detailed below, and can be found attached as tab-delimited text files as Appendix M. The effects of a change in equity fraction from –5% to +5% of its original value were investigated for the three projects using Module Three. Figure 7.9 presents the results from this analysis.

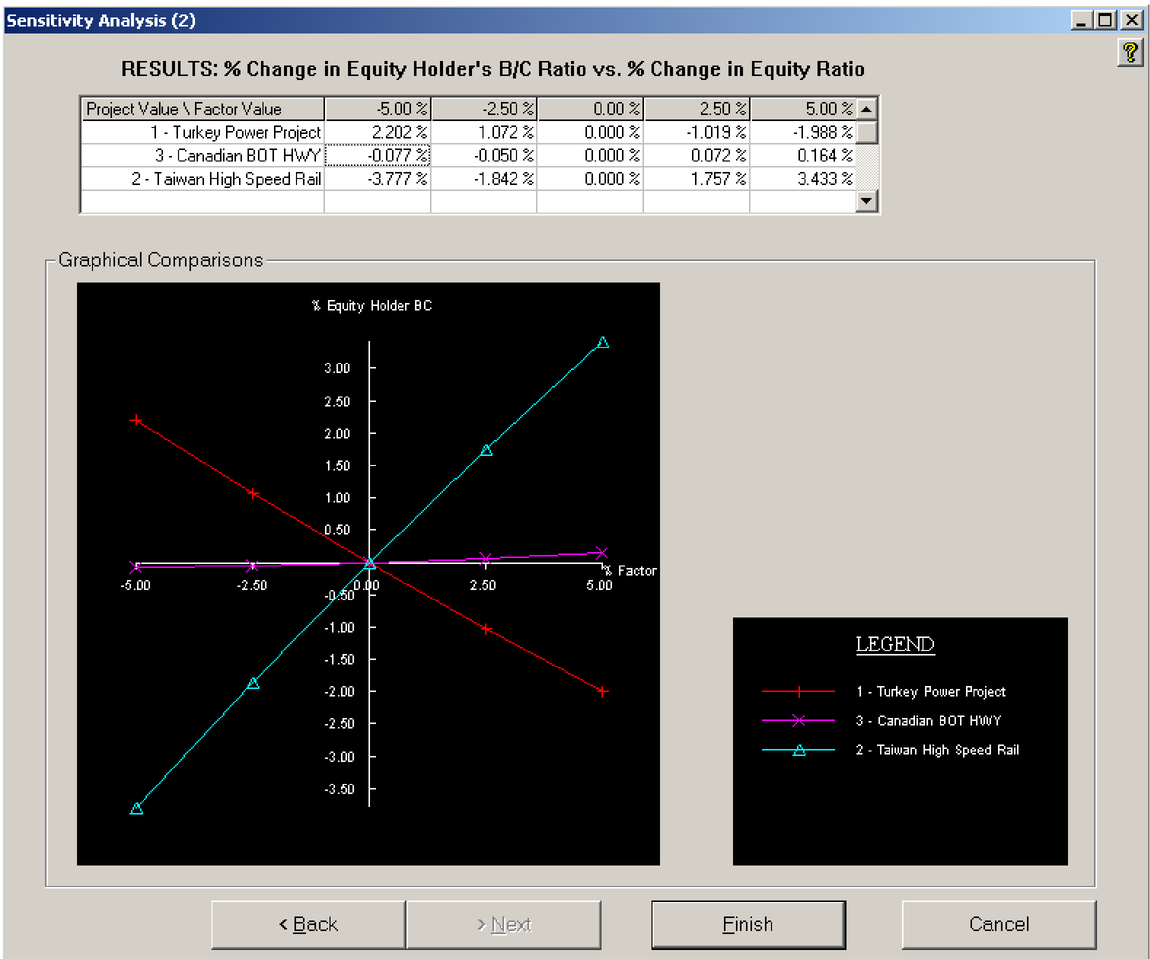


Figure 7.9 Sensitivity Analysis Results – Equity Fraction

From this figure it can be seen that the Turkey project behaves in an unusual manner. As the equity fraction increases, the equity holder B/C ratio decreases, whereas with the other two projects the B/C ratio increases. This unusual decrease in equity holder B/C ratio is due to the fact that the increase in expenditure required from equity holders actually outweighs the savings made in reduced debt payments. Also, it is evident that the Turkish and Taiwanese projects are much more sensitive to the equity fraction than the Canadian project. Thus, if either of these two projects were to go ahead, every effort should be made to ensure a suitable equity fraction is achieved.

ECCO's Module Three not only provides useful information to equity holders, but also to debtors and government parties. It facilitates negotiations between parties by allowing each to see which financial and non-financial factors are most critical and should be more strictly managed in order for a project investment to remain feasible for the equity holders.

The non-financial factor, "Approval and Permit", was selected for sensitivity analysis for the three case study projects in order to demonstrate how ECCO's Module Three can be used to identify the sensitivity of various projects to changes in non-financial factors. Figure 7.10 presents the results of this analysis from which it is evident that the Taiwan HSR project and the Canadian BOT Hwy are highly sensitive to the "Approval and Permit" risk factor, followed closely by, compared to the Turkey HEPP project. In the case that the Taiwanese and Canadian projects go ahead, it is particularly important to ensure government support in the form of timely approvals and permits. For example, the government party may agree to take contractual responsibility for any consequences of delays to approvals and permits on the project. In this way, contractual negotiations between parties become streamlined.

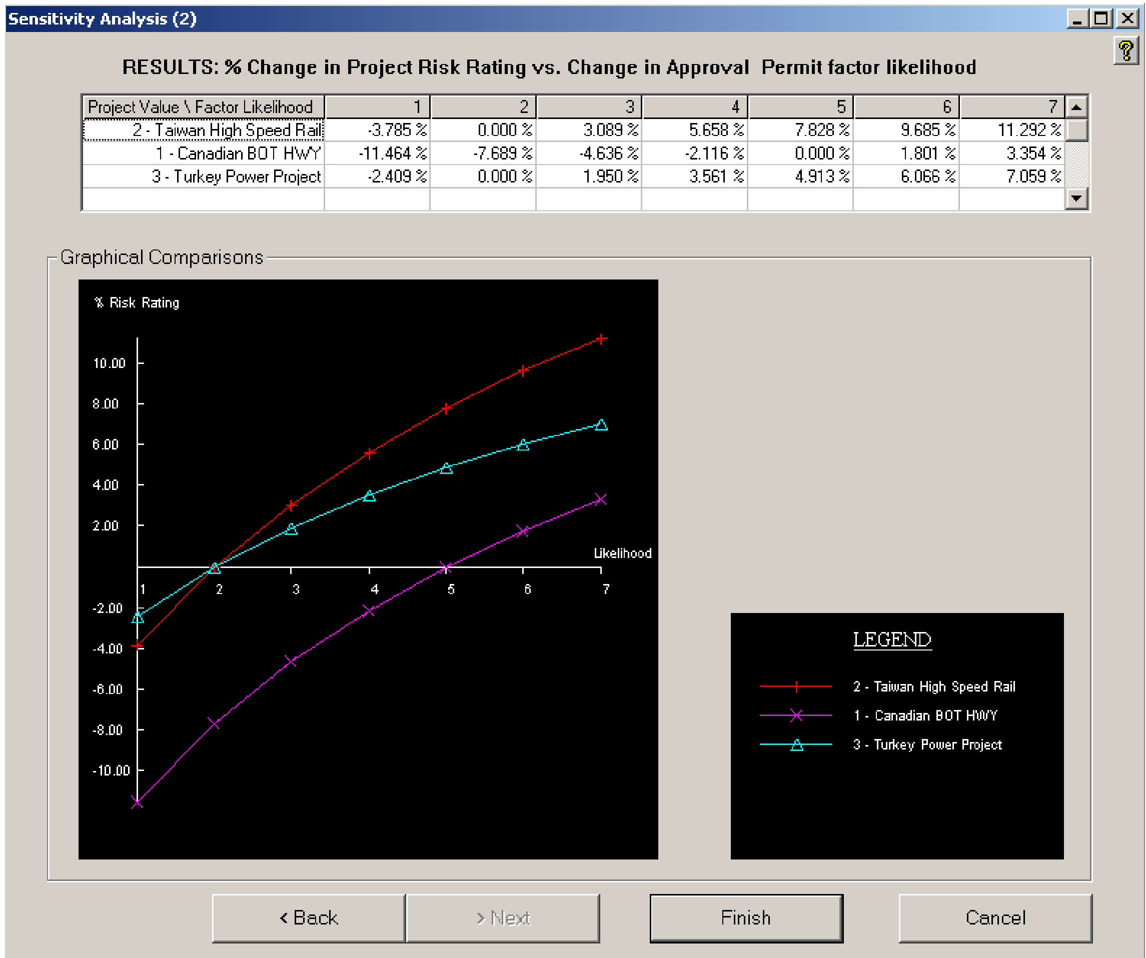


Figure 7.10 Sensitivity Analysis Results – Approval and Permits Risk Factor

7.10 LIMITATIONS OF ECCO SOFTWARE

The vast capabilities of the developed DSS, ECCO, have been clearly demonstrated in the preceding sections of this chapter. However, as with any newly developed system, ECCO has a number of limitations. The following sections present and discuss the limitations encountered whilst conducting the verification process, and the validation of the three project case studies.

7.10.1 Module One

ECCO's main objective was to evaluate and compare any type of CPI option, be it a road, bridge, power plant, or high-speed rail project at the feasibility stage. Therefore, ECCO employs a generic financial model. If ECCO is applied to modelling options once they are past this initial feasibility stage, for example, in the negotiations phase, its generic financial model may be limiting as it does not provide for multiple debt sources, complex repayment schemes, revenues to be generated during construction, or even detailed revenue estimation formulations. Although it was not designed for this purpose, modelling difficulties can sometimes be alleviated by adapting the input data, or using spreadsheet applications such as Excel© to pre-calculate revenue forecasting formulations and transferring them into the project data text files (as performed for case study projects).

Through conducting the case studies, it became evident that the various people rating risk factor importance, likelihood and influences had a different perception of the linguistic rating scale. This made it hard to make an assessment of whether one project was indeed more risky than another, or whether it was simply a matter of difference in perceptions. Therefore, risk factor importance, likelihood and influence ratings must be made by the same analyst or group of analysts for all projects being compared. The group's evaluation of the CPI options can then be derived using techniques such as the geometric mean (Saaty, 2001). This would ensure that there is no difference in the perception of rating scales between projects, and could also be applied to the input of uncertainty surrounding financial factors. This is in line with the fuzzy-based approach to collaborative decision-making developed by Yang et al. (2001).

7.10.2 Module Two

Module Two can only evaluate a maximum of five (5) projects at a time.

7.10.3 Module Three

Module Three, allows analysts to observe the varying sensitivity to any of the factors common to all projects being analysed. It has a slight limitation in that any non-financial or financial factors, not labelled exactly the same in all project data files, will not be available for sensitivity analysis. This limitation can be overcome by using common names for both non-financial and financial factors.

7.11 SUMMARY

The main purpose of Chapter 7 was to validate and verify the developed software program, ECCO. Any software can only be verified and validated in terms of its intended purpose. The intended purpose of ECCO was to provide an effective and efficient system for the evaluation and comparison of various CPI opportunities by meeting all ten requirements identified. Thus, the validation and verification test objectives were threefold:

1. Verify that each individual component of ECCO's three modules fulfil their set of established requirements;
2. Validate that ECCO as an overall system complies with all ten requirements identified, and truly does provide an effective and efficient system for the evaluation and comparison of various CPI options; and
3. Demonstrate the capabilities, and identify the limitations of the developed ECCO software.

The preceding sections detail the processes followed and the results gained in quest of these objectives. Each of the three modules was verified successfully. The ability to truly validate ECCO as a final product was limited by an absence of complete case study data. Hence true validation of ECCO was limited to its financial component. However, efforts were made to demonstrate how ECCO's modelling of the non-financial component could considerably influence the CPI's overall feasibility and that the inclusion of generic interdependencies in the risk factor framework does impact upon the CPI's risk rating.

CHAPTER 8

CONCLUSIONS, CONTRIBUTIONS AND IMPLICATIONS

8.1 GENERAL

This chapter outlines the three types of findings from the research, these being its conclusions, contributions and implications. It begins by summarising the key outputs of the work presented in each chapter. It then identifies important contributions made by the research to extend and further develop the existing body of knowledge. Finally, this chapter outlines the implications of the work for other researchers and the construction industry, and also suggests a number of possible directions for future research.

8.2 CONCLUSIONS

The main objective of this research project was to develop an effective and efficient decision support system to evaluate and compare concession project investment (CPI) opportunities at the feasibility stage. With this end in mind, the secondary objectives listed below were also identified:

1. Undertake a critical literature review of risks concession project investments, investment appraisal, current risk assessment practice in industry, CPI DSS requirements, mathematical modelling techniques, CPI financial analysis

models, decision-making techniques, CPI risk factor frameworks (RFF) and currently available DSSs.

2. Select the most effective, yet efficient techniques in the following areas for implementation in the CPI DSS design: mathematical modelling techniques, CPI financial analysis models, decision-making techniques and CPI RFFs.

3. Design the DSS architecture based upon the best techniques selected in Step 2 and thus develop the conceptual DSS.

4. Obtain specific industry input via a pilot study to refine the DSS generic CPI RFF, by identifying and quantifying all risk factor interdependencies.

5. Fully develop the conceptual DSS design of Step 4 as a computer software package ECCO (Evaluate and Compare Concession Options) with accompanying user manual and help files, to provide industry with a practical, user-friendly decision-making tool.

6. Obtain industry input via reported national and international case studies to validate the DSS and demonstrate its capabilities in evaluating and comparing CPI options.

These objectives have successfully been achieved, as described below:

- Chapter 2 presented a review of literature, which allowed the DSS design to be optimised. The risky nature of CPIs, investment appraisal and risk assessment practice in the construction industry were discussed, highlighting the industry's need for an effective yet efficient DSS. Various techniques in the areas of decision-making, financial modelling, mathematical modelling and CPI risk factor frameworks including currently available DSSs reported in the literature, were also investigated from which ten DSS requirements were proposed.

- In Chapter 3, justification was given for the selection of techniques in the area of mathematical modelling techniques, financial analysis models, decision making techniques and CPI risk factor frameworks that would, together, be used to develop the conceptual DSS. Great effort was focussed on the selection of the optimal decision-making technique that would later be used as the foundational structure for the DSS design. Three techniques, believed to be the most appropriate, were investigated with respect to their effectiveness and efficiency in meeting the relevant DSS requirements from which the ANP was chosen. Possibility theory and probability theory were compared on the basis of capability and practicality in modelling the uncertainty in CPIs at the feasibility stage. As a result, possibility theory was found to be the most suitable mathematical modelling technique for this particular purpose. The financial analysis models found in literature either did not provide adequate project performance measures, or required too much detail in defining parameters, loans, and project scheduling. Thus, a novel financial analysis model was derived comprising a total of 11 secondary financial performance measures encompassing those used by the various parties and implemented in the DSS. This model was designed to be largely generic to suit the level of data definition available at the feasibility stage. Finally, the refined risk factor framework developed by Wang et al. (2002) was selected as the basis for the DSS generic RFF as it was found to be the most advanced framework reported in the literature. Although this framework was originally developed for international projects, it was chosen based upon the assumption that concession projects face much the same risks as large-scale international projects due to similarities in the complexity of financial arrangements and organisational structure, and the ability of country and market environments to significantly affect project viability.

- A unique implementation of the selected techniques was proposed for the development of a new DSS which met all ten identified requirements. The proposed DSS architecture is detailed in Chapter 4. The DSS design comprised three separate modules for model definition, model evaluation and ranking, and sensitivity analysis. The purpose, structure and implementation of these modules was largely determined by the primary performance measure selected as the basis for overall rankings of the projects, being the ANP project rating method. This rating method extends the traditional financial benefit-cost (B/C) ratio to incorporate non-financial factors via the inclusion of an opportunity-risk (O/R) ratio, hence providing a holistic evaluation of the CPI options. A combination of the developed financial analysis model and possibility theory was used to define the financial component of the modules, whilst the ANP was again applied to the modelling of the non-financial component (risks and opportunities). However, it was adapted to allow for each project to have its own individual risk factor framework. A generic CPI RFF was developed as an option when using the DSS. This RFF contains the four (4) most critical risk factors identified by Wang et al. (2002) at the country, market and project levels of the project, as well as the quantified interdependencies between these factors, as identified by the pilot study.

- Chapter 5 presented results from the pilot study conducted to verify and adapt the selected risk factor framework with accompanying Risk Influence Matrix (RIM), and also quantified all interactions of the adapted RIM. From the results of this pilot study, the final RIM was developed for implementation in the DSS generic RFF.

- Chapter 6 outlined the production of the proposed DSS as a computer software program, ECCO (Evaluate and Compare Concession Options), using the Visual C++ development environment. This ensured the time and resource efficiency of the system. A user manual and various help topics were also developed to provide analysts with an adequate understanding of the processes followed by ECCO and how to best use the program.

- The proposed DSS was verified and validated in Chapter 7 using 3 CPI case study projects of varying scale, type (transport and power) and host country. Although the ability to truly validate ECCO as a final product was limited by an absence of complete case study data, ECCO's financial component was validated and its capabilities and minor limitations in modelling transport and power plant projects were successfully demonstrated in this Chapter. However, efforts were made to demonstrate how ECCO's modelling of the non-financial component could considerably influence the CPI's overall feasibility and that the inclusion of generic interdependencies in the risk factor framework does impact upon the CPI's risk rating.

- Finally, validation results give evidence that: 1) the inclusion of non-financial aspects in the CPI model can considerably influence the CPI's overall feasibility; 2) the inclusion of generic interdependencies in the risk factor framework does impact upon the CPI's risk rating; 3) the inclusion of uncertainty in financial factors in the project model can significantly affect results; 4) the use of possibility distributions to accurately reflect the uncertainty in financial estimates gives a greater understanding of all possible outcomes for the project; and 5) the ability to conduct sensitivity analysis gives insight into which financial/ non-financial factors are most critical and therefore require more strict management.

8.3 CONTRIBUTIONS TO ACADEMIC KNOWLEDGE BASE AND IMPLICATIONS FOR RESEARCH

Due to the relative youth of this branch of research, the construction industry lacks a DSS that is capable of evaluating and comparing several CPI options. Available DSSs are all limited in their capacity to incorporate both financial and non-financial aspects of an investment, as well as the uncertainties commonly encountered at the feasibility stage of a project in the most efficient and effective manner. This research project contributed to the academic knowledge base in the research field of CPI evaluation in the following ways by:

- Providing a critical review of existing techniques and systems available for the modelling of CPIs.

- Building upon the eight aspects of a CPI that a DSS must cater for identified by Abdel-Aziz (2000), by proposing two additional aspects: 1) the identification of important non-financial factors contributing to uncertainties (both risks and opportunities); and 2) the interdependency of factors (both financial and non-financial).

- Proposing adaptations to the ANP technique to allow for different RFFs (factors, importance weightings, and interdependencies) to be developed for the non-financial component of each CPI model allowing the DSS to reflect the unique investment situation encountered on each individual project. However, it should be mentioned that additional testing of this adaptation should be carried out.

- Proposing a novel financial analysis model that best models the financial component of the CPI at the feasibility stage. All reported models either required too high a level of data definition for evaluations at the feasibility stage, or did not provide sufficient performance measures.

- Developing and implementing an innovative DSS design as computer software using a unique combination of possibility theory, the ANP Project Rating Method, and a novel financial analysis model designed to meet all 10 requirements in an efficient and effective manner. To the best of the author's knowledge this blend of techniques, particularly the ANP technique, has not been previously applied to the evaluation and comparison of CPI options.

- Refining and extending the RFF developed by Wang et al. (2002). Wang et al. (2002), similar to other researchers in the area, assume that the most significant interdependencies only flow down from higher levels to lower levels (e.g. project level factor influences a market or project level factor), or within a level, but not from lower levels to higher levels (e.g. market level factor influences project level factor). This research proposes that interdependencies can, in fact, flow from lower levels to higher levels, and confirmed this using industry input via a pilot study. Also, to the author's knowledge no research has focussed upon the quantification of risk factor interdependencies. This research has conducted a pilot study as a preliminary investigation into the quantification of the identified interdependencies using a linguistic scale.

It is therefore believed that this research project provides a strong foundation for the continual building and application by researchers to achieve the ultimate goal of meeting the construction industry's needs in this area.

8.4 IMPLICATIONS FOR THE CONSTRUCTION INDUSTRY

Although concession projects theoretically present a win-win-win solution to the problem of infrastructure provision, this has not been the case in many countries. The underperformance of concession projects has been attributed to the inability of project sponsors and promoters to predict the impact of all financial and non-financial (risk) factors associated with CPIs.

In order to gain a competitive edge in these markets, companies must therefore be able to select the CPIs which provide the greatest benefits, both financial and non-financial. It is imperative that whether benefits are purely financial or a combination of financial and non-financial gains, CPI options are compared as objectively as possible and feasibility studies incorporate risk analysis techniques in conjunction with traditional economic analysis. However, despite the fact that there are a myriad of risk analysis techniques for the appraisal of project investment opportunities, statistics show that construction companies concentrate primarily on establishing the financial viability of a project and fail to undertake adequate formal risk assessment before making the decision to go ahead.

In fact there are a vast and diverse number of Decision Support Systems (DSSs) developed over recent years for the modelling of high-risk construction project investments, such as CPIs, which incorporate the analysis of both financial and non-financial (risk) aspects of a project. However, these are all limited in their capacity to incorporate both financial and non-financial aspects of an investment and the uncertainties commonly encountered at the feasibility stage in the most efficient and effective manner. These two criteria, efficiency and effectiveness, are integral to the usefulness of the final developed DSS to the industry and unless a DSS accurately captures the real-life investment characteristics in a resource and time efficient manner, industry will not be receptive to it (Akintoye and Macleod, 1997).

This research has first identified the requirements of such a DSS before selecting the various modelling techniques that when implemented in combination together, can successfully fulfil all these requirements in the most efficient and effective manner. A conceptual DSS design was developed using the selected techniques, and then produced as a computer software package, ECCO. The direct benefits to the construction industry from the development of ECCO include:

- Clear identification of project risk (non-financial) factors that may have otherwise been overlooked;
- Streamlined project rating system, which takes into account the combined effect of finances, risk, and uncertainty on the overall project viability;
- Economic performance measures calculated are those commonly used by the various parties involved (equity holders, debtors, government);
- Time and resources efficiencies due to streamlined approach and development of system as software program ECCO;
- Facilitation of Go/No-go decision through quantitative results;
- Increased confidence that predictions are realistic;
- Analysis results can be used as a tool for improved contractual negotiations between equity holders, debtors, and government; and
- Identification of critical risk factors for input into the selected project's risk management plan.

8.5 RECOMMENDATIONS FOR FUTURE RESEARCH

Recommendations for future research as a result of this project are listed below.

- This research project made no attempt to develop an opportunities factor framework. Although government bodies around the world (particularly the National Audit Office in the UK), have conducted research into the non-financial benefits or opportunities created by concession projects for government parties, no research has been found that focuses on identifying the non-financial opportunities for private sector parties. Thus, future research is needed in this area to ensure both positive and negative aspects of a CPI opportunity are taken into consideration. This research should result in the development of a generic opportunities factor framework for CPIs from the perspective of equity holders.

- Further research is needed to better understand risks and opportunities faced by the industry through the development of country specific and project type (road, rail, power) specific risk factor and opportunity factor frameworks. As part of this research, particular effort should be made to better quantify the interdependencies between the factors in these frameworks. To the best of the author's knowledge, no other work has been published in this area of quantifying non-financial factor interdependencies for CPIs. For this purpose, it is suggested that larger-scale, project type, and host country specific questionnaires be conducted.

- Extensive real-life case studies should be conducted to provide more evidence for the validity of the developed DSS and assess the degree of effectiveness and efficiency achieved by its use, compared to currently available systems. The results of these case studies should reinforce the importance of using a holistic approach to the evaluation and ranking of CPI options at the feasibility stage before a go-no go decision is made.

- Further testing of the proposed adaptations made to the ANP technique to allow for different RFFs (factors, importance weightings, and interdependencies) to be developed for the non-financial component of each CPI model.

- Lastly, while the research focussed on project evaluation at the feasibility stage, further research should be undertaken to extend the DSS to incorporate modules for modelling negotiations and even project monitoring.

8.6 CLOSURE

This research made fundamental contributions to the area of risk analysis and management by developing a DSS capable of incorporating both financial and non-financial (risk and opportunity) factors in the evaluation and ranking of CPI options. The literature review, DSS development and validation provided a unique insight into the impact of non-financial factors and their interdependencies, on the overall feasibility of a CPI option from the perspective of the construction industry.

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APPENDIX A

POSSIBILITY THEORY METHODS:

THE VERTEX METHOD

This method makes use of the α-cut representations of fuzzy sets. While it is an approximate computational technique, it is highly efficient compared with the exact method of non-linear programming, with an accuracy that is much better than the conventional discretisation approach (Dong et al., 1987).

Suppose y is a function of n variables; i.e. $y = f(x_1, x_2, ...x_n)$ and each x_i, $i = 1,..., n$ is an interval variable represented by $X_i = [a_i, b_i]$. Assuming that y is continuous in the n-dimensional rectangular region with 2^n vertices, then the value of interval function Y can be obtained by:

$Y = f(X_1, X_2, \ldots X_n)$

$Y = [\min_j (fc_j), \max_j (fc_j))]$, $j = 1, \ldots, 2^n$, where c_j is the ordinate of the j-th vertex.

The algorithm consists of the following four (4) steps:

1. Select an α value where $0 < \alpha < 1$;
2. Find the interval(s) in X and Y which correspond(s) to this α, these intervals are known as the α-cuts;
3. Using the binary algebraic operations on intervals, compute the interval(s) of f(x) corresponding to those of X and Y; and
4. Repeat the above steps for different values of α to complete an α-cut representation of the solution. Processing more α-cuts, however, increases the computational requirements.

Example: A and B are a triangular [0.4, 0.5, 0.6] and trapezoidal [0.3, 0.4, 0.5, 0.7] possibility distribution, respectively.

If C = A + B, an approximate calculation of C is (see Figure A.1):

1. Take an α-cut at 0.0, $A_{0.0}$ = [0.4, 0.6] , $B_{0.0}$ = [0.3, 0.7], thus $C_{0.0}$ = [0.7, 1.3];
2. Take an α-cut at 1.0, $A_{1.0}$ = [0.5] and $B_{1.0}$ = [0.4, 0.5], thus $C_{1.0}$ = [0.9, 1.0]; and
3. The resulting distribution is [0.7, 0.9, 1.0, 1.3].

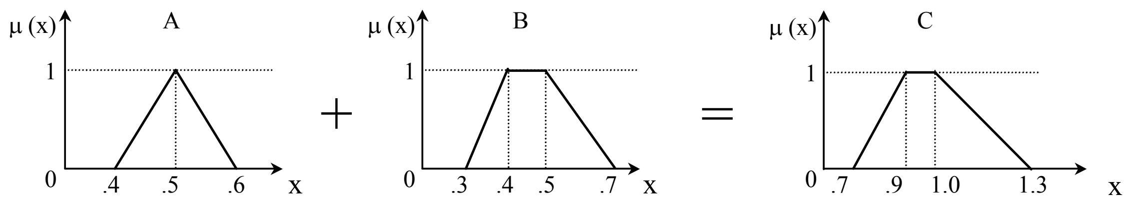


Figure A.1 Vertex Method Calculation of A + B = C

THE FUZZY AVERAGING METHOD

Fuzzy averaging is the aggregation of opinions (given as fuzzy numbers), regarding the uncertainty associated with the various criteria, in order to obtain an overall picture or conclusion about the situation. The fuzzy average (Bojadziev and Bojadziev, 1996), V_i, is given by:

$$V_i = \frac{\sum_{j=1}^{J} w_j \times p_{ij}}{\sum_{j=1}^{J} w_j} \qquad (i = 1,\ldots,I)$$

Where: V_i is the fuzzy aggregate assessment of the project

w_j is the weight given to the criterion j

p_{ij} is the characteristic value associated with each criterion

Example: Suppose Factor A was defined by a trapezoidal distribution [0.6, 0.7, 0.8, 0.9] and it had a relative importance of 0.4 compared to Factor X [0.4, 0.5, 0.55, 0.7], also a trapezoidal distribution. The resultant combined distribution is equal to:

= 0.4 (A) + 0.6(X)

= [0.24, 0.28, 0.32, 0.36] + [0.24, 0.3, 0.33, 0.42]

= [(0.24 + 0.24), (0.28 + 0.3), (0.32 + 0.33), (0.36+0.42)]

=[0.48, 0.58, 0.65, 0.78]

THE RANKING INDEX MODEL

An index for ranking fuzzy numbers that is suitable for economic analysis has been proposed (Smith, 1995). This index is based on the difference of area of a rectangle and the area under the possibility distribution of each alternative. The following equation for this ranking index is given by Choobineh and Behrens (1992).

$$K_j = 0.5 \cdot [1 - \frac{RA_j - LA_j}{R - L}]$$

The R and L correspond to the maximum and minimum of the domain of the utility function of the decision-maker, respectively. R, L, RA_j and LA_j are shown in Figure A.2. The value of the ranking is bounded by zero and one.

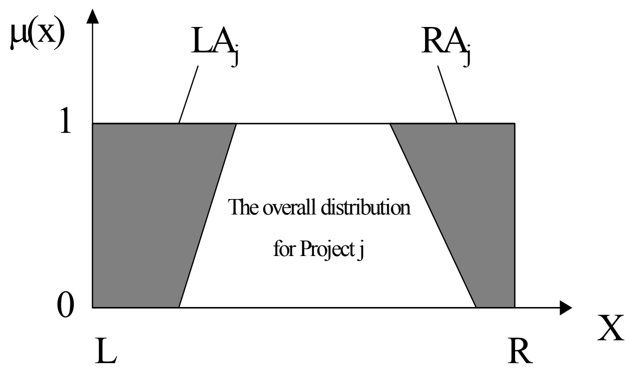


Figure A.2 The Areas Used in the Ranking Index

Example: The two projects A and B need to be ranked (see Figure A.3). The overall distribution is A [0.40, 0.52, 0.81, 0.93] and B [0.22, 0.41, 0.48, 0.93].

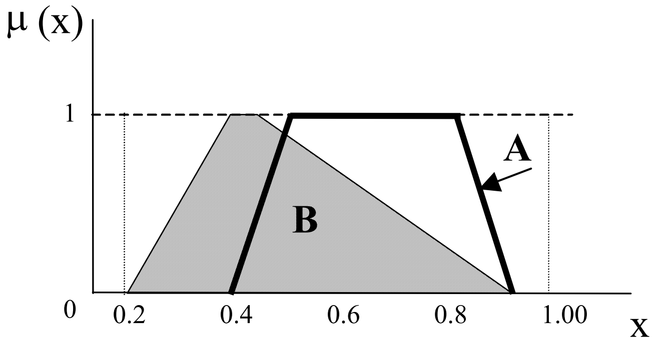


Figure A.3 Two Possibility Distributions A and B

Using the Ranking Index Model:

Take a range of L = 0.2 and R = 1.0

Project A: $RA_A = 0.13$, $LA_A = 0.27$, $K_A = 0.59$

Project B: $RA_B = 0.13$, $LA_B = 0.27$, $K_B = 0.39$

Therefore, $K_A > K_B$, and Project A dominates Project B.

APPENDIX B

QUESTIONNAIRE – RISK FACTOR INTERACTION IN CONCESSION PROJECTS

Concession projects are by nature, high-risk investments. Thus it is crucial to ensure adequate risk assessment takes place before any decisions are made to invest. However, not only should such risk assessment take into consideration the existence of risk, but also the interaction of these risks, as it is well documented that these interactions can significantly affect the results of any risk assessments. This questionnaire forms part of a larger project to develop a Decision Support System (DSS) that evaluates and compares several concession project investment options. It aims to build upon research conducted by Hastak and Shaked (2000) and Wang et al. (2002), which identified, classified, and quantified (via survey) the criticality of international project risk factors. **Table 1** presents the 4 most critical risk factors at the Country, Market, and Project levels as identified in a comprehensive, international survey on international construction projects by Wang *et al*. (2002). Although the above research focussed primarily on international project risk, it has been adopted as a basis for the following work on concession projects, on the assumption that concession projects face much the same risks as international projects due to similarities in complexity of financial arrangements and organisational structure, and the ability of country and market environment to significantly affect project viability.

More specifically this questionnaire aims to broadly quantify all significant interactions between the more critical risk factors on concession projects. Influences of higher level factors on lower level factors have already been identified by Wang et al. (2002), however it is believed that other influences exist between same level factors and possibly even from lower level factors on higher level factors.

TABLE 1 –Most Critical Risk Factors Previously Identified By Wang *et al.* (2002)

COUNTRY LEVEL	**C1**	Approval and Permit – Delay or refusal
	C2	Change in Law / Justice Reinforcement –Inconsistency in application
	C3	Corruption
	C4	Political Instability
MARKET LEVEL	**M1**	Local Partner's Creditworthiness- Financial soundness & staff reliability
	M2	Corporate Fraud - Problems with ethics and governance
	M3	Termination of Joint Venture/Agreement with Local Partner
	M4	Inflation & Interest Rates – Immature local economic & banking systems
PROJECT LEVEL	**P1**	Cost Overrun
	P2	Improper Design – Incompatibility with local conditions
	P3	Improper Quality Control - By local partner
	P4	Improper Project Management –Inappropriate structure, planning, management

HOW YOU CAN HELP…

You can help us in our research by broadly quantifying the strength of influences that you believe exist between risk factors. You can do this by simply filling the appropriate cells of **Table 2** (direction of influence is from COLUMNS to ROWS), with a number from 0-7 according to the scale given, or a question mark (?) where you feel unable to answer (please also write in shaded cells if you think influences exist in any of those cells).

For Example: Say the risk of "Column C3 –Corruption" in host country **strongly influences** the risk of "Row C1 -Approval and Permit", then you would place "5" in Column C3, Row C1.

CONTACT DETAILS:
Name (optional) ____________________
Email: ____________________

What type of concession projects, and countries has your research focussed on?

No. Projects	Project Type (e.g. road, power)	Countries

SCALE OF INFLUENCE (2,4,6 can also can also be used)

TABLE 2 – RISK INFLUENCE MATRIX OF SELECTED FACTORS

Direction of Influence	C1- Approval and Permit	C2- Change in Law / Justice Reinforcement	C3 - Corruption	C4 - Political Instability	M1 - Local Partner's Creditworthiness	M2 - Corporate Fraud	M3 - Termination of Joint Venture	M4 - Inflation and Interest Rates	P1 - Cost Overrun	P2 - Improper Design	P3 - Improper Quality Control	P4- Improper Project Management
C1 - Approval and Permit												
C2 - Change in Law / Justice Reinforcement												
C3 - Corruption												
C4 - Political Instability												
M1 - Local Partner's Creditworthiness												
M2 - Corporate Fraud												
M3 - Termination of Joint Venture												
M4 - Inflation and Interest Rates												
P1 - Cost Overrun												
P2 - Improper Design												
P3 - Improper Quality Control												
P4 - Improper Project Management												

N.B. Please place a "?" where unable to answer, or write in shaded boxes where appropriate.

THANK YOU SO MUCH FOR YOUR TIME!!!

APPENDIX C

QUESTIONNAIRE – RISK FACTOR INTERACTION IN INTERNATIONAL PROJECTS

International projects are by nature, high-risk investments. Thus it is crucial to ensure adequate risk assessment takes place before any decisions are made. It is the aim of this questionnaire to build upon research conducted by other researchers, to identify and broadly quantify all significant interactions between the more critical risk factors on international projects. **Table 1** presents the 4 most critical risk factors at the Country, Market, and Project levels as identified in a comprehensive, international survey on international construction projects.

TABLE 1 –Most Critical Project Risk Factors As Previously Identified By Others

COUNTRY LEVEL	**C1**	Approval and Permit – Delay or refusal
	C2	Change in Law / Justice Reinforcement –Inconsistency in application
	C3	Corruption
	C4	Political Instability
MARKET LEVEL	**M1**	Local Partner's Creditworthiness- Financial soundness & staff reliability
	M2	Corporate Fraud - Problems with ethics and governance
	M3	Termination of Joint Venture/Agreement with Local Partner
	M4	Inflation & Interest Rates – Immature local economic & banking systems
PROJECT LEVEL	**P1**	Cost Overrun
	P2	Improper Design – Incompatibility with local conditions
	P3	Improper Quality Control - By local partner
	P4	Improper Project Management –Inappropriate structure, planning, management

HOW YOU CAN HELP…

You can help us in our research by broadly quantifying the strength of influences that you believe exist between risk factors. You can do this by simply filling the appropriate cells of **Table 2** (direction of influence is from COLUMNS to ROWS), with a number from 0-7 according to the scale given, or a question mark (?) where you feel unable to answer (Please also write in shaded cells if you think influences exist in any of those cells).

> **For Example:** Say the risk of "C3 - Corruption" in the host country **strongly** influences the risk of "C1 -Approval and Permit delay or refusal", then you would place a "5" in Column C3, Row C1.

THANK YOU SO MUCH FOR YOUR TIME!!!

CONTACT DETAILS (optional):

Name: ______________________________

Phone (w): ______________ Fax (w): ______________

Email: ______________________________

Position (please specify): ______________________________

Name of Organisation (optional): ______________________________

Personal experience in international construction projects:

No. Projects	Countries	Role/Capacity

Has your organization been involved in any international PPP projects? ☐ Yes ☐ No

If yes, Type of Project (e.g. road, rail, water)	Countries

SCALE OF INFLUENCE (2, 4, 6 can also be used)

0 – No 1 - Weak 3 – Moderate 5 - Strong 7 –Extreme

TABLE 2 – RISK INFLUENCE MATRIX OF SELECTED FACTORS

Direction of Influence	C1- Approval and Permit	C2- Change in Law / Justice Reinforcement	C3 - Corruption	C4 - Political Instability	M1 - Local Partner's Creditworthiness	M2 - Corporate Fraud	M3 - Termination of Joint Venture	M4 - Inflation and Interest Rates	P1 - Cost Overrun	P2 - Improper Design	P3 - Improper Quality Control	P4- Improper Project Management
C1 - Approval and Permit												
C2 - Change in Law / Justice Reinforcement												
C3 - Corruption												
C4 - Political Instability												
M1 - Local Partner's Creditworthiness												
M2 - Corporate Fraud												
M3 - Termination of Joint Venture												
M4 - Inflation and Interest Rates												
P1 - Cost Overrun												
P2 - Improper Design												
P3 - Improper Quality Control												
P4 - Improper Project Management												

N.B. Please place a "?" where unable to answer, or write in shaded boxes where appropriate.

APPENDIX D

Non-Pooled T-Test (Two-Tailed) Results – Two Sub Samples of Pilot Study at 0.05 Significance Level

Impacting Risk Factor	Impacted Risk Factor	Mean (μ) Sample 1	Variance(σ) Sample 1	Mean (μ) Sample 2	Variance (σ) Sample 2	Test Statistic (t)
C1	C3	3.11	6.36	4.27	5.78	**-1.14**
	M3	3.56	4.53	3.79	2.80	**-0.29**
	P1	4.20	3.51	3.93	3.92	**0.34**
C2	C1	4.60	3.60	4.13	2.84	**0.63**
	C4	3.75	3.93	3.60	3.11	**0.19**
	M2	2.20	1.96	3.07	2.64	**-1.42**
	M3	3.80	2.18	3.33	3.38	**0.70**
	P1	4.30	1.57	3.57	3.03	**1.22**
	P2	2.50	5.61	2.13	2.12	**0.44**
	P3	2.20	4.40	1.79	2.49	**0.53**
	P4	2.30	4.01	1.79	2.49	**0.68**
C3	C1	4.90	3.21	4.80	4.89	**0.12**
	C2	3.10	3.66	3.60	6.11	**-0.57**
	M1	3.50	3.39	3.40	3.11	**0.14**
	M2	4.10	1.21	4.27	4.35	**-0.26**
	M3	2.90	2.10	3.80	5.46	**-1.19**
	M4	1.89	3.86	3.47	5.84	**-1.79**
	P3	3.20	4.18	3.79	4.80	**-0.68**
	P4	3.10	4.32	3.71	3.60	**-0.75**
C4	C1	5.40	2.27	4.60	1.69	**1.37**
	C2	5.30	2.01	4.13	3.84	**1.73**
	C3	5.20	3.51	4.67	3.67	**0.69**
	M1	3.90	4.10	3.47	3.84	**0.53**
	M2	3.10	1.88	3.53	4.41	**-0.62**
	M3	4.10	2.77	3.87	4.27	**0.31**
	M4	5.80	1.07	4.40	4.40	**2.21***
	P1	3.90	4.32	4.07	4.07	**-0.20**
M1	M2	2.70	4.23	3.73	5.07	**-1.18**
	M3	4.70	2.46	4.40	3.69	**0.43**
	P1	3.40	2.71	3.33	3.52	**0.09**
M2	M1	4.30	2.90	3.67	4.24	**0.84**
	M3	5.00	2.00	4.20	4.31	**1.15**
	P1	3.90	4.32	3.47	3.98	**0.52**
	P2	2.60	3.82	3.47	3.12	**-1.13**
	P3	2.80	4.84	4.07	3.46	**-1.50**
	P4	3.40	5.16	3.79	3.26	**-0.45**
M3	P1	4.89	5.11	4.20	4.03	**0.78**
M4	C4	4.20	1.96	3.57	3.65	**0.95**
	M1	3.10	2.32	2.87	3.70	**0.34**
	M3	2.80	2.40	3.20	3.60	**-0.58**
	P1	5.10	0.99	4.27	4.35	**1.34**
	P2	0.89	1.61	1.80	2.46	**-1.60**

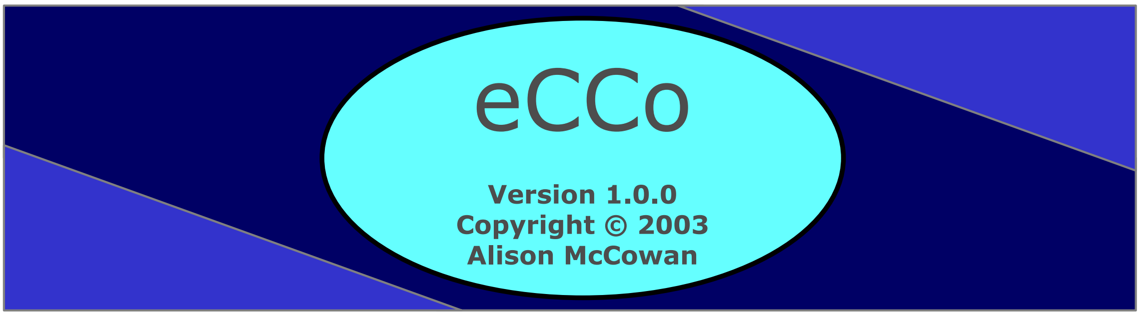
N.B.- α = 0.025, thus if | t| > 2.069, results from two sub-samples are statistically different.
*** indicates test statistic, t >2.069.**

Non-Pooled T-Test (Two-Tailed) Results – Two Sub Samples of Pilot Study at 0.05 Significance Level (Continued)

Impacting Risk Factor	Impacted Risk Factor	Mean (μ) Sample 1	Variance(σ) Sample 1	Mean (μ) Sample 2	Variance (σ) Sample 2	Test Statistic (t)
P1	**M1**	2.90	4.10	3.50	3.65	**-0.74**
	M3	4.40	2.49	4.60	2.97	**-0.30**
P2	**P1**	5.60	0.71	5.00	1.57	**1.43**
P3	**P1**	4.80	0.84	4.47	2.27	**0.69**
	P2	2.60	4.27	3.73	3.64	**-1.39**
P4	**P1**	5.30	0.46	5.27	1.35	**0.09**
	P2	3.30	4.01	3.93	3.92	**-0.78**
	P3	4.40	3.60	5.14	1.21	**-1.12**

N.B.- α = 0.025, thus if | t| > 2.069, results from two sub-samples are statistically different.
*** indicates test statistic, t >2.069.**

APPENDIX E



A Decision Support System (DSS) to

Evaluate and Compare Concession Options

USER MANUAL

Version 1.0.0

December 2003

Developed by:

Alison McCowan

As part of her PhD research project

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1. INSTALLATION

ECCO has only been released as a Demo Version as part of the developer's PhD research project. This version of ECCO does not include installation files and must be run from the CD-ROM provided for confidentiality and copyright purposes.

2. GETTING STARTED…

About ECCO

ECCO (Evaluate and Compare Concession Options) was developed to provide an effective yet efficient Decision Support System (DSS) for the construction industry to evaluate and compare concession project investment (CPI) opportunities at the feasibility stage. Concession projects can be defined as privately financed infrastructure projects where the government grants the private sector a licence or concession to deliver infrastructure services of a certain type for a set length of time. For Example: BOOT: Build-Own-Operate-Transfer and BOT: Build-Operate-Transfer projects.

ECCO evaluates and ranks various CPI options by incorporating both financial and non-financial aspects of an investment, as well as the uncertainties commonly encountered at the feasibility stage. Based upon the most suitable techniques in the areas of mathematical modelling, financial analysis, risk factor frameworks and decision-making, ECCO's design caters for the different perspectives of equity holders, lenders, and government parties by calculating a total of 15 project performance measures, including 11 financial, 3 non-financial, and one combined (financial and non-financial) measure in a time and resource efficient manner. ECCO is also able to compare the sensitivity of up to five projects to changes in any single factor (financial or non-financial) common to all projects selected.

Overview of ECCO

ECCO is an easy-to-use dialog based application much like a commonly used Wizard program. ECCO comprises three basic modules: 1) Model Definition, 2) Model Evaluation and Ranking, and 3) Sensitivity Analysis (Figure 1). Module One performs the function of creating individual project investment models including definition of financial factors (e.g. construction costs, operations and maintenance costs, revenues and financial parameters), and non-financial factors (e.g. risks and opportunities). Once one or more individual project investment models have been developed, Module Two can then be used to evaluate, compare, and rank up to five projects. ECCO's design also caters for the determination of the criticality of selected factors (non-financial or financial) on various project investment options via its Sensitivity Analysis module, Module Three. Each of the three modules caters for the creation of tab-delimited output files that can be opened in Notepad, Microsoft Word or Microsoft Excel for further analysis or printing.

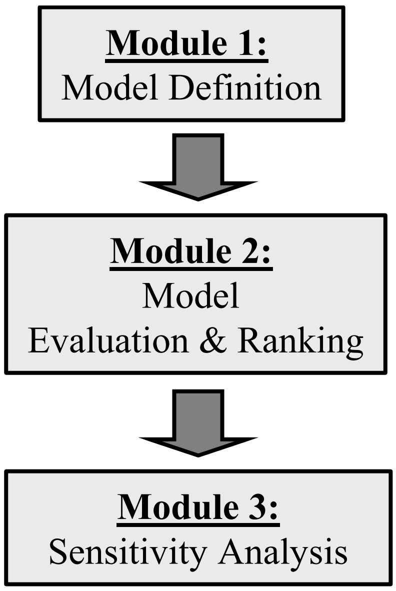


Figure 1 - Flowchart of DSS Modules

3. HOW TO…CREATE/EDIT A CPI MODEL (MODULE ONE)

The level of input data required by ECCO has been kept in line with that typically available to analysts at the feasibility stage of a project, in order to maximise user time and resource efficiencies. The possibility (fuzzy) theory is used to define both financial and non-financial data in the program. Also, to make risk assessment easier for the analyst, a generic CPI RFF is also offered as an option when using the DSS. This RFF contains the four (4) most critical risk factors at the country, market and project levels of the project, as well as the quantified interdependencies between these factors, as identified by a pilot study questionnaire involving academics/researchers and industry practitioners.

This section gives step-by-step instructions on how to develop a CPI model using Module One.

Getting Started in Module One

1. To access Module One, click on the "Project Data" button on the main ECCO dialog (Figure 2).

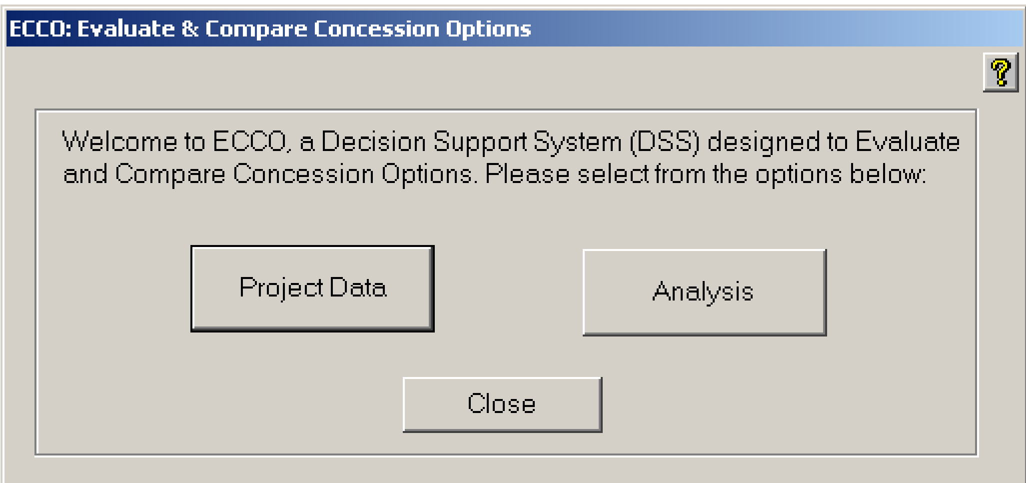


Figure 2 - The Main ECCO Dialog

2. ECCO will ask whether you wish to edit an existing project data file. Clicking on "Yes" will invoke the common Open "Source File" dialog (Figure 3), from which ECCO will open a selected model and read the data into the relevant dialog boxes. The Project Data dialog, shown in Figure 4, is then displayed. Clicking on "no" will simply take you straight to the Project Data dialog.

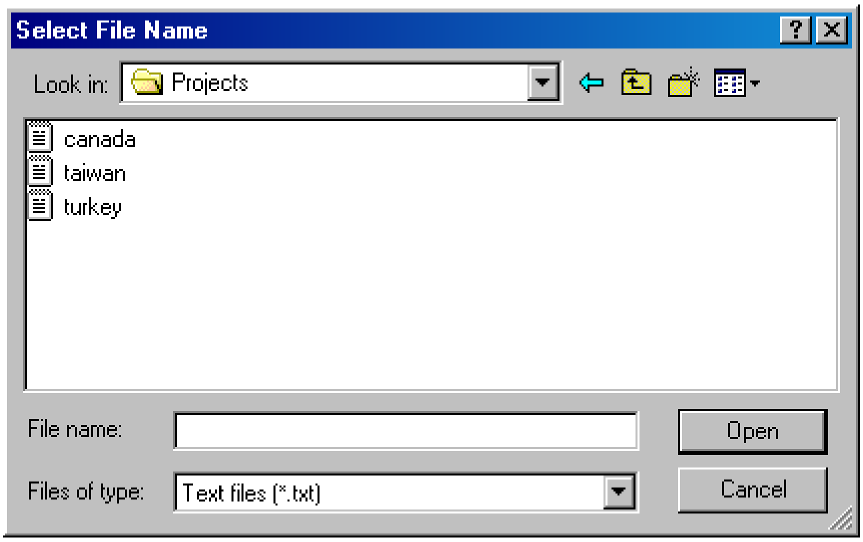


Figure 3 - Open "Source File" Dialog

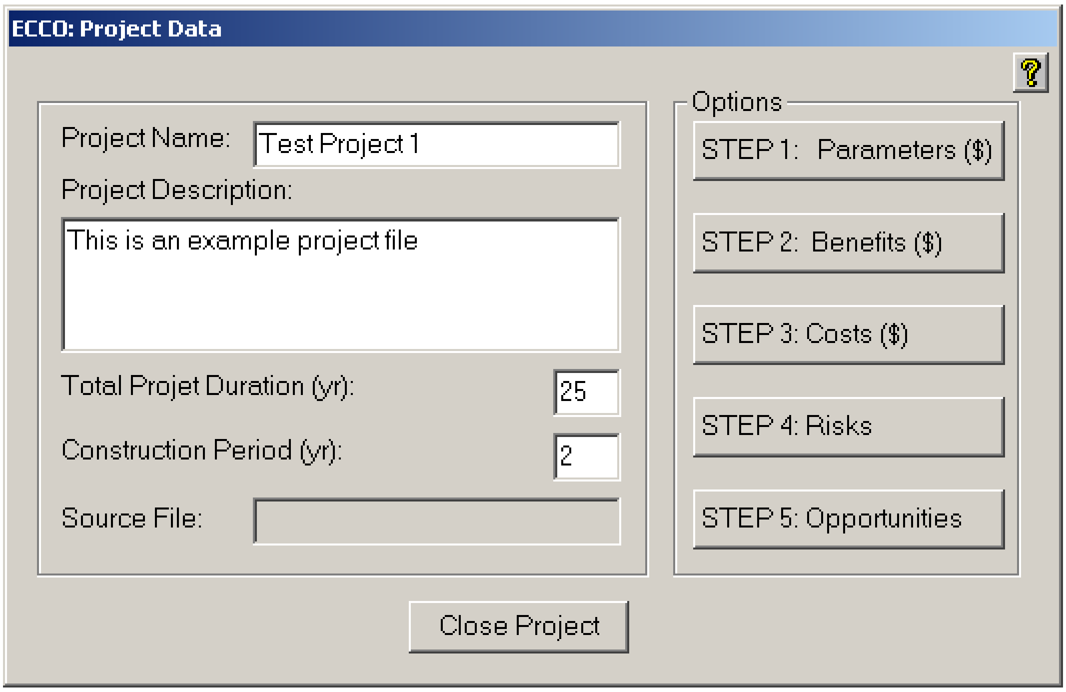


Figure 4 - Project Data Dialog

3. Enter the following general project information into the edit boxes provided: project name; a brief description; total project duration (yr); and construction period (yr). ECCO will not proceed without these details.

Now you are ready to begin working through the 5-step CPI definition process.

Step 1: Parameters ($)

1. Click on the "STEP 1: Parameters ($)" button on the Project Data dialog to open the Financial Parameters dialog shown in Figure 5.

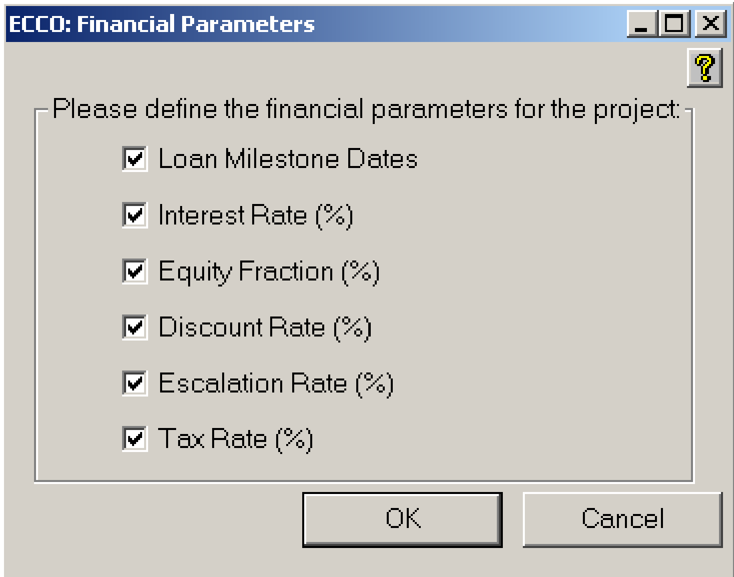


Figure 5 - Financial Parameters Dialog

2. Click on the first tick box, "Loan Milestone Dates", and enter values for the loan grace period (assumed to be at least equal to the construction period) and the loan repayment period in years (Figure 6). The default settings for the loan grace and operations period are the construction period and the operations period, respectively.
3. Once values have been entered/edited, click on "OK" to return to the Financial Parameters dialog. ECCO will show an error message if the values entered in these boxes are not appropriate (e.g. if the grace period and loan repayment period sum to greater than the total project duration).

Figure 6 - Loan Milestone Dates Dialog

Enter the remaining financial parameters, the loan interest rate, equity fraction, discount rate, escalation rate and tax rate. These parameters are defined as % values via individual dialogs, identical in design to the Interest Rate dialog (Figure 8). These parameters may be defined as any of the four, possibility distribution types described below and demonstrated in Figure 7. Simply select the distribution type, and enter appropriate values in the boxes provided.

1. A single value (with 100% certainty; e.g. design cost is a lump sum of $100,000);
2. An interval (defined by an equally likely range; e.g. design cost is somewhere between $80,000 and $130,000);
3. A triangular distribution (defined by a most likely value; e.g. design cost is about $100,000, and will not be less than $80,000 or greater than $130,000); and
4. A trapezoidal distribution (defined by a most likely range; e.g. design cost is most likely in the range of $100,000–$120,000 and and will not be less than $80,000 or greater than $130,000).

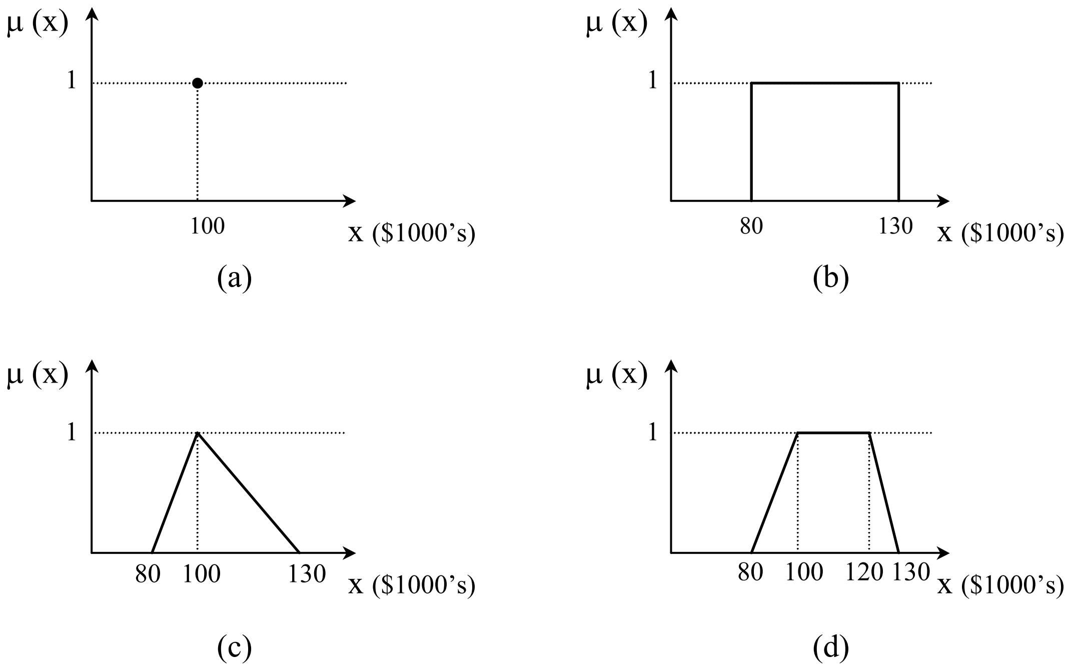


Figure 7 - Analyst's Perception of Design Cost: (a) Single Value; (b) Interval; (c) Triangular Distribution; (d) Trapezoidal Distribution.

4. Click on "OK" to return to the Financial Parameters dialog until all parameters have been defined (i.e. all tick boxes are ticked).
5. Return to the Project Data dialog by clicking on "OK".

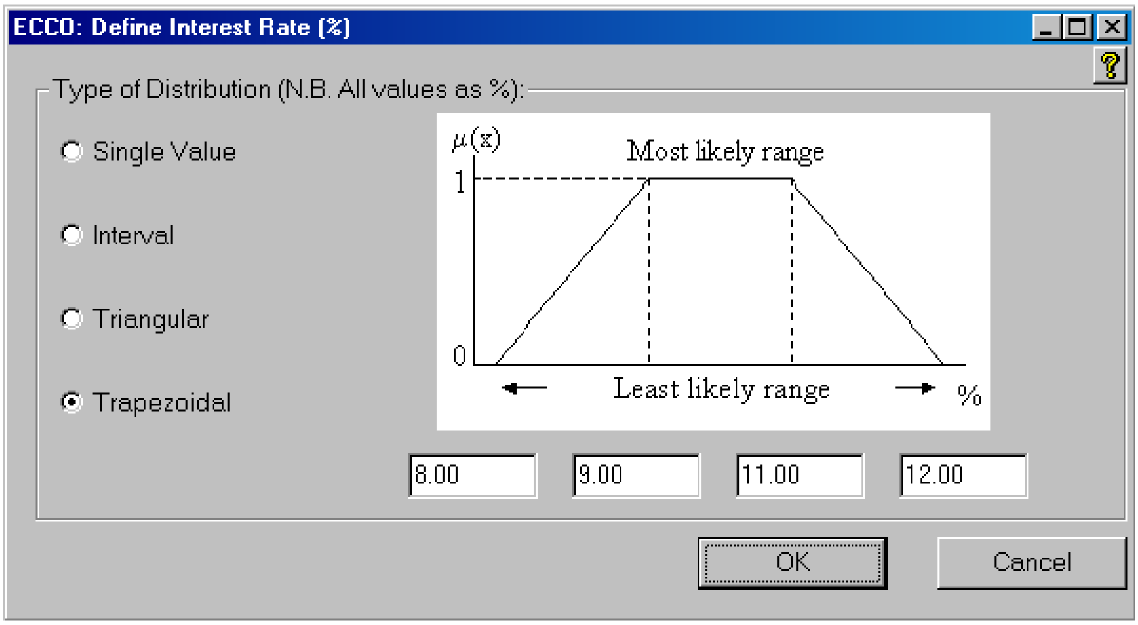


Figure 8 - Financial Parameters Definition Dialog

Step 2: Benefits ($)

1. Click on the "STEP 2: Benefits ($)" button on the Project Data dialog to open the Revenue dialog shown in Figure 9. The table on this dialog contains all financial benefits of the project (i.e. any forecast revenue streams of the project, such as toll charges) and cannot be edited directly.
2. Use the "Edit Stream", "Add Stream" and "Remove Stream" buttons to edit, create or delete revenue streams in the table. Clicking on the "Add Stream" button, or highlighting a revenue stream (row) in the table and clicking on the "Edit Stream" button will open the Define Financial Data dialog (Figure 10) and feed in the relevant data to the dialog. Highlighting a Revenue Stream in the table and clicking on the "Remove Stream" button will remove the highlighted revenue stream from the table.

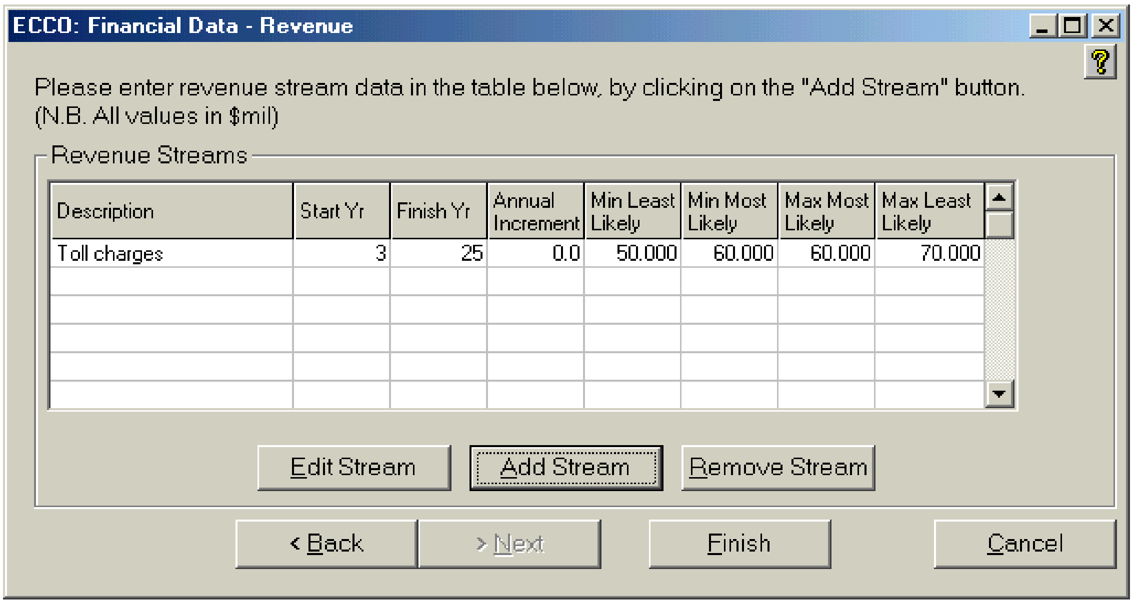


Figure 9 - Revenue Dialog

3. When editing/creating a revenue stream, enter the description, timing and value of the stream into the relevant boxes on the Define Financial Data dialog. Stream values must be defined as one of the four possibility distribution types (described in Step1). Stream timing may be in the form of a one-off payment in a specific year of the project's life, a set of annual payments over a period, or annually increasing/decreasing payments over a set period. This latter option is suitable for when demand is forecast to increase, or unit prices are expected to decrease over time.

4. Click on "OK" to return to the Revenue dialog.
5. When all revenue data has been entered click on the "Finish" button to return to the Project Data dialog.

N.B. It is assumed by the program that revenue cannot be generated by the project until the facility has been fully constructed. Thus, ECCO will not allow the entering of start or finish year values less than the construction period, or greater than the total project duration.

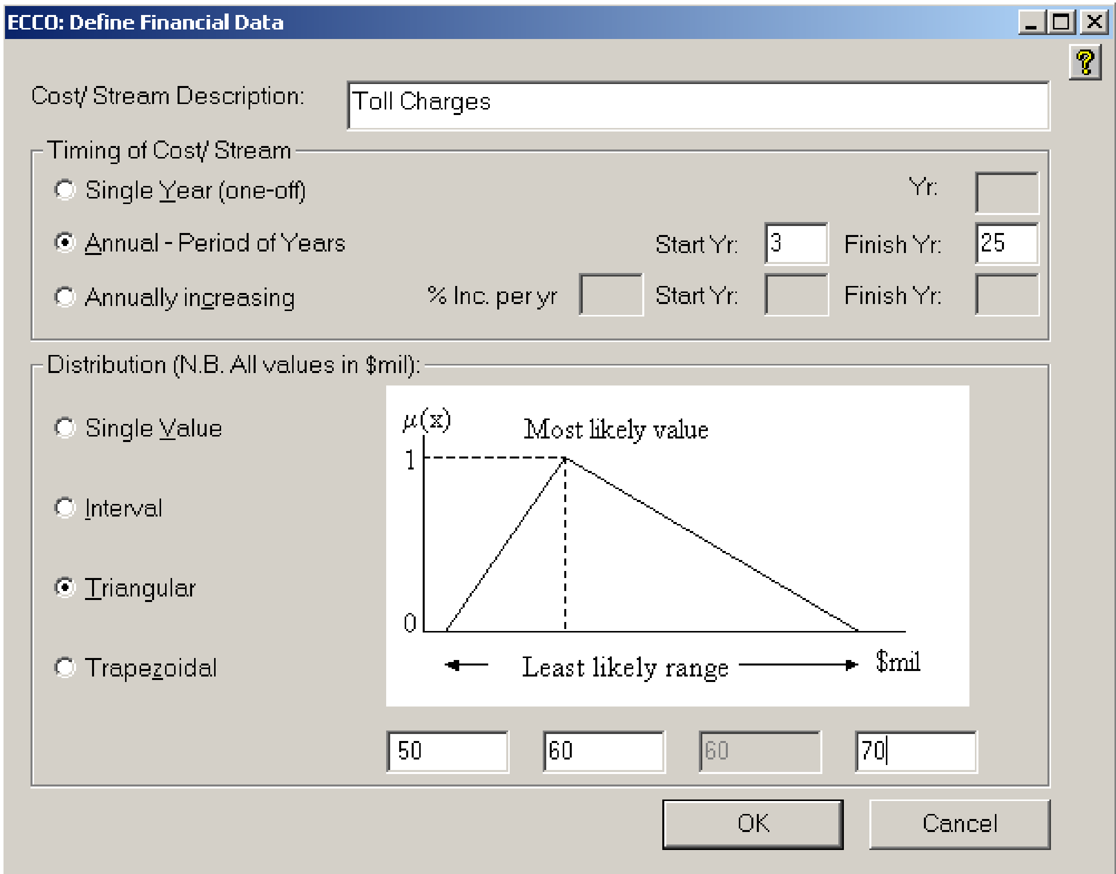


Figure 10 - Define Financial Data Dialog

Step 3: Costs ($)

1. Click on the "STEP 3: Costs ($)" button on the Project Data dialog to open the Construction Costs dialog. Construction costs are entered in the same manner as revenue streams in Step 2, via the Construction Costs dialog, which is identical in layout to the Revenue dialog.

2. Edit the construction cost data via the "Edit Cost", "Add Cost" and "Remove Cost" buttons as per Step 2 instructions.
3. Once all construction costs have been entered correctly, click on the "Next" button to open the Operations Costs dialog.
4. Again, edit the operations and maintenance cost data via the "Edit Cost", "Add Cost" and "Remove Cost" buttons as per Step 2 instructions.
5. Once all operations costs (both operations and maintenance) have been entered correctly, click on the "Finish" button to return to the Project Data dialog.

Step 4: Risks

1. Click on the "STEP 4: Risks" button on the Project Data dialog to open the Risk Data (1) dialog, shown in Figure 11.

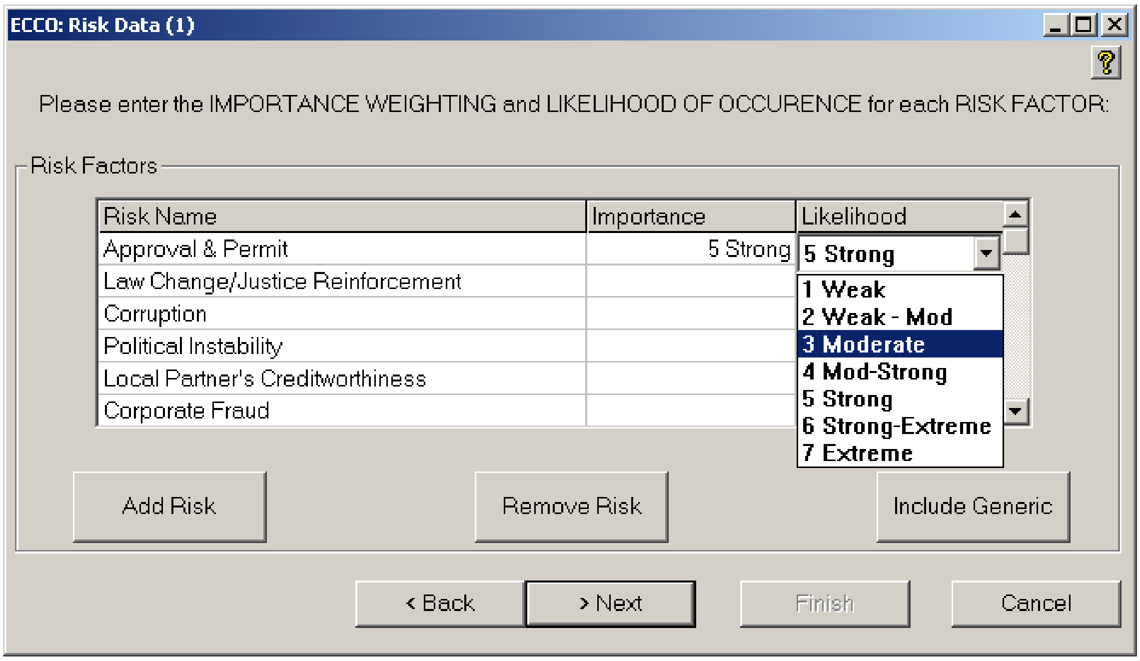


Figure 11 - Risk Data (1) Dialog

2. Enter the name, importance weighting, and likelihood values of any risk factors (negatively impacting non-financial factors) surrounding the project investment directly into the table provided. Use the 7-point linguistic scale (Figure 12) dropdown lists in Columns 2 and 3 to define risk factor importance and likelihood values. To add a row to the table click on the "Add Factor" button.

Or remove any of the risk factors in the table by highlighting the unwanted row, and clicking on the "Remove Factor".

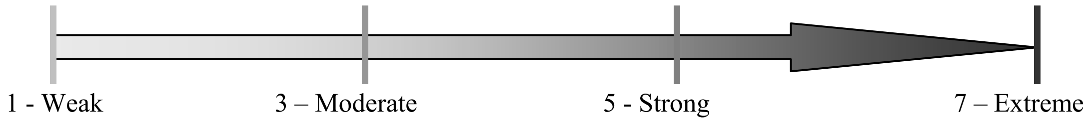


Figure 12 - 7-Point Linguistic Scale (2, 4, 6 can also be used)

3. If you wish to use the generic set of risk factors provided by ECCO, simply click on the "Include Generic" button. ECCO will ask whether you would like to keep the existing risk factors (already in the table), before entering the generic risk factors into the first column of the table. Importance weightings and likelihood values will then need to be assigned to the generic risk factors.
4. Once all risk factors have been entered, click on the "Next" button to proceed to the Risk Data (2) dialog (Figure 13).
5. Enter any influences that exist between risk factor directly into the table. Dropdown lists of the risk factors entered in the Risk Data (1) dialog are provided in the Influenced Risk and Influencing Risk columns, and the 7-point linguistic rating scale is provided in the Strength of Influence column, to assist in this process.

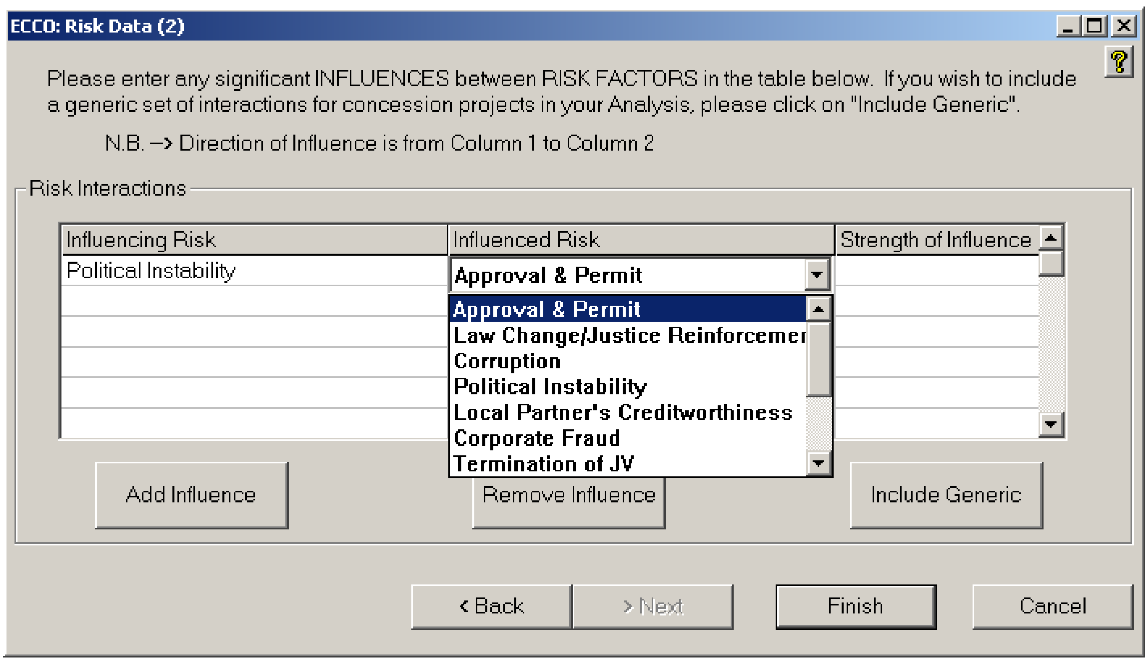


Figure 13 - Risk Data (2) Dialog

6. If you wish to use the generic set of risk factor influences identified by a pilot study questionnaire involving academics/researchers and industry practitioners, simply click on the "Include Generic" button. ECCO will ask whether you would like to keep the existing influences (already in the table), and check which of the generic risk factors are contained in the table of the Risk Data (1) dialog, before entering the relevant generic risk factor influences and their strengths, into the table.
7. Once all risk factor data has been entered correctly, click on the "Finish" button to return to the Project Data dialog.

Step 5: Opportunities

1. Click on the "STEP 5: Opportunities" button on the Project Data dialog to open the Opportunities Data (1) dialog. Opportunity factors (positively impacting non-financial factors) of the project investment are entered in the same manner as risk factors in Step 4, via the Opportunities Data (1) and Opportunities Data (2) dialog, which are almost identical to the Risk Data (1) and Risk Data (2) dialogs respectively. However, a generic set of opportunity factors is not provided in this Step.
2. Enter all opportunity factors into the table on the Opportunities Data (1) dialog as per Step 4 instructions.
3. Once all opportunity factors have been entered correctly, click on the "Next" button to open the Opportunities Data (2) dialog.
4. Enter all influences that exist between opportunity factors entered in the Opportunities Data (1) dialog as per Step 4 instructions.
5. Once all opportunity factor data has been entered correctly, click on the "Finish" button to return to the Project Data dialog.

Exiting Module One

You can exit the module at any time by returning to the Project Data dialog and clicking on the Close Project button, at which time you can either save the developed model as a tab-delimited text file or discard it. When saving the model, do not include the ".txt" extension in your file name, as ECCO will automatically add this. For instructions on how to open tab-delimited output files in Notepad©, Microsoft Word© or Microsoft Excel© for further analysis or printing, please see Section 6.

4. HOW TO…EVALUATE AND COMPARE CPIS (MODULE TWO)

From the data contained in project data files, ECCO's Module Two evaluates each of the selected project models and ranks them on the basis of their ANP Project Ratings (or adapted version of this rating). The ANP Project Rating Method is shown in Figure 14.

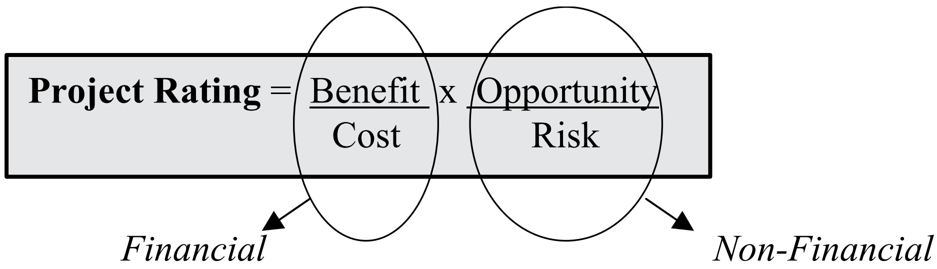


Figure 14 - ANP Project Rating Method

ECCO then displays analysis results in both tabulated and graphical form. The following tabulated results of the calculated performance measures are presented as equivalent single values (centroid of possibility distributions), in order of project ranking:

- Project name
- Cost NPV ($mil)
- Equity holder's NPV ($mil)
- Equity holder's B/C ratio
- Equity holder's IRR (%)
- Equity holder's payback period (yr)
- Overall project NPV ($mil)
- Overall project B/C ratio
- Overall project payback period (yr)
- Average DSCR
- Opportunity rating

- Risk rating
- O/R Ratio
- Project Ranking (based on ANP Project Rating)

Graphical comparisons of the projects financial performance measures are also displayed on this dialog. All financial performance measures listed below, except cumulative cash flows and annual DSCR values, are displayed in the graphical comparisons window as possibility distributions, whilst cumulative cash flows and DSCRs are presented as non-discounted, annual equivalent single values.

Equity Holder:

- NPV ($mil)
- B/C ratio
- Cost NPV ($mil)
- Cumulative cash flows ($mil)
- Payback period (yr)
- IRR (%)

Lenders:

- DSCR

Overall Project:

- NPV ($mil)
- B/C ratio
- Cumulative cash flows ($mil)
- Payback Period (yr)

This section gives step-by-step instructions on how to evaluate and rank a CPI model using Module Two…

1. To access Module Two, click on the “Project Data” button on the Main ECCO dialog (Figure 2). This will open the Analysis (1) dialog.
2. Enter the number of projects (must be between one and five) to be included in the analysis in the box provided.

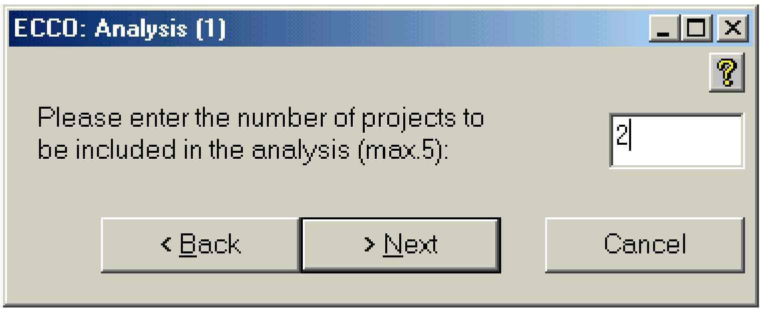


Figure 15 - Analysis (1) Dialog

3. Click on "OK" to open the Analysis (2) dialog (Figure 16).
4. Enter the file location of each CPI to be analysed in the boxes provided by clicking on the "Browse" button beside each box. If the CPI models to be analysed are purely non-financial (contain no financial data), tick the "Non-Financial Analysis Only" box situated at the bottom of the dialog.

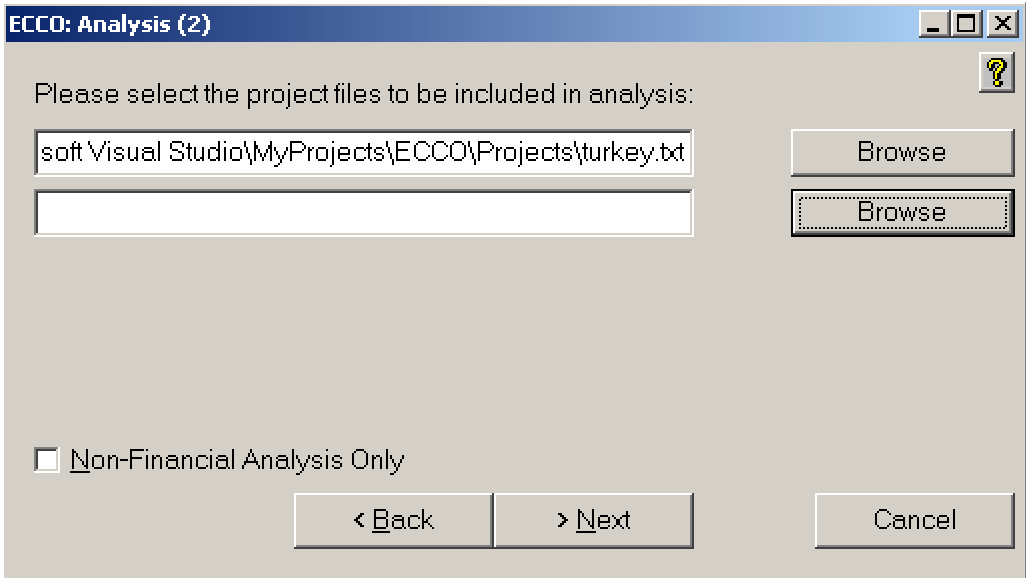
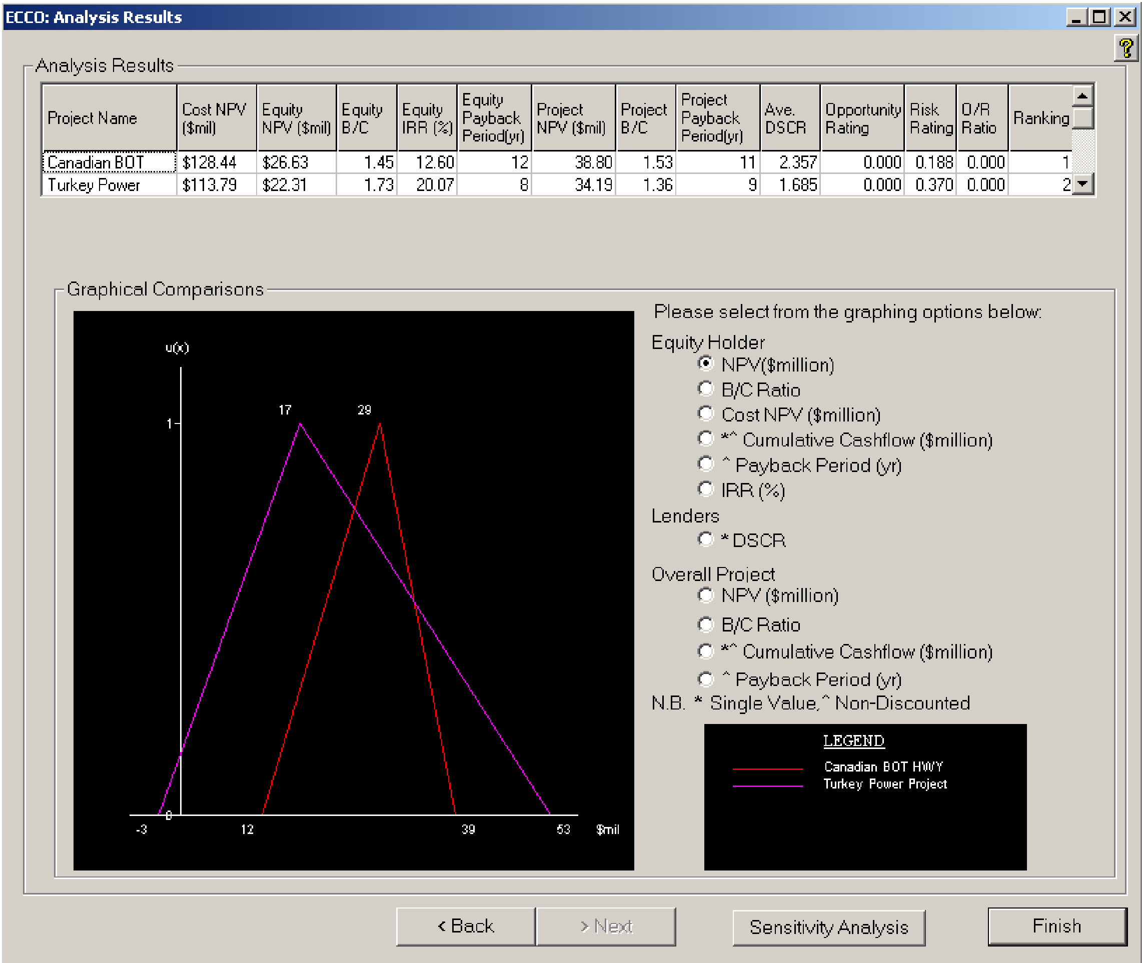


Figure 16 - Analysis (2) Dialog

5. Once all project file boxes provided have been filled, click on "OK" to begin analysis. ECCO will then open each project's tab-delimited text file, read in the data, and analyse the project. It will then rank the projects according to their respective Project Ratings (ANP Project Rating Method, Figure 14) and open the Analysis Results dialog shown in Figure 17 where results of the analysis are displayed in both tabulated and graphical form.

6. If sensitivity analysis is not required, click on the "Finish" button to return to the Main ECCO dialog. ECCO will ask if you wish to save the analysis results as a tab delimited text file first.

N.B. When saving the analysis results, <u>do not</u> include the ".txt" extension in your file name, as ECCO will automatically add this. For instructions on how to open tab-delimited output files in Notepad©, Microsoft Word© or Microsoft Excel© for further analysis or printing, please see Section 6.



Project Name	Cost NPV ($mil)	Equity NPV ($mil)	Equity B/C	Equity IRR (%)	Equity Payback Period(yr)	Project NPV ($mil)	Project B/C	Project Payback Period(yr)	Ave. DSCR	Opportunity Rating	Risk Rating	O/R Ratio	Ranking
Canadian BOT	$128.44	$26.63	1.45	12.60	12	38.80	1.53	11	2.357	0.000	0.188	0.000	1
Turkey Power	$113.79	$22.31	1.73	20.07	8	34.19	1.36	9	1.685	0.000	0.370	0.000	2

Figure 17 - Analysis Results Dialog

5. HOW TO…CONDUCT SENSITIVITY ANALYSIS (MODULE THREE)

The purpose of the Sensitivity Analysis Module is to assist in comparing the sensitivity of selected projects to changes in any single factor (financial or non-financial) common to all the projects selected. It is not the purpose of this module to perform Scenario Analysis. Scenario Analysis can be performed simply by editing existing models in Module One, to create different project scenarios, and then evaluating and comparing the models using Module Two. The sensitivity analysis module of ECCO can be accessed via the Sensitivity Analysis button at the bottom of the Analysis Results dialog in Module Two. The sensitivity analysis can therefore only be conducted on projects previously selected for evaluation in Module Two, although not all projects evaluated must be included.

Results are presented in both tabulated and graphical form. In the case of financial factors, five values across the defined range are used to generate results. In the case of non-financial factors, seven values are used. Also, different performance measures are used to depict the sensitivity of the projects depending on what type of factor is selected for analysis. If a financial factor has been analysed the results will be of the % change in the selected factor vs. the % change in the equity holder's B/C ratio. Whereas if a non-financial factor has been selected, the results will be of the factor's likelihood value vs. the % change in the project's risk or opportunity rating as appropriate. These performance measures were selected because they form part of the ANP Project Rating Method.

This section gives step-by-step instructions on how to conduct sensitivity analysis on a set of CPIs using Module Three…

1. Click on the "Sensitivity Analysis" button on the Analysis Results dialog to open the Sensitivity Analysis (1) dialog (Figure 18). This dialog contains a list of the projects available for analysis in the left-hand list box of "Step 1".

2. Select the projects to be included in the analysis by using the left and right arrow buttons to move them into the right-hand list box. ECCO will then generate a list of financial and non-financial factors common to ALL projects selected, including additional options to analyse: all construction costs; all O&M costs; or all revenue costs, in the list box of "Step 2".
3. Select the factor to be analysed from the list provided in "Step 2", and enter a range for analysis (Step 3) according to the type of factor being analysed as follows:
   - Financial factors (e.g. interest rate, cash flows) - the range is defined as being between a negative %age and positive %age of its value; and
   - Non-financial factors - the module automatically conducts analysis for the entire range of likelihood values (1 to 7) for the selected factor.

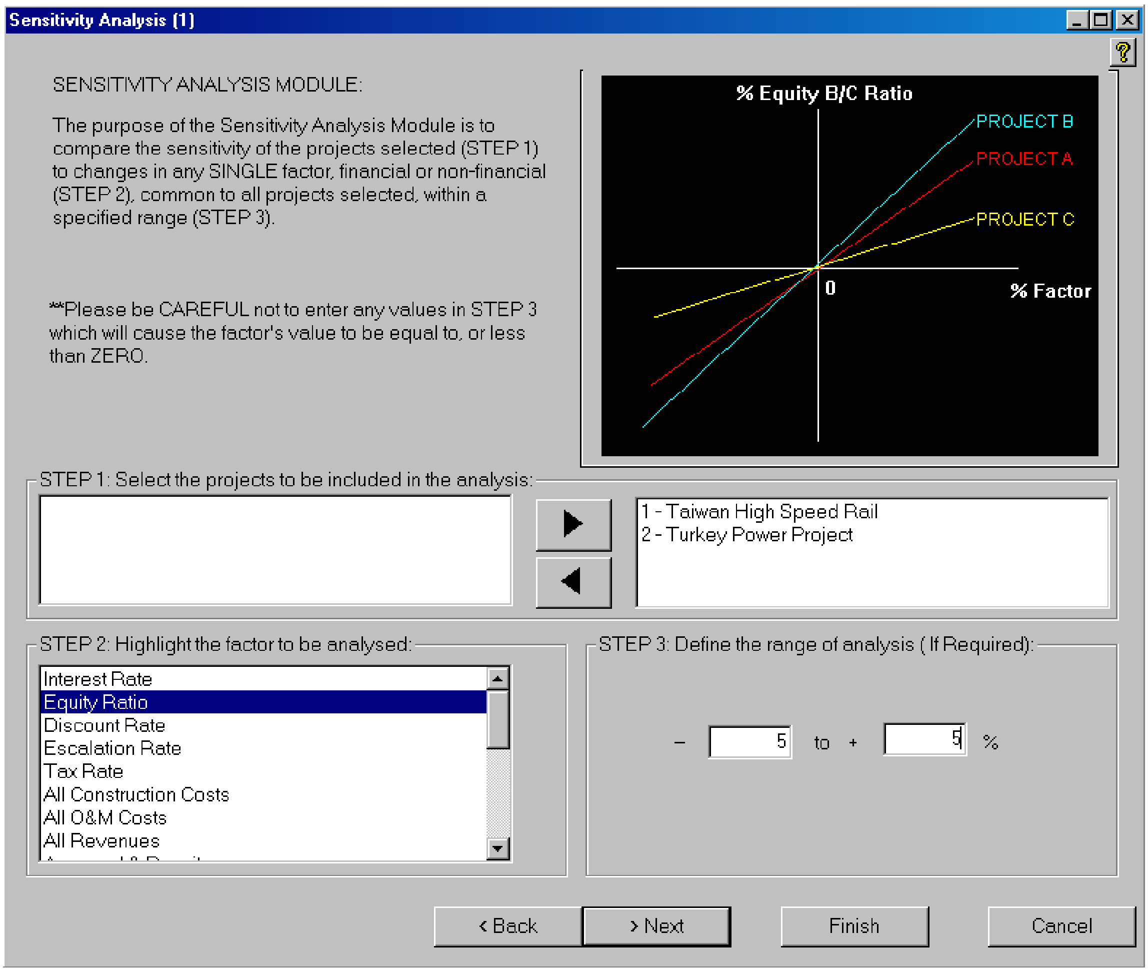


Figure 18 - Sensitivity Analysis (1) Dialog

4. Click on “Next” to open the Sensitivity Analysis (2) dialog, shown in Figure 19, to view results in both tabulated and graphical form.
5. Click on the “Finish” button to return to the Analysis Results dialog. ECCO will first ask if you wish to save the sensitivity analysis results as a tab delimited text file.

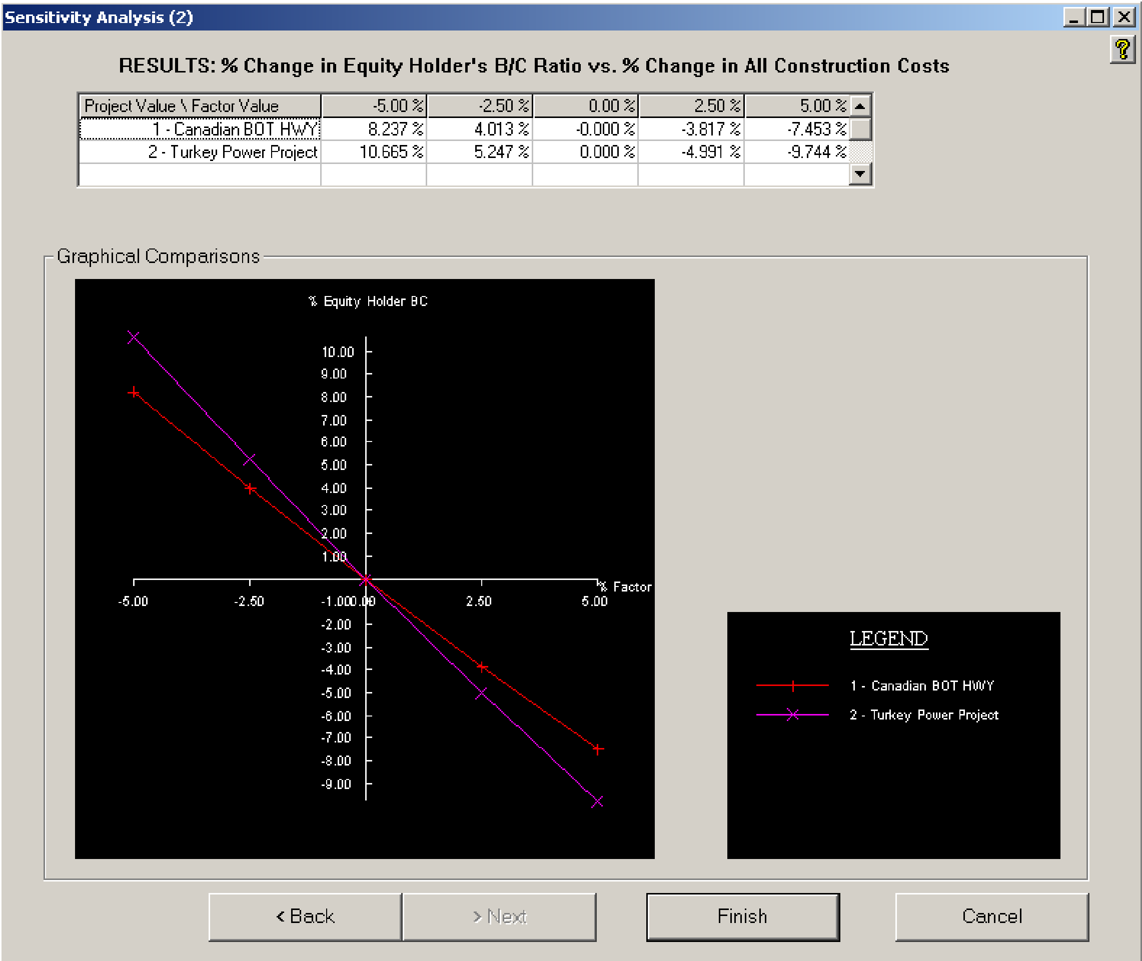


Figure 19 - Sensitivity Analysis (2) Dialog –Financial Factor

N.B. When saving the analysis results, do not include the “.txt” extension in your file name, as ECCO will automatically add this. For instructions on how to open tab-delimited output files in Notepad©, Microsoft Word© or Microsoft Excel© for further analysis or printing, please see Section 6.

6. HOW TO…WORK WITH TAB-DELIMITED FILES

ECCO produces CPI project data files, analysis results files, and sensitivity analysis results files in a tab-delimited text file (.txt) format. These files may be opened using Notepad©, Microsoft Word© or Microsoft Excel© to further analyse results, to be included in feasibility reports, or to directly edit CPI project data files for use in ECCO.

Since these files are tab-delimited, they look best (formatting wise) in Microsoft Excel©. Thus, when producing feasibility reports using these files, or further analysing results, it is recommended to use Microsoft Excel© to open the files and simply change column widths to suit the data. Microsoft Excel© also facilitates the graphing of results for analysis and reporting purposes.

Alternatively, the use of Microsoft Word© is recommended when directly editing CPI model data files. If extensive data must be entered into the CPI model from another calculations file (e.g. Microsoft Excel©), cutting and pasting data into an existing CPI project data file may save a lot of time. However, this is not as easy as it seems! If you choose to edit a file this way, make sure that the formatting of the CPI project data file is not changed, or else ECCO will not be able to read in the data from the file.

To do this, it is recommended to click on the "" (Show ALL) button on the Standard Toolbar, at the top of the Microsoft Word© screen before starting editing. This will indicate where all tabs ("→"), spaces ("·"), and paragraph or enter ("¶") characters are located in the file. Take note of the original formatting before editing, and make sure you do not change this formatting. For example, each line of financial data ends with a tab followed by a space, and then a paragraph (or enter) character, (→ · ¶). Once you have finished editing the file, make sure you save the file as a text file (.txt) <u>not</u> a Microsoft Word© file (.doc).

Following the above guidelines should enable you to directly edit a CPI project data file for use in ECCO.

7. SAMPLE FILES

To help you become familiar with ECCO, sample CPI project data files of 3 real-life projects in Turkey, Taiwan and Canada developed as part of the developer's PhD research project. These files are available from the "Sample Files" folder, in the main ECCO directory.

8. TECHNICAL SUPPORT

For further queries or suggestions, please email the developer, Alison McCowan:
alimccowan@yahoo.com

APPENDIX F

VERIFICATION – FINANCIAL ANALYSIS MODEL

TURKEY HEPP PROJECT

- ***CPI MODEL 1 (ECCO PROJECT DATA FILE)***
- ***ECCO ANALYSIS RESULTS FILE***
- ***EXCEL SPREADSHEET OF FINANCIAL CALCULATIONS***

PROJECT DATA FILE - TURKEY CPI MODEL 1

PROJECT DATA FILE

Project Name:	Turkey Power	Project
Project Description:	Bakatjan et al.	(2003) paper
Project Duration:	24	
Construction Period:	4	

FINANCIAL PARAMETERS

Grace Period	4
Repayment Period	10

Description	Min Least Likely	Min Most Likely	Max Most Likely	Max Least Likely
Equity Fraction	0.3169	0.3169	0.3169	0.3169
Interest Rate	0.1	0.1	0.1	0.1
Discount Rate	0.12	0.12	0.12	0.12
Escalation Rate	0.041	0.041	0.041	0.041
Tax Rate	0.11	0.11	0.11	0.11

CONSTRUCTION COSTS ($million)

No. of Construction Costs: 4

Description	Start Yr	Finish Yr	Inc.(%)	Min Least Likely	Min Most Likely	Max Most Likely	Max Least Likely
year1	1	1	0	16.57	16.57	16.57	16.57
year2	2	2	0	36.455	36.455	36.455	36.455
year3	3	3	0	39.77	39.77	39.77	39.77
year4	4	4	0	39.77	39.77	39.77	39.77

OPERATIONS COSTS ($million)

No. of Operation Costs: 1

Description	Start Yr	Finish Yr	Inc.(%)	Min Least Likely	Min Most Likely	Max Most Likely	Max Least Likely
Annual Ops	5	24	0	0.79	0.79	0.79	0.79

REVENUE STREAMS ($million)

No. of Revenue Streams: 11

Description	Start Yr	Finish Yr	Inc.(%)	Min Least Likely	Min Most Likely	Max Most Likely	Max Least Likely
rev1	5	5	0	36.684	36.684	36.684	36.684
rev2	6	6	0	34.85	34.85	34.85	34.85
rev3	7	7	0	33.109	33.109	33.109	33.109
rev4	8	8	0	31.454	31.454	31.454	31.454
rev5	9	9	0	29.879	29.879	29.879	29.879
rev6	10	10	0	28.386	28.386	28.386	28.386
rev7	11	11	0	26.965	26.965	26.965	26.965
rev8	12	12	0	25.618	25.618	25.618	25.618
rev9	13	13	0	24.336	24.336	24.336	24.336
rev10	14	14	0	23.118	23.118	23.118	23.118
rev11	15	24	0	9.106	9.106	9.106	9.106

NON-FINANCIAL DATA

No. of Risk Factors: 12

Risk Factor	Weighting	Likelihood
Approval & Permit	2	2
Law Change/Justice Reinf	5	3
Corruption	2	2
Political Instability	5	3
Local Partner's Creditworthiness	3	1
Corporate Fraud	2	1
Termination of JV	7	3
Inflation & Interest Rates	5	5
Cost Overrun	5	3
Improper Design	5	2
Improper Quality Control	3	3
Improper Project Mgmt	5	2

No. of Risk Interactions: 0

Influencing	Influenced	Strength

No. of Opportunity Factors: 0

Opportunity	Weighting	Likelihood

No. of Opport. Interactions: 0

Influencing	Influenced	Strength

ECCO RESULTS FILE - TURKEY CPI MODEL 1

TABULATED COMPARISON OF RESULTS

Project	Overall NPV($mil)	Overall B/C	Cost NPV($mil)	Equity NPV($mil)	Equity B/C Ratio	Opp's	Risks	O/R Ratio	B/CR Rating	BO/CR Rating	Min DSCR	Ranking
Turkey Power Project	20.202	1.184	122.116	7.268	1.188	0	0.373	0	3.182	0	1.139	1

****

PROJECT: Turkey Power Project

Financial Analysis Results

Description	**Min Least Likely**	**Min Most Likely**	**Max Most Likely**	**Max Least Likely**	**Single Value**
Overall NPV ($mil)	$20.20	$20.20	$20.20	$20.20	$20.20
Overall B/C Ratio	1.184	1.184	1.184	1.184	1.184
Project Payback Period(yr)	9	9	9	9	9
Cost NPV ($mil)	$122.12	$122.12	$122.12	$122.12	$122.12
Equity NPV ($mil)	$7.27	$7.27	$7.27	$7.27	$7.27
Equity B/C Ratio	1.188	1.188	1.188	1.188	1.188
Equity Payback Period(yr)	8	8	8	8	8
Equity IRR	0.1485	0.1485	0.1485	0.1485	0.1485

Overall Project Cashflows ($mil)

Year	Cashflows ($mil)
1	-$16.57
2	-$54.52
3	-$97.62
4	-$142.48
5	-$109.63
6	-$78.40
7	-$48.73
8	-$20.53
9	$6.27
10	$31.75
11	$55.95
12	$78.96
13	$100.83
14	$121.61
15	$129.92
16	$138.23
17	$146.54
18	$154.86
19	$163.17
20	$171.48
21	$179.79
22	$188.10
23	$196.41
24	$204.73

Equity Holders Cashflows ($mil)

Year	Cashflows ($mil)
1	-$6.92
2	-$21.66
3	-$37.28
4	-$52.47
5	-$36.77
6	-$22.79
7	-$10.44
8	$0.34
9	$9.62
10	$17.45
11	$23.89
12	$29.00
13	$32.81
14	$35.37
15	$43.68
16	$51.99
17	$60.31
18	$68.62
19	$76.93
20	$85.24
21	$93.55
22	$101.86
23	$110.18
24	$118.49

Annual DSCRs

Year of Repayment	DSCR
1	1.853
2	1.76
3	1.671
4	1.586
5	1.504
6	1.426
7	1.35
8	1.277
9	1.207
10	1.139

Non-Financial Analysis Results

Opportunities Overall Rating (0-1):	0
Risk Overall Rating (0-1):	0.373
OVERALL BOCR RATING (0-1):	0

****

FINANCIAL CALCULATOR SPREADSHEET
TURKEY HEPP POWER PROJECT - FINANCIAL ANALYSIS

PARAMETERS

Construction Period	4	yrs
Ops Period	20	yrs
Repayment Period	10	yrs
Discount Rate	0.12	
Escalation	0.041	
Interest rate	0.1	
Equity Fraction	0.3169	
Tax Rate	0.11	

Yr of Construction	**1**	**2**	**3**	**4**	**TOTALS**	
Amount$$ (Base Cost)	16571	36455	39770	39770	**132566**	**$US thousand**
EDC	0.00	1494.66	3327.99	5095.01		
IDC	5253.45	8580.65	6182.45	3064.73		
TPC = BC+EDC+IDC	21824.45	46530.30	49280.44	47929.74	**165565**	**$US thousand**
discounted TPC	**19486.12**	**37093.67**	**35076.85**	**30460.22**	**122117**	**$US thousand**

CONSTRUCTION RESULTS	
TPC =	**165565 $US thousand**
Thus, Depreciation =	**8278 $US thousand/yr**
Debt Installment (DI) =	**18406 $US thousand/yr for 10yrs**

NCA CALCULATIONS

Year of Operation	1	2	3	4	5	6	7	8	9	10
Revenue (Table 6)	36684	34850	33109	31454	29879	28386	26965	25618	24336	23118
DEP (above)	8278	8278	8278	8278	8278	8278	8278	8278	8278	8278
OM expense (table 6)	790	790	790	790	790	790	790	790	790	790
PBIT (Eq. 11)	27616	25782	24041	22386	20811	19318	17897	16550	15268	14050
DI (above)	18406	18406	18406	18406	18406	18406	18406	18406	18406	18406
TAX (eq. 9)	1793.66	1669.98	1564.34	1476.74	1407.39	1357.44	1326.85	1316.97	1328.06	1361.41
NCA = PBIT-TAX+DEP-DI=REVi-Di	15694	13984	12349	10781	9276	7832	6442	5105	3812	2561
Discounted NCA	8905.34	7084.70	5585.87	4354.34	3344.85	2521.85	1851.94	1310.31	873.58	523.93
DSCR	1.853	1.760	1.671	1.586	1.504	1.426	1.350	1.277	1.207	1.139
REVi	34100.34	32390.02	30754.66	29187.26	27681.61	26238.56	24848.15	23511.03	22217.94	20966.59
CUMFLOW	-131464.6	-99074.58	-68319.92	-39132.66	-11451.04	14787.51	39635.66	63146.70	85364.63	106331.22
Discounted REVi	19349.45	16409.79	13911.85	11788.25	9982.27	8448.11	7143.25	6034.70	5091.78	4290.18

NCA CALCULATIONS (Continued)

Year of Operation	11	12	13	14	15	16	17	18	19	20	TOTAL
Revenue	9106.00	9106.00	9106.00	9106.00	9106.00	9106.00	9106.00	9106.00	9106.00	9106.00	
DEP (above)	8278.25	8278.25	8278.25	8278.25	8278.25	8278.25	8278.25	8278.25	8278.25	8278.25	
OM expense	790.00	790.00	790.00	790.00	790.00	790.00	790.00	790.00	790.00	790.00	
PBIT	37.75	37.75	37.75	37.75	37.75	37.75	37.75	37.75	37.75	37.75	
DI	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
TAX	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15	
NCA = PBIT-TAX+DEP-DI=REVi-Di	8311.85	8311.85	8311.85	8311.85	8311.85	8311.85	8311.85	8311.85	8311.85	8311.85	**170953.81**
Discounted NCA	1518.54	1355.84	1210.57	1080.87	965.06	861.66	769.34	686.91	613.31	547.60	**45966.43**
DSCR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**14.77**
REVi	8311.85	8311.85	8311.85	8311.85	8311.85	8311.85	8311.85	8311.85	8311.85	8311.85	
CUMFLOW	114643.07	122954.91	131266.76	139578.61	147890.46	156202.30	164514.15	172826.00	181137.84	189449.69	
Discounted REVi	1518.54	1355.84	1210.57	1080.87	965.06	861.66	769.34	686.91	613.31	547.60	**112059.34**

Sum of Discounted NCA =	**45966 $US thousand**	
Sum of Discounted REVi	**112059.34 $US thousand**	

RESULTS using EXCEL	**Equity NPV**	**7268 $US thousand**
	IRR (%)	**14.85 %**
	Ave. DSCR	**1.477**

APPENDIX G

VERIFICATION – FINANCIAL ANALYSIS MODEL

(“FUZZY TEST” ECCO PROJECT DATA FILE)

PROJECT DATA FILE

Project Name: Fuzzy test
Project Description: blah
Project Duration: 4
Construction Period: 2

FINANCIAL PARAMETERS
Grace Period 2
Repayment Period 2

Description	**Min Least Likely**	**Min Most Likely**	**Max Most Likely**	**Max Least Likely**
Equity Fraction	0.18	0.2	0.2	0.25
Interest Rate	0.08	0.09	0.09	0.11
Discount Rate	0.085	0.1	0.1	0.11
Escalation Rate	0.035	0.04	0.04	0.042
Tax Rate	0.11	0.13	0.13	0.14

CONSTRUCTION COSTS ($mil)

No. of Construction Costs: 1

Description	**Start Yr**	**Finish Yr**	**Inc.(%)**	**Min Least Likely**	**Min Most Likely**	**Max Most Likely**	**Max Least Likely**
construction	1	2	0	85	100	100	115

OPERATIONS COSTS ($mil)

No. of Operation Costs: 1

Description	**Start Yr**	**Finish Yr**	**Inc.(%)**	**Min Least Likely**	**Min Most Likely**	**Max Most Likely**	**Max Least Likely**
Ops	3	4	0	95	100	100	110

REVENUE STREAMS ($mil)

No. of Revenue Streams: 1

Description	**Start Yr**	**Finish Yr**	**Inc.(%)**	**Min Least Likely**	**Min Most Likely**	**Max Most Likely**	**Max Least Likely**
revenues	3	4	25	380	400	400	420

NON-FINANCIAL DATA

No. of Risk Factors: 0

Risk Factor	Weighting	Likelihood

No. of Risk Interactions: 0

Influencing	Influenced	Strength

No. of Opportunity Factors: 0

Opportunity	Weighting	Likelihood

No. of Opport. Interactions: 0

Influencing	Influenced	Strength

APPENDIX H

VERIFICATION – NON-FINANCIAL MODEL

- ***ECCO Project Data File – Test 1***
- ***ECCO Project Data File – Test 2***
- ***Super Decisions Model***

1. ECCO Project Data File – Test 1

PROJECT DATA FILE

Project Name: Test Project 1
Project Description: This file is used to verify the non-financial analysis, and sensitivity analysis calcs performed by ECCO.

Project Duration: 5
Construction Period: 1

FINANCIAL PARAMETERS
Grace Period 1
Repayment Period 4

Description	Min Least Likely	Min Most Likely	Max Most Likely	Max Least Likely
Equity Fraction	0	0	0	0
Interest Rate	0	0	0	0
Discount Rate	0	0	0	0
Escalation Rate	0	0	0	0
Tax Rate	0	0	0	0

CONSTRUCTION COSTS ($,000)

No. of Construction Costs: 0

Description	Start Yr	Finish Yr	Inc.(%)	Min Least Likely	Min Most Likely	Max Most Likely	Max Least Likely

OPERATIONS COSTS ($mil)

No. of Operation Costs: 0

Description	Start Yr	Finish Yr	Inc.(%)	Min Least Likely	Min Most Likely	Max Most Likely	Max Least Likely

REVENUE STREAMS ($mil)

No. of Revenue Streams: 0

Description	Start Yr	Finish Yr	Inc.(%)	Min Least Likely	Min Most Likely	Max Most Likely	Max Least Likely

NON-FINANCIAL DATA

No. of Risk Factors: 5

Risk Factor	Weighting	Likelihood
financing	6	4
social	3	2
political	5	3
technological	1	3
environmental	1	5

No. of Risk Interactions: 6

Influencing	**Influenced**	**Strength**
political	social	6
environmental	political	2
political	financing	4
technological	financing	2
social	political	2
environmental	technological	2

No. of Opportunity Factors: 0

Opportunity	**Weighting**	**Likelihood**

No. of Opport. Interactions: 0

Influencing	**Influenced**	**Strength**

2. *ECCO Project Data File – Test 2*

PROJECT DATA FILE

Project Name: Test Project 2

Project Description: This file is used to verify the non-financial analysis, and sensitivity analysis calcs performed by ECCO.

Project Duration: 5
Construction Period: 1

FINANCIAL PARAMETERS
Grace Period 1
Repayment Period 4

Description	**Min Least Likely**	**Min Most Likely**	**Max Most Likely**	**Max Least Likely**
Equity Fraction	0	0	0	0
Interest Rate	0	0	0	0
Discount Rate	0	0	0	0
Escalation Rate	0	0	0	0
Tax Rate	0	0	0	0

CONSTRUCTION COSTS ($mil)

No. of Construction Costs: 0

Description	**Start Yr**	**Finish Yr**	**Inc.(%)**	**Min Least Likely**	**Min Most Likely**	**Max Most Likely**	**Max Least Likely**

OPERATIONS COSTS ($mil)

No. of Operation Costs: 0

Description	**Start Yr**	**Finish Yr**	**Inc.(%)**	**Min Least Likely**	**Min Most Likely**	**Max Most Likely**	**Max Least Likely**

REVENUE STREAMS ($mil)

No. of Revenue Streams: 0

Description	Start Yr	Finish Yr	Inc.(%)	Min Least Likely	Min Most Likely	Max Most Likely	Max Least Likely

NON-FINANCIAL DATA

No. of Risk Factors: 5

Risk Factor	Weighting	Likelihood
financing	6	2
social	3	4
political	5	5
technological	1	3
environmental	1	1

No. of Risk Interactions: 6

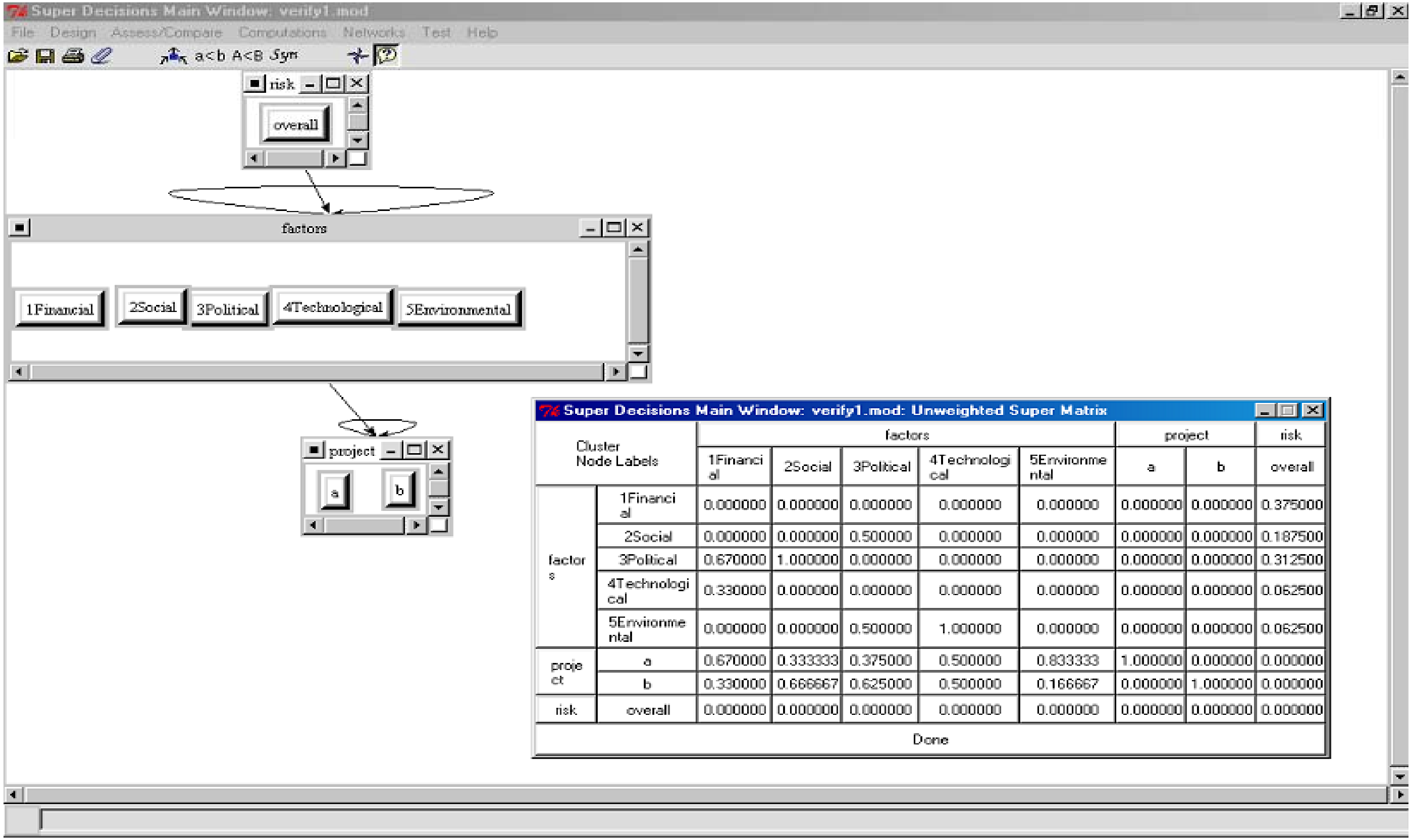
Influencing	Influenced	Strength
political	social	6
environmental	political	2
political	financing	4
technological	financing	2
social	political	2
environmental	technological	2

No. of Opportunity Factors: 0

Opportunity	Weighting	Likelihood

No. of Opport. Interactions: 0

Influencing	Influenced	Strength



Cluster	Node Labels	factors					project		risk
		1Financial	2Social	3Political	4Technological	5Environmental	a	b	overall
factors	1Financial	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.375000
	2Social	0.000000	0.000000	0.500000	0.000000	0.000000	0.000000	0.000000	0.187500
	3Political	0.670000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.312500
	4Technological	0.330000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.062500
	5Environmental	0.000000	0.000000	0.500000	1.000000	0.000000	0.000000	0.000000	0.062500
project	a	0.670000	0.333333	0.375000	0.500000	0.833333	1.000000	0.000000	0.000000
	b	0.330000	0.666667	0.625000	0.500000	0.166667	0.000000	1.000000	0.000000
risk	overall	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

Super Decisions Model

APPENDIX I

VALIDATION – CASE STUDY ONE

ECCO PROJECT DATA FILE – MODEL 2

PROJECT DATA FILE

Project Name: Turkey Power Project
Project Description: Bakatjan et al. (2003) paper
Project Duration: 24
Construction Period: 4

FINANCIAL PARAMETERS
Grace Period 4
Repayment Period 10

Description	Min Least Likely	Min Most Likely	Max Most Likely	Max Least Likely
Equity Fraction	0.28	0.3169	0.3169	0.35
Interest Rate	0.09	0.1	0.1	0.11
Discount Rate	0.09	0.12	0.12	0.125
Escalation Rate	0.035	0.041	0.041	0.045
Tax Rate	0.11	0.11	0.11	0.11

CONSTRUCTION COSTS ($million)

No. of Construction Costs: 4

Description	Start Yr	Finish Yr	Inc.(%)	Min Least Likely	Min Most Likely	Max Most Likely	Max Least Likely
year1	1	1	0.000	13.843	15.207	15.207	16.571
year2	2	2	0.000	30.454	33.455	33.455	36.455
year3	3	3	0.000	33.223	36.496	36.496	39.770
year4	4	4	0.000	33.223	36.496	36.496	39.770

OPERATIONS COSTS ($million)

No. of Operation Costs: 1

Description	Start Yr	Finish Yr	Inc.(%)	Min Least Likely	Min Most Likely	Max Most Likely	Max Least Likely
Annual Ops	5	24	0	0.715	0.752	1.003	1.053

REVENUE STREAMS ($million)

No. of Revenue Streams: 11

Description	Start Yr	Finish Yr	Inc.(%)	Min Least Likely	Min Most Likely	Max Most Likely	Max Least Likely
rev1	5	5	0	35.168	37.411	37.723	39.826
rev2	6	6	0	33.410	35.540	35.837	37.835
rev3	7	7	0	31.739	33.763	34.045	35.943

rev4	8	8	0	30.152	32.075	32.343	34.146
rev5	9	9	0	28.645	30.471	30.726	32.439
rev6	10	10	0	27.213	28.948	29.190	30.817
rev7	11	11	0	25.852	27.500	27.730	29.276
rev8	12	12	0	24.559	26.125	26.344	27.812
rev9	13	13	0	23.331	24.819	25.026	26.422
rev10	14	14	0	22.165	23.578	23.775	25.101
rev11	15	24	0	6.590	8.278	8.529	10.328

NON-FINANCIAL DATA

No. of Risk Factors: 12

Risk Factor	Weighting	Likelihood
Approval & Permit	2	2
Law Change/Justice Reinf	5	3
Corruption	2	2
Political Instability	5	3
Local Partner's Creditworthiness	3	1
Corporate Fraud	2	1
Termination of JV	7	3
Inflation & Interest Rates	5	5
Cost Overrun	5	3
Improper Design	5	2
Improper Quality Control	3	3
Improper Project Mgmt	5	2

No. of Risk Interactions: 37

Influencing	Influenced	Strength
Approval & Permit	Corruption	4
Approval & Permit	Termination of JV	4
Approval & Permit	Cost Overrun	4
Law Change/Justice Reinforcement	Approval & Permit	4
Law Change/Justice Reinforcement	Political Instability	4
Law Change/Justice Reinforcement	Termination of JV	4
Law Change/Justice Reinforcement	Cost Overrun	4
Corruption	Approval & Permit	5
Corruption	Law Change/Justice Reinforcement	3
Corruption	Local Partner's Creditworthiness	3
Corruption	Corporate Fraud	4
Corruption	Termination of JV	3
Corruption	Improper Quality Control	4
Corruption	Improper Project Mgmt	3
Political Instability	Approval & Permit	5
Political Instability	Law Change/Justice Reinforcement	5
Political Instability	Corruption	5
Political Instability	Local Partner's Creditworthiness	4
Political Instability	Corporate Fraud	3
Political Instability	Termination of JV	4
Political Instability	Inflation & Interest Rates	5
Political Instability	Cost Overrun	4

Local Partner's Creditworthiness	Corporate Fraud	3
Local Partner's Creditworthiness	Termination of JV	5
Local Partner's Creditworthiness	Cost Overrun	3
Corporate Fraud	Local Partner's Creditworthiness	4
Corporate Fraud	Termination of JV	5
Corporate Fraud	Cost Overrun	4
Corporate Fraud	Improper Design	3
Corporate Fraud	Improper Quality Control	4
Corporate Fraud	Improper Project Mgmt	4
Termination of JV	Cost Overrun	4
Inflation & Interest Rates	Political Instability	4
Inflation & Interest Rates	Termination of JV	3
Inflation & Interest Rates	Cost Overrun	5
Cost Overrun	Local Partner's Creditworthiness	3
Cost Overrun	Termination of JV	5

No. of Opportunity Factors: 0

Opportunity	Weighting	Likelihood

No. of Opport. Interactions: 0

Influencing	Influenced	Strength

APPENDIX J

<u>VALIDATION – CASE STUDY TWO</u>

- ***FINANCIAL DATA SPREADSHEET***
- ***ECCO PROJECT DATA FILE – CPI MODEL 1***
- ***ECCO PROJECT DATA FILE – CPI MODEL 2***

	Total	Construction Period	Phase	Development Period						Construction Period								Operating Period								
Basic Data Input Area *(Unit: Million)*		Subtotal	Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	1	2	3	4	5	6	7	8	9
			Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003.1	2003.2	2004.2	2005.2	2006.2	2007.2	2008.2	2009.2	2010.2	2011.2
Ridership (unit: person-mile/year)	354,729	0																4213	8636	8857	9088	9329	9584	9851	10147	10472
Ticket Price (including 5% value-added tax)	0	0																0.21	0.21	0.22	0.23	0.24	0.24	0.25	0.26	0.27
Operating Revenue (excluding 5% value-added tax)	127,195	0																824.48	1,749.34	1,856.96	1,971.99	2,095.34	2,227.81	1,369.99	2,526.71	2,698.90
Revenue from Affiliated Business	0	0																								
Net Income from Land Development	9,697	(180)														(176.36)	(3.21)	(33.27)	(1.58)	0.61	(4.79)	16.91	6.06	6.18	47.52	25.45
Revenue from the Sale of Equipment	0	0																								
Operating/Maintenance Cost	43,251	32															32.24	291.52	613.94	638.18	682.06	751.94	818.79	883.70	949.58	1,022.48
Cost of Asset Purchasing During Operation	1,453	0																							179.70	265.70
Cost of Asset Replacement During Operation	8,474	0																								

	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Subtotal
	2012.2	2013.2	2014.2	2015.2	2016.2	2017.2	2018.2	2019.2	2020.2	2021.2	2022.2	2023.2	2024.2	2025.2	2026.2	2027.2	2028.2	2029.2	2030.2	2031.2	2032.2	2033.1	
Ridership (unit: person-mile/year)	10709	10946	11134	11321	11506	11693	11880	12069	12263	12460	12663	12873	13077	13284	13495	13710	13929	14153	14381	14613	14851	7545	274,553.75
Ticket Price (including 5% value-added tax)	0.28	0.29	0.30	0.31	0.32	0.33	0.34	0.36	0.37	0.38	0.40	0.41	0.42	0.44	0.45	0.47	0.49	0.50	0.52	0.54	0.56	0.58	
Operating Revenue (excluding 5% value-added tax)	2,856.72	3,021.93	3,181.63	3,348.07	3,522.68	3,704.35	3,895.49	4,095.89	4,307.52	4,529.86	4,764.83	5,013.39	5,270.98	5,541.77	5,826.95	6,126.98	6,442.89	6,775.21	7,125.37	7,493.99	7,882.34	4,144.86	108,873.10
Revenue from Affiliated Business																							0.00
Net Income from Land Development	22.67	13.15	17.70	77.27	24.36	28.36	36.79	30.55	194.97	52.00	94.79	63.76	277.27	207.21	142.61	183.82	155.33	170.61	187.45	206.00	226.30	7,400.42	9,813.39
Revenue from the Sale of Equipment																							0.00
Operating/Maintenance Cost	1,066.79	1,113.15	1,161.45	1,211.88	1,264.55	1,319.45	1,376.85	1,436.61	1,499.63	1,564.00	1,631.82	1,702.67	1,777.21	1,853.58	1,933.94	2,017.88	2,105.52	2,196.79	2,274.85	2,355.70	2,439.39	1,263.12	36,566.21
Cost of Asset Purchasing During Operation	82.48									314.85	465.52	144.55											1,007.39
Cost of Asset Replacement During Operation															1,341.82	1,983.94	5,147.76						8,473.52

CASE STUDY TWO (MODEL 1)
PROJECT DATA FILE

Project Name: Taiwan HSR
Project Description:
Project Duration: 44
Construction Period: 14

FINANCIAL PARAMETERS
Grace Period 14
Repayment Period 12

Description	Min Least Likely	Min Most Likely	Max Most Likely	Max Least Likely
Equity Fraction	0.3	0.3	0.3	0.3
Interest Rate	0.09	0.09	0.09	0.09
Discount Rate	0.135	0.135	0.135	0.135
Escalation Rate	0.035	0.035	0.035	0.035
Tax Rate	0.25	0.25	0.25	0.25

CONSTRUCTION COSTS ($mil)

No. of Construction Costs: 9

Description	Start Yr	Finish Yr	Inc.(%)	Min Least Likely	Min Most Likely	Max Most Likely	Max Least Likely
1995	6	6	0	1	1	1	1
1996	7	7	0	24	24	24	24
1997	8	8	0	126	126	126	126
1998	9	9	0	496	496	496	496
1999	10	10	0	1347	1347	1347	1347
2000	11	11	0	2248	2248	2248	2248
2001	12	12	0	2204	2204	2204	2204
2002	13	13	0	1951	1951	1951	1951
2003	14	14	0	1042	1042	1042	1042

OPERATIONS COSTS ($mil)

No. of Operation Costs: 30

Description	Start Yr	Finish Yr	Inc.(%)	Min Least Likely	Min Most Likely	Max Most Likely	Max Least Likely
2004	15	15	0	937.7	937.7	937.7	937.7
2005	16	16	0	638.18	638.18	638.18	638.18
2006	17	17	0	682.06	682.06	682.06	682.06
2007	18	18	0	751.94	751.94	751.94	751.94
2008	19	19	0	818.79	818.79	818.79	818.79
2009	20	20	0	883.7	883.7	883.7	883.7
2010	21	21	0	1129.28	1129.28	1129.28	1129.28
2011	22	22	0	1288.18	1288.18	1288.18	1288.18
2012	23	23	0	1149.27	1149.27	1149.27	1149.27
2013	24	24	0	1113.15	1113.15	1113.15	1113.15
2014	25	25	0	1161.45	1161.45	1161.45	1161.45
2015	26	26	0	1211.88	1211.88	1211.88	1211.88
2016	27	27	0	1264.55	1264.55	1264.55	1264.55
2017	28	28	0	1319.45	1319.45	1319.45	1319.45
2018	29	29	0	1376.85	1376.85	1376.85	1376.85

2019	30	30	0	1436.61	1436.61	1436.61	1436.61
2020	31	31	0	1499.03	1499.03	1499.03	1499.03
2021	32	32	0	1878.85	1878.85	1878.85	1878.85
2022	33	33	0	2097.34	2097.34	2097.34	2097.34
2023	34	34	0	1847.22	1847.22	1847.22	1847.22
2024	35	35	0	1777.21	1777.21	1777.21	1777.21
2025	36	36	0	1853.58	1853.58	1853.58	1853.58
2026	37	37	0	3275.76	3275.76	3275.76	3275.76
2027	38	38	0	4001.82	4001.82	4001.82	4001.82
2028	39	39	0	7253.28	7253.28	7253.28	7253.28
2029	40	40	0	2196.79	2196.79	2196.79	2196.79
2030	41	41	0	2274.85	2274.85	2274.85	2274.85
2031	42	42	0	2355.7	2355.7	2355.7	2355.7
2032	43	43	0	2439.39	2439.39	2439.39	2439.39
2033	44	44	0	1263.12	1263.12	1263.12	1263.12

REVENUE STREAMS ($mil)

No. of Revenue Streams: 30

Description	**Start Yr**	**Finish Yr**	**Inc.(%)**	**Min Least Likely**	**Min Most Likely**	**Max Most Likely**	**Max Least Likely**
2004	15	15	0	2359.4	2359.4	2359.4	2359.4
2005	16	16	0	1857.57	1857.57	1857.57	1857.57
2006	17	17	0	1967.2	1967.2	1967.2	1967.2
2007	18	18	0	2112.25	2112.25	2112.25	2112.25
2008	19	19	0	2233.87	2233.87	2233.87	2233.87
2009	20	20	0	2376.17	2376.17	2376.17	2376.17
2010	21	21	0	2574.23	2574.23	2574.23	2574.23
2011	22	22	0	2724.35	2724.35	2724.35	2724.35
2012	23	23	0	2879.39	2879.39	2879.39	2879.39
2013	24	24	0	3035.08	3035.08	3035.08	3035.08
2014	25	25	0	3199.33	3199.33	3199.33	3199.33
2015	26	26	0	3425.34	3425.34	3425.34	3425.34
2016	27	27	0	3546.44	3546.44	3546.44	3546.44
2017	28	28	0	3732.71	3732.71	3732.71	3732.71
2018	29	29	0	3932.28	3932.28	3932.28	3932.28
2019	30	30	0	4126.44	4126.44	4126.44	4126.44
2020	31	31	0	4502.49	4502.49	4502.49	4502.49
2021	32	32	0	4581.86	4581.86	4581.86	4581.86
2022	33	33	0	4859.62	4859.62	4859.62	4859.62
2023	34	34	0	5077.15	5077.15	5077.15	5077.15
2024	35	35	0	5548.25	5548.25	5548.25	5548.25
2025	36	36	0	5748.98	5748.98	5748.98	5748.98
2026	37	37	0	5969.56	5969.56	5969.56	5969.56
2027	38	38	0	6310.8	6310.8	6310.8	6310.8
2028	39	39	0	6598.22	6598.22	6598.22	6598.22
2029	40	40	0	6945.82	6945.82	6945.82	6945.82
2030	41	41	0	7312.82	7312.82	7312.82	7312.82
2031	42	42	0	7699.99	7699.99	7699.99	7699.99
2032	43	43	0	8108.64	8108.64	8108.64	8108.64
2033	44	44	0	11545.28	11545.28	11545.28	11545.28

NON-FINANCIAL DATA

No. of Risk Factors: 12

Risk Factor	**Weighting**	**Likelihood**
Approval & Permit	6	2
Law Change/Justice Reinf	4	1
Corruption	4	4
Political Instability	4	2
Local Partner's Creditworthiness	5	3
Corporate Fraud	5	3
Termination of JV	5	2
Inflation & Interest Rates	5	4
Cost Overrun	6	4
Improper Design	6	3
Improper Quality Control	6	4
Improper Project Mgmt	4	6

No. of Risk Interactions: 0
Influencing Influenced Strength

No. of Opportunity Factors: 0
Opportunity Weighting Likelihood

No. of Opport. Interactions: 0
Influencing Influenced Strength

CASE STUDY TWO (MODEL 2)
PROJECT DATA FILE

Project Name: Taiwan HSR (fuzzy)
Project Description:
Project Duration: 44
Construction Period: 14

FINANCIAL PARAMETERS
Grace Period 14
Repayment Period 12

Description	Min Least Likely	Min Most Likely	Max Most Likely	Max Least Likely
Equity Fraction	0.27	0.3	0.3	0.33
Interest Rate	0.085	0.09	0.09	0.095
Discount Rate	0.125	0.135	0.135	0.14
Escalation Rate	0.032	0.035	0.035	0.038
Tax Rate	0.25	0.25	0.25	0.25

CONSTRUCTION COSTS ($million)

No. of Construction Costs: 9

Description	Start Yr	Finish Yr	Inc.(%)	Min Least Likely	Min Most Likely	Max Most Likely	Max Least Likely
1995	6	6	0	0.9	1	1	1.1
1996	7	7	0	22	24	24	26
1997	8	8	0	113.4	126	126	138.6
1998	9	9	0	455	496	496	535
1999	10	10	0	1250	1347	1347	1445
2000	11	11	0	2030	2248	2248	2450
2001	12	12	0	2095	2204	2204	2314
2002	13	13	0	1860	1951	1951	2040
2003	14	14	0	942	1042	1042	1142

OPERATIONS COSTS ($million)

No. of Operation Costs: 30

Description	Start Yr	Finish Yr	Inc.(%)	Min Least Likely	Min Most Likely	Max Most Likely	Max Least Likely
2004	15	15	0	890.815	937.7	937.7	984.585
2005	16	16	0	606.271	638.18	638.18	670.089
2006	17	17	0	647.957	682.06	682.06	716.163
2007	18	18	0	714.343	751.94	751.94	789.537
2008	19	19	0	777.851	818.79	818.79	859.73
2009	20	20	0	839.515	883.7	883.7	927.885
2010	21	21	0	1072.816	1129.28	1129.28	1185.744
2011	22	22	0	1223.771	1288.18	1288.18	1352.589
2012	23	23	0	1091.807	1149.27	1149.27	1206.734
2013	24	24	0	1057.493	1113.15	1113.15	1168.808
2014	25	25	0	1103.378	1161.45	1161.45	1219.523
2015	26	26	0	1151.286	1211.88	1211.88	1272.474
2016	27	27	0	1201.323	1264.55	1264.55	1327.778
2017	28	28	0	1253.478	1319.45	1319.45	1385.423

2018	29	29	0	1308.008	1376.85	1376.85	1445.693
2019	30	30	0	1364.78	1436.61	1436.61	1508.441
2020	31	31	0	1424.079	1499.03	1499.03	1573.982
2021	32	32	0	1784.908	1878.85	1878.85	1972.793
2022	33	33	0	1992.473	2097.34	2097.34	2202.207
2023	34	34	0	1754.859	1847.22	1847.22	1939.581
2024	35	35	0	1688.35	1777.21	1777.21	1866.071
2025	36	36	0	1760.901	1853.58	1853.58	1946.259
2026	37	37	0	3111.972	3275.76	3275.76	3439.548
2027	38	38	0	3801.729	4001.82	4001.82	4201.911
2028	39	39	0	6890.616	7253.28	7253.28	7615.944
2029	40	40	0	2086.951	2196.79	2196.79	2306.63
2030	41	41	0	2161.108	2274.85	2274.85	2388.593
2031	42	42	0	2237.915	2355.7	2355.7	2473.485
2032	43	43	0	2317.421	2439.39	2439.39	2561.36
2033	44	44	0	1199.964	1263.12	1263.12	1326.276

REVENUE STREAMS ($million)

No. of Revenue Streams: 30

Description	Start Yr	Finish Yr	Inc.(%)	Min Least Likely	Min Most Likely	Max Most Likely	Max Least Likely
2004	15	15	0	2241.43	2359.4	2359.4	2477.37
2005	16	16	0	1764.692	1857.57	1857.57	1950.449
2006	17	17	0	1868.84	1967.2	1967.2	2065.56
2007	18	18	0	2006.638	2112.25	2112.25	2217.863
2008	19	19	0	2122.177	2233.87	2233.87	2345.564
2010	20	20	0	2445.519	2574.23	2574.23	2702.942
2009	21	21	0	2257.362	2376.17	2376.17	2494.979
2011	22	22	0	2588.133	2724.35	2724.35	2860.568
2012	23	23	0	2735.421	2879.39	2879.39	3023.36
2013	24	24	0	2883.326	3035.08	3035.08	3186.834
2014	25	25	0	3039.364	3199.33	3199.33	3359.297
2015	26	26	0	3254.073	3425.34	3425.34	3596.607
2016	27	27	0	3369.118	3546.44	3546.44	3723.762
2017	28	28	0	3546.075	3732.71	3732.71	3919.346
2018	29	29	0	3735.666	3932.28	3932.28	4128.894
2019	30	30	0	3920.118	4126.44	4126.44	4332.762
2020	31	31	0	4277.366	4502.49	4502.49	4727.615
2021	32	32	0	4352.767	4581.86	4581.86	4810.953
2022	33	33	0	4616.639	4859.62	4859.62	5102.601
2023	34	34	0	4823.293	5077.15	5077.15	5331.008
2024	35	35	0	5270.838	5548.25	5548.25	5825.663
2025	36	36	0	5461.531	5748.98	5748.98	6036.429
2026	37	37	0	5671.082	5969.56	5969.56	6268.038
2027	38	38	0	5995.26	6310.8	6310.8	6626.34
2028	39	39	0	6268.309	6598.22	6598.22	6928.131
2029	40	40	0	6598.529	6945.82	6945.82	7293.111
2030	41	41	0	6947.179	7312.82	7312.82	7678.461
2031	42	42	0	7314.991	7699.99	7699.99	8084.99
2032	43	43	0	7703.208	8108.64	8108.64	8514.072
2033	44	44	0	10968.02	11545.28	11545.28	12122.54

NON-FINANCIAL DATA

No. of Risk Factors: 12

Risk Factor	Weighting	Likelihood
Approval & Permit	6	2
Law Change/Justice Reinf	4	1
Corruption	4	4
Political Instability	4	2
Local Partner's Creditworthiness	5	3
Corporate Fraud	5	3
Termination of JV	5	2
Inflation & Interest Rates	5	4
Cost Overrun	6	4
Improper Design	6	3
Improper Quality Control	6	4
Improper Project Mgmt	4	6

No. of Risk Interactions: 43

Influencing	Influenced	Strength
Approval & Permit	Corruption	4
Approval & Permit	Termination of JV	4
Approval & Permit	Cost Overrun	4
Law Change/Justice Reinf	Approval & Permit	4
Law Change/Justice Reinf	Political Instability	4
Law Change/Justice Reinf	Termination of JV	4
Law Change/Justice Reinf	Cost Overrun	4
Corruption	Approval & Permit	5
Corruption	Law Change/Justice Reinf	3
Corruption	Local Partner's Creditworthiness	3
Corruption	Corporate Fraud	4
Corruption	Termination of JV	3
Corruption	Improper Quality Control	4
Corruption	Improper Project Mgmt	3
Political Instability	Approval & Permit	5
Political Instability	Law Change/Justice Reinf	5
Political Instability	Corruption	5
Political Instability	Local Partner's Creditworthiness	4
Political Instability	Corporate Fraud	3
Political Instability	Termination of JV	4
Political Instability	Inflation & Interest Rates	5
Political Instability	Cost Overrun	4
Local Partner's Creditworthiness	Corporate Fraud	3
Local Partner's Creditworthiness	Termination of JV	5
Local Partner's Creditworthiness	Cost Overrun	3
Corporate Fraud	Local Partner's Creditworthiness	4
Corporate Fraud	Termination of JV	5
Corporate Fraud	Cost Overrun	4
Corporate Fraud	Improper Design	3
Corporate Fraud	Improper Quality Control	4
Corporate Fraud	Improper Project Mgmt	4

Termination of JV	Cost Overrun	4
Inflation & Interest Rates	Political Instability	4
Inflation & Interest Rates	Termination of JV	3
Inflation & Interest Rates	Cost Overrun	5
Cost Overrun	Local Partner's Creditworthiness	3
Cost Overrun	Termination of JV	5
Improper Design	Cost Overrun	5
Improper Quality Control	Cost Overrun	5
Improper Quality Control	Improper Design	3
Improper Project Mgmt	Cost Overrun	5
Improper Project Mgmt	Improper Design	4
Improper Project Mgmt	Improper Quality Control	5

No. of Opportunity Factors: 0

Opportunity Weighting Likelihood

No. of Opport. Interactions: 0

Influencing Influenced Strength

APPENDIX K

VALIDATION – CASE STUDY THREE

- ***ECCO PROJECT DATA FILE – MODEL 1***
- ***ECCO PROJECT DATA FILE – MODEL 2***

CASE STUDY THREE (MODEL 1)
PROJECT DATA FILE

Project Name: Canadian BOT HWY
Project Description: Taken from case study in PhD dissertation of Dr. Ahmed Abdel-Aziz
Project Duration: 32
Construction Period: 2

FINANCIAL PARAMETERS
Grace Period 9
Repayment Period 23

Description	Min Least Likely	Min Most Likely	Max Most Likely	Max Least Likely
Equity Fraction	0.4741	0.4741	0.4741	0.4741
Interest Rate	0.1063	0.1063	0.1063	0.1063
Discount Rate	0.0825	0.0825	0.0825	0.0825
Escalation Rate	0.0235	0.0235	0.0235	0.0235
Tax Rate	0	0	0	0

CONSTRUCTION COSTS ($million)

No. of Construction Costs: 5

Description	Start Yr	Finish Yr	Inc.(%)	Min Least Likely	Min Most Likely	Max Most Likely	Max Least Likely
design	1	1	0	13	13	13	13
roadcon1	1	1	0	12.025	12.025	12.025	12.025
roadcon2	2	2	0	43.725	43.725	43.725	43.725
structure1	1	1	0	6.472	6.472	6.472	6.472
structure2	2	2	0	8.778	8.778	8.778	8.778

OPERATIONS COSTS ($million)

No. of Operation Costs: 33

Description	Start Yr	Finish Yr	Inc.(%)	Min Least Likely	Min Most Likely	Max Most Likely	Max Least Likely
OMcost3	3	3	0	3.037	3.037	3.037	3.037
OMcost4	4	4	0	3.104	3.104	3.104	3.104
OMcost5	5	5	0	3.173	3.173	3.173	3.173
OMcost6	6	6	0	3.244	3.244	3.244	3.244
OMcost7	7	7	0	3.318	3.318	3.318	3.318
OMcost8	8	8	0	3.393	3.393	3.393	3.393
OMcost9	9	9	0	3.471	3.471	3.471	3.471
OMcost10	10	10	0	3.552	3.552	3.552	3.552
OMcost11	11	11	0	3.634	3.634	3.634	3.634
OMcost12	12	12	0	3.72	3.72	3.72	3.72
OMcost13	13	13	0	3.808	3.808	3.808	3.808
OMcost14	14	14	0	3.898	3.898	3.898	3.898
OMcost15	15	15	0	3.992	3.992	3.992	3.992
OMcost16	16	16	0	4.088	4.088	4.088	4.088
OMcost17	17	17	0	4.188	4.188	4.188	4.188
OMcost18	18	18	0	4.291	4.291	4.291	4.291
OMcost19	19	19	0	4.397	4.397	4.397	4.397

OMcost20	20	20	0	4.506	4.506	4.506	4.506
OMcost21	21	21	0	4.619	4.619	4.619	4.619
OMcost22	22	22	0	4.736	4.736	4.736	4.736
OMcost23	23	23	0	4.856	4.856	4.856	4.856
OMcost24	24	24	0	4.981	4.981	4.981	4.981
OMcost25	25	25	0	5.11	5.11	5.11	5.11
OMcost26	26	26	0	5.243	5.243	5.243	5.243
OMcost27	27	27	0	5.38	5.38	5.38	5.38
OMcost28	28	28	0	5.523	5.523	5.523	5.523
OMcost29	29	29	0	5.67	5.67	5.67	5.67
OMcost30	30	30	0	5.822	5.822	5.822	5.822
OMcost31	31	31	0	5.98	5.98	5.98	5.98
OMcost32	32	32	0	6.144	6.144	6.144	6.144
Majormaint1	12	12	0	13.959	13.959	13.959	13.959
MajorMaint2	22	22	0	18.367	18.367	18.367	18.367
MajorMaint3	32	32	0	26.122	26.122	26.122	26.122

REVENUE STREAMS ($million)

No. of Revenue Streams: 31

Description	Start Yr	Finish Yr	Inc.(%)	Min Least Likely	Min Most Likely	Max Most Likely	Max Least Likely
GovtCont	3	3	0	26	26	26	26
Tolls3	3	3	0	8.196	8.196	8.196	8.196
Tolls4	4	4	0	8.85	8.85	8.85	8.85
Tolls5	5	5	0	9.529	9.529	9.529	9.529
Tolls6	6	6	0	10.226	10.226	10.226	10.226
Tolls7	7	7	0	10.94	10.94	10.94	10.94
Tolls8	8	8	0	11.675	11.675	11.675	11.675
Tolls9	9	9	0	12.446	12.446	12.446	12.446
Tolls10	10	10	0	13.269	13.269	13.269	13.269
Tolls11	11	11	0	14.157	14.157	14.157	14.157
Tolls12	12	12	0	15.118	15.118	15.118	15.118
Tolls13	13	13	0	16.15	16.15	16.15	16.15
Tolls14	14	14	0	17.241	17.241	17.241	17.241
Tolls15	15	15	0	18.375	18.375	18.375	18.375
Tolls16	16	16	0	19.541	19.541	19.541	19.541
Tolls17	17	17	0	20.737	20.737	20.737	20.737
Tolls18	18	18	0	21.973	21.973	21.973	21.973
Tolls19	19	19	0	23.276	23.276	23.276	23.276
Tolls20	20	20	0	24.674	24.674	24.674	24.674
Tolls21	21	21	0	26.194	26.194	26.194	26.194
Tolls22	22	22	0	27.849	27.849	27.849	27.849
Tolls23	23	23	0	29.635	29.635	29.635	29.635
Tolls24	24	24	0	31.53	31.53	31.53	31.53
Tolls25	25	25	0	33.507	33.507	33.507	33.507
Tolls26	26	26	0	35.545	35.545	35.545	35.545
Tolls27	27	27	0	37.64	37.64	37.64	37.64
Tolls28	28	28	0	39.814	39.814	39.814	39.814
Tolls29	29	29	0	42.114	42.114	42.114	42.114
Tolls30	30	30	0	44.594	44.594	44.594	44.594
Tolls31	31	31	0	47.301	47.301	47.301	47.301
Tolls32	32	32	0	50.26	50.26	50.26	50.26

NON-FINANCIAL DATA

No. of Risk Factors: 12

Risk Factor	Weighting	Likelihood
Approval & Permit	5	5
Law Change/Justice Reinf	5	1
Corruption	5	0
Political Instability	5	0
Local Partner's Creditworthiness	3	1
Corporate Fraud	3	1
Termination of JV	3	1
Inflation & Interest Rates	5	3
Cost Overrun	5	4
Improper Design	5	1
Improper Quality Control	3	3
Improper Project Mgmt	5	3

No. of Risk Interactions: 0

Influencing	Influenced	Strength

No. of Opportunity Factors: 0

Opportunity	Weighting	Likelihood

No. of Opport. Interactions: 0

Influencing	Influenced	Strength

CASE STUDY THREE (MODEL 2)
PROJECT DATA FILE

Project Name: Canadian BOT HWY
Project Description: Taken from case study in PhD dissertation of Dr. Ahmed Abdel-Aziz
Project Duration: 32
Construction Period: 2

FINANCIAL PARAMETERS
Grace Period 9
Repayment Period 23

Description	Min Least Likely	Min Most Likely	Max Most Likely	Max Least Likely
Equity Fraction	0.442	0.48	0.48	0.504
Interest Rate	0.1052	0.1063	0.1063	0.112
Discount Rate	0.0825	0.0825	0.0825	0.0825
Escalation Rate	0.0235	0.0235	0.0235	0.0235
Tax Rate	0	0	0	0

CONSTRUCTION COSTS ($million)

No. of Construction Costs: 5

Description	Start Yr	Finish Yr	Inc.(%)	Min Least Likely	Min Most Likely	Max Most Likely	Max Least Likely
design	1	1	0	12.35	13	13	13.65
roadcon1	1	1	0	11.424	12.025	12.025	12.626
roadcon2	2	2	0	41.539	43.275	43.275	45.439
structure1	1	1	0	6.148	6.472	6.472	6.796
structure2	2	2	0	8.339	8.778	8.778	9.217

OPERATIONS COSTS ($million)

No. of Operation Costs: 33

Description	Start Yr	Finish Yr	Inc.(%)	Min Least Likely	Min Most Likely	Max Most Likely	Max Least Likely
OMcost3	3	3	0	3.037	3.037	3.037	3.037
OMcost4	4	4	0	3.104	3.104	3.104	3.105
OMcost5	5	5	0	3.172	3.173	3.173	3.174
OMcost6	6	6	0	3.243	3.244	3.244	3.246
OMcost7	7	7	0	3.315	3.318	3.318	3.32
OMcost8	8	8	0	3.39	3.393	3.393	3.397
OMcost9	9	9	0	3.467	3.471	3.471	3.476
OMcost10	10	10	0	3.545	3.552	3.552	3.558
OMcost11	11	11	0	3.627	3.634	3.634	3.642
OMcost12	12	12	0	3.71	3.72	3.72	3.729
OMcost13	13	13	0	3.796	3.808	3.808	3.819
OMcost14	14	14	0	3.884	3.898	3.898	3.912
OMcost15	15	15	0	3.975	3.992	3.992	4.009
OMcost16	16	16	0	4.069	4.088	4.088	4.108
OMcost17	17	17	0	4.165	4.188	4.188	4.211
OMcost18	18	18	0	4.264	4.291	4.291	4.318
OMcost19	19	19	0	4.367	4.397	4.397	4.428

OMcost20	20	20	0	4.472	4.506	4.506	4.542
OMcost21	21	21	0	4.58	4.619	4.619	4.66
OMcost22	22	22	0	4.691	4.736	4.736	4.782
OMcost23	23	23	0	4.806	4.856	4.856	4.909
OMcost24	24	24	0	4.924	4.981	4.981	5.04
OMcost25	25	25	0	5.046	5.11	5.11	5.177
OMcost26	26	26	0	5.171	5.243	5.243	5.318
OMcost27	27	27	0	5.3	5.38	5.38	5.465
OMcost28	28	28	0	5.434	5.523	5.523	5.618
OMcost29	29	29	0	5.571	5.67	5.67	5.776
OMcost30	30	30	0	5.713	5.822	5.822	5.941
OMcost31	31	31	0	5.859	5.98	5.98	6.112
OMcost32	32	32	0	6.01	6.144	6.144	6.291
Majormaint1	12	12	0	12.208	13.959	13.959	18.751
MajorMaint2	22	22	0	15.568	18.367	18.367	25.453
MajorMaint3	32	32	0	21.05	26.122	26.122	38.07

REVENUE STREAMS ($million)

No. of Revenue Streams: 31

Description	**Start Yr**	**Finish Yr**	**Inc.(%)**	**Min Least Likely**	**Min Most Likely**	**Max Most Likely**	**Max Least Likely**
GovtCont	3	3	0	26	26	26	26
Tolls3	3	3	0	8.193	8.196	8.196	8.198
Tolls4	4	4	0	8.845	8.85	8.85	8.855
Tolls5	5	5	0	9.520	9.529	9.529	9.539
Tolls6	6	6	0	10.212	10.226	10.226	10.241
Tolls7	7	7	0	10.917	10.94	10.94	10.962
Tolls8	8	8	0	11.644	11.675	11.675	11.707
Tolls9	9	9	0	12.403	12.446	12.446	12.49
Tolls10	10	10	0	13.211	13.269	13.269	13.327
Tolls11	11	11	0	14.081	14.157	14.157	14.233
Tolls12	12	12	0	15.021	15.118	15.118	15.215
Tolls13	13	13	0	16.027	16.15	16.15	16.273
Tolls14	14	14	0	17.089	17.241	17.241	17.394
Tolls15	15	15	0	18.189	18.375	18.375	18.564
Tolls16	16	16	0	19.315	19.541	19.541	19.771
Tolls17	17	17	0	20.464	20.737	20.737	21.012
Tolls18	18	18	0	21.649	21.973	21.973	22.302
Tolls19	19	19	0	22.892	23.276	23.276	23.665
Tolls20	20	20	0	24.222	24.674	24.674	25.133
Tolls21	21	21	0	25.665	26.194	26.194	26.733
Tolls22	22	22	0	27.231	27.849	27.849	28.48
Tolls23	23	23	0	28.916	29.635	29.635	30.37
Tolls24	24	24	0	30.697	31.53	31.53	32.384
Tolls25	25	25	0	32.547	33.507	33.507	34.495
Tolls26	26	26	0	34.442	35.545	35.545	36.681
Tolls27	27	27	0	36.381	37.64	37.64	38.94
Tolls28	28	28	0	38.382	39.814	39.814	41.297
Tolls29	29	29	0	40.489	42.114	42.114	43.801
Tolls30	30	30	0	42.753	44.594	44.594	46.51
Tolls31	31	31	0	45.218	47.301	47.301	49.476
Tolls32	32	32	0	47.903	50.26	50.26	52.727

NON-FINANCIAL DATA

No. of Risk Factors: 12

Risk Factor	Weighting	Likelihood
Approval & Permit	5	5
Law Change/Justice Reinf	5	1
Corruption	5	0
Political Instability	5	0
Local Partner's Creditworthiness	3	1
Corporate Fraud	3	1
Termination of JV	3	1
Inflation & Interest Rates	5	3
Cost Overrun	5	4
Improper Design	5	1
Improper Quality Control	3	3
Improper Project Mgmt	5	3

No. of Risk Interactions: 40

Influencing	Influenced	Strength
Approval & Permit	Cost Overrun	3
Law Change/Justice Reinf	Approval & Permit	3
Law Change/Justice Reinf	Termination of JV	3
Law Change/Justice Reinf	Cost Overrun	3
Corruption	Approval & Permit	7
Corruption	Law Change/Justice Reinf	3
Corruption	Local Partner's Creditworthiness	1
Corruption	Corporate Fraud	3
Corruption	Termination of JV	1
Corruption	Improper Quality Control	1
Corruption	Improper Project Mgmt	1
Political Instability	Approval & Permit	5
Political Instability	Law Change/Justice Reinf	5
Political Instability	Corruption	5
Political Instability	Local Partner's Creditworthiness	1
Political Instability	Corporate Fraud	1
Political Instability	Termination of JV	3
Political Instability	Cost Overrun	1
Local Partner's Creditworthiness	Termination of JV	3
Corporate Fraud	Local Partner's Creditworthiness	5
Corporate Fraud	Termination of JV	5
Corporate Fraud	Cost Overrun	1
Corporate Fraud	Improper Design	1
Corporate Fraud	Improper Quality Control	1
Corporate Fraud	Improper Project Mgmt	3
Inflation & Interest Rates	Political Instability	3
Inflation & Interest Rates	Cost Overrun	5
Cost Overrun	Local Partner's Creditworthiness	5
Cost Overrun	Termination of JV	5
Improper Design	Cost Overrun	5
Improper Quality Control	Cost Overrun	3
Improper Quality Control	Improper Design	1
Improper Project Mgmt	Cost Overrun	5
Improper Project Mgmt	Improper Quality Control	3
Law Change/Justice Reinf	Improper Design	1
Law Change/Justice Reinf	Improper Quality Control	1
Law Change/Justice Reinf	Improper Project Mgmt	1

Corruption	Inflation & Interest Rates	3
Political Instability	Inflation & Interest Rates	7
Local Partner's Creditworthiness	Cost Overrun	1

No. of Opportunity Factors: 0

Opportunity Weighting Likelihood

No. of Opport. Interactions: 0

Influencing Influenced Strength

APPENDIX L

VALIDATION – ANALYSIS RUN 4

ECCO ANALYSIS RESULTS FILE – THREE CASE STUDY PROJECTS

TABULATED COMPARISON OF RESULTS

Project	Cost NPV ($mil)	Equity NPV($mil)	Equity B/C	Equity Payback (yr)	Equity IRR(%)	Project NPV ($mil)	Project B/C	Project Payback (yr)	Ave DSCR	Opp's	Risks	O/R Ratio	B/CR Rating	BO/CR Rating	Ranking
Canadian BOT HWY	128.44	25.82	1.435	12	12.47	38.23	1.527	11	2.334	0	0.188	0	7.633	0	1
Turkey Power Project	114.82	22.00	1.714	8	19.66	33.85	1.350	9	1.675	0.000	0.370	0.000	4.630	0.000	2
Taiwan High Speed Rail	4035.37	-771.13	0.373	31	9.27	371.49	1.078	26	0.928	0.000	0.408	0.000	0.915	0.000	3

PROJECT: Canadian BOT HWY

Financial Analysis Results

Description	Min Least Likely	Min Most Likely	Max Most Likely	Max Least Likely	Single Value
Overall NPV ($mil)	$26.43	$40.06	$40.06	$48.21	$38.23
Overall B/C Ratio	1.346	1.547	1.547	1.688	1.527
Project Payback Period(yr)	10	10	10	11	11
Cost NPV ($mil)	$117.72	$126.40	$126.40	$141.20	$128.44
Equity NPV ($mil)	$9.41	$28.65	$28.65	$39.41	$25.82
Equity B/C Ratio	1.151	1.472	1.472	1.681	1.435
Equity Payback Period(yr)	8	9	9	17	12
Equity IRR (%)	10	12.8	12.8	14.6	12.4667

Overall Project Cashflows

Year	Cashflows ($mil)
1	-$31.50
2	-$84.92
3	-$53.76
4	-$48.02
5	-$41.66
6	-$34.68
7	-$27.06
8	-$18.77
9	-$9.80
10	-$0.08
11	$10.44
12	$6.87
13	$19.21
14	$32.55
15	$46.94
16	$62.39
17	$78.94
18	$96.63
19	$115.51
20	$135.68
21	$157.25
22	$160.57
23	$185.36
24	$211.91
25	$240.32
26	$270.63
27	$302.90
28	$337.21
29	$373.67
30	$412.46
31	$453.81
32	$469.55

Equity Holders Cashflows

Year	Cashflows ($mil)
1	-$26.89
2	-$69.23
3	-$38.07
4	-$32.32
5	-$25.97
6	-$18.99
7	-$11.36
8	-$3.08
9	$5.89
10	$6.54
11	$7.99
12	-$4.66
13	-$1.60
14	$2.57
15	$7.78
16	$14.06

17	$21.44
18	$29.95
19	$39.66
20	$50.65
21	$63.06
22	$57.21
23	$72.82
24	$90.20
25	$109.43
26	$130.57
27	$153.67
28	$178.80
29	$206.09
30	$235.71
31	$267.89
32	$274.45

Year of Repayment	DSCR
1	1.082
2	1.172
3	-0.439
4	1.375
5	1.487
6	1.603
7	1.723
8	1.845
9	1.972
10	2.106
11	2.251
12	2.408
13	0.404
14	2.768
15	2.966
16	3.174
17	3.388
18	3.608
19	3.837
20	4.08
21	4.342
22	4.63
23	1.893

Non-Financial Analysis Results

Opportunities Overall Rating (0-1):	0
Risk Overall Rating (0-1):	0.188
OVERALL BOCR RATING (0-1):	0

PROJECT: Taiwan High Speed Rail

Financial Analysis Results

Description	Min Least Likely	Min Most Likely	Max Most Likely	Max Least Likely	Single Value
Overall NPV ($mil)	-$1,136.31	$209.58	$209.58	$2,041.19	$371.49
Overall B/C Ratio	0.785	1.041	1.041	1.409	1.078
Project Payback Period(yr)	24	25	25	27	26
Cost NPV ($mil)	$3,353.04	$3,935.31	$3,935.31	$4,817.75	$4,035.37
Equity NPV ($mil)	-$1,376.34	-$792.21	-$792.21	-$144.83	-$771.13
Equity B/C Ratio	-0.072	0.329	0.329	0.862	0.373
Equity Payback Period(yr)	28	30	30	33	31
Equity IRR (%)	6.8	9.2	9.2	11.8	9.2667

Overall Project Cashflows

Year	Cashflows ($mil)
1	$0.00
2	$0.00
3	$0.00
4	$0.00
5	$0.00
6	-$1.19
7	-$30.72
8	-$191.27
9	-$844.44
10	-$2,683.40
11	-$5,853.42
12	-$9,076.07
13	-$12,027.40
14	-$13,661.69
15	-$12,455.14
16	-$11,400.32
17	-$10,296.18
18	-$9,135.67
19	-$7,934.09
20	-$6,525.91
21	-$5,450.46
22	-$4,233.06
23	-$2,795.19
24	-$1,213.47
25	$455.22
26	$2,255.59
27	$4,107.29
28	$6,057.51
29	$8,114.36
30	$10,272.01
31	$12,664.88
32	$14,832.42
33	$17,044.41
34	$19,607.13
35	$22,575.69

36	$25,637.52
37	$27,798.14
38	$29,670.16
39	$29,319.14
40	$33,021.19
41	$36,939.94
42	$41,088.44
43	$45,480.65
44	$53,332.55

Equity Holders Cashflows

Year	Cashflows ($mil)
1	$0.00
2	$0.00
3	$0.00
4	$0.00
5	$0.00
6	-$0.66
7	-$15.79
8	-$92.55
9	-$383.57
10	-$1,148.55
11	-$2,383.94
12	-$3,556.85
13	-$4,564.26
14	-$5,090.08
15	-$5,262.24
16	-$5,599.27
17	-$5,901.31
18	-$6,162.60
19	-$6,399.84
20	-$6,449.06
21	-$6,878.23
22	-$7,174.84
23	-$7,275.35
24	-$7,258.58
25	-$7,183.84
26	-$7,009.03
27	-$5,156.95
28	-$3,206.35
29	-$1,149.11
30	$1,008.92
31	$3,402.18
32	$5,570.09
33	$7,782.46
34	$10,345.57
35	$13,314.51
36	$16,376.72
37	$18,537.73
38	$20,410.13
39	$20,059.49
40	$23,761.92
41	$27,681.06
42	$31,829.94
43	$36,222.54
44	$44,074.82

Year of Repayment	DSCR
1	0.914
2	0.81
3	0.832
4	0.858
5	0.873
6	0.991
7	0.773
8	0.849
9	0.97
10	1.044
11	1.08
12	1.143

Non-Financial Analysis Results

Opportunities Overall Rating (0-1):	0
Risk Overall Rating (0-1):	0.408
OVERALL BOCR RATING (0-1):	0

PROJECT: Turkey Power Project

Financial Analysis Results

Description	Min Least Likely	Min Most Likely	Max Most Likely	Max Least Likely	Single Value
Overall NPV ($mil)	$3.81	$28.75	$31.42	$67.88	$33.85
Overall B/C Ratio	1.035	1.285	1.312	1.718	1.35
Project Payback Period(yr)	8	9	9	10	9
Cost NPV ($mil)	$98.72	$112.07	$112.07	$133.66	$114.82
Equity NPV ($mil)	-$6.38	$15.48	$17.63	$56.11	$22.00
Equity B/C Ratio	0.83	1.436	1.497	2.858	1.714
Equity Payback Period(yr)	6	7	8	10	8
Equity IRR (%)	9.8	18.8	19.6	30	19.66

Overall Project Cashflows

Year	Cashflows ($mil)
1	-$15.21
2	-$50.02
3	-$89.54
4	-$130.67
5	-$97.23
6	-$65.46
7	-$35.27
8	-$6.59
9	$20.66
10	$46.55
11	$71.15
12	$94.52

13	$116.73
14	$137.82
15	$145.39
16	$152.95
17	$160.51
18	$168.07
19	$175.63
20	$183.19
21	$190.75
22	$198.31
23	$205.87
24	$213.43

Equity Holders Cashflows

Year	Cashflows ($mil)
1	-$6.38
2	-$19.96
3	-$34.34
4	-$48.32
5	-$30.62
6	-$14.66
7	-$0.36
8	$12.34
9	$23.51
10	$32.73
11	$40.83
12	$47.57
13	$53.01
14	$57.18
15	$64.74
16	$72.31
17	$79.87
18	$87.44
19	$95.00
20	$102.57
21	$110.13
22	$117.70
23	$125.26
24	$132.83

Year of Repayment	DSCR
1	2.101
2	1.995
3	1.894
4	1.797
5	1.705
6	1.616
7	1.53
8	1.448
9	1.369
10	1.293

Non-Financial Analysis Results

Opportunities Overall Rating (0-1):	0
Risk Overall Rating (0-1):	0.37
OVERALL BOCR RATING (0-1):	0

APPENDIX M

VALIDATION – SENSITIVITY ANALYSIS RESULTS

ECCO – SA RESULTS FILE: FINANCIAL (Equity Fraction)

SENSITIVITY ANALYSIS RESULTS FILE

Factor Analysed: Equity Ratio

TABLE 1: % CHANGE IN EQUITY HOLDER B/C RATIO vs. % CHANGE IN FACTOR VALUE

Project/Factor	-5.00%	-2.50%	0.00%	2.50%	5.00%
2 - Taiwan High Speed Rail	-3.777	-1.842	0	1.757	3.433
1 - Canadian BOT HWY	-0.077	-0.05	0	0.072	0.164
3 - Turkey Power Project	2.202	1.072	0	-1.019	-1.988

ECCO – SA RESULTS FILE: NON-FINANCIAL (Approval and Permit)

SENSITIVITY ANALYSIS RESULTS FILE

Risk Factor Analysed: Approval & Permit

TABLE 1: % CHANGE IN RISK RATING vs. CHANGE IN FACTOR LIKELIHOOD

Project/Factor Likelihood	1	2	3	4	5	6	7
1 - Canadian BOT HWY	-11.464	-7.689	-4.636	-2.116	0	1.801	3.354
3 - Turkey Power Project	-2.409	0	1.95	3.561	4.913	6.066	7.059
2 - Taiwan High Speed Rail	-3.785	0	3.089	5.658	7.828	9.685	11.292