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Designing a Stakeholder-Centric Framework for Cost-Benefit Analysis of Transport Infrastructure Projects

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Declaration

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Abstract

Transport infrastructure development is a crucial part of regional and national long-term growth strategies. The planning and implementation of transport infrastructure is key to regional development as it allows governments to promote the competitive advantages of the local market (e.g. labour and logistics costs) and to attract entrepreneurs and investors. However, the cost of these projects is a major issue, thus it is crucial to carefully examine project proposals before selection. Cost-benefit Analysis (CBA) is a conventional technique used for this purpose that allows decision-makers to prioritise promising investment candidates based on economic and social merit. Even though CBA has been widely applied in the evaluation of transport infrastructure projects in both developed and developing countries, it still has limitations. Scholars have identified a range of CBA issues occurring across technical, financial, socio-economic, and environmental groups of factors, but the central problems of CBA including stakeholder engagement and evaluation method selection remain unanswered.

The Constructive Research Approach (CRA) was selected for this project because it is a research methodology for producing solutions that can be demonstrated through their implementation. CRA was implemented using five main steps. The first step was the identification of the relevant practical problem via the researcher's experience and direct feedback from experts. The next step focused on obtaining pre-understanding of the research topic through a survey of CBA literature from 1844 to 2018 in order to structure the CBA schools of thought and to identify cost-benefit factors and the associated methods used for their evaluation in transport infrastructure projects. The third step was to construct two main artefacts: the skeleton of the stakeholder-centric CBA framework and its quantitative assessment system. Refinement and validation of the CBA framework followed. During framework development, five research seminars with colleagues in the ECIC were organised and then seven in-depth interviews with experts were conducted for validation purposes. Moreover, the quantitative aspects of the stakeholder-centric CBA framework were optimised by using the Visual Basic programming language to develop a computer application, termed CBAFS, to implement the framework and to perform CBA assessments.

The key outcome of the research program, a stakeholder-centric CBA framework, allows practitioners to identify key stakeholders and to elicit their actual needs before identifying cost-benefit factors and associated methods for evaluation. The stakeholder-centric CBA framework provides a specific process consisting of seven steps for combining 'hard' and 'soft' systems approaches. The iterative cycle of the framework invokes soft systems approaches to tackle the issue of stakeholder engagement. Complementary to this, the CBAFS software employs a 'hard' systems approach to structure the execution of a CBA by an evaluation team through the following processes: (1) translation of stakeholder needs into measurable attributes; (2) selection of cost-benefit factors and associated evaluation methods; (3) implementation of the project evaluation; and (4) generation of cost-benefit information for stakeholder debate. The unique aspect of the stakeholder-centric CBA framework is that it allows stakeholders to be fully involved in the CBA process and this increases the transparency of the decision-making process. The stakeholder-centric CBA framework encourages cooperation between the evaluation team and key stakeholders such as construction contractors, design experts, financiers, economists, and environmentalists, and this enables the project evaluation team to better capture the values of the input parameters and more thoughtfully interpret the CBA evaluation. Moreover, the 'satisficing' benchmark, proposed in this study is extremely useful in determining the degree of consensus among key stakeholders on the planned investment decision.

This research makes three significant contributions to the body of literature. The first contribution is through the structuring of the main CBA schools of thought and the elucidation of the differences between them in terms of philosophical viewpoints, assumptions, and constraints. The second contribution is the compilation of a comprehensive list of cost-benefit factors that can be incorporated into an evaluation program for any specific transport infrastructure project. Thirdly, the capstone contribution is the innovative artefact produced from this research: a stakeholder-centric CBA framework which allows practitioners to combine 'soft' systems approaches and 'hard' systems approaches to deal with previously-described technical and social issues in contemporary CBA practise. This framework enhances the ability of decision-makers to arrive at appropriately sustainable and feasible decisions regarding investment in transport infrastructure projects.

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Glossary List

B/C – Benefit/Cost Ratio

CATWOE – Customer(s), Actor(s), Transformation Process, Worldview(s), Owner(s) and Environmental Constraint(s)

CBA- Cost- Benefit Analysis

CBAFS – Cost-Benefit analysis Facilities Software

CRA – Constructive Research Approach

DTEI – Department for Transport, Energy and Infrastructure

IRR – Internal Rate of Return

NPV – Net Present Value

PP – Payback Period

SCF – Stakeholder-Centric CBA Framework

SSM – Soft Systems Methodology

TIPs – Transport Infrastructure Projects

TSI – Total Systems Intervention

VBA – Visual Basic Application

VOC – The Value of Operating Cost

VOT – The Value of Travel Time

Chapter 1
Introduction

1.1. Introduction

Chapter 1 starts with a brief description of the role of transport infrastructure projects and presents common issues concerning the evaluation of project proposals. This chapter continues with providing an overview of cost-benefit analysis before highlighting critical issues arising in the evaluation of transport infrastructure projects using traditional CBA. The focus is then shifted to establishing study objectives and formulating research questions for the research program. Next, this chapter briefly introduces the chosen research method applied for designing the research procedure, the 'Constructive Research Approach'. Chapter 1 ends with the outline of the doctoral thesis.

1.2. The Importance of Transport Infrastructure Projects

The World Bank (2018, p. 1) highlighted the importance of transport infrastructure in the following statement:

> "Transport infrastructure is a crucial driver of economic and social development. Transport infrastructure connects people to jobs, education, and health services; it enables the supply of goods and services around the world; and allows people to interact and generate the knowledge and solutions that foster long-term growth".

The development of transport infrastructure projects is a clear contributor to economic growth; many firms report that transport infrastructure development brings real benefits, including reduction of inventory cost, increased distribution to new markets, and access to the local labour market (Ernst and Young, 1996). In particular, Aschauer (1989) found that the building of infrastructure contributes to a 40 percent increase in productivity in the US market. The development of a transport infrastructure network enables both suppliers and customers to remove trade barriers between regions. Such development allows manufacturers to take advantage of using regional resources such as land and labour (Ivanova, 2003); and thus improve the competitive advantage of firms and increase their efficiency. This is particularly true for developing countries, where the complete absence of well-developed transport infrastructure networks acts as a serious constraint to economic growth (Hilling, 2003). Moreover, transport infrastructure improvements have certain effects upon the choice of geographical locations for business (Ivanova, 2003), where economic agents such as firms and entrepreneurs make their investment decisions based upon the availability of transport infrastructure within a region.

Inadequacy in transport systems creates a significant barrier for countries, especially developing countries, aiming to export their products. The logistics costs of a developing country such as Vietnam are estimated at between 18% and 20% of GDP (Blancas, Isbell, Isbell, Tan, & Tao, 2014), while these only account for 9% to 14% of GDP for developed countries. Logistics costs typically includes four elements: the cost of ordering, the cost of moving (e.g. from input to output), the cost of in-transit stockholding and inventorying, and the cost caused by stock-outs (Holl, 2006). All four of these are affected by faster and more reliable transport (Allen, Mahmoud, & McNeil, 1985). On average, in China, transportation costs account for 44% of logistics costs and 6% of market revenue (Chang, 1998). Even though transportation costs seem to be coming down, they still make up one third of total global logistics costs (Tseng, Yue, & Taylor, 2005). The role of transportation in a logistics system is described as not only a bridge between producers and customers, but also as a competitive advantage for local business (Tseng et al., 2005). Undoubtedly, the completion of key transport infrastructure projects will significantly influence the performance of the logistics system in the affected geographical regions.

In addition to the logistics system, Prideaux (2000, p. 56) describes the relationship between the transport infrastructure system and tourism as ‘‘the operation of, and interaction between, transport modes, ways and terminals that support tourists into and out of destinations and also the provision of transport services within the destination”. The author asserts that travel cost, travel time, and the distance between tourism destinations has a significant influence on the choice of transport types for tourism. Similarly, Martin and Witt (1988) state that the value of travel time and travel cost are key factors in tourist destination selection. Furthermore, the development of transport infrastructure has positive effects on travel comfort (Khadaroo & Seetanah, 2008), which is one of the critical factors determining whether people travel to new places. In other words, tourists prefer to maintain the same comfort level as at home while travelling (Mo, Howard, & Havitz, 1993) and they consider the availability of efficient, reliable and safe travel in their travel selection (Khadaroo & Seetanah, 2008). In a recent study, Nguyen, Cook, and Ireland (2017) also asserted that there is a correlative relationship between infrastructure development and the growth rate of the tourism market in the context of developing countries.

From the information presented above, it is clear that the development of transport infrastructure is important not only to provide convenient and safe routes for travellers but also to provide opportunities for both investors and local businesses in many sectors of the economy.

1.3. Project Evaluation Issues in the Transport Infrastructure domain

The construction of physical transport infrastructure projects consumes a significant amount of resources (e.g. capital and human resources) and the operation of the resulting infrastructure projects often has considerable impacts on local communities that can last for decades. Thus, transport infrastructure planning and financing are often controversial topics that receive significant attention from potential stakeholders, including investors, governments, communities, and the public media. Those involved parties have different interests and opinions about the selection of project investment, and the conflict between viewpoints is a complex problem in project evaluation. In practice, the lack of consensus among key stakeholders usually leads to project delays and cost overruns during the project planning and implementation stages.

In addition, Flyvbjerg (2007) states that a significant problem in the planning of large-scale infrastructure projects is the high level of misinformation about the benefits generated from project investment and the actual costs of implementation. The complexity of cost-benefit identification and measurement creates significant challenges for decision-makers in deciding whether to proceed with an infrastructure project and which option to select and, in turn, this leads to unexpected risks generated from misinformation. Flyvbjerg (2007) illustrate the impact of these two issues with a simple equation:

Underestimated cost + overestimated benefit = project approval

That is not always the best projects that get implemented, but the projects which look best on paper. In other words, it is not uncommon to read about investments in transport infrastructure projects that have proven infeasible due to the inaccuracy of the project cost and benefit estimation (particularly overestimated usage of toll ways) (O'Sullivan, 2013). The reason for overestimation of benefits mainly arises from limitations in forecasting. As pointed out by Flyvbjerg (2007), when considering rail transport, average traffic shortfall is 51.4% which is combined with an average cost overrun of 44.7%. Regarding road transport, an average cost overrun of 20.4% and there is a fifty-fifty chance of the traffic forecast being incorrect by over 20%. Projects in general are inherently risky, due to their long planning horizons and complex interfaces.

In practice, there are many other issues in transport project appraisals including unclear objectives, errors in planning assumptions, model errors, treatment of non-quantifiable impacts, and analysis methodology selection (Mackie & Preston, 1998). These authors also highlighted critical problems relating to the methodologies used for project evaluation, such as the assessment of project lifespan, double counting and the treatment of systems effects. Similarly, Nakamura (2000) raised many questions as to the scope of the methodology used for evaluation. Two interesting questions raised by this author are as follows: "How far are non-marketable values and indirect economic impacts on the relevant region incorporated in the evaluation?" and "What kind of method is used to integrate values of various items which have been included?" There have been many debates which attempt to answer these questions, but none has resulted in agreement among researchers.

1.4. Cost-Benefit Analysis for Transport Infrastructure Projects

1.4.1. Cost-Benefit analysis background

Transport infrastructure development requires a considerable capital investment and related resources and, not surprisingly, is subject to substantial project appraisal processes (Nguyen, Cook, & Ireland, 2017). Evaluation of project proposals is a vital task that is time-consuming and expensive, and this is why evaluators and decision-makers tend to fall back on tried-and-trusted methods such as Cost-Benefit Analysis. CBA is a systematic method that principally relies on enumerating costs and benefits (e.g. cost-reduction and labour saving) to assess investment options (David, Ngulube, & Dube, 2013). Indeed, Nickel, Ross, and Rhodes (2009) declare that CBA in transport infrastructure projects is a preferred method utilised in the performance assessment in government sectors around the world for high-value projects.

CBA was first used in a comprehensive way under the ‘Federal Navigation Act – 1936’ of the USA. This act mandated that assessing proposed waterway infrastructure must be undertaken using CBA (Barrell & Hills, 1972). In fact, CBA had become popular by the end of the 1960s and was being used in both developing and developed countries in order to assist with selecting critical infrastructure projects. All members of the European Union with the exception of Luxembourg still use CBA in order to evaluate public sector transport infrastructure projects (Bristow & Nellthorp, 2000). Since the 1970s, CBA has been applied to almost all projects sponsored by The World Bank (Independent Evaluation Group, 2010) and subsequently used by international development organisations such as The Asian Development Bank (ADB, 2013). In Japan, CBA is formally used to evaluate overseas projects under Japan’s Official Development Assistance schemes (Nakamura, 2000).

In order to understand the nature of CBA, a brief review of common definitions of CBA is presented in Table 1.1. The second column provides insight into the philosophical evaluation viewpoint from which each definition arises.

Table 1.1. CBA definitions in the domain of transport infrastructure projects

List	CBA definitions	Philosophical Position	Citation
1	Cost-benefit analysis is a practical way to assess the feasibility of investment projects. CBA requires both a short-term and long-term view on the consequences of the investment project; it also considers a wider view on the side effects of the project on people, firms and different groups. The use of CBA implies ‘the enumeration and evaluation of all the relevant costs and benefits’.	Generalist	(Barrell & Hills, 1972)
2	Cost-benefit analysis is an ex-ante evaluation tool that supports decision-makers to plan infrastructure projects. CBA provides an integral overview to alternative plans with regard to estimated costs and possible benefits. CBA attempts to translate the project cost and benefit into monetary terms used for comparison.	Planner	(Beukers, Bertolini, & Te Brömmelstroet, 2012)

3	Cost-benefit analysis is a partial equilibrium technique used for 'investment planning' or 'project appraisal'. This technique aims to estimate the net contribution of a project used to test the achievement possibilities of project implementation for a set of given objectives.	Economist	(Beukers et al., 2012)
4	The aim of cost-benefit analysis is to provide estimations on project costs and benefits that can be used to structure the discussion regarding spending decisions. The applicability of CBA depends on the existence of spending objectives which can be estimated to some approximation for comparison and selection.	Policymaker	(Clements, 1995)
5	Cost–benefit analysis (CBA) is a tool used to evaluate the potential socio-economic impact of investment projects. This tool supports decision-makers to select 'feasible' options for transport infrastructure development.	Socio-Economic viewpoint	(Damart & Roy, 2009)
6	CBA is a rational and systematic process that can weigh the pros and cons of a project or policy. CBA considers the evaluation of basic options of an investment project including 'do it or not'; and also presents evaluation requirements at several different scales such as nothing, minimum, and at least to several requirements.	Policymaker	(Jones, Moura, & Domingos, 2014)
7	CBA is a 'method for organising information to aid decisions about the allocation of resources'. Two main features of CBA include: • costs and benefits are expressed as much as possible in money terms used for comparisons; and • costs and benefits are assessed under a 'global' perspective, rather than that of any particular individual or interest group.	Financialist	(Commonwealth of Australia, 2006)

From the CBA definitions above, it can be seen that the main purposes of CBA are to assess the desirability of investment projects; to evaluate the potential socio-economic impacts of public investment choices; to support decision making for project approval or project prioritisation; and to structure the discussion on spending decisions. In general, a typical process of cost-benefit analysis has eight steps as shown in Figure 1.1.

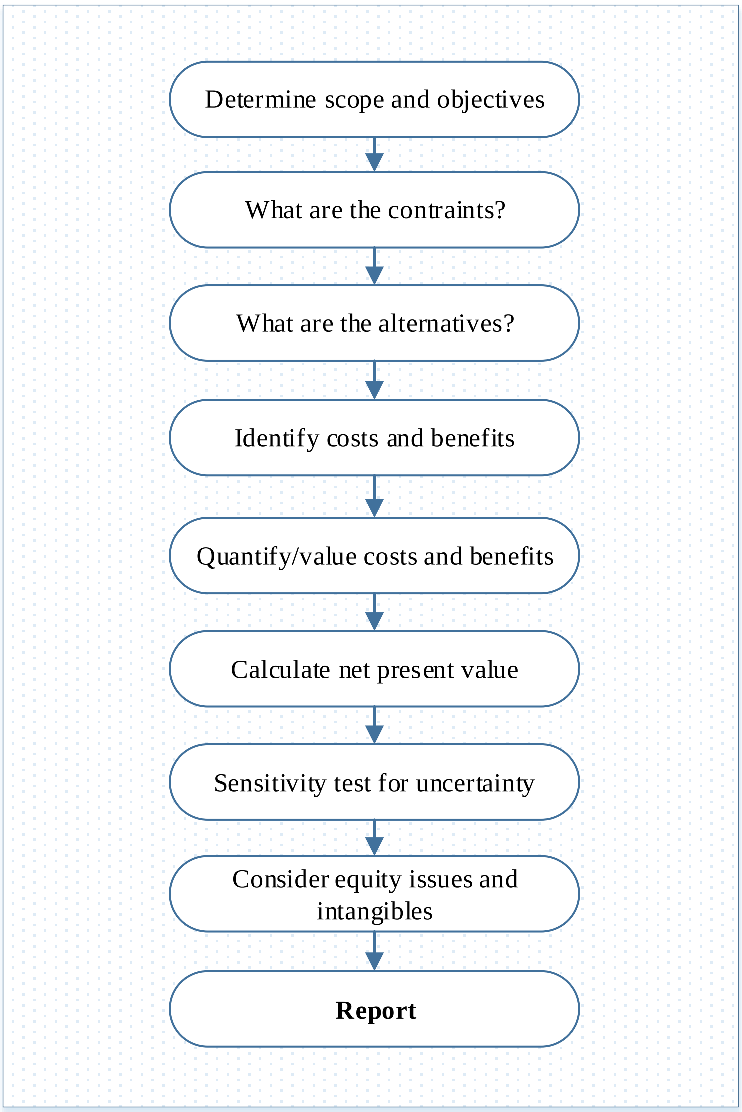


Figure 1.1. Overview of the CBA process. Adapted from the Commonwealth of Australia (2006)

When undertaking CBA, the benefit of a project is defined as being the present value of the consumption stream achieved by the project. This calculation takes into account any reinvestment of project returns in private capital formation, at the same time discounting the consumption stream using the social rate of discount (Commonwealth of Australia, 2006). The cost of a project is defined as that stream of consumption that would be missed due to the displacement of private investment and/or consumption. This process again takes into account reinvestment of returns from displaced private investment and also discounts the consumption stream which is not received by the social rate of discount. Based on the present value rule, the basic equation of CBA can be written in the following form.

$$V_0 = -c_0 + \frac{\sum(b_1 - c_1)}{1+i} + \frac{\sum(b_2 - c_2)}{(1+i)^2} + \cdots + \frac{\sum(b_n - c_n)}{(1+i)^n} \quad \text{(Equation 1.1)}$$

Where V_0 = net present value

c_0 = investment costs

b_t = present value of benefit flow at time t

c_t = present value of cost flow at time t

$t = 1, 2, 3, \ldots, n$ is the time-index (typically years)

i = discount rate

It can be seen that this approach focuses mainly on the financial aspect and relies on the Discounted Cash Flow (DCF) method to generate the evaluation outcome. In particular, the DCF method uses future free cash flow projections and then discounts these to arrive at a present value estimate, which in turn is used to evaluate the potential for investment (The European Commission, 2014). Net Present Value (NPV), V_0, is calculated by discounting all cash outflows (project costs) and inflows (project benefits) of an investment by a chosen specific rate of return. In other words, the present value of 'benefits' minus the present value of the 'costs' is the NPV. Therefore, if the NPV:

- is positive, it implies that the cash inflows from the investment will yield a higher return than the cost of capital, and, therefore, the project should be undertaken

- is negative, it implies that the cash inflows from the investment will yield a return which is lower than that required to satisfy the providers of capital, and, therefore the project should be rejected

- is exactly zero, it implies that the investment has generated exactly the required returns as the cost of capital to satisfy the providers of capital. Thus, the decision should be reconsidered as the project will not return any value.

The main principle of CBA is to enable decision-makers to compare alternative options based on single values such as Net Present Value (NPV) or Benefit-Cost Ratio (BCR) (Nellthorp, Mackie, & Bristow, 1998; Thomopoulos, Grant-Muller, & Tight, 2009) and/or Internal Rate of Return (IRR) (Pohl and Mihaljek, 1992). The core of the conventional approach to CBA is that all impacts are quantified in monetary terms and this provides quantitative measurements to enable comparisons between diverse alternative options. The Equation 1.1, presented above, has been widely applied for financial assessment of most transport infrastructure projects.

1.4.2. CBA application issues in project proposal selection

CBA guidebooks (The Asian Development Bank, 2013; The European Commission, 2008) provide formal guidance to practitioners undertaking project evaluation and enable practitioners to make comparisons between options to support investment selection. However, CBA has been found wanting in practice. Common issues reported are: the lack of appreciation of the relationship between financial and economic factors in the CBA (Florio, 2006); the CBA does not capture the fact that project delays and other risks may make the whole project infeasible (Brzozowska, 2007); failure to recognise conflicts among key stakeholders during the decision-making process (Beukers et al., 2012); and failure to capture all relevant costs and benefits (Eliasson & Lundberg, 2012).

The initial survey of CBA literature identified a range of factors that can be considered when undertaking a CBA. These can be categorised into the following groups: financial, technical, environmental, socio-economic and political. The iceberg model, Figure 1.2, shows these five groups and illustrates that the two visible aspects of CBA are technical and financial, while the remaining three groups are more complicated and difficult to capture and quantify, and as such sit below the surface. The iceberg was used to demonstrate the complexity level of transport infrastructure project evaluation. While financial and technical factors (e.g. project cost estimation, project revenue and technology applied) can be clearly defined, socio-economic and environmental factors are difficult to take in account as well as to quantify; for example, biosphere ecosystem, carbon emission, climate change, business opportunities, the number of jobs created, and public improvements. Thus, environmental and socio-economic groups are illustrated as sitting below the surface of the iceberg model. At the bottom of the iceberg model is the political group which depends on the political system of each country or State. Many scholars have investigated factors in this group (Salahuddin and Islam, 2008) but many challenges still need to be addressed.

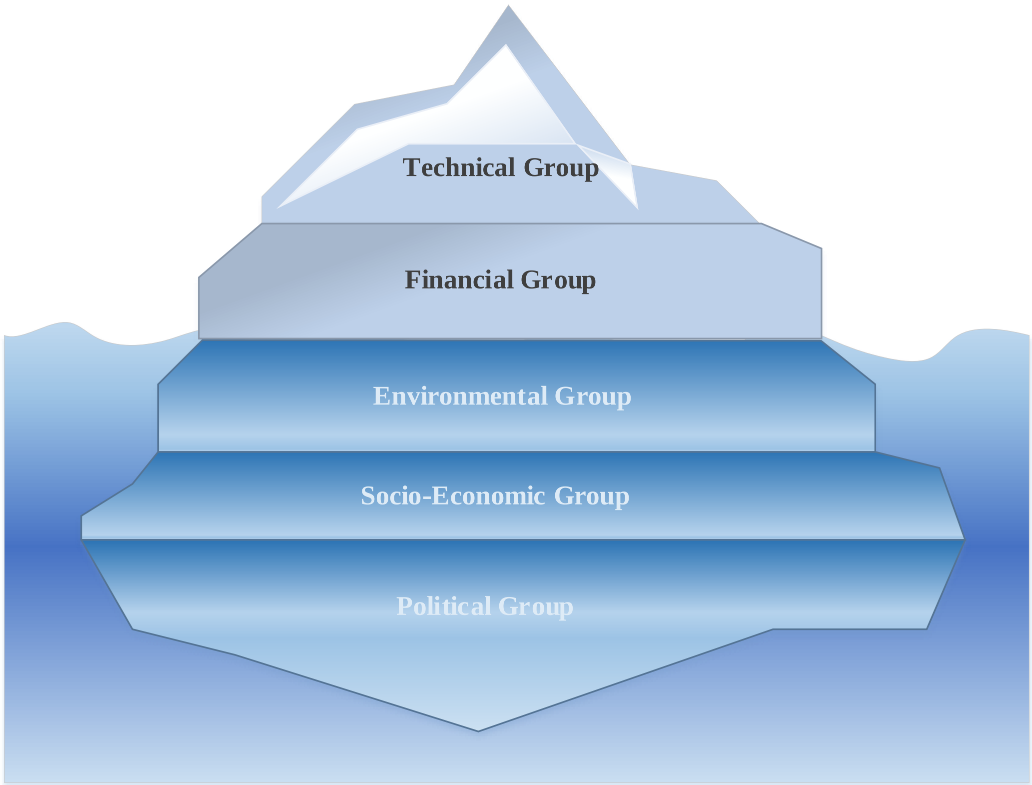


Figure 1.2. The iceberg model of CBA groups of factors

Even though scholars have presented a range of approaches to improve CBA application, the implementation of CBA has several major issues including:

- The boundary of CBA application is unclear. Most studies focus on investigating issues of project impact measurement, but few studies establish the CBA boundary before conducting research. There is little written that highlights the difference between CBA for *transport infrastructure networks* and CBA for specific infrastructure projects.

- Lack of appreciation of the difference in evaluation viewpoints (e.g. private investors, local governments, and non-government organisations). Different stakeholders have different interpretations of CBA and this is a main cause of controversial debates about the costs and benefits of project investment.

- Inadequate rationale for CBA method selection. Researchers tend to select their ‘favourite’ methods, based on their theoretical stance, and ignore the availability of other methods for CBA.

- The applicability of CBA is questionable due to the knowledge gap between theoretical approaches and practical approaches. Researchers often focus on measuring project impacts over the long-term, while practitioners concentrate more on technical and financial aspects of project in the short-term.

- The complexity of frameworks proposed by researchers tends to be difficult to apply because they require a high level of expertise for implementation.

It is clear that there is a significant gap in our understanding of the nature of CBA and its application in practice. Thus, this study seeks an approach to deal with the issues mentioned above, and then, in addition, proposes a comprehensive solution that can support project evaluators and decision-makers to confidently finalise their investment decisions for transport infrastructure projects.

1.5. Study Objectives and Research Questions

The main aim of this research is to develop a stakeholder-centric CBA framework for transport infrastructure projects by structuring CBA schools of thought, exploring cost-benefit factors, investigating critical issues of project evaluation, and proposing solution options. The study has four foci, including:

1) To understand the nature of CBA in the domain of transport infrastructure projects.

2) To identify a list of cost-benefit factors and associated evaluation methods used for CBA of transport infrastructure projects.

3) To understand the difference between the evaluation viewpoints of stakeholders. This study seeks a new approach to CBA and to use it to design a CBA framework that enables decision-makers to finalise an investment decision that can achieve an acceptable level of consensus among key stakeholders.

4) To produce a novel CBA framework that incorporates a wide range of non-financial factors and also allows stakeholders to be involved in the CBA process.

Based on these main objectives, the study program addresses the following four research questions:

1) What factors need to be included in CBA for a transport infrastructure project?

2) How can the various components, including financial costs and social benefits of the CBA system, be incorporated?

3) What tools and techniques are best suited to produce the CBA outputs?

4) How can the results of CBA designed be validated?

In order to answer these questions, the Constructive Research Approach (CRA) is selected and applied in this research program.

1.6. Research Methodology

A Constructive Research Approach (CRA) was proposed and employed because it provides the means to construct the novel CBA framework which can address practical and theoretical gaps (Kasanen, Lukka, & Siitonen, 1993; Lukka, 2000). In this study, the overall output of the CRA employed is the creation of a stakeholder-centric CBA framework for transport infrastructure projects. The implementation of the proposed framework enables decision-makers to have better-informed investment decisions through more comprehensive and explicit prioritisation of stakeholder needs and the inclusion of a combination of cost-benefit factors. The framework is well placed to contribute significantly to the advancement of the CBA discipline.

Technically, CRA entails “building an artefact (practical, theoretical or both) that solves a domain-specific problem in order to create knowledge about how the problem can be solved (or understood, explained or modelled) in principle” (Crnkovic, 2010, p. 163). The CRA comprises the following features, as espoused by Piirainen and Gonzalez (2013):

1) A focus on real-life problems;
2) An innovative artefact, intended to solve the problem, is produced;
3) The artefact is tested through the application;

4) There is teamwork between the researcher and practitioners;
5) The artefact is linked to existing theoretical knowledge;
6) The artefact creates a theoretical contribution.

Based on the core features addressed, the detailed design of the Constructive Research Approach applied for this research program is presented in Chapter 3.

1.7. Research Scope and Limitation

In this study, the researcher focuses on studying CBA for a specific transport infrastructure project to propose the evaluation framework. The researcher concentrates on four main groups of cost-benefit factors: technical, financial, socio-economic and environmental for his investigation. The primary audiences for this research are decision-makers and practitioners who are currently using CBA for project proposal selection.

Transport infrastructure projects have many complex aspects (e.g. socio-economic and environmental), but this study does not use the complex system approach since this approach tends to focus on modelling complex situations with complex models that require many parameters and variables (Hooker, 2011). Typically, complex models rely strongly on mathematical foundations and modelling techniques, and this creates knowledge and experience barriers for practitioners in application and implementation.

Instead, the Constructive Research Approach is applied to build the stakeholder-centric CBA framework for transport infrastructure projects. The Constructive Research Approach relies on cooperation between the researcher and practitioners to ensure that the outcome of the research program is applicable to the evaluation of investment projects. Due to the fact that the length of the PhD program was three years, there are certain limitations regarding practical collaboration. The researcher did invite experts to be involved and to contribute their voices during CBA framework development; however, there still needs to be further cooperation between the researcher and practitioners in the framework implementation stage for transport infrastructure projects.

1.8. Expected Research Contributions to Knowledge

The main contributions of the study program to the body of knowledge include the following:

- The findings of this research should enable researchers to better understand the nature of CBA for transport infrastructure projects including the schools of thought and associated approaches to CBA. In addition, the list of cost-benefit factors identified in this study will alert practitioners to potentially hidden factors that may affect project performance.

- The stakeholder-centric CBA framework, as the main result of this study, provides a comprehensive set of knowledge and methodology elements (such as an overarching process, methods, techniques and a computer tool) to support the conduct of a CBA. This framework allows evaluation teams to select 'appropriate' methods and techniques for CBA and supports decision-makers to make well-informed decisions that can reach consensus among key stakeholders.

- The Constructive Research Approach led to the construction of the multi-methodological constructs (that included soft and hard systems thinking) for the stakeholder-centric CBA framework. This construct links the theoretical and practical aspects of CBA for transport infrastructure projects and provides tool support for socially aware CBA evaluation and decision support in the targeted domain. In accordance with the precepts of CRA, the construct has indeed extended the literature, as evidenced by the publications that have arisen from this study.

1.9. Outline of the Thesis

There are seven chapters in this thesis; Chapter 1- Introduction; Chapter 2- Literature Review; Chapter 3- Research Methodology; Chapter 4- Stakeholder-Centric CBA Framework; Chapter 5 – A Supporting Tool for Stakeholder-Centric CBA Framework; Chapter 6 – A Case Study and Research Discussion; and Chapter 7- Conclusion. Figure 1.3 provides an overview of the thesis structure.

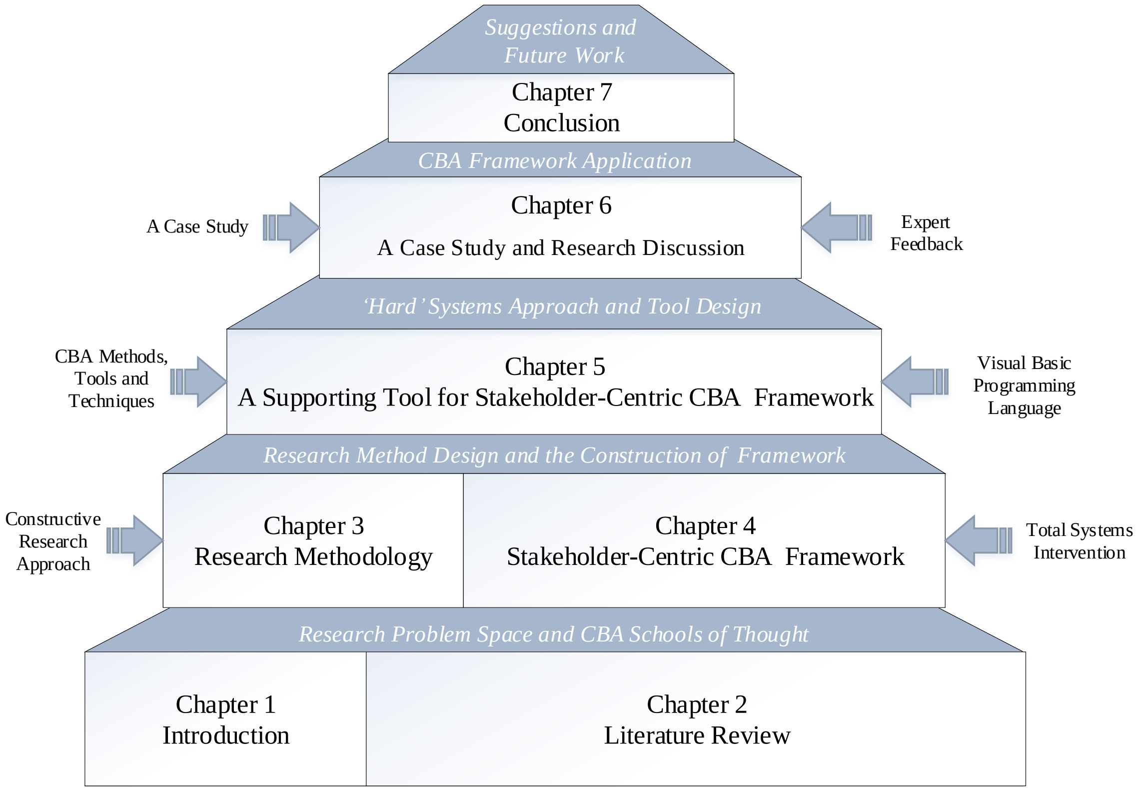


Figure 1.3. Thesis flowchart

Chapter 1 introduces the research problem and presents an overview of the research program. It starts by highlighting the role of transport infrastructure projects before discussing common limitations in project evaluation and selection. Chapter 1 then focuses on identifying critical issues of CBA and clarifying the research direction by presenting research questions. In addition, this chapter provides a short description of the research methodology to be employed in the research program. At the end of Chapter 1, potential research contributions to knowledge are laid out and the structure of the thesis is outlined.

Chapter 2 focuses on reviewing the schools of thought present in the CBA literature in order to systematically document CBA approaches and their associated methods, tools and techniques. This chapter also identifies a list of cost-benefit factors that could be incorporated into evaluation programs. The strengths and weaknesses of CBA are classified into specific categories to highlight the major difficulties in the use of CBA. In addition, Chapter 2 focuses on clarifying the role of CBA for a specific transport infrastructure project, in comparison with a project for transport infrastructure networks. This enables the researcher to clearly concentrate on the scope of a specific project and to propose focussed solutions.

Chapter 3 starts with the rationale for selecting the methodology to serve as the basis for carrying out the research program. This chapter continues with providing justifications for the use of the Constructive Research Approach for the study. The chapter then presents the fundamental steps for constructing the stakeholder-centric CBA framework and highlights the main processes for validating its applicability.

Chapter 4 reviews the need to develop the stakeholder-centric CBA framework for transport infrastructure projects. The Total Systems Intervention approach is then applied to design the main steps of the stakeholder-centric CBA framework. The chapter then concentrates on each step to describe the main activities required for the stakeholder-centric CBA framework implementation. The CBA processes are also presented in detail to support practitioners in their decision-making.

Chapter 5 focuses on designing the supporting tool for the stakeholder-centric CBA framework. This chapter concentrates on the 'hard' aspect of the proposed framework to illustrate the selection of evaluation methods for generating cost-benefit information for stakeholder debates. Chapter 5 provides detailed information on the construction of the supporting tool (CBAFS), including software design requirements, the use of the programming language, and descriptions of the main functions of the CBAFS software.

Chapter 6 presents a case study to demonstrate how traditional and stakeholder-centric CBA frameworks can be applied to a given investment situation, before highlighting major differences between the processes. The chapter also discusses how to validate the utility of the stakeholder-centric framework. Findings from expert interviews are then used to justify the utility and efficacy of the proposed framework and to provide insights into how to operationalise empirical knowledge in an industry-consulting context.

Chapter 7 summarises the main points of the thesis and then highlights the findings of the research program. The originality of the research and its contributions to the body of knowledge are summarised. The chapter also presents major implications of the stakeholder-centric CBA framework for the evaluation of transport infrastructure projects. Finally, the chapter presents limitations of the framework and proposes future work that should be carried out to improve the utility and applicability of the proposed framework.

1.10. Summary

Transport infrastructure projects play a crucial role in stimulating the development of economic sectors in most countries. Cost-benefit analysis is a conventional technique used to make comparisons between investment options in transport infrastructure projects. Chapter 1 has provided a brief overview of CBA and highlighted the practical challenges of applying CBA. This chapter also identified study objectives and crucial research questions to provide a clear direction for the research program. In order to achieve its given objectives, the Constructive Research Approach is used to design the research program. The outcome is the design of the innovative stakeholder-centric CBA framework that can assist practitioners in selecting evaluation methods and support decision-makers to arrive at the most feasible decision for transport infrastructure project investment. The next chapter focuses on reviewing the literature on CBA to clarify the strengths and weaknesses of existing approaches. The survey of the literature uncovers core components used to establish the research foundation and informs further stages of the research program.

Chapter 2

Cost-Benefit Analysis Literature Review

2.1. Introduction

Physical infrastructure projects play a vital role in creating transport connections between cities and regions and are considered a major contributing factor to economic growth. These projects have interrelationships with various economic sectors (e.g. labour market and industries) and need to satisfy the multiple objectives of stakeholders (Grimsey and Lewis 2002). Infrastructure projects absorb a significant amount of capital and other resources for construction and operations in the long term, and thus it is important to identify both the benefits and the potential risks of project proposals before seeking investment; otherwise, common disruptive project issues are liable to manifest themselves: poor stakeholder dissatisfaction, cost overruns, and project delays (Flyvbjerg, 2007). The success of a transport infrastructure project depends strongly on the quality of the investment decisions made by policymakers (Goodman & Hastak, 2006). In order to deal with this matter, planners use analytical techniques which have been evolving over many decades, such as Cost-Benefit Analysis (CBA), to produce the evidence needed to support sound investment decisions.

CBA is concerned with comparing and evaluating and projected costs of all types against the total set of expected benefits (O'leary, 1979). CBA enables decision-makers to allocate resources efficiently and to minimise project risks during construction stage. However, an increase in the complexity level of infrastructure projects, the rapid development of technology, and the greater involvement of stakeholders can create difficulties for evaluators in recognising the potential impacts of project investment, as well as in selecting the ‘right’ CBA methods for evaluation. Although scholars have proposed combining methods to improve the outcome of CBA, few studies focus on identifying cost-benefit factors and associated methods for project evaluation. This chapter seeks to rectify this deficiency by clarifying the nature of CBA, highlighting its contributions and challenges, identifying and categorising cost-benefit factors, and importantly, clarifying the application of CBA techniques for specific cases. The research sought to answer following questions:

Q1. What is the historical background of CBA?

Q2. What are key contributions of CBA to transport infrastructure project evaluation?

Q3. What are the factors inherent in the CBA of transport infrastructure projects?

Q4. What are the boundaries of CBA application in relation to a specific transport infrastructure project?

In order to answer these questions, a review of CBA literature has been conducted to provide a fundamental, in-depth understanding of CBA and its application in the context of transport infrastructure projects. The selected analysis period, from 1844 to 2018, covers the key developments of CBA and highlights contributors and their key contributions.

The body of this chapter opens by describing the literature review approach selected. It then examines an increasing incorporation of additional aspects in the calculation of CBA over time. This is followed by a description of the documented strengths and weaknesses of CBA for transport infrastructure projects and an elucidation of the cost-benefit factors that have a significant impact on investment decisions for such projects. This chapter then justifies the application scope of CBA for a specific transport infrastructure project. The final part of this chapter formulates specific groups of factors and associated methods used to incorporate these factors into the CBA program for transport infrastructure projects.

2.2. Database Construction

Large databases of publications were accessed to find original studies which were published 1844-2018 on the topic of CBA in transport infrastructure projects. Google scholar, Scopus, Science Direct and the Web of Science were selected because they give a very comprehensive coverage of the relevant literature (Kousha & Thelwall, 2007; Spink, Jansen, Blakely, & Koshman, 2006). Keywords selected to the search included cost benefit analysis, socio-economic factors and transport infrastructure: these were applied in various combinations to surface relevant findings. All articles selected for review were written in the English language. Analysis was undertaken using EndNote and NVivo™ software.

The review process involved a pre-review based on the abstract, keywords and conclusions. Next, articles were stored in an EndNote database system and analysed in terms of time series and citations. Following this, the EndNote system was linked with NVivo™ in order to organise, analyse and synthesise the dataset. NVivo™ software is able to undertake content analysis across a vast range of literature. This software coded the main themes of CBA and identified connections between articles.

The initial search found 275 papers which were related to CBA in the transportation infrastructure sector. Next papers were selected featured financial, economic and social aspects of CBA, and this selection resulted in 105 articles. This dataset was used in order to identify key CBA milestones and also produced a list of critical factors which are used for early-stage CBA project evaluation. The current research is focused upon key stakeholder groups of decision-makers, experts and practitioners.

2.3.The Nature of CBA and Its Applications in Transportation

2.3.1. The formation of CBA (1844-1958)

The basic purpose of cost-benefit analysis is to provide the information needed to produce an evidence-based business case, or justification, that can inform project investment decisions. CBA analysis applied financial calculations and supplementary financial analysis that contained measurements of the project costs and benefits to its consumers and to society as a whole (Feldstein, 1964). In particular, CBA aimed to provide an estimation to costs and benefits of available alternatives, and then translate them as much as possible into monetary terms for comparisons (Brent, 2007). CBA has been used in a wide variety of governmental institutions: federal, regional, state and local governments. It has been a required input into assessments of many US federal investment decisions and has been used as well, in the analysis of state and local highway projects, park development projects and, to a lesser extent, to analyse alternative investments in human services, such as health, welfare and educational programs (David, 1979). In general, key contributors to the development history of CBA for transport infrastructure projects are highlighted and depicted in Figure 2.1.

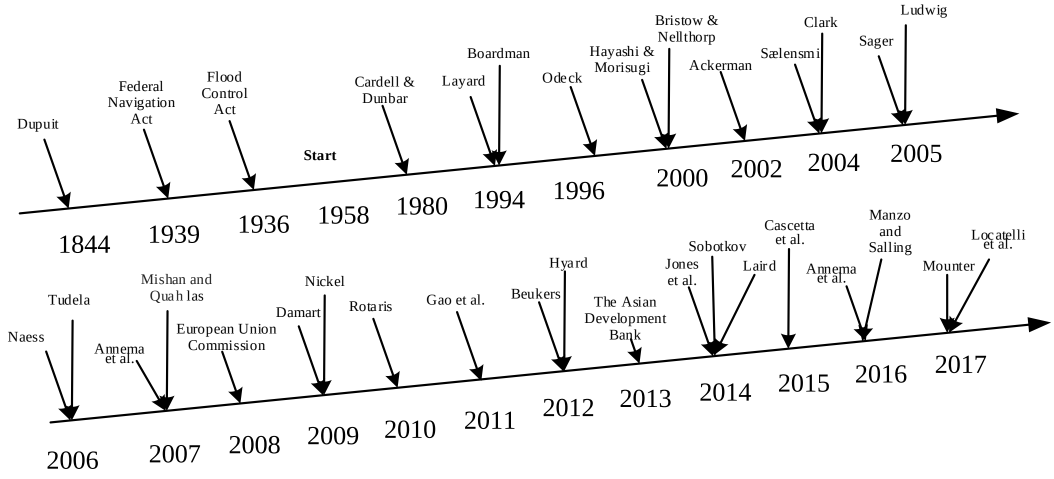


Figure 2.1. The development history of the literature on CBA in relation to transport infrastructure domain.[1]

The original CBA concept is attributed to Jules Dupuit, a French economist. In 1844, he introduced the idea of 'social benefit' (Damart & Roy, 2009). Following this, the River and Harbor Act of 1902 commissioned the US Corps of Engineers to provide a report on the 'desirability' of their projects, and it was part of the commission that the report would include the 'benefits to commerce', as well as the project cost (Barrell & Hills, 1972). The New Deal era in the United States emerged in response to the Great Depression, and the Flood Control Act of 1936 triggered initiated a change in Government direction through its statement that flood control schemes would be authorised only if the benefits "to whomsoever they might accrue" were greater than the estimated cost.

Developments in the field of water resources marked the real beginnings of CBA in the 1950s and 60s. Topics such as: 'systems analysis' (McKean, 1958), 'water resource development' (Eckstein, 1958), and 'multiple purpose river development' (Krutilla & Eckstein, 1958) started to appear in the literature. Thus Feldstein (1960) focused upon the social time preference discount rate in the evaluation of public investment projects using CBA. Next Beesley and Foster (1965) proposed the further application of CBA techniques in their analysis of the Victoria line; and Foster, in the 1960s, wrote about the contribution of economics in his study, 'the transport problem'. This paper highlighted the theoretical framework of CBA as applied to road and rail projects. CBA also emerged as part of the system entitled 'planning programming budgeting system' introduced in

[1] Figure 2.1 was a result of synthesising a set of data and designed by the researcher

1962 in the USA which categorises the various functions of budgeting (Schick, 1966). By this time, CBA was starting to impact most budgeting practices, building on the belief that it is necessary to rationalise project expenses to fulfil project objectives. The CBA technique has been extended and expanded since this time to cover a range of domains, including transport infrastructure, and this can be seen in the free periods identified below.

2.3.2. Macro-micro economic approaches to CBA (1958-1990)

During the period 1960 to 1990, macro and micro economic approaches for CBA of transport infrastructure projects and programs became popular. In using macroeconomic approaches, researchers tended to apply Keynesian or Neo-classical approaches in order to give econometric estimations of production that would unfold 'with and without' the proposed transport infrastructure. Such indices, including gross domestic product (GDP), domestic consumption, and domestic employment, were utilised as measures of welfare. Microeconomic approaches, on the other hand, are generally based upon the Kaldor-Hicks concept that a public measure will necessarily bring a net benefit to society if the advantaged parties can compensate those who are disadvantaged and yet still enjoy a net benefit (Grimsey & Lewis, 2002). Kaldor–Hicks methods therefore are generally used as assessments of potential improvements, rather than as efficiency goals in themselves. In addition to Kaldor–Hicks, welfare concepts adapted from the demand theory of Marshall (1920), Hicks (1941) and Henderson (1941), were often applied to assess the sum of variations in consumers' and producers' surplus. Figure 2.2 shows the development of CBA approaches in this time period.

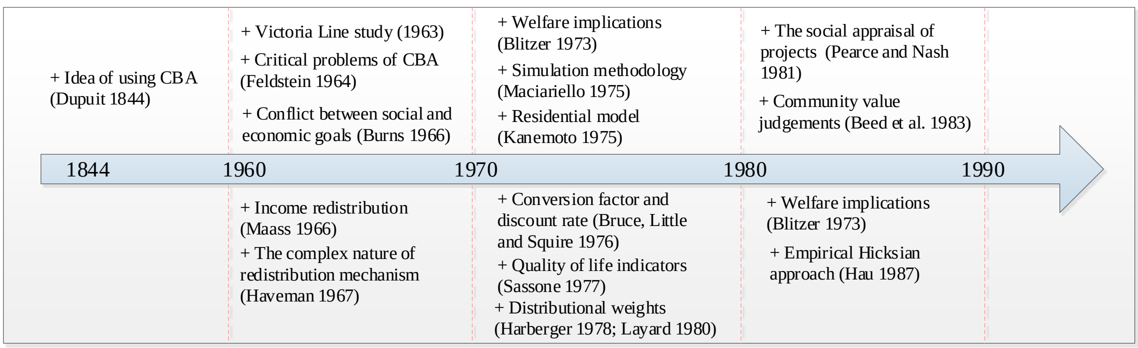


Figure 2.2. Major development of CBA literature during the period from 1960 to 1990

The first contribution to the development of CBA in this period was by Feldstein (1964), when he highlighted a critical problem of cost-benefit analyses regarding the physical benefit prediction from different types of investment: for example, benefits of attracting users from other roads and the effects of an increase in total use of transportation. Broadly, the conflict between economic and social goals for growth in development projects was first mentioned by Burns (1966). The author highlighted the difference between social welfare programs and economic development projects. Maass (1962) identified a critical issue of CBA in ranking projects in the United States: CBA only considered economic efficiency and did not mention income redistribution. His work received the significant attention of scholars, and Haveman (1967) in his study, published in the Economics Journal, emphasised three main factors: (1) the need to recognise the complex nature of the redistribution mechanism, (2) the difficulty of examining the content of welfare programs; and (3) the long-term impact of the project plan due to the constant change of design parameters. Similarly, studies carried out by Blitzer (1973) and Pearce and Nash (1981) also focused on welfare implications and assumptions to clarify the redistribution mechanism. Little and Mirrlees (1968), in an interesting study of industrial projects, provided CBA guidelines for practitioners in developing countries. The author referred to economic principles and emphasised the need to integrate CBA into policy making and planning.

Between the years 1970 to 1990, scholars focused on specific issues of CBA related to the time factor, social discount rate, conversion factor, and project resource allocation. In terms of the time factor in cash flow projections, Georgi (1973) surveyed works on existing techniques used in CBA and the author claimed that the time factor presents a problem in making national investment decisions in transport infrastructure. The reason for this issue arising is that cost and benefit flow from different possible investments at different times; therefore, risk and uncertainty in the planning calculation should be considered in the forecast. The time factor was also considered in a study by Maciariello (1975) when the author proposed a simulation methodology to illustrate a comparative-dynamic procedure for CBA. In his study, a dynamic urban simulation model was constructed featuring different scenarios associated with the base case (without public projects) and the project case (approval for implementation) to predict the course of events over a twenty-five-year period.

In addition to the time factor, the social discount factor received the attention of researchers: for example, social cost-benefit analysis (Bruce, Little, & Squire, 1976), and cost-benefit analysis and the overall control of public expenditure (Florio, 1990). These authors focused on issues relating to procedures for selecting the social discount rate and communicating the meaning of this factor to involved parties. Furthermore, certain integrated methods were proposed in this period to deal with critical CBA issues. These included the residential model of Kanemoto (1977), the Monte Carole technique proposed by O'leary (1979), the community value judgements of Beed, Andrews, Lacey, and Moriarty (1983), and the empirical Hicksian approach of Hau (1987). Empirical contributions from scholars over this time were fundamental in developing new ***integrated approaches*** to CBA in transport infrastructure projects over the next period.

2.3.3. Incorporation of socio-economic and environmental aspects in CBA (1990-2010)

Unlike microeconomic and macroeconomic approaches to CBA, this period marked a change in scholars' perspectives as they focused on the socio-economic and environmental issues in CBA as applied to transport infrastructure projects. Critical CBA issues regarding land use impact assessment, the identification of environmental consequences, and the indirect impacts of project investment, were identified by both researchers and organizations in this period. In response, scholars proposed models that were able to provide estimations and forecasts for use in project evaluation against each individual project context. The development of CBA in this time period is shown in Figure 2.3.

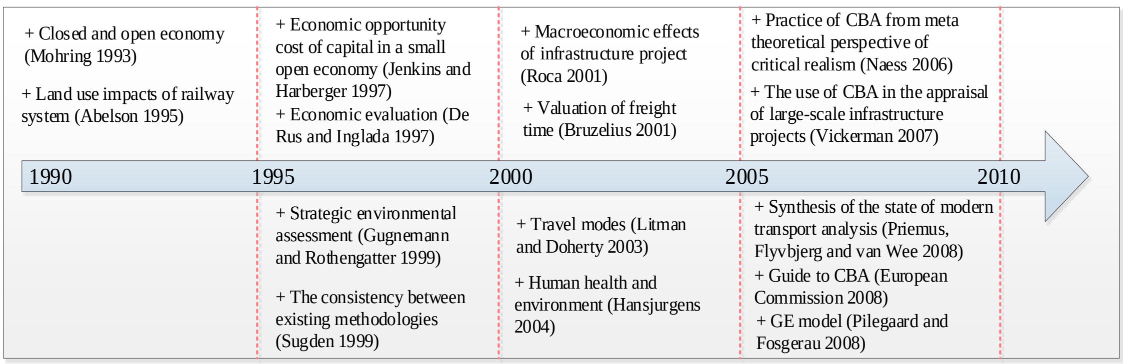


Figure 2.3. Major development of CBA literature during the period from 1990 to 2010

The first contribution in this period came from the work of Mohring (1993), who investigated the hidden aspects of cost-benefit analysis in the context of closed and open economies. The author highlighted that during the process of CBA in an 'open economy', the key focus is on the direct benefits of involving stakeholders and ignores the gains and losses of project outsiders. Over the period, the social aspects of project investment have additionally become the focus of researchers, with attention on topics such as the land use impacts of railway systems (Abelson, 1995), strategic environmental assessment (Guhnemann & Rothengatter, 1999), the macroeconomic effects of infrastructure projects (Roca, 2001), and social time preference rate (Murty, Dhavala, Ghosh, & Singh, 2006). As the result of studies in this period, a range of methods, were proposed to deal with recognising and identifying the socio-economic factors of a project investment.

Typical examples include the 'economic evaluation' of a high-speed train (De Rus & Inglada, 1997), the'total cost analysis' for all types of transportation modes (DeCorla-Souza, Everett, Gardner, & Culp, 1997), 'Leontief's input-output' model for the Barcelona 4th ring road project (Asensio & Roca, 2001), 'multi-criteria analyses' for 'intelligent' transport systems (Leviäkangas & Lähesmaa, 2002), the 'benefit estimation method' for transport networks (Kidokoro, 2004), the 'Molino model' (Proost, Van der Loo, de Palma, & Lindsey, 2005) for a tunnel and three alternative tolling schemes, the 'CBA-DK model' for a road project (Salling & Leleur, 2006), a 'contingent valuation method' for interchange lines in Pinglin, Taiwan (Feng & Wang, 2007), the application of 'game theory' for transport networks, including high-speed rail, hub and airlines (Adler, Nash, & Pels, 2010) and the 'general equilibrium model' for rail and road projects (Calthrop, De Borger, & Proost, 2010). It would seem that scholars were trying to generate new methods to ameliorate the CBA for transport infrastructure projects. The similarity in approach of these authors is that they focus on specific issues such as financial assessment, economic evaluation, and project risk in order to arrive at a solution for that specific issue. These solutions, however, may not always be systemic due to the narrow viewpoint of CBA studies.

In this period, several surveys were conducted to review existing CBA methodologies and these surveys showed that no agreement had been reached on appropriate evaluation techniques for these methodologies. This was explained by Sugden (1999) when he investigated the consistency between existing methodologies used for transport project evaluation in the UK. The author addressed the problems of developing a consistent CBA methodology and highlighted the main differences between existing methodologies that relate to the treatment of project impacts (e.g. indirect tax revenue, the treatment of user benefits, and treating accident risks). Sugden then claims that it is essential to incorporate existing methodologies into a 'new approach to appraisal' in order to provide criteria and sub-criteria that would correspond with the costs and benefits in a comprehensive CBA. Annema, Koopmans, and van Wee (2007) reviewed 13 large investment proposals in the Netherlands in order to identify methodologies used for CBA in transport infrastructure projects. The authors stated that standardised CBA practice, as published in guidelines by the Dutch government, had not yet fulfilled its potential due to unclear responses to the wider economic impacts, along with poor transparency in methods.

In addition to proposing tools and techniques, certain scholars reviewed studies on CBA to provide insights into specific problems during the decision-making process. Bruzelius (2001) carried out a survey to review studies on the evaluation of freight time and associated factors affecting goods, as well as to examine the effects of logistics improvement on the outcome of CBA technique in Sweden. The author discussed two basic approaches used to determine unit values in CBA: the use of market prices in identifying vehicle operating cost savings; and alternatives for undertaking a shipment, regarding choices between different routes or modes. In another study, Litman and Doherty (2003) examined the differences in benefits and costs based on options in travel modes and conditions. The authors primarily focused on personal land transport and related information on freight and air transport. Moreover, Dionne and Lanoie (2004) presented the concept of the 'value of a statistical life' (VOSL) which refers to the value of a healthy life for a whole group of people, with these authors claiming that VOSL should be used in the CBA of projects involving changes in road safety.

Broadly, experts have discussed the problems of CBA in regard to environmental consequences and uncertain factors in investment projects. Hansjürgens (2004) presented the possibilities and limitations of CBA in measuring the project effects on human health and the natural environment. Similarly, Næss (2006) discussed the practice of CBA in the context of transport infrastructure, concluding that CBA tends to neglect long-term environmental consequences. Additionally, uncertain factors in forecasts were also a major concern of researchers in this period. Vickerman (2007) reviewed the problems surrounding the use of CBA in large-scale infrastructure projects and states that there were particular challenges in achieving evaluation outcomes for these projects: for example, producing traffic forecasts over a long period, and estimating wider transport benefits within the imperfect competition of transport sectors. In reviewing a holistic picture of CBA, Priemus, Flyvbjerg, and van Wee (2008) focused on important aspects of mega projects including economics, planning, sociology, geography, management science, psychology and public policy, to provide a synthesis of the state of modern transport system analysis. From the research considered above, it can be seen that socio-economic aspects of CBA in transport infrastructure projects were investigated by scholars in order to address the challenges of CBA application in practice.

In summary, scholars in this period mainly focused on the environmental consequences and land use impact of CBA and proposed a range of methods and techniques to deal with the issues not previously addressed. However, due to the fact that each method has its own strengths and weaknesses, the question 'which methods/techniques are able to solve the critical issues of CBA?' needs to be further investigated.

2.3.4. Stakeholder driven CBA methods (2010-2018)

Scholars in this period were interested in researching the role of key stakeholders in the implementation stage of CBA and combining approaches that address transport infrastructure issues. First, an interesting study by Beukers et al. (2012) used two research techniques (focus group sessions and open in-depth interviews) to investigate CBA process issues in the Netherlands. The authors found that the greatest CBA implementation challenge was a deficit in communication between participants, including economists and town planners, during the CBA process. They reported that existing communication approaches do not provide sufficient room for addressing the uncertainties and nuances involved in making an investment decision.

In a similar vein, Eliasson and Lundberg (2012), contrasted planners' rankings and politicians' rankings, and found that planners' rankings of investments are affected by benefit–cost ratios (BCRs), especially for low and moderate BCRs, while politicians' rankings are not affected. Further, Mouter, Annema, and van Wee (2013), in their systematic overview of key actors' attitudes in Dutch CBA practice towards the role of

CBA in the decision-making process for spatial-infrastructure projects, showed that while economists mostly believe that not enough value is assigned to CBA in the decision-making process, spatial (urban) planners mainly believe that too much value is assigned to the CBA. These authors used two techniques including interviews and questionnaires to support their findings. This result opened up a new chapter in CBA research which captured the interests of both scholars and practitioners, focused around the assigning of values for project evaluation.

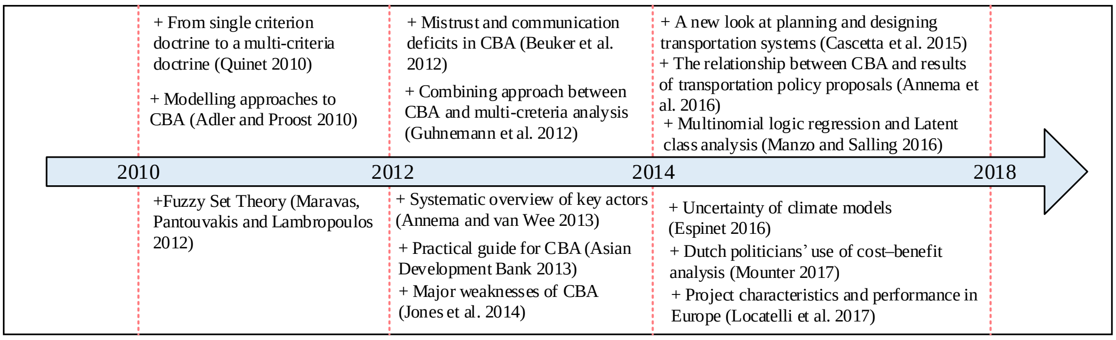


Figure 2.4. Major developments in CBA literature during the period from 2010 to 2018

Cascetta et al. (2015) highlighted the dynamism and complexity of the decision-making process, where different actors (e.g. stakeholders, professionals and decision-makers) have informal interactions within the different contexts of transportation projects. The authors presented five levels of stakeholder engagement that are associated with stakeholder identification, listening, information giving, consultation and participation. Cascetta et al. then proposed a conceptual model used to combine the potential benefits of rational decision-making and stakeholder engagement for the transportation planning process. Quantitative analysis plays a vital role in the success of the transportation decision-making model and this creates a unique point of view compared to other studies. Furthermore, CBA experts also pay close attention to the role of stakeholders, especially local communities and activist groups, to investigate their impacts on project success. Locatelli, Invernizzi, and Brookes (2017) highlighted the significant correlation between the compensation of the local community and delays in the construction of infrastructure projects. This is one of the important factors that should be incorporated and presented in risk assessment of CBA.

Recently, significant findings regarding politics and corruption in development projects were highlighted by several scholars. Mouter (2017) investigated the effect of CBA on the decision-making processes of Dutch politicians. The author identified seven barriers that hamper the use of CBA, with three of these each providing a different view on the usability of CBA: (1) politicians prefer to form their opinions based on conversations; (2) politicians do not trust CBA's impartiality; (3) politicians receive the CBA too late. In this context, Locatelli, Mariani, Sainati, and Greco (2017) discussed different types of corruption and investigated their potential impacts on project costs and benefits. The authors recommend that future research activities should be undertaken to measure the correlation between corruption and project performance.

In this period, scholars not only focused on investigating the role of key stakeholders in the CBA, they also introduced modelling techniques that have the potential for combination and integration with traditional methods. The first such contribution came from Adler and Proost (2010), where they focused on modelling approaches, including the general equilibrium model, the partial equilibrium game-theoretic model, and the partial equilibrium model, to perform an economic assessment of large, inter-urban transport modes, including air transport and high-speed rail. Next, Maravas, Pantouvakis, and Lambropoulos (2012) used Fuzzy Set Theory to model the uncertainty of critical variables in risk analysis. The application of this model was examined in a sample transport project to show its advantages in comparison with traditional methods.

The details of certain methodologies (methods) used for CBA were identified in the practical guide for cost-benefit analysis developed by The Asian Development Bank (2013). This guide continues to be used to provide an overview of the methodological developments in cost-benefit analysis and to make recommendations for improvements in the economic analysis of selected sectors in Asian countries. Recently, Manzo and Salling (2016) combined a conventional life-cycle assessment (LCA) approach with standard transport cost-benefit analysis to resolve the limitations of CBA in identifying indirect environmental impacts of an infrastructure project. These authors integrated a UNITE-DSS model (including deterministic and stochastic calculations) with an LCA module to test a case study regarding the construction of a new fixed link across the Roskilde Fjord in Frederikssund, Denmark. Interestingly, Beria, Bertolin, and Grimaldi (2018) proposed a combined approach between transport models and cost-benefit analysis to support decision-makers. These authors attempted to use modelling software, entitled GIS, to visualise the network effect of new infrastructure before integrating forecasts into CBA in order to improve the awareness of investment choices. From studies presented above, it is clear that stakeholder is a central topic in this period and there is an increasing trend of combining modelling techniques with traditional methods to improve the effectiveness of CBA for transport infrastructure projects.

2.3.5. Summary of development trajectory of CBA

Over the last 60 years researchers and practitioners working in the transport discipline have made significant contributions to the development of CBA from its beginnings in research literature when it was considered to be a simple technique to support experts in making investment decisions. CBA then quickly showed its potential capacity when it was applied to both macro and microeconomic analysis. A number of debates have recognised the pros and cons of macro and microeconomic approaches to CBA. Since the 1990s, scholars have directed their attention to the critical issue of project evaluation, including land-impact identification and environmental-consequences assessment. Many proposals have been presented during this period to improve the outcome of CBA. Both experts and practitioners introduced integrated methods that aim to provide criteria and sub-criteria for project appraisal.

The development of CBA continues with an emphasis on the role of stakeholders in the CBA process for large-scale infrastructure projects. Several surveys have been carried out to investigate the complex relationships between different stakeholder groups during the CBA process. Furthermore, the development of technology has allowed researchers to employ modelling and simulation approaches to address the complex issues of transport infrastructure projects arising from socio-economic assessments. The availability of modelling techniques empowers researchers to combine CBA with other methods and techniques to improve the outcome of decision-making processes.

2.4. CBA Strengths and Weaknesses in Project Evaluation

Due to the rapid changes in external environmental factors, including political, economic, social, technical, legal and environmental, commonly appearing under the acronym, PESTLE (Schoemaker, 1995), transport infrastructure projects have tended to become more complex and to contain more uncertainties. This creates a significant challenge for project evaluators in recognising the impact of threats and opportunities from the external environment, on ultimate project success. Although scholars have presented a range of tools and techniques for CBA, it is difficult to find alignment on recommended CBA usage. Given that the debate on CBA usage is showing little signs of convergence, we instead turn our view to the strengths and weaknesses of CBA, to reveal CBA limitations, as well as to seek new approaches to CBA. Table 2.1, derived from the literature review, provides supporting evidence for the four main categories of strengths of CBA: project ranking, project evaluation, the decision-making process, and CBA usability.

Table 2.1. CBA strengths in the evaluation of transport infrastructure projects

Index	Main categories	CBA strengths
1	Project Ranking	- CBA has great advantages in comparing transportation investments across travel modes and making a comparison between investment options such as new highway vs management alternatives (DeCorla-Souza et al., 1997). - CBA is a useful tool in the planning stage of the public sector for selecting a range of alternatives and making comparisons between projects with different lengths (Næss, 2006). - CBA is useful for evaluators when they want to enlighten the benefits of a single investment, and CBA comes into its own when it allows experts to compare the relative merits of alternative investments (Eliasson & Lundberg, 2012).
2	Project Evaluation	- CBA allows researchers to investigate the degree of consensus on measurement and evaluation of the appraisal (Bristow & Nellthorp, 2000), and to understand the difference between components used for project evaluation (Hayashi & Morisugi, 2000). - CBA allows us to explore the interaction between key stakeholders including winners and losers in the decision-making process (Damart & Roy, 2009), and to present a model which is consistent with a general network topology to estimate costs and gain benefits (Gao, Frejinger, & Ben-Akiva, 2011).
3	Decision-Making Process	- CBA is a useful method to provide guidance for selecting criteria used for making investment decisions. The purpose of these criteria is to ensure that aggregate benefits to society outweigh net aggregate costs (Nickel et al., 2009). - CBA results have indeed affected planners' selection of investments for the National Transport Investment Plan in Sweden (Eliasson & Lundberg, 2012). - CBA is an effective tool used to investigate the relationship between political attitudes and changes in analytic results (Sager & Ravlum, 2005).
4	Usability	- CBA is not only an evaluation method used to compare the benefits and costs of a programme, but it is also a framework that allows evaluators to systematically identify the effects of a specific measure (Hansjürgens, 2004). - CBA has been applied in a range of fields, and it is a relatively easy tool for deciding whether to make a change (Næss, 2006). - CBA is considered as 'a common language', known and used worldwide (Beria, Maltese, & Mariotti, 2012), and CBA is widely used, firmly embedded in project appraisal (Browne & Ryan, 2011).

Based on the strengths of CBA presented in the four main categories in Table 2.1, it can be seen that CBA is beneficial to evaluators in seeking a formal framework for project appraisal at the planning stage. In terms of CBA weaknesses, six main categories are elaborated in Table 2.2: establishing CBA assumptions and constraints, setting up CBA objectives, measuring local socio-economic impacts, assessing environmental consequences, proposing CBA calculation methods, identifying risk, and validating the CBA processes.

Table 2.2. CBA weaknesses in transport infrastructure projects

List	Main Categories	CBA Weaknesses
1	CBA objectives	- In CBA it is difficult to resolve conflicts between incommensurable values and project goals: for example, environmental preservation and irrigation development (Harris, 1991). - There is a difference in establishing project objectives when solving traffic problems is the main focus of evaluators while a vision for spatial economic developments does not get a sufficient level of attention (Beukers et al., 2012). - Objectives, criteria and attributes presented in CBA are often in conflict: for example, environmental consequences and social issues are usually difficult to quantify and make comparisons (Barfod & Salling, 2015).
2	Social and economic impact assessment	- CBA does not provide information regarding winners and losers in a project and ignores equity issues (Ackerman & Heinzerling, 2002). - CBA misses important information in regards to expected synergy and agglomeration effects (van Wee, 2007). - Mackie highlighted the difficulty in appraising the effect of infrastructure investment on the regional economy and the author claims that "the interaction between transport and the wider economy, and its treatment in appraisal, is one of the most lively current topics" (MacKie, 2010, p. 19). - The difference between 'wider economic benefits' and 'agglomeration effects' is a complicated problem for CBA in practice and requires further investigation (Eliasson & Lundberg, 2012).
3	Environmental Consequences	- The monetisation of environmental impacts in CBA is highly questionable (Barfod & Salling, 2015; Browne & Ryan, 2011; Gühnemann, Laird, & Pearman, 2012; Macharis & Bernardini, 2015). - Ludwig, Brock, and Carpenter (2005) state that it is important to integrate environmental consequences in the long term into a discounting factor which is used for calculating the results of CBA.

4	CBA calculation methods	- Current CBA methodology is not able to capture all relevant costs and benefits (Eliasson & Lundberg, 2012). - The relationship between financial and economic factors in the CBA often is overlooked, and this is one of the main weaknesses of CBA during the analysis process (Florio, 2006). - There is criticism regarding calculation methods used for measuring and translating project impacts into monetary terms (Mackie & Preston, 1998). - The problems of selecting the proper discount rate choice (Ackerman, Heinzerling, & Massey, 2005; Kirkpatrick & Weiss, 1996). - It is difficult to use static methods to analyse social problems since these problems often have unique characteristics. Social problems are complex, which means that causes and effects are manifold and nonlinear (Maciariello, 1975).
5	Risk and Uncertainty	- Flyvbjerg, Bruzelius, and Rothengatter (2003) pay close attention to the importance of the technology used for development projects. The new technologies often have uncertainties related to costs and implementation time. - The possibility of project delays and other risks may make the whole project to become unrealistic. This can undermine the result of evaluation indices, especially to rules of using net present value (Brzozowska, 2007). - When CBA project documents are assessed, risk analysis emerges as one of the weaknesses (Belli & Guerrero, 2009).
6	CBA Validation	- Lack of understanding of whether the socio-economic problems have been mapped onto monetary valuations appropriately (Ackerman & Heinzerling, 2002) and the ethics of the decision-making process (van Wee, 2012). - The need for completeness and correctness (Annema et al., 2007). - Clark, Sartorius, and Bamberger (2004) criticised the ways to interpret CBA results regarding the potential benefits and costs of an investment project before the investment decision made.

To summarise, CBA shows many advantages in project evaluation. Perhaps the most critical weaknesses are that it is not clear which factors need to be included in a particular CBA and how these should be monetised to enable analyses to be conducted meaningfully. The first issue is explored in the next section which sets out to enumerate the range of cost-benefit factors that have been proposed for transport infrastructure projects.

2.5. Exploring the range of Cost-Benefit Factors which have an Impact on Transport Infrastructure Projects

Several studies have been carried out to identify cost-benefit factors used for project evaluation such as 'Guide to Cost-benefit Analysis of Investment Projects' from The European Commission (2008) and 'Cost-benefit Analysis for Development' by The Asian Development Bank (2013). However, these publications highly focused on financial and economic factors to propose relevant analytical methods and techniques for project evaluation. There are still a number of cost-benefit factors in transport infrastructure projects that have not been captured in studies, even though the factors would have a potential impact on project success. Thus, it is crucial to seek and identify all major cost-benefit factors of relevance to transport infrastructure projects. From the database system set by the NVivo™ software, a variety of factors are taken into account and presented in Table 2.3. Each factor is traced back to the relevant CBA literature.

Table 2.3. Cost-benefit factors identified in the transport infrastructure literature

List	Cost-benefit factors	Group	Descriptions	Referred to by
1	**Capital costs**			
1.1	Land cost	Finance	Costs for land compensation, land clearance, and site preparation.	(Abelson, 1995; Litman & Doherty, 2003; The European Commission, 2008).
1.2	Construction cost	Finance	Direct costs in the execution stage including project management cost.	(Beed et al., 1983; Litman & Doherty, 2003; Olsson, Økland, & Halvorsen, 2012; Salling & Leleur, 2006; The European Commission, 2008).
1.3	Plant and machinery cost	Finance	Costs related to machinery systems and plant.	(Litman & Doherty, 2003; The European Commission, 2008).
1.4	Labour training	Finance	This cost is associated with a new capital project or one that requires additional operator training.	(The European Commission, 2008)
1.5	Interest payments	Finance	Loans or equity	(The European Commission, 2008)

2	**Planning & design cost**	Finance	Costs used for survey, design, preparation and planning.	(Daniel, 2002; Litman & Doherty, 2003; The European Commission, 2008; Thompson, Rosenbaum, & Hall, 2008).
3	**System operation & maintenance cost**	Finance	All the costs to operate and maintain the new or upgraded service.	(Brambilla & Erba, 2004; Daniel, 2002; DeCorla-Souza et al., 1997; Olsson et al., 2012; Proost et al., 2005; Raju, 2008; The European Commission, 2008).
4	**User costs and benefits**			
4.1	Capital and vehicle operating cost	Finance	This cost includes fuel consumption and depreciation cost.	(Abelson, 1995; Barrell & Hills, 1972; Beed et al., 1983; Brambilla & Erba, 2004; DeCorla-Souza et al., 1997; Feldstein, 1964; Jorge & de Rus, 2004; Litman & Doherty, 2003; Lynch, 2002).
4.2	Ticket Fares	Finance	This is user cost and it occurs when users access new infrastructure, e.g. toll road, tunnel.	(DeCorla-Souza et al., 1997; Olsson et al., 2012; The European Commission, 2008).
4.3	Vehicle operating cost (VOC) savings	Finance	The cost savings to the owner (or operator) of a motor vehicles.	(The European Commission, 2008)
4.4	Traffic congestion reduction	Socio-Economic	Indirect benefits regarding traffic congestion reduction.	(Hettich, 1983; Litman & Doherty, 2003; Lynch, 2002; Salling & Banister, 2009).
4.5	Travel time savings	Socio-Economic	Travel-time savings of business people, commuters and other travellers.	(Abelson, 1995; Barrell & Hills, 1972; Brambilla & Erba, 2004; Daniel, 2002; Feldstein, 1964; Lynch, 2002).
4.6	Travel safety/traffic accident reduction	Socio-Economic	Social benefits regarding traffic accident reduction (e.g. vehicle damage, injuries and deaths).	(Abelson, 1995; Lynch, 2002; Meunier, Walther, Worsley, Dahl, & Le Maître, 2016; Olsson et al., 2012; Singh, Ghosh, Dhavala, & Murty, 2006; The European Commission, 2008).

4.7	Accessibility benefits for business trips	Socio-Economic	Depend on users' perspectives; accessibility could be considered as a benefit or cost.	(Vickerman, 2008)
5	**Non-user costs and benefits**			
5.1	Saving in foreign exchange	Socio-Economic	Cost savings related to foreign exchange (e.g. material import and equipment purchase).	(Meunier et al., 2016; Murty et al., 2006)
5.2	Traffic administration service	Socio-Economic	Costs used for traffic management.	(Beed et al., 1983; Brambilla & Erba, 2004; Litman, 2009; Salling & Banister, 2009; The European Commission, 2008).
5.3	Taxes and fees paid by vehicle owners.	Socio-Economic	Because of an increase in number of vehicles, taxes and fees are indirect benefits contributing to the local budget.	(Beed et al., 1983; DeCorla-Souza et al., 1997; Litman & Doherty, 2003; Olsson et al., 2012; Salling & Banister, 2009).
5.4	An increase in traffic	Socio-Economic	Indirect benefits regarding an increase in traffic volume.	(Jorge & de Rus, 2004).
5.5	Trade logistics improvement	Socio-Economic	Indirect benefits arising from saving time and cost in logistics activities.	(Bruzelius, 2001; Feldstein, 1964; Litman & Doherty, 2003; Quinet, 2006; The European Commission, 2008; Van Wee, 2007).
5.6	Air pollution/emissions (carbon dioxide, NOx, SO_2)	Environmental	Environmental cost regarding air pollution during project execution.	(Abelson, 1995; Daniel, 2002; Lynch, 2002; Meunier et al., 2016; Murty et al., 2006; The European Commission, 2008).
5.7	Noise pollution	Environmental	Environmental cost regarding noise pollution during project execution.	(Daniel, 2002; Meunier et al., 2016; The European Commission, 2008).
5.8	Chemical waste, polluted soil and water pollution	Environmental	Environmental costs regarding waste pollution during project execution.	(Abelson, 1995; Bruzelius, 2001; Hettich, 1983; Litman & Doherty, 2003; Raju, 2008; Singh et al., 2006).

5.9	Unemployment rate/Labour market	Socio-Economic	Social benefits regarding labour market development in the locality.	(Nickel et al., 2009; Quinet, 2006; Vickerman, 2008).
5.10	Businesses relocation, and traffic delays during project construction	Socio-Economic	Intangible costs as a result of relocation.	(Abelson, 1995; Nickel et al., 2009).
5.11	Population growth	Socio-Economic	Indirect benefits/costs regarding a change in immigration trend.	(DeCorla-Souza et al., 1997; Lynch, 2002)
5.12	Public services include education and health care	Socio-Economic	Indirect benefits gained from project operation.	(The European Commission, 2008)
5.13	Real estate market development	Socio-Economic	An increasing value as a result of infrastructure improvements.	(Abelson, 1995; Feldstein, 1964; Hettich, 1983; Litman & Doherty, 2003; Nickel et al., 2009).
5.14	Tourism industry development	Socio-Economic	Economic benefits as a result of travel time reduction and cost savings.	(The European Commission, 2008)
5.15	Agriculture development	Socio-Economic	Economic benefits as a result of infrastructure improvements.	(The European Commission, 2008)
5.16	Economic growth	Socio-Economic	Economic development growth rate in general.	(The European Commission, 2008)
5.17	Landscape improvement	Socio-Economic	Project architecture creates a landmark for landscape of local place.	(Brambilla & Erba, 2004; Cascetta & Cartenì, 2014; Quinet, 2010; The European Commission, 2008).
5.18	Impacts on ecosystems and biodiversity	Environmental	Indirect costs as a result of ecosystems imbalance.	(The European Commission, 2008)
5.19	Climate change	Environmental	Environmental costs as a result of implementing a large-scale project.	(Brambilla & Erba, 2004; Martin & Point, 2012; Olsson et al., 2012; The European Commission, 2008).
5.20	Loss of cultural, historic, recreational and natural resources and loss of open space.	Socio-Economic	Indirect costs as a result of changes in culture and natural resource.	(DeCorla-Souza et al., 1997)

Categorising cost-benefit factors into specific groups helps both researchers and practitioners to maintain their focus on key factors in order to build an effective assessment system. This is important because it is difficult to measure the impact of all factors in monetary terms and thus it is valuable to concentrate on those key factors that relate to project objectives, resources and expert viewpoints used for project evaluation.

2.6. The Identification of the CBA Boundary for Transport Infrastructure Projects

From the CBA literature review as previously discussed, it is clear that few studies examine the exact parameters of CBA and this leads to ambiguity about the actual role of CBA for transport infrastructure projects (Figure 2.5). CBA for transport infrastructure networks is broader than that for a specific project, since the former principally focuses on macroeconomic objectives (e.g. GDP, economic growth rate, unemployment rate, and the macroeconomic policy) as established by the highest government of countries. For example, the implementation of transport infrastructure networks, in some cases, is considered a central policy instrument for governments in order to achieve the goal of cohesion. Investment in transport infrastructure networks often creates multiple effects, including direct effects, indirect effects and a wide range of impacts on the whole economy and industrial sectors, and it these effects may need to be measured over a long time period. Moreover, the impacts of transport infrastructure networks are distributed across geographical areas or population groups (Halden, 2002); this can create significant challenges for impact recognition and evaluation. The principles of macroeconomic analysis are often applied to CBA to support the investment policies of the higher governments of countries.

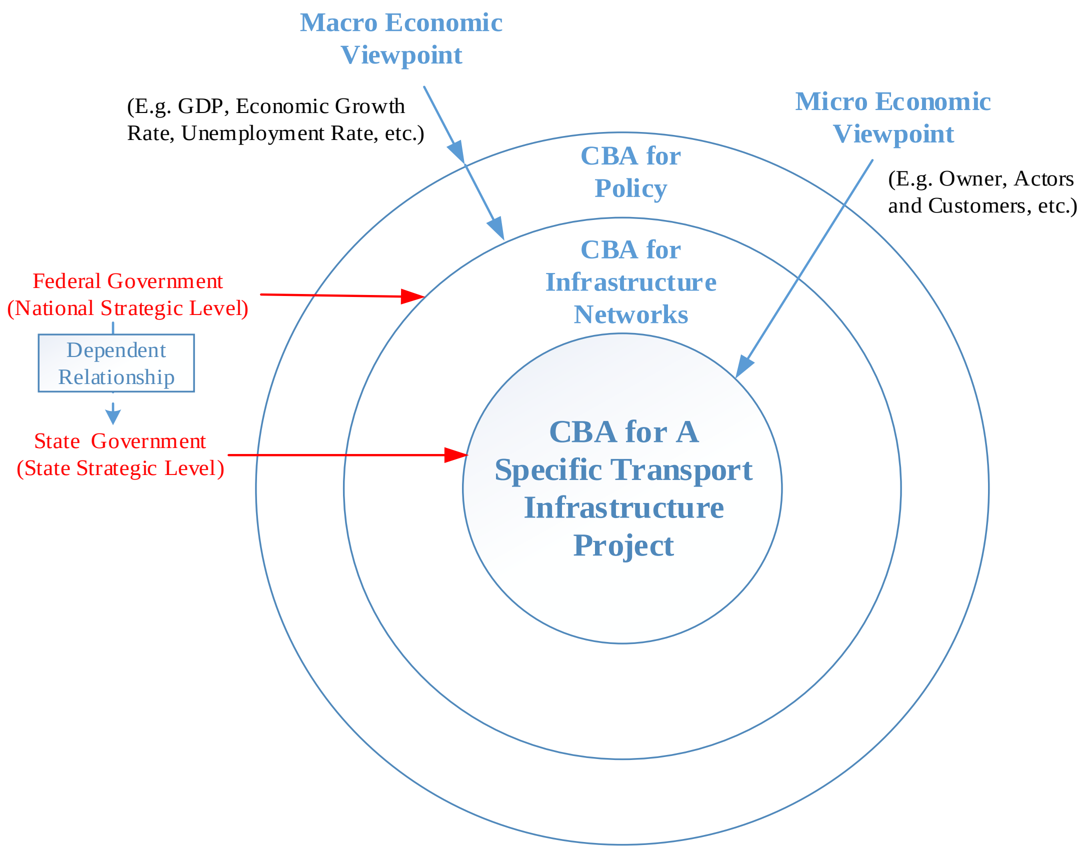


Figure 2.5. Overview of CBA types

In this research program, the focus is on the evaluation of a specific transport infrastructure project. The scope of CBA for a specific project is smaller than that for transport infrastructure networks. In other words, CBA for a specific project concentrates on measuring microeconomic objectives, and its attention is on key project stakeholders such as project owners, customers and actors, in order to determine project feasibility. Based on PEST factors (Political, Economic, Social-Cultural, and Technological) proposed by Aguilar (1967), CBA for a specific project focuses on the following groups for its investigation: technical, financial, socio-economic, environmental and political. From the literature review and the synthesis of evaluation reports, a short list of cost-benefit factors for each group is depicted in Figure 2.6. The two most visible aspects of CBA are technical and financial, since decision-makers are concerned with common issues such as traffic forecasts, technology risks, construction safety and budget estimation spending on project investment over time. The three remaining aspects are socio-economic, environmental and political; these are more complicated than the first two groups.

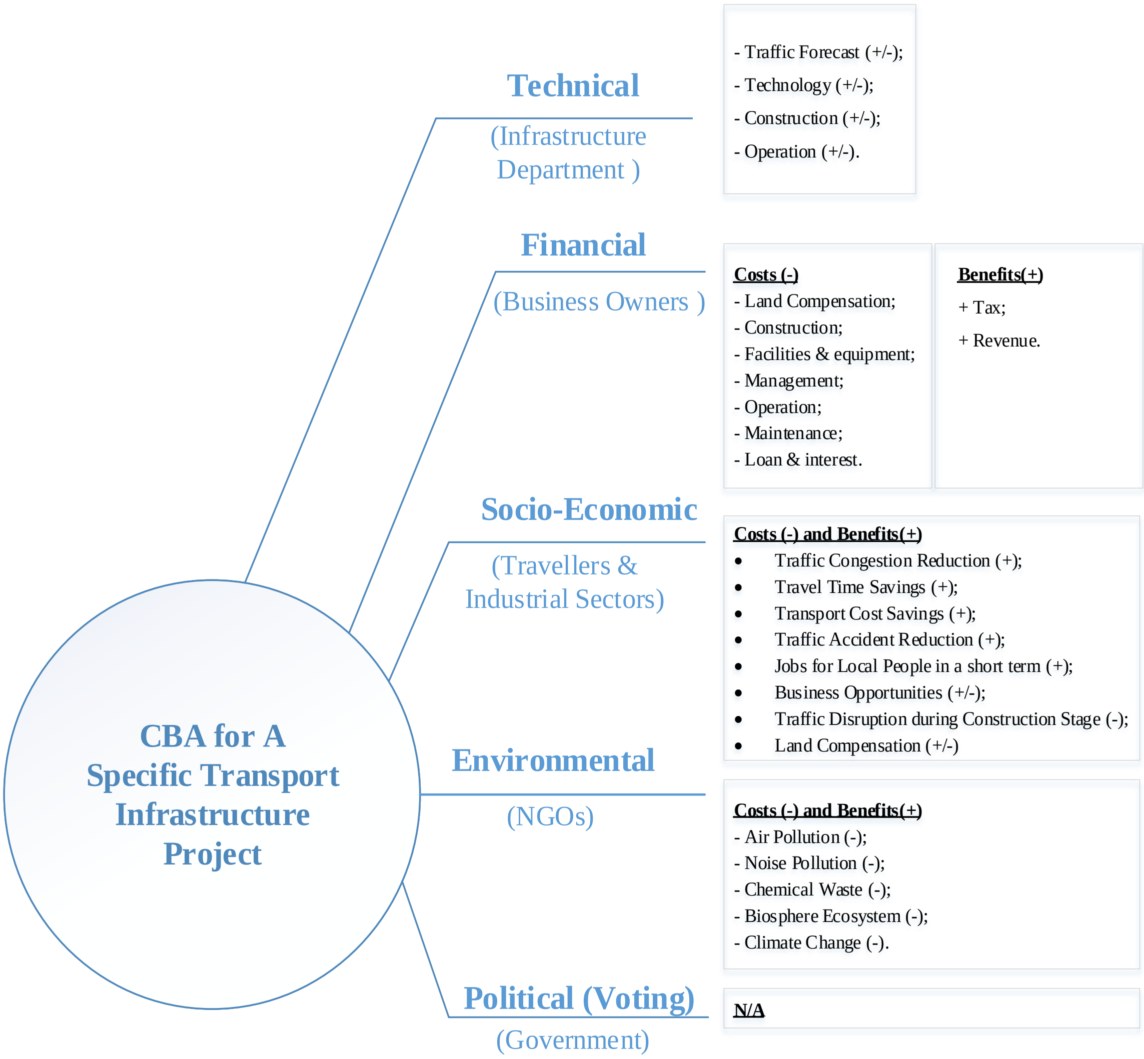


Figure 2.6. CBA for a specific transport project showing five categories

In the socio-economic group, CBA focuses on assessing the project impacts on specific groups such as travellers, local community and industrial sectors. The potential benefits gained from project investment would be traffic congestion reduction, travel time savings and transport cost savings. Adverse effects on the local community would include traffic disruption during construction time and the loss of business opportunities in the investment area. In addition to the socio-economic group, environmental factors are various and complicated to measure for example, air pollution, noise pollution, chemical waste from project implementation, carbon emissions from project and vehicles, and impact on ecosystems within the investment project area.

The last group is the most complex, in terms of the political factors associated with infrastructure projects. Since the interpretation of political factors depends on philosophical positions such as Machiavellianism, agency and ethical positions (Cantarelli, Flybjerg, Molin, & van Wee, 2010), it is difficult to clarify the boundaries of this group. Moreover, the differences in political systems as associated with laws, rules and governance mechanisms of states, can lead to different political factors that are difficult to recognise. *The main focus of CBA for a specific transport infrastructure project should, therefore, be on the first four main aspects: technical, financial, socio-economic and environmental aspects.*

2.7. Typical Methods and Techniques used for or incorporated in CBA for a specific Transport Project

This section introduces typical methods used for or incorporated into CBA programs. Since the selection of methods (techniques) depends on the problem context, the study examines the functionality of methods and then categorises them into specific groups for selection, including financial, technical, socio-economic and environmental factors. For each group, several typical functionality methods are selected for presentation.

First, financial analysis is a fundamental component of project evaluation, and the primary purpose of this step is to assess the project profitability for the project owner and to verify the project's financial sustainability. Financial analysis should be carried out from the viewpoint of the infrastructure owner, since it allows investors to assess the actual profitability of the investment and to examine the independence of internal payments (e.g. capital cost, loan and project cash flow). Some typical methods and techniques widely applied for financial analysis are Discounted Cash Flow, Terminal Value, and Financial Sustainability (Table 2.4).

Table 2.4. Typical methods and techniques for the financial group

Methods & Techniques	Descriptions	Strengths	Weaknesses
Discounted Cash Flow (DCF)	DCF is a valuation method used to examine the investment opportunity of infrastructure projects (The European Commission, 2008). It focuses on discounting future cash flow projections of the project to arrive at a present value used for evaluation and investment decision-making.	DCF is widely applied and presented in policy documents. It is considered to be a reliable measure that minimises subjective viewpoints presented in accounting policies.	The outcome of DCF depends strongly on the assumptions and forecast made by evaluators. Any changes applied to input parameters can lead to considerable changes in the evaluation outcome.
Terminal Value (TV)	TV is the value of a project's expected cash flow beyond the explicit forecast horizon (Fuguitt & Wilcox, 1999).	TV considers the value of future cash flow several years beyond the project operation period. It allows evaluators to estimate the value of the project beyond the forecast period.	The limitation of this method entails assumptions to the project growth rate used for valuation. Inaccuracy in the assumptions made can provide an incorrect value.
Financial Sustainability	This technique is applied to examine the financial sustainability of project proposals. The financial status of a proposed project is sustainable when the risk of running out of cash during the construction and operation stages is nil (The European Commission, 2008). The difference between inflows and outflows (as benefits and costs) of the project each year will show the deficit or surplus used to measure potential risks of the future cash flow.	The advantage of financial sustainability is that it allows evaluators to recognise unusual points in the cash flow of the project.	This technique also has limitations regarding assumptions related to loan agreement conditions. In other words, these conditions depend on the project schedule and the initial capital cost raised.

Next, Systems Engineering (SE) approaches are well-known and are often used to deal with technical evaluations. There are many such evaluation techniques used in SE and these can be incorporated in CBA for transport infrastructure projects. Typical methods applied for analysis and evaluation are Multi-Attribute Trade Space Exploration technique, the Risk Assessment method, and the Multi-Criteria Analysis technique.

Table 2.5. Methods and techniques for the technical group

Methods & Techniques	Descriptions	Strengths	Weaknesses
Multi-Attribute Trade Space Exploration (MATE) technique	MATE is a method that focuses on the perceived value of stakeholders regarding project costs and benefits to establish decision metrics (Nickel et al., 2009). MATE is applied to explore the trade space of project proposals; and it also appreciates the importance of key decision-makers in proposing solutions.	MATE provides a broader view on project proposals. The information obtained from MATE can support decision-makers with differing interests to be open with negotiations that are a key for achieving an acceptable level of consensus.	MATE is a technical method and lacks consideration of 'soft' factors contributing to the consensus between stakeholders. Such considerations need to be weighed in finalising the investment decision.
Risk Assessment technique.	This technique allows an evaluation team to identify potential risks and to assess their impacts on the infrastructure project. The key steps presented in a risk management framework are identifying and defining risk, assessing risk impacts, proposing solutions and monitoring risk treatment solutions (Alberts & Dorofee, 2010; Rose, 2013).	This technique has been widely applied to construction projects. The risk management framework provides a comprehensive procedure with specific steps for identification, assessment and management of risks.	This technique requires user experience and risk analysis skills for evaluation and estimation, since any inaccuracy in the estimation can lead to poor advice to the decision-maker.
Multi-Criteria Analysis (MCA)	MCA is a decision-making method that relies on a number of criteria to assess project proposals and to select the most promising one. MCA permits the incorporation of stakeholders' opinions into the decision-making process (Macharis & Bernardini, 2015).	The great advantage of MCA is to incorporate criteria and factors that are hard to quantify or express as a monetary value into the decision-making process; for example, environmental impacts and business opportunities.	In some cases, the overlap between the criteria or objectives listed creates confusion for decision-makers. The accuracy level of MCA depends on a set of criteria used for evaluation, user-experience and the expert panel that provides assessment for selection.

Third, the socio-economic group includes both conventional economic approaches and social analysis approaches. Conventional economic analysis approaches are fundamentally based on the principles of a perfect competitive market to provide solutions, while social analysis approaches focus on community concerns. Table 2.6 introduces typical methods and techniques, including the Shadow Price method, Stated Preference method; and Residential Value method used for evaluation and analysis.

Table 2.6. Methods and techniques for socio-economic group

Methods & Techniques	**Descriptions**	**Strengths**	**Weaknesses**
Shadow Price method	Shadow Price is a method used to convert non-market values (e.g. unknowable or difficult to calculate costs) into monetary terms (Georgi, 1973). The Willingness-to-Pay principle is applied to measure the value of a good or service that people are willing to pay for its use.	This method is simple and widely applied for translating financial terms into economic terms for the purpose of project economic evaluation.	Shadow pricing relies on certain assumptions and premises, so some scholars criticise the accuracy level of this method.
Stated Preference method	Stated Preference method focuses on investigating whether people are willing to pay to use a public good or service through questionnaire surveys (Department of Finance and Administration, 2006).	This is a simple method to estimate what people are willing to pay for public goods.	The difficulty with non-marketed output valuation is to understand the behaviour of a range of different stakeholders with different sample sizes used for the survey.
Residential Value (RV) method	RV method focuses on estimating the value of an infrastructure project at the end of its projected lifetime (Jones et al., 2014). RV, depending on whether a project was sold at the end of the time horizon, can be calculated as the residual market value of fixed capital or the residual value of all assets and liabilities.	The advantage of the residual value method is that it can provide estimations for land usage in order to investigate transportation interactions, and to recognise regional impacts.	This method is often overlooked and no agreement on the methodology has been accepted.
CBA-DK method	The CBA-DK is a combined method that relies on both deterministic calculation of CBA and stochastic calculations associated with risk assessments. The risk analysis, as presented in CBA-DK, is carried out by using Monte Carlo simulation. The CBA-DK focuses on three key parties; users, operators and authorities.	The CBA-DK method allows analysts to identify potential risks during the appraisal stage of infrastructure projects from the perspectives of users, operators and authorities (Salling & Leleur, 2006).	There is no agreement on the proposed method of implementation in the transport infrastructure area. In addition, the determination of non-monetary impacts of the project is not considered.

Finally, the environmental group principally focuses on environmental aspects of project implementation such as environmental pollution, the biosphere of natural ecosystems and carbon emissions. Table 2.7 introduces three approaches: the Contingent Valuation method, the Hedonic Pricing technique and the Dose-Response technique.

Table 2.7. Methods and techniques for the environmental group

Methods & Techniques	**Descriptions**	**Strengths**	**Weaknesses**
Contingent Valuation (CV) method	Contingent Valuation is used to measure the value that a person places on a good. CV uses two principles; willingness to pay (WTP) and willingness to accept (WTA) to investigate whether people are willing to pay to obtain a specified good or accept to give up a good (Feng & Wang, 2007).	This is a promising method for the evaluation of environmental resources (Niklitschek & León, 1996).	Contingent Valuation focuses strongly on dealing with environmental impacts, but it does not pay attention to the economic impacts of a project proposed.
Hedonic Pricing technique	The fundamental principle of this method is to use price differentials in existing markets as proxies for prices with certain attributes (Quah & Toh, 2011). A typical example is to estimate the value of reducing ambient noise level in the residential area. The Hedonic Pricing Technique is used to compare the price of two properties which are similar in every way, except for the ambient noise level.	This technique is simple, but Hedonic Pricing models are more complex when applied with multiple regression techniques. These techniques are used to identify the marginal effect of a particular attribute on price.	The key criticism of using the Hedonic Pricing technique is that it relies on assumptions of the perfect market to estimate the price. In practice, the market is imperfect, and price differentials will not reflect the actual price of various attributes
The Dose-Response technique	This technique concentrates on investigating the complex relationship between externalities (the ‘dose’) and response (the ‘effect’). A typical example of using the Dose-Response technique is to assess the effects of acid rain on buildings in North America.	The advantage of this technique is that it provides an open view of the causes and effects of a project investment selection.	The accuracy level of this method depends on the experience of analysts.

In conclusion, this section has reviewed typical methods and techniques that can be incorporated into CBA for a specific transport infrastructure project. This work aims to provide an overview of the potential combinations of CBA and different methods and techniques, incorporating different CBA groups (financial, technical, socio-economic, and environmental). There may be other methods that are not presented in this section but these can be examined and selected for assessment in accordance with the evaluator's purpose.

2.8. Research Gap

From the CBA literature review and the detailed analysis presented above, certain gaps in research have been identified:

- The application boundary of CBA for transport infrastructure projects is unclear, thus creating difficulties for both researchers and practitioners in selecting methods for implementation and evaluation. Therefore, information presented in section 2.6 can support analysts in better identifying this boundary of CBA for use in projects.

- The selection of preferred methods depends on CBA schools of thought. Even though researchers have attempted to combine different methods to propose a 'holistic' approach, they seem, nevertheless, to select their preferred methods for project evaluation. In other words, the underpinning philosophy for such combinations remains unclear.

- Stakeholder engagement is a central topic in CBA and researchers have addressed important issues relating to stakeholder viewpoints and the relationships among key parties in project evaluation. However, proposed solutions to these problems are 'hard' and passive. Specifically, the researchers focus on capturing stakeholder needs rather than encouraging them to participate in the full CBA analysis process for transport infrastructure projects.

Hence, this research program focuses on clarifying these problems and proposing a comprehensive CBA framework that enables practitioners to fully deal with the critical issues presented above. *This study particularly focuses on two central problems, which are the rationale for selecting evaluation methods and stakeholder engagement issues in a specific transport infrastructure project.*

2.9. Summary

The literature shows that CBA plays a vital role in assessing proposals in the initial stage of transport infrastructure projects. CBA enables both researchers and practitioners to recognise, analyse and make comparisons between benefits and costs of investment proposals, before selection. The evolution of CBA can be characterised into four main eras (1844-1958; 1958-1990; 1990-2010 and 2010-2018), differentiated by the activity and worldview of CBA scholars and practitioners. The first epoch saw the development of the first class of project-centric quantitative assessment. The second period introduced greater contextual awareness, greater recognition of social factors, and more systemic analysis stemming from microeconomic and macroeconomic approaches. The subsequent period examined socio-economic and environmental factors, whereas the final period concentrated on stakeholder inclusion and the vital role of stakeholders' involvement during the decision-making processes.

In order to identify the current state of CBA thinking, a list of acknowledged strengths and weaknesses was produced. The latter indicated the need for a comprehensive list of cost-benefit factors from which practitioners would be able to assemble a preferred set of factors for a given CBA. The role of CBA for transport infrastructure projects was re-evaluated to make clear its application boundaries. Typical methods and techniques associated with different CBA groups are introduced to recognise their strengths and weaknesses, and to investigate the relationship between these methods and cost-benefit factors used for a comprehensive evaluation program. Finally, the central problems of CBA were highlighted to make clear the focus point of the PhD study program.

Chapter 3
Research Methodology

3.1. Introduction

The objective of this chapter is to describe the rationale for the choice of the research methodology employed in this study and to describe the approach chosen and how it was employed. This chapter opens with a discussion of the selection of an approach to address the CBA problems identified in the last chapter. Focus then turns to describing the Constructive Research Approach (CRA) chosen and its main processes.

3.2. The Rationale for Selecting the Research Approach

3.2.1. The nature of the problems to be investigated

According to Leedy and Ormrod (2001, p. 64), research originates by identifying unanswered questions or identifying an unsolved problem. The unanswered question for this research program has been identified as:

> *How can cost-benefit analysis practices be improved to provide decision makers with solid evidence for making investment decisions that are informed by all salient factors and are inclusive and 'satisficing'*[2] *the views of key stakeholders?*

The expected outcome of this research is a new construct that could underpin improved CBA practice. This construct needs to address the findings from the literature survey presented in Chapter 2 that identified the need to solve two main problems encountered in project proposal appraisal. The first problem involves how to select cost-benefit factors and their associated evaluation methods, while the second problem relates to resolving stakeholder engagement issues during the decision-making process. Both of these problems are practical in nature and involve synthesis rather than analysis.

[2] For explanation of 'satisficing', please see Chapter 4 and Appendix Q

3.2.2. The selection of a research approach

In seeking to produce and identify a new conceptual framework or model for a socio-technical system, the work of Génova, Llorens, and Morato (2012) on human artefacts becomes relevant.

The authors note that:

> "The concept of 'artefact' encompasses not only physical devices, but also conceptual and social systems: information structures, knowledge representations, methods, processes, organisations, etc." (2012 p.116).

They go on to say that:

> "In the last decades of the 20th century a growing conviction consolidated: the scientific method developed for studying and analysing *natural phenomena* was not apt to understand the design and construction of *human artefacts*" (2012 p.116).

Given the nature of the research problem, scientific approaches that are underpinned by logical positivism are unlikely to be appropriate to synthesise a new *human artefact,* in this case a CBA framework. Similarly, while improving stakeholder engagement can be tackled with interpretive approaches, they are not strong on synthesising new generic frameworks to guide practice. A research methodology that is well suited to the identification, definition and design of new constructs is Constructive Research. Constructive Research is a methodology that not only addresses problems arising from practice, but also seeks theoretical connections between defined problems and the related literature (Kasanen et al., 1993; Lukka, 2000). Constructive Research is a research methodology that can produce managerial solutions that can be demonstrated through their implementation. It enables researchers to identify problems based on their own experience and supporting evidence from other studies. Problems identified are used to propose research questions for the study program. These questions are addressed by designing a construct (or constructing a solution) which is operationalised to determine the workability and appropriateness of the designed construct.

Table 3.1 lists the features of the research problem and examines the suitability of constructive research to tackle this class of problem.

Table 3.1. Research problem features and Constructive Research Approach for this study

Index	Research Problems Features	Constructive Research Approach
1	The research problem addressed in this study directly relates to the stakeholder engagement issue and the rationale of evaluation method selection in CBA. These are practical and real-world problems that have received much attention from practitioners and researchers.	Lukka (2000) points out that Constructive Research is a research approach used for providing novel constructions to cope with real-world issues; it is also an approach that can make significant contributions to the theory of the discipline in which it is applied.
2	The critical problems of CBA for the evaluation of transport infrastructure project exhibits both technical and social aspects.	The philosophy of Constructive Research empowers the researcher to investigate practical CBA issues which exist across both technical and social phenomena (Oyegoke, 2011).
3	The researcher seeks a solution that is built on an academic base that can provide a strong foundation for solution justification.	The Constructive Research approach enables researchers to address practical, relevant problems of CBA based on their experience and on theoretical studies (Kasanen et al., 1993).
4	The researcher wants to produce something useful that helps managers to do their job.	The research results generated from applying Constructive Research can have both practical and theoretical relevance (Crnkovic, 2010) which enable the researcher to make significant contributions to the discipline.
5	The researcher wants to influence norms through a new framework for CBA of transport infrastructure projects.	The Constructive Research implies a cooperation between researchers and practitioners, so it enables researchers to influence existing norms (Lukka, 2000).
6	The researcher aims to make contributions to knowledge through having created something novel and of value to both practitioners and researchers.	A construction can differ profoundly from anything previously existing, and this can be examined and understood, so the construction has undeniable epistemological value (Lukka, 2000).

From Table 3.1, it is clear that the Constructive Research approach is well matched to features of the research problems addressed in the study. Constructive Research not only establishes a strong foundation for constructing the artefact (the stakeholder-centric CBA framework) but also provides the means for researchers to achieve their objectives.

3.3. Overview of the Constructive Research Approach

Constructive research "implies the building of an artefact (practical, theoretical or both) that solves a domain-specific problem in order to create knowledge about how the problem can be solved (or understood, explained or modelled) in principle" (Crnkovic, 2010, p. 363). Lukka (2000) explains that human artefacts (e.g. diagrams, plans, organisation structure, and designing systems) can be considered constructions. Although inspirations for artefacts can come from nature, all of them, nevertheless, result from a design and development process. The two basic logics of Constructive Research are deductive and inductive processes (Kasanen et al., 1993; Lukka, 2000) applied to undertake the main research. The primary purpose of deductive logic is to apply pre-existing general theories to a particular situation. In contrast, inductive logic focuses on taking result statements from particular situations and then applying these statements to general cases. The main processes of Constructive Research can be described as the abductive logic of reasoning (Lehtiranta, Junnonen, Kärnä, & Pekuri, 2015), which involves a cyclical repetition between the inductive and deductive processes. Figure 3.1 shows the main processes of Constructive Research.

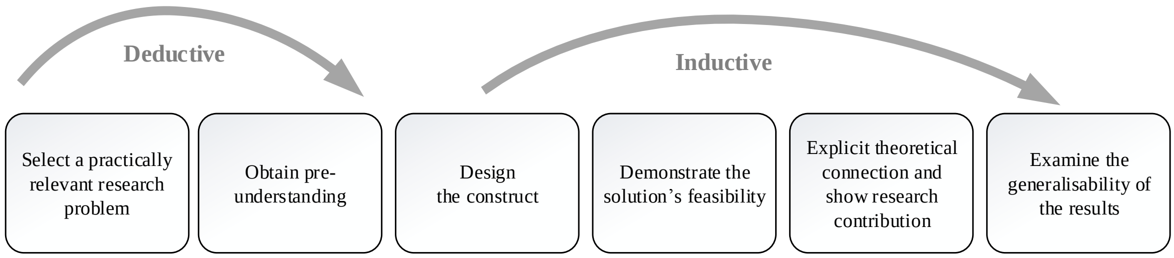


Figure 3.1. The Constructive Research Process. Adapted from Kasanen et al. (1993)

In the case of CBA undertaken in this research program, deductive logic can be expressed as a process through which the researcher, after practical problem identification, conducts a survey of literature to inform the need for designing the construct in the situation where the problem was initially defined. Next, inductive logic is the process through which the researcher designs the construct, highlights theoretical and practical contributions of the research to knowledge and illustrates the practical applicability of the designed construct in general.

Based on the research activities to be addressed and the activity flow in Figure 3.1, Figure 3.2 illustrate the process flow of the Constructive Research approach employed in this research program.

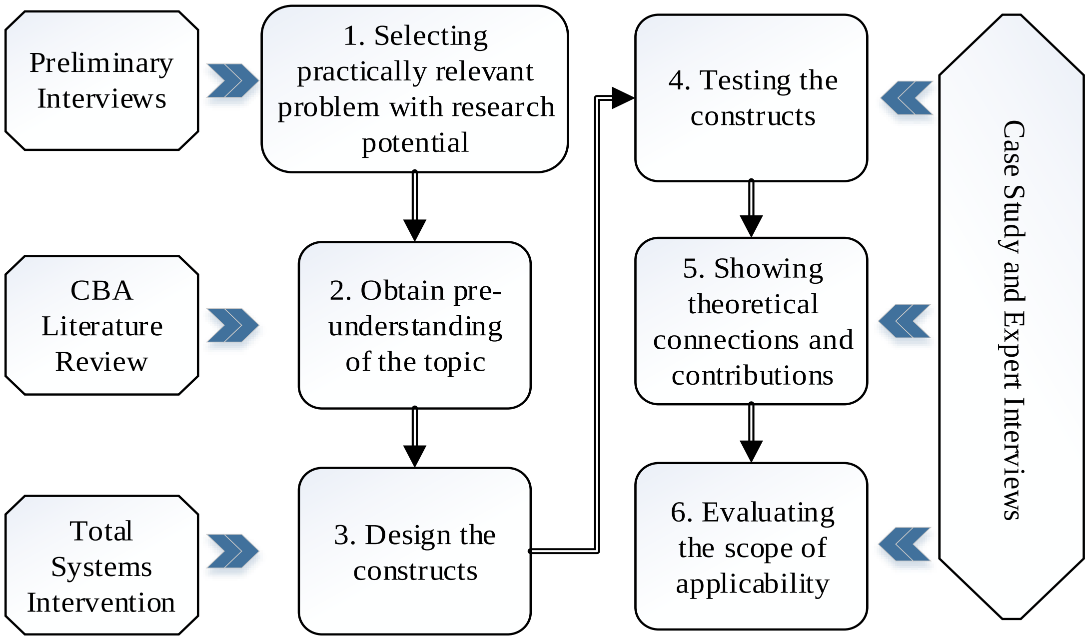


Figure 3.2. Constructive research design for the research program

In the first step, the researcher identified the relevant practical problem from his own experience in conjunction with informal interviews with experts in project evaluation. Once the CBA problem was identified, the research program then identified existing models and used these to inform the initial design of the stakeholder-centric CBA framework. Next, Total Systems Intervention[3] was applied to identify appropriate methods for undertaking CBA and synthesising them to produce the top-level CBA framework definition. The design step also includes identifying CBA attributes, analysis methods, application techniques and the types of tools that could be used to implement the construct. Once the design of the stakeholder-centric CBA framework was established, a second construct was produced: a computer-aided CBA tool that embodies

[3] For details of Total Systems Intervention, please see Section 3.4.3 below and Chapter 4

much of the framework. Evaluation of the constructs was achieved through a case study that was used to appraise the utility and efficacy of the proposed framework. Expert interviews were conducted as final stage of the study program in order to build an argument regarding the validity and the applicability of the stakeholder-centric CBA framework. Theoretical connections were then drawn to conclude the work. The following section provides details of Constructive Research design for this study.

3.4. Details of the Constructive Research Design

3.4.1. Identifying a practical relevant problem

Constructive Research problems can be identified via anecdotal evidence, the experience of the researcher, or from the results of theoretical studies (Oyegoke, 2011). The researcher has worked for several construction investment companies and universities in different roles, including investment expert, project manager, and lecturer (see the author's biography). The researcher, from his experience, recognised critical issues with CBA when used for transport infrastructure projects. In 2014, the researcher undertook the Master of Applied Project Management at Adelaide University and carried out a research project, entitled 'Socio-economic cost-benefit analysis for transport infrastructure projects' (Nguyen, Cook, & Ireland, 2017). In 2016, the researcher continued with this topic and he conducted several interviews with experts in Vietnam to investigate the barriers to CBA application for project proposal selection.

The findings of these informal interviews provided insights into critical CBA issues including the unclear boundary of CBA application, the role of stakeholders in the CBA process, and the challenges associated with the selection of appropriate methodologies, methods and techniques for any given project evaluation. In addition to conducting interviews, the researcher presented two papers at international conferences (Systems Science and Industrial Engineering) to gather the feedback of experts on the need for framework development (see the list of publications). Moreover, five research seminars with colleagues in the ECIC from 2016 to 2018 were organised to provide feedback on the usability of the proposed framework.

3.4.2. Obtaining pre-understanding of the research topic

In order to understand the nature of CBA in the domain of transport infrastructure projects, the Web of Science, Scopus and Science Direct databases were searched for original studies published between 1844 and 2018 on CBA for transport infrastructure projects. Selected keywords, including cost-benefit analysis, socio-economic factors and transport infrastructure, were used in different combinations to identify relevant studies. This literature review focused on CBA schools of thought, CBA strengths and weaknesses, cost-benefit factors and associated methods incorporated into CBA programs.

The literature review identified several critical issues with CBA for transport infrastructure projects. Firstly, objectives, criteria, and attributes employed in CBA are often unclear: for example, environmental consequences and social issues are usually difficult to quantify and compare (Barfod & Salling, 2015). In addition, there is criticism regarding calculation methods used for measuring and translating project impacts into monetary terms: and this criticism also raises a question of whether to leave these effects out of the CBA analysis or not (Mackie & Preston, 1998). Thirdly, Clark et al. (2004) emphasised the difficulties in interpreting CBA results to make clear the potential benefits and costs of an investment project, especially when considering benefit factors for which it is difficult to provide specific measurements. Moreover, the current CBA methodology is not able to capture all relevant costs and benefits (Eliasson & Lundberg, 2012).

Even though authors have proposed several solutions for the problems mentioned above, a significant gap addressed in this study relates to a lack of stakeholder engagement in CBA and also the rationale for method selection in project evaluation. The findings of the ‘pre-understanding’ step enabled the researcher to better understand the nature of CBA for transport infrastructure projects, as well as to recognise the pros and cons of CBA implementation in practice. This clarification of critical CBA issues provided strong justifications for the need to develop a new stakeholder-centric CBA framework and the motivation for the researcher to pursue it.

3.4.3. Designing the constructs

The construction of the stakeholder-centric CBA framework was based on the principles of Total Systems Intervention (TSI) as proposed by Flood and Jackson (1991). The philosophy of TSI enables the researcher to better comprehend the core issues in a problem situation by using multiple kinds of systemic enquiry. The first two main steps from TSI, *creativity* and *choice*, were applied to outline the structure of the stakeholder-centric CBA framework for transport infrastructure projects. In particular, 'soft' systems and 'hard' systems approaches are used to construct a specific procedure for problem solving. The soft systems approach is used to deal with stakeholder engagement issues, while a hard systems approach is selected to build a quantitative assessment system for CBA. The combination of both hard and soft systems approaches provides a holistic approach to CBA for transport infrastructure projects.

The details of the stakeholder-centric CBA framework and its supporting tool (software) are presented in Chapter 4 and Chapter 5 respectively. The application of the stakeholder-centric CBA framework and the findings extracted from the analysis of expert interviews are discussed in Chapter 6.

3.4.4. Validating the stakeholder-centric CBA framework

Borsboom, Mellenbergh, and van Heerden (2004, p. 1061) provide a simple definition for the concept of validity: "A test is valid if it measures what it purports to measure". In other words, conception validity is a question of whether a method used for measurement is aligned with its purpose. In this research, the main purpose of validating the stakeholder-centric CBA framework is to provide critiques on strengths and weaknesses of the proposed framework, as well as to examine its applicability. In practice, it would take time to validate the outcome of evaluation framework implementation; thus the market-based validation technique, proposed by Kasanen, was selected after careful consideration. In Constructive Research, Kasanen et al. (1993) proposed market-based validation as the means for validating managerial constructions. Market-based validation includes three different levels: weak, semi-strong and strong. The weak market test is valid when managers agree to apply the construct for their decisions. The semi-strong market requires the proof of use of the construction beyond the case organisation itself. The strong market test is passed when the financial benefits to several businesses from the use of the construction can be demonstrated. The latter two tests are generally beyond the scope of a PhD program.

This study focuses on decision-makers responsible for the selection of investment options for specific transport infrastructure projects; thus the validation test falls into the first level of market test: 'the manager is willing to use the construct for problem-solving and decision-making' (Kasanen et al., 1993). The validation test has two parts: a case study demonstration and experts' validation.

- Firstly, a case study was selected to demonstrate how the stakeholder-centric CBA framework can be applied to project proposal selection. Data related to the case study was collected and loaded into the CBA tool 'CBAFS software', created by the researcher, and the tool was configured to produce a CBA output in the form of a quantitative assessment. The secondary data of the Northern Connector was used to provide detailed critiques on the strengths and weaknesses of the approaches adopted. The secondary data of the case study, itself, cannot be validated but the data was used to provide a holistic picture of an infrastructure project evaluation.

- Secondly, the framework was described to experts, who were shown the CBAFS tools populated with the case study and then, subsequently interviewed. The interviews, each approximately 60 minutes in length, were conducted with both individuals and small groups of experts. During the interviews, experts were asked to provide comments on the utility and efficacy of the stakeholder-centric CBA framework and to suggest modifications for improvement. The findings of the interviews were used to argue the validity of the stakeholder-centric CBA framework.

3.4.5. Clarifying theoretical connections and research contribution

In the constructive approach, the initial theoretical connection should be made in the form of a literature review analysis to address the knowledge gap and to specify the core problem (Oyegoke, 2011). The literature review in this thesis structures the CBA schools of thought and highlights the strengths and weaknesses of CBA for transport infrastructure projects. It identifies the core issues arising from the use of the traditional CBA approach in terms of method selection and stakeholder engagement. It further examines existing approaches to CBA and provides a list of cost-benefit factors that should be considered for infrastructure evaluation programs.

The research contribution includes the review work and the construction of the stakeholder-centric CBA framework that provides a holistic approach to CBA and that allows practitioners to tackle both technical and social issues in project proposal selection. The flexible nature of the proposed framework enables practitioners to select 'appropriate' methods for evaluation to suit specific project circumstances. The framework also addresses stakeholder engagement issues.

The outputs from the research program allow interested scholars and practitioners to better understand the nature of CBA, to address practical CBA problems, and to select methods within the stakeholder-centric CBA framework which best match their needs.

The details of the theoretical connections and the research contributions are presented in Chapter 7 of the thesis.

3.5. Summary

Chapter 3 opens by stating the research problem and the research methodology selected to tackle it. This chapter then justifies the selection of the Constructive Research approach for the research program. The reasons for the selection of the Constructive Research approach are: (1) this approach best matches the research problem; (2) it provides the means to construct a novel framework addressing practical and theoretical gaps; (3) the proposed outcome of the research program, a stakeholder-centric CBA framework, is well placed to contribute to the advancement of the discipline. The chapter then describes the design of the Constructive Research approach employed for the research project. The next chapter, Chapter 4, describes the design of the construct: the stakeholder-centric CBA framework for transport infrastructure projects.

Chapter 4

Stakeholder-Centric Cost-Benefit Analysis Framework for Transport Infrastructure Projects

4.1. Introduction

The literature review presented in Chapter 2 has identified a range of CBA issues for transport infrastructure projects: for example, the objectives, criteria and attributes present in CBAs are often in conflict (Barfod & Salling, 2015). Also, the relationship between the financial and economic factors in the CBA is often overlooked (Florio, 2006), there is a lack of understanding of whether socio-economic problems have been appropriately mapped onto monetary valuations (Ackerman & Heinzerling, 2002), and there are concerns about the ethics of the decision-making process (van Wee, 2012). It is clear that researchers, based on their foundational schools of thought, tend to focus on specific cost-benefit factors in their investigations. In particular, researchers tend to focus on just one of the four main groups of CBA factors: technical, financial, socio-economic and environmental. Few studies focus on investigating issues relating to the selection of CBA evaluation methods or stakeholder engagement. Even though researchers have attempted to clarify inappropriate method selection (Annema et al., 2007; Eliasson & Lundberg, 2012; Sugden, 1999) and stakeholder engagement issues (Beukers et al., 2012; Cascetta et al., 2015; Mouter et al., 2013), studies have not clearly identified the root causes behind these issues, thus leaving unanswered questions. In addition, the relationship between evaluation method selection and stakeholder engagement has not been identified (Figure 4.1).

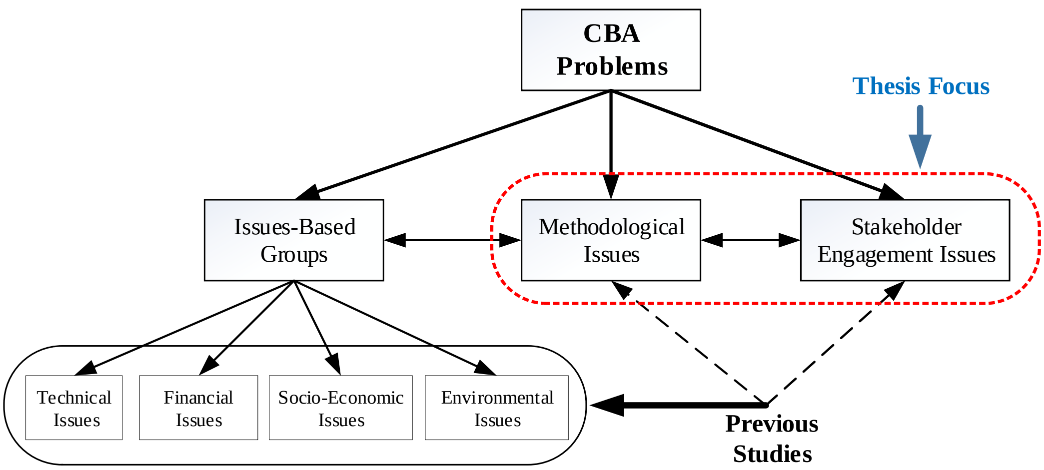


Figure 4.1. CBA problems and the boundary of studies

Figure 4.1 shows that the most significant issues raised are the engagement of stakeholders during CBA processes and the inadequate rationale used by practitioners for selecting CBA evaluation methods. In this study, Chapter 4 focuses on describing the design process of a stakeholder-centric CBA framework that seeks to overcome the major issues as stated above.

4.2.Overview of CBA Framework Design Process

The creation of a novel construction is best performed using a structured design approach. Figure 4.2, adopted from Department of Defence, 2001, illustrates a simple design approach which is adapted from engineering design and is described in IEEE 1220:2015. The process starts with a statement of needs, objectives, and constraints.

The needs analysis process analyses how the framework will be used by a CBA evaluation team, and how stakeholder engagement will be achieved and stakeholder consensus facilitated. This process will determine which functions or activities the CBA framework should be able to support.

The functional analysis process identifies the functional flow of the key activities which the CBA Framework needs to embody. The functional analysis also needs to identify the top-level approaches and their internal processes that can support the activity set.

The synthesis process converts the functional design produced in the functional analysis process into an operationalised CBA framework. The synthesis will include methodologies, methods, processes, tools and techniques along with the CBA attribute set.

Each step is discussed further in the sections below.

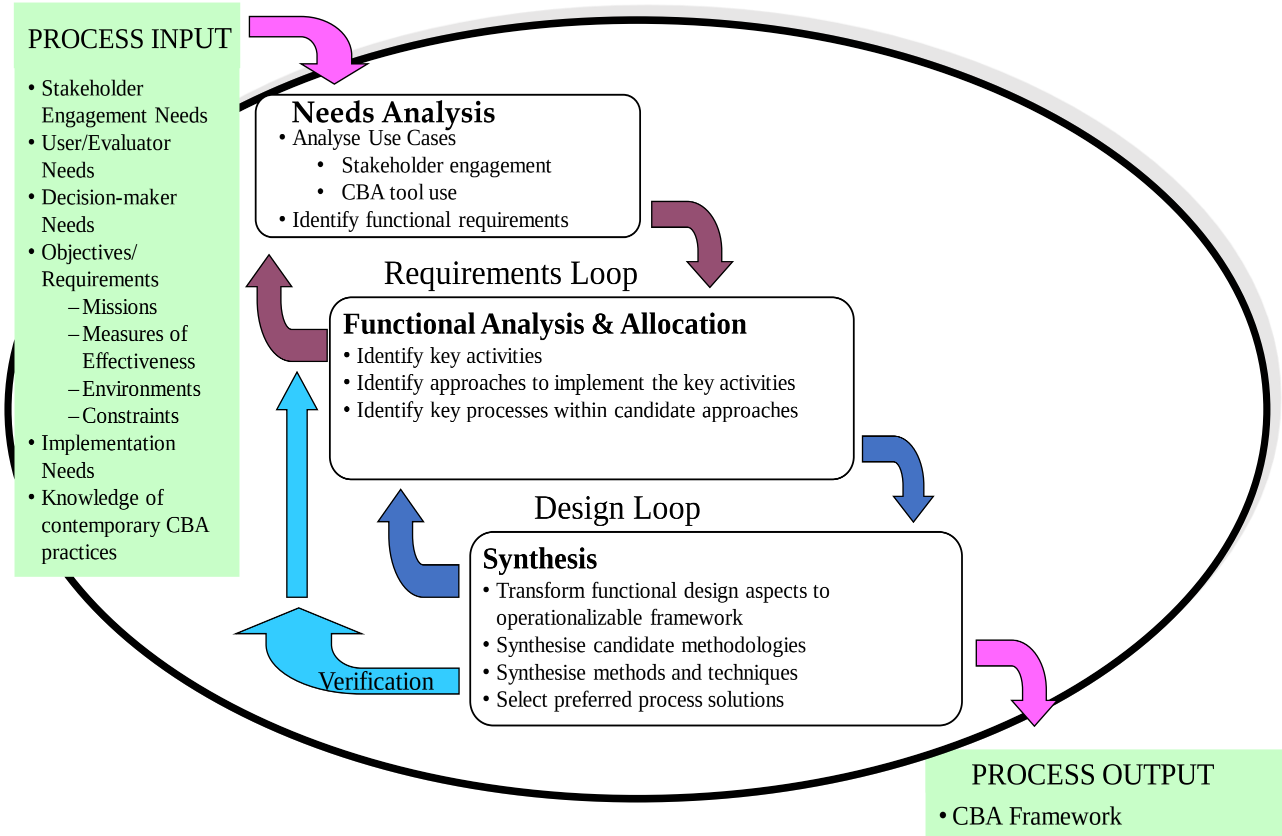


Figure 4.2. CBA framework design process. Adopted from DoD (2001)

4.3. CBA Framework Needs Analysis

4.3.1. Disparate stakeholder viewpoints

In practice, there will be a range of stakeholders who influence the decision-making process for any transport infrastructure project. It is usual for there to be a disparate set of views across the stakeholder groups and for power to be unequally distributed (Cascetta et al., 2015). Appendix D provides a comprehensive list of the acknowledged stakeholders and Table 4.1 lists key stakeholder groups and their imperatives.

Table 4.1. Project stakeholder groups and viewpoints

List	Stakeholders	Viewpoints
1	Investors can come from the private or government sectors.	In the case of private investors, they are liable to focus strongly on the financial aspects of CBA in order to justify investment. Key indicators used for this group include profit, payback period, and financial sustainability (The European Commission, 2008). In contrast, governments are likely to be more concerned with the benefit to society of the investment project that is reflected via indicators such as traffic congestion reduction, travel time savings, transport cost savings, number of jobs created and environmental impacts.
2	Urban planners usually focus on the master plan of a city	This group often focuses on infrastructure system planning (Van Assche, Beunen, Duineveld, & de Jong, 2013) rather than on implementation. In addition, planners would be most concerned about how the individual project contributes to the ongoing future vision for the region as captured in a master plan or similar.
3	The local community includes people living in the investment area of the proposed project.	The primary concerns of the local community would be potential impacts of project implementation on their daily activities (Olander & Landin, 2005), such as traffic interruption and environmental pollution. Such groups often focus on direct, short-term cost-benefit factors such traffic disruption, noise, and environmental impact. Longer-term issues which the local community may consider to be important might include for example, safety and future enhanced business opportunities.
4	Travellers are the people who use the infrastructure.	This group focuses on benefit factors of project operation in the future such as cost, travel time, air pollution and safety to justify the feasibility of proposals. Travellers, in most cases, have a positive view on the necessity of project implementation because they directly benefit from project approval.
5	Pressure groups can be landowners, trade associations, non-government organisations and the like.	For landowners, their primary concerns would be the direct impact of project implementation on the amenity of their land (Abelson, 1995), so they may concentrate on the opportunity cost. In the case of NGOs, their attention is often on the environmental aspects of the project investment and cultural heritage factors. Pressure groups tend to hold strong views that emphasise their particular areas of concern, and often consider that non-financial costs outweigh project financial benefits.
6	Media includes both public and private organisations.	Public media refers to public service broadcasting such as television, radio, and electronic media (Scannell, 2005) which are mainly sponsored by government and aim to spread information to the public. This group focuses on controversial project topics to investigate social issues and this often has indirect impacts on the decision-making process via its communication channels. In contrast, commercial media groups are concerned with ratings and potential conflicts of interest. This group, in some cases, is affected by private sponsors and the accuracy of information provided by commercial media is questionable.

Stakeholders, based on their norms and beliefs, will emphasise different CBA factors and derived metrics and interpret the overall CBA in different ways. Table 4.1 shows that there is a range of imperatives, some of which reflect opposing views; thus, it is not surprising that the stakeholders are a pluralist group where it is common to have some stakeholders who are irreconcilably opposed to the project. In practice, stakeholders, depending on their interest, may use their power to impact the decision-making process of transport infrastructure projects. Thus, the problematical situation is: how can a CBA be designed to explicitly accommodate the diverse perspectives and motivations of the project's stakeholder groups? This complex situation is portrayed in Figure 4.3.

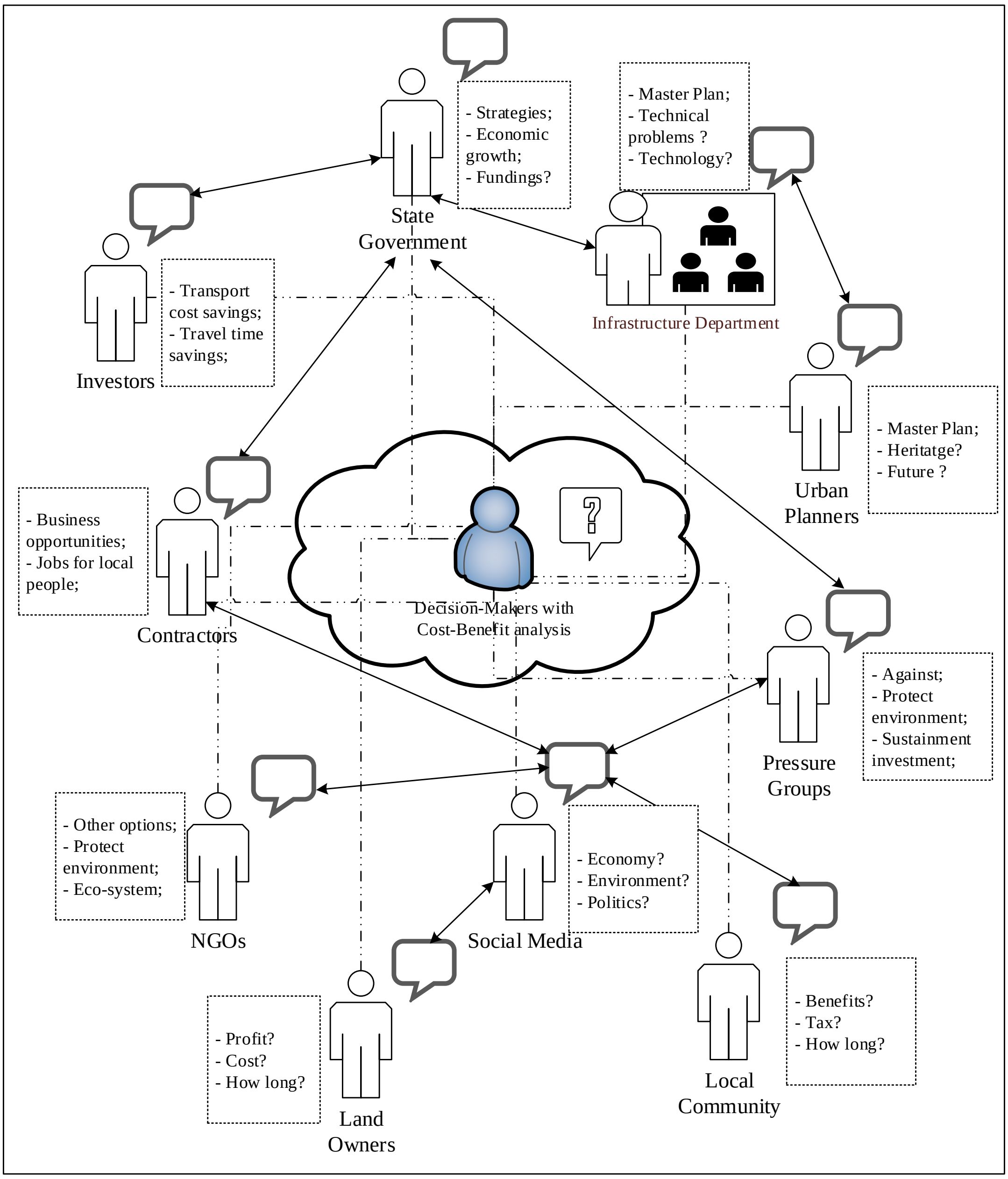


Figure 4.3. Overview of the CBA problematical situation

In the conventional framework, practitioners often use a ‘hard’ analysis process to capture stakeholder needs (Aaltonen, 2011) and then carry out evaluation activities without the continuous involvement of key stakeholders. In particular, several stakeholder workshops are often carried out at the initial stage of transport project analysis, but these activities are limited and not considered by practitioners at the later decision-making stage. Decisions based on the ‘hard’ approach without continuous stakeholder involvement often reflect the analyst’s viewpoint, rather than reflecting the diversity of stakeholder viewpoints on the cost and benefit of a project investment (Maciariello, 1975). Stakeholders, based on their understanding and beliefs, usually interpret a CBA in different ways and this may create an obstruction for reaching consensus among the key parties involved.

In addition, stakeholder groups depend on information provided to them about the CBA and the interactions between them and others during the decision-making process. The current CBA paradigm (e.g. that used by The European Commission (2008) and The Asian Development Bank (2013)) has a major limitation in not creating an open space for stakeholder discussions (Beukers et al., 2012) and it also lacks processes that allow stakeholders to be directly involved in the decision-making process of selecting a particular transport infrastructure project. Thus, it is essential to develop a framework that can empower stakeholder participation and provide an opportunity for stakeholders to discuss their problems with the project proposal and to suggest solutions.

Table 4.2 shows some typical needs for stakeholder engagement in a CBA for transport infrastructure projects.

Table 4.2. The needs for addressing stakeholder engagement

Index	Need	Reference
1	Stakeholder engagement in complex projects is a crucial step that aims to involve all project stakeholders in the planning, decision making and implementation phases of a project, in order to reduce the likelihood of conflict and to set clear project priorities.	(Deegan & Parkin, 2011; Webler & Tuler, 2000)
2	Stakeholder participation is the keystone of debate: inadequate or incomplete identification or representation of stakeholders could certainly weaken the process.	(Damart & Roy, 2009)
3	Scholars emphasise the importance of effective communication in stakeholder engagement to ensure the feasibility of investment projects.	(Bakens, Foliente, & Jasuja, 2005; Genus, 1997; Mok, Shen, & Yang, 2015; Patel, Kok, & Rothman, 2007)
4	The diversity in a stakeholder community could be an obstacle for stakeholder engagement with mega projects. Thus, it is crucial to seek practical approaches to address this problem.	(Feige, Wallbaum, & Krank, 2011)
5	Public engagement in infrastructure projects, is considered as a practicable means to safeguard public interest.	(Batheram, 2005; Rowe & Frewer, 2000; Rowe & Frewer, 2004)
6	The design perspective of CBA should include an adequate understanding of the social interrelations which are embedded in the process of designing, constructing, and operating construction projects; this will add to the transparency of decision-making.	(Rohracher, 2001; Valdes-Vasquez & Klotz, 2012)

4.3.2. Needs of the evaluators

The review of the CBA literature in Chapter 2 identified that most evaluation methods used for a CBA are founded in 'hard' approaches which concentrate on measuring project impacts quantitatively: for example, traffic forecast models, cost estimation methods and risk assessments. 'Soft' methods, on the other hand, are often applied to investigate the social and environmental issues relating to a project investment, using methods such as community satisfaction surveys (Feng & Wang, 2007), stakeholder interviews (Beukers et al., 2012) and workshops. The 'soft' approach aims to investigate complex issues and then to flesh out the problematical situation before making suggestions for improvements (Burge, 2015). A combination of approaches (e.g. 'hard' & 'hard' or 'hard' and 'soft' or 'soft' and soft') is sometimes applied to CBA, such as the COBA model (Sugden, 1999), the COSIMA model (Leleur, Petersen & Barfod 2007), and the CBA-DK model (Gissel, 1999). However, such combinations are more likely to be an *ad hoc* combination of methods, rather than a rational combination of evaluation methods based on strong arguments (Figure 4.4).

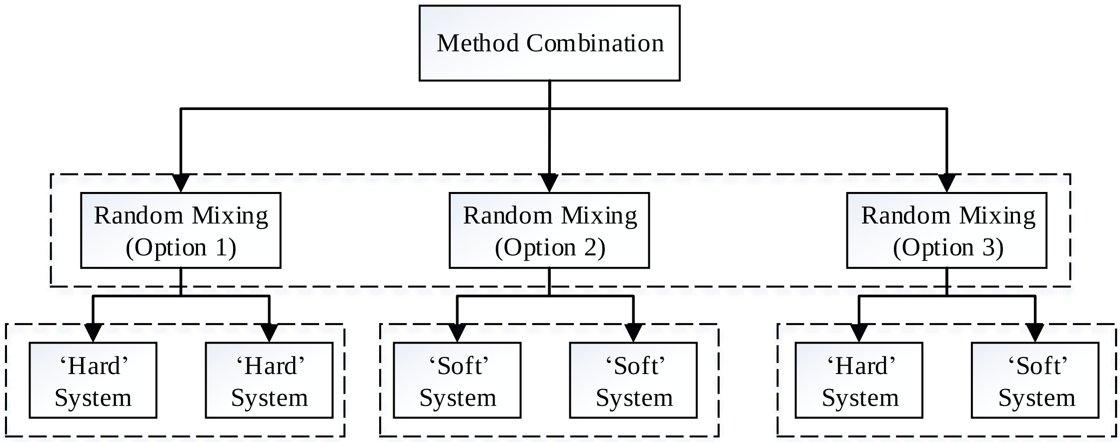


Figure 4.4. Mixed methods used in CBA for transport infrastructure projects

In other words, CBA researchers do not tend to provide sufficient justifications for their selection. Instead they tend to select their 'favourite' methods, based on the theoretical stance and methods with which they feel comfortable for their evaluation program. Flood and Romm (1995) claim that practitioners may use one method according to its logic and then eclectically add on other methods in terms of a certain logic without considering alternative methods (derived from other theoretical underpinnings). Thus, there is a need to properly justify the selection and combination of evaluation methods for the CBA. Table 4.3 addresses typical needs of the evaluation team for the selection of evaluation methods to be used in a CBA for transport infrastructure projects.

Table 4.3. The needs of evaluators

Index	Evaluator Needs	Reference
1	Guide CBA attribute selection along with weights, thresholds, and evaluation methods.	(Butler, 2002)
2	Propose methods that allow practitioners to be able to learn and perform evaluation activities.	(Cook, Bender, Spencer, & Waite, 2015; Forestry Department, 1996)
3	Minimise the expenditure of time and effort required to establish the new methods including software installation and training time.	(Lutters, van Houten, Bernard, Mermoz, & Schutte, 2014; Patricia, Andrew, Bron, Alice, & Chris, 2015)
4	Select evaluation methods, which should be simple for data collection and analysis.	(Befani, 2016; Forestry Department, 1996)
5	Ensure the degree of consistency of information generated from evaluation methods selected.	(Cook et al., 2015)
6	Support the evaluation team to answer important questions or focus on the key issues of project evaluation.	(Befani, 2016; Forestry Department, 1996; Patricia et al., 2015)

4.3.3. Needs of the decision makers

Decision-makers for investments in transport infrastructure projects at the State level are typically representatives of local government (e.g. Department of Transport). These people, based on the availability of information provided by the evaluation team, need to make judgements about the future of the project proposal. The literature presented in Chapter 2 identifies that one of the greatest challenges for decision-makers is to make an investment decision that can take account of stakeholder perspectives. It is clear that the importance of the decision-making process at the planning stage is not only to select the 'right' project (Williams & Samset, 2010) but also to *incorporate the differences between stakeholder perspectives and to reflect a sufficient degree of consensus among key parties.* Table 4.4 addresses typical needs of decision-makers with a CBA.

Table 4.4. The needs of the decision-maker

Index	Needs	Reference
1	Ability to re-do analysis on demand.	
2	Address stakeholder concerns.	(Williams & Samset, 2010)
3	Produce convincing and evidence-based documents.	(Flyvbjerg, 2009; Williams & Samset, 2010)
4	Adopt choices that are merely 'good enough' or 'satisficing'.	(Gorod, Nguyen, & Hallo, 2017; Isenberg, 1991)
5	Minimise the exercise of power in the investment decision-making process.	(Habermas, 1984)

In addition to the stakeholder need analysis presented in Table 4.1, Table 4.2, Table 4.3 and Table 4.4, the main findings from interviews with experts in Vietnam were used to establish the assessment matrix for stakeholder need analysis (see the Appendix F: House of Quality). The results of using the House of Quality technique enables the researcher to recognise main attributes used for project evaluation, before seeking a promising model for the construction of the evaluation framework. In addition, the researcher also attended the AnyLogic modelling Course in Melbourne 2017 to obtain the advice of experts as well as to develop the initial conceptual model for project evaluation.

4.4. Functional and Activity Analysis

From the CBA Framework Needs Analysis presented above, it can be concluded that the two significant problems of the CBA are inadequate stakeholder engagement and the lack of rationale behind CBA method selection. The first problem of the CBA directly relates to the problematic situation of decision-makers with the CBA, while the second problem refers to the underpinning philosophy of method selection and combination. Moreover, the selection of evaluation methods for the CBA needs to reflect the stakeholders' motivation, to ensure that the investment decisions made in relation to the CBA are feasible and sustainable. It is clear that these two problems are complex and require a holistic approach to problem-solving.

4.4.1. The rationale of selecting Total Systems Intervention to deal with CBA issues

Systems thinking is an appropriate approach for the complex problems identified. Systems thinking is defined as "the art and science of making reliable inferences about behaviour by developing an increasingly deep understanding of underlying structure" (Richmond, 1994, p. 6). The core aspects of systems thinking involve a holistic view and appreciating other people's perspectives (Chapman, 2004). The strength of systems thinking is reflected through its adaptability to change. From the literature, Table 4.5 shows three waves of the development of systems thinking, and each wave reflects the viewpoints of the researchers involved during that particular historical period.

Table 4.5. Waves of systems thinking. Adapted from Reynolds and Holwell (2010)

Waves of Systems Thinking	Selected Systems Approaches
First Wave of Systems Thinking (Hard)	General systems theory (Bertalanffy 1956)
	Classical (first order) cybernetics, 'mechanistic' cybernetics (Ashby 1956)
	Operations research (Churchman et al. 1957)
	Systems engineering (Hall 1962)
	Socio-technical systems (Trist et al. 1963)
	RAND-systems analysis (Optner 1965)
	System dynamics (Forrester 1971; Meadows et al. 1972)
Second Wave of Systems Thinking (Soft)	Inquiring systems design (Churchman 1971)
	Second order cybernetics (Bateson 1972)
	Soft systems methodology (Checkland 1972)
	Strategic assumption surfacing and testing (Mason and Mitroff 1981)
	Interactive management (Ackoff 1981)
	Cognitive mapping for strategic options development and analysis (Eden 1988)
Third Wave of Systems Thinking (Combined)	Critical systems heuristics (Ulrich 1983)
	System of systems methodologies (Jackson 1990)
	Liberating systems theory (Flood 1990)
	Interpretive systemology (Fuenmayor 1991)
	Total systems intervention (Flood and Jackson 1991)
	Systemic intervention (Midgley 2000)

The first wave of systems thinking focuses on 'hard' systems, designed to solve 'defined' issues, while the second wave of systems thinking focuses perspectives on human issues. The third wave is considered to be a combination of the first and second waves of systems thinking and this wave adds an emphasis on power relations and how these affect the evaluation outcome (Reynolds & Holwell, 2010). The selection of an approach needs to satisfy the mandatory requirements of problem-solving, including systems philosophy, and to provide a set of applied principles for making judgements and directing action (Rousseau, 2018). In this study, the major problems addressed in the previous section (4.1.2) are both technical and social in nature, so these two aspects require a combined approach for problem solving. Total Systems Intervention (TSI), located in the third wave of systems thinking, is the most appropriate for this research, because it inherently deals with methodological choice from a range of systems approaches and the synthesis of their findings. The underpinning philosophy of Total Systems Intervention is 'critical systems thinking' which relies on three positions: complementarism, sociological awareness, and human well-being and emancipation (Flood & Jackson, 1991). These philosophical positions of TSI enable the researcher to explore the following:

- The first position of TSI, complementarism, refers to the value of the 'picking and mixing' strategy of the pragmatist (Flood & Jackson, 1991). However, Flood and Jackson state that complementarism should set out the argument between combining 'pragmatist' and 'isolationist' in an explicit way. Pragmatists argue that management scientists should not concern themselves with theoretical issues, but should instead focus on building tools and techniques verified in practice (Flood & Jackson, 1991). The reason for this is that management consultants, when under pressure, want to solve problems quickly and make their clients happy. The outcome - success or failure, in this case, does not reflect the nature of the 'learning' which should be related back to a set of theoretical presuppositions before testing in practice, therefore providing a more acceptable outcome for the client. In contrast, isolationism implies the selection of only one method or methodology. Even though the analysts may know of several approaches, they may prefer to select their favourite approach for solving any problem. Isolationalism divides Science into factions, where scientists can stand on a theoretical position and follow their favourite approach (Flood & Romm, 1995). It is clear that the complementarism position of TSI allows the researcher to appreciate the strengths and weaknesses of possible approaches before going forward with the selection strategy for evaluation methods.

- Secondly, the sociological awareness position refers to organisational and societal pressures that require management scientists to select different systems methodologies to tackle a range of problems at different points in time (Flood & Jackson, 1991). This position allows the researcher to recognise the social consequences of using particular methodologies (methods) for tackling problems. For example, the use of 'soft' systems methodologies may have deleterious social consequences if conditions related to open and free debate are absent.

- Ultimately, a position that emphasises human well-being and emancipation focuses on maximising the potential of individuals, working through organisations and in society (Flood & Jackson, 1991). The exercise of power in the societal process may prevent open discussions where people have opportunities to contribute their voice to a project's success. Thus, the position based on human well-being and emancipation, aims to free people from their constraints and to empower them to learn and be involved in a process of genuine democracy. This position is aligned with the purpose of the current study, where the researcher aims to create an open space for cost-benefit debate between key stakeholders of transport infrastructure projects.

In summary, dealing with cost-benefit factors across the four main groups (technical, financial, socio-economic, and environmental) requires various approaches, so the first and second position of TSI enables the evaluator to 'pick and mix' methods with confidence. The third position of TSI empowers CBA practitioners to recognise the diverse perspectives and motivations of stakeholders, as well as to seek consensus among the key parties (Flood & Romm, 1995). Moreover, TSI was built based on a theoretical foundation of critical systems thinking that has been employed by practitioners in many disciplines (Flood, 1995). Thus, the principles of TSI are practical: for example, in appreciating the strengths and weaknesses of methods and considering the use of methods in a complementary way. TSI principles are embedded in two phases: creativity and choice, so enabling the researcher to establish a strong foundation for the stakeholder-centric CBA framework development.

4.4.2. TSI creativity phase

According to Flood and Jackson (1991), the primary purpose of a creativity task is to use systems metaphors to recognise and structure the problems of an organisation (system). This task helps managers to think creatively about their situation and to identify metaphors that capture the organisation's or the system's objectives. Some typical metaphors are the machine metaphor (closed system view), the organic metaphor (open system view), the neuro-cybernetic metaphor (viable system view), the cultural metaphor, and the political metaphor (Flood & Jackson, 1991).

- A machine is recognised as a technical apparatus with defined functions. The machine (closed system) is set by specific activities that are operated in a routine way to achieve given objectives. The closed system places its emphasis on control, while little concern is given to the environment (Kendall & Kendall, 1993).

- Secondly, the organic metaphor (open system view) incorporates ideas drawn from biological studies (cells and organisms) and links these ideas to those of evolution. The open system view considers a system as a complex network of elements and relationships in which interactions among elements create feedback loops existing in a changing environment (Flood & Jackson, 1991).

- The neuro-cybernetic metaphor (viable system view) was developed at the same time as the open systems view, however, the viable system view emphasises active learning and control, rather than passive adaptability. The neuro-cybernetic metaphor looks at a system as a brain that can be tested by its ability to communicate and learn (Cook, Kasser, & Ferris, 2003).

- The cultural metaphor refers to the typical features of culture in organisations or groups, such as values, norms and beliefs (Flood & Jackson, 1991).

- Culture plays a vital role in organisations since it determines how organisations react to changes both from the internal and external environments (Hofstede & Hofstede, 2005).

- The political metaphor focuses on situations in which the relationship between individuals and groups is affected by the pursuit of power (Flood & Jackson, 1991).

These metaphors are applied to structure the main problems of CBA. The four main groups of factors of a CBA for a transport infrastructure project are technical, financial, socio-economic and environmental and each group has a unique character that matches different system metaphors, as follows:

- The technical group refers to technical factors used in cost-benefit analysis for transport infrastructure projects: for example, traffic forecast, construction schedule, technology risk and construction safety. During the development of the construction industry, these factors can be defined, and practitioners have many tools and techniques to deal with these technical issues. The underlying metaphor addressed is that of a machine (closed system view).

- The financial group for CBA includes a range of factors such as project cost estimation, the discount rate, and project lifecycle for assessment, operational revenue estimation and tax types. These factors have been addressed in many studies and practitioners also have many methods and techniques to perform cost estimation. The underlying metaphor for this group is that of a machine (closed system view).

- The environmental group focuses on environmental factors: for instance, air pollution, noise pollution, chemical waste, biosphere ecosystem, carbon emission and climate change. Several factors can be addressed well, such as air pollution, noise pollution and chemical waste, while other factors related to project impacts on the biosphere of natural ecosystems and climate change are more difficult to quantify. Climate change is a controversial topic, and the involvement of individuals in this topic depends on their norms and beliefs; thus the underlying metaphor would be that of a culture.

- The socio-economic group has many complicated factors, including congestion reduction, travel time savings, transport cost savings, traffic disruption during the construction stage, business opportunities, the number of jobs created, and public amenity improvements. This group has a character that matches different system metaphors of machine, culture and political system. Firstly, the underlying metaphor of some factors, including congestion reduction, travel time savings, transport cost savings, is the machine. On the other hand, some factors such as business opportunities, public improvements and environmental protection are under the consideration of different stakeholder groups. Project stakeholders have different interests and voices in the decision-making process of the investment project, and the likelihood of viewpoint conflict is very high. Hence, the underlying metaphors for most socio-economic issues would be both cultural and political.

From the above analyses, it can be seen that a CBA for a transport infrastructure project is a complicated process that requires evaluators to consider a number of factors that underpin different system metaphors. Based on the system metaphors addressed, the next step is to seek appropriate systems approaches for problem-solving.

4.4.3. TSI choice phase

The choice of an appropriate methodology will guide problem management in a way that ensures solutions are matched with the problems found. Using the guidelines of TSI enables us to link systems metaphors to systems methodologies (Flood & Jackson, 1991). Flood and Jackson categorised the problem context into six groups: Simple-Unitary (S-U), Complex-Unitary (C-U), Simple-Pluralist (S-P), Complex-Pluralist (C-P), Simple-Coercive (S-C) and Complex-Coercive (C-C). This study does not discuss the differences among methodologies, rather it concentrates on the way to structure CBA problems to recognise the underlying metaphors and to seek solutions. Table 4.6 addresses common factors in the four main groups of cost-benefit analysis for transport infrastructure projects; it then highlights metaphors and associated approaches.

Table 4.6. Systems metaphors and associated systems approaches

CBA critical issues	Type of problem-contexts	Underlying Metaphors	Choice of Approach
The financial group includes main factors: project cost estimation, the discount rate, and project lifecycle for assessment, operational revenue estimation and tax types.	S-U	Machine	‘Hard’ systems (e.g. conventional financial systems)
The technical group includes main factors: traffic forecast, construction risk, technology risk and project safety.	S-U	Machine	‘Hard’ systems (e.g. systems engineering)
The environmental group includes main factors: air pollution, noise pollution, chemical waste, biosphere ecosystem, carbon emission and climate change.	S-U C-P	Machine Culture	‘Hard’ systems (e.g. operational research) ‘Soft’ systems (e.g. soft systems methodology)
The Socio-Economic group includes main factors: social discount rate, traffic congestion reduction, travel time savings, transport cost savings, traffic disruption during the construction stage, business opportunities, the number of jobs created, stakeholder engagement and public improvements.	S-U C-P	Machine Culture Political	‘Hard’ systems (e.g. systems engineering) ‘Soft’ systems (e.g. soft systems methodology)

Table 4.6 shows that some issues of a CBA can be addressed in four main groups and the common underlying metaphor is that of a machine (closed system) that requires ‘hard’ system approaches. In addition, numerous CBA problems in the environmental and socio-economic groups are complex, invoking cultural and political metaphors. These metaphors require ‘soft’ systems approaches for problem solving.

4.5. Synthesis

From Table 4.6, it is clear that the combination of soft systems and hard systems approaches is ideal for a cost-benefit analysis of transport infrastructure projects. The underlying metaphors associated with cost-benefit factors help practitioners to gain insights into difficult-to-understand phenomena and then to seek ‘appropriate’ methods for the CBA. It should be noted that the significant challenge for a CBA is to support the decision-makers to make an investment decision that can reach consensus, or at least a degree of acceptance, among key stakeholders. Thus, Soft Systems Methodology (SSM), addressed in Table 4.6, is appropriate for solving such problems. SSM was designed to tackle complex issues through systematic learning about the problem, decision-making processes, and levers of change (Checkland & Poulter, 2006).

SSM is an action research methodology. It has the advantage of allowing both researchers and practitioners to utilise conceptual models as a basis for structuring debates and discussions. In this way, issues arising due to conflicting objectives, needs, purposes, values and can be comprehensively understood and discussed (Checkland & Scholes, 1990). Using the SSM approach enables analysts and participants to better understand different perspectives of the situation, to identify the problem and then to solve it through *learning,* rather than through *the replacement of the current situation* with an accepted ideal solution (Checkland & Poulter, 2006). Four typical activities of SSM are: addressing the initial problematical; making purposeful activity models which are thought to be relevant to the situation (being built based on a worldview); using models to explore the real situation; and defining/taking actions to enhance the situation.

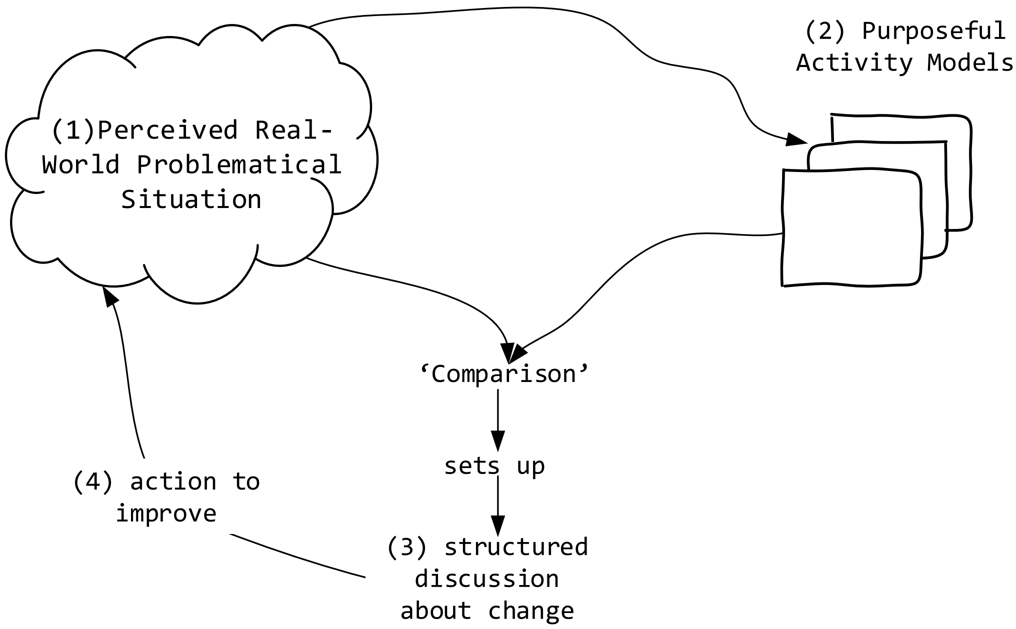


Figure 4.5. The iconic representation of SSM's learning cycle. Adapted from Checkland (2000)

The interesting point of SSM is it that it takes the 'messy' arguments of the real world caused by people having different perceptions and creates purposeful activity models (conceptual models) for comparison and finding the root causes of issues. However, conceptual models are not models of the real world that people experience (Burge, 2015) and this may create a barrier for practitioners in implementing the CBA program. In practice, the reliability and validity of cost-benefit information is often neglected (Williams & Samset, 2010) so this leads to irrational discussions between stakeholders. Thus, the researcher must clarify the differences between stakeholders' viewpoints using a 'hard' system to provide supplementary cost-benefit information that assists stakeholders in their debate: for example, project cost, travel time savings, transport cost reduction, project revenue estimation, environmental impacts, and project risks.

The learning cycle of SSM can be used as the main process for decision-making since SSM enables researchers to capture contrasting worldviews in the investment situation. SSM attempts to draw in and explore the diversity of viewpoints, and it accepts this difference between views as a part of the decision-making and intervention process (Flood & Jackson, 1991). The combination of SSM and 'hard' systems allows practitioners to take advantage of traditional methods and techniques that have been widely used over decades, overlaid with soft systems approaches. The initial outline of the combination of SSM and 'hard' systems is depicted in Figure 4.6. This outline provides an optimal way of structuring the proposed stakeholder-centric CBA framework.

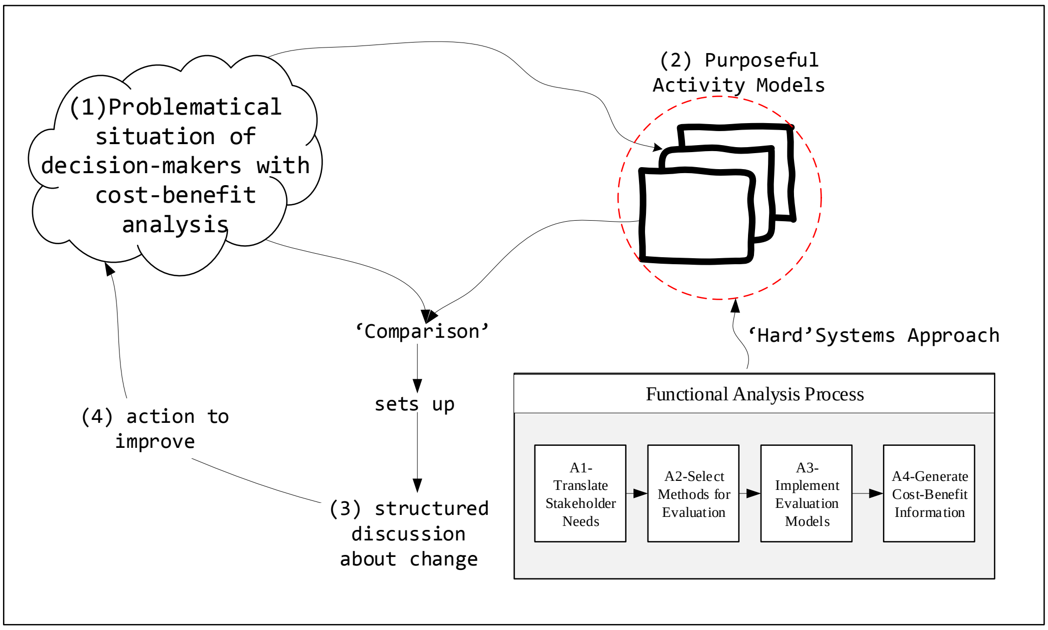


Figure 4.6. The outline of the combination of SSM and 'hard' systems approach in CBA. Adopted from Soft Systems Methodology's learning cycle (Checkland & Poulter, 2006)

In this diagram, the functional and analysis process box within a ‘hard’ system gives specific instructions to practitioners on how to produce cost-benefit information for comparison. The adoption of the stakeholder-centric CBA framework sets up logical sequential steps and the necessary processes for carrying out a comprehensive evaluation program for transport infrastructure projects. The stakeholder-centric CBA framework can be described as the combination of the learning cycle of SSM which is informed by the ‘hard’ system analyses processes to deal with both technical and social issues during the decision-making process. The following diagram is viewed as a cyclic process of a CBA in the feasibility analysis stage of investment projects (Figure 4.7). It is developed based upon figures 4.5 and 4.6 and elaborates seven concrete steps for implementation in practice.

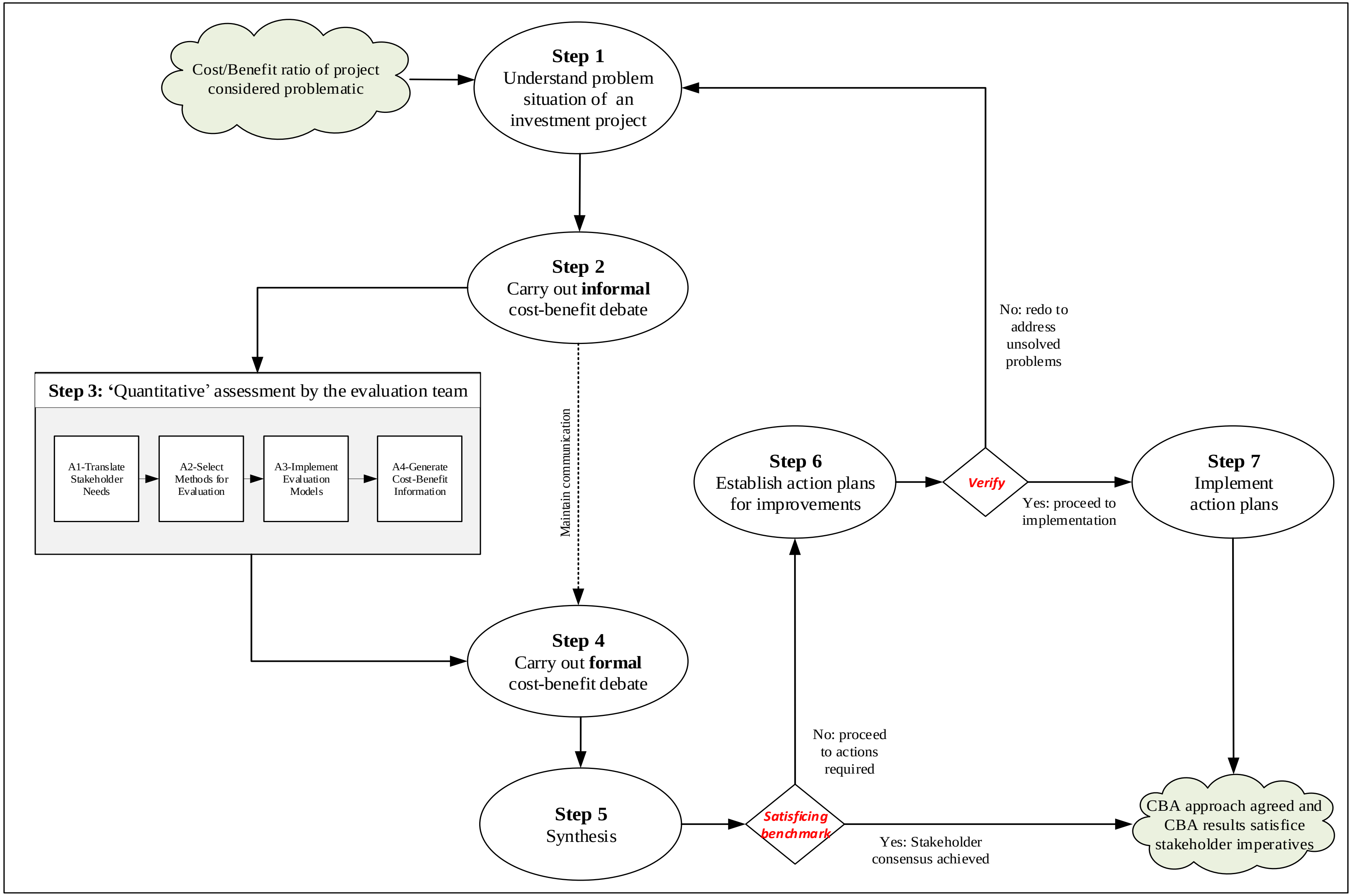


Figure 4.7. The stakeholder-centric CBA framework for transport infrastructure projects

In order to set up the 'hard' CBA system of the stakeholder-centric CBA framework (see Step 3 depicted in Figure 4.7), functional analysis or quantitative assessment is applied to capture system requirements and to develop 'hard' functions for assessment. Functional analysis is a top-down process that translates system requirements into detailed functional criteria used for program development (Blanchard, Fabrycky, & Fabrycky, 1990). The results of functional analysis are the identification of system functions and associated processes used for implementation. In this study, there are four functions of 'hard' CBA system, which are: A1-Translate Stakeholder Needs; A2- Select Methods, Tools and Techniques, A3- Implement Evaluation Models; and A4- Generate CBA Output. The description of each given function of the 'hard' CBA system is presented in the following points:

- Translate stakeholder needs (A1): According to Freeman (2010, p. 6), stakeholders are "any group or individuals who can affect or are affected by the achievement of the organisation/projects' objectives". Stakeholder analysis is an important step in project evaluation, since this step focuses on identifying stakeholder groups, defining the impacts of these groups on the project and recognising the potential impact of the project on them. This step uses common tools and techniques such as the House of Quality, Brainstorming, Nominal Group Technique, scenario building, and Delphi methods (Cook, 2013). In this research, the House of Quality (HoQ) method, which is a part of Quality Function Deployment (QFD), is ideal for understanding the stakeholders' voice. This method is used to develop a relationship matrix with different attributes to investigate the difference between the customers' perspective and the system engineering perspective (Appendix F).

- Select methods for quantitative evaluation (A2): There is a range of CBA methods, tools and techniques here. The success of a methodology has much to do with the choice of an appropriate tool (Jones, 1992). Each tool can be incredibly useful in the right situation and not all are appropriate for every problem of interest. However relying solely on one tool may not present the whole picture and may send the wrong message to decision-makers (Kennedy, 2009). Thus, it is essential to select the most appropriate CBA methods, tools and techniques with care, and apply them wisely. Based on previous studies, the author proposes nine attributes for method selection, including: Relevance, Acceptability, Cost, Data Requirement, Execution Time, Efficiency, Consistency, Learnability and Adaptability (Appendix C). The Evaluation team can use these attributes to assess candidate methods and to select the 'right' ones for assessment.

- Implement evaluation models (A3): This function focuses on implementing the selected methods and techniques for evaluation. Depending on cost-benefit factors and associated methods, project inputs are determined and collected for the evaluation program. Supporting tools may be used to generate the outcomes for comparison.

- Generate Cost-Benefit output (A4): Following the priority of cost-benefit factors within four groups (technical, financial, socio-economic and environmental), function A4 is operated to generate a full report to decision-makers; and vital information from the report can be sent to crucial stakeholders for debate.

Next, the IDEF0 format is used to produce a functional analysis process for the 'hard' aspects of the CBA system with functions addressed above (Figure 4.8).

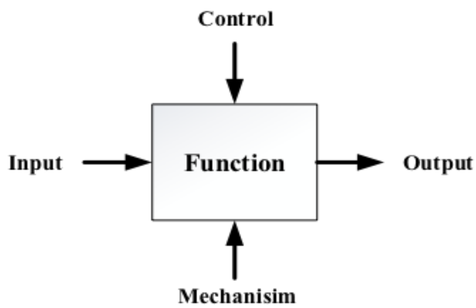


Figure 4.8. IDEF0 format. Adapted from ISO/IEC/IEEE-31320-1:2012(E)

The IDEF0 model here is based on a simple syntax that consists of four components: input, output, mechanism and control. Input refers to data, information and material that flow into a function. Similarly, the output is a result of function implementation. The implementation of a given function requires a mechanism that provides resources and tools to complete the function process. Control refers to constraints, regulations and conditions that can affect the functional performance. The operation of a 'hard' CBA system is depicted in Figure 4.9. For each given function of the 'hard' CBA system, all components of the IDEF0 model are carefully examined to identify required resources and constraints used for the 'hard' CBA functions' operation.

Figure 4.9 shows the unfolding of the sub-processes and factors required for operation. The whole process of generating supplementary information for the CBA can be carried out via the CBAFS software developed by the author. The details of CBAFS software are presented in Chapter 5 as a supporting tool for stakeholder-centric CBA framework implementation.

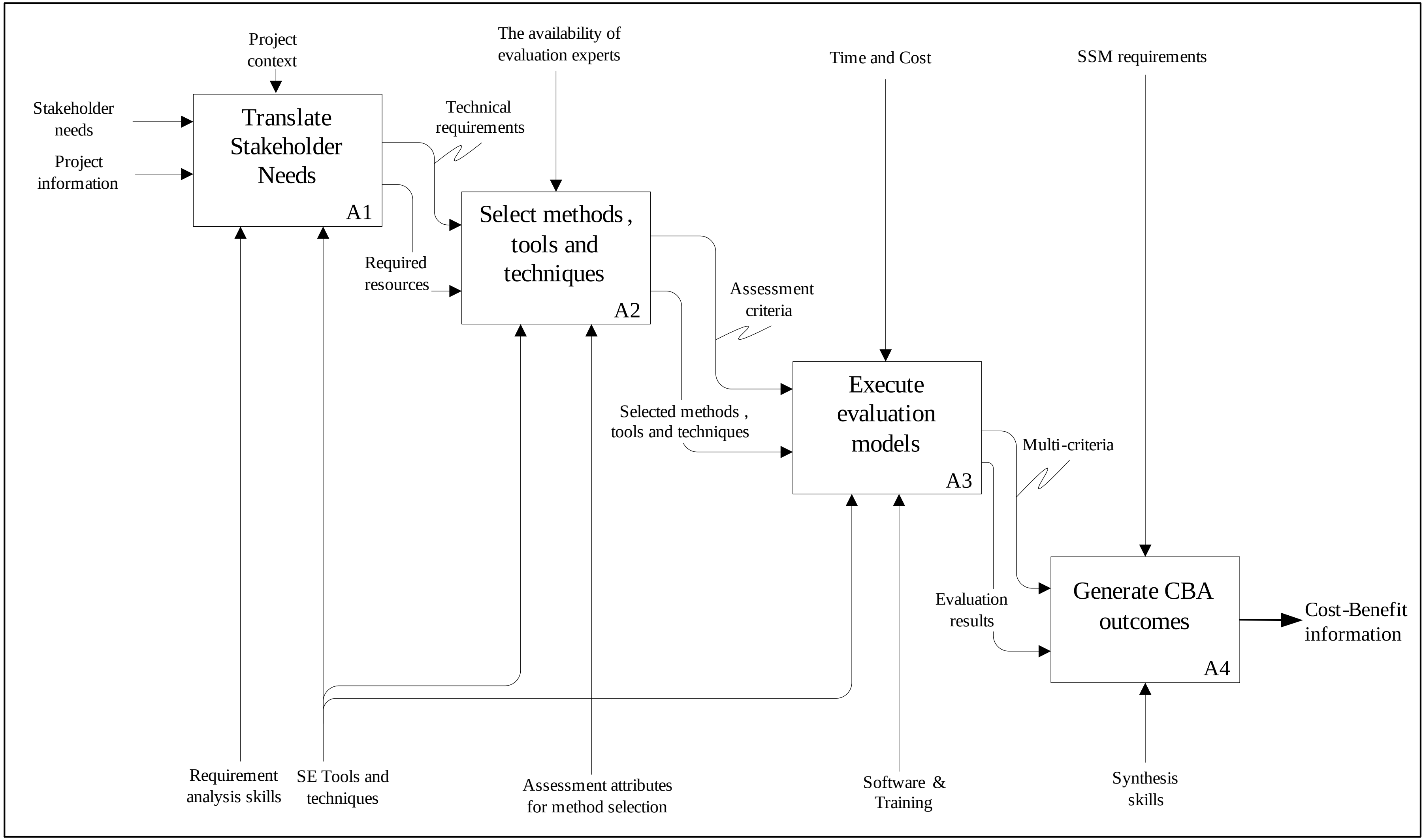


Figure 4.9. The expansion of 'quantitative' assessment system in Figure 4.7

(The flowchart of the hard CBA system)

4.6. The Description of the Stakeholder-Centric CBA Framework

In this study, the design of the stakeholder-centric CBA framework was firmly based on Functional Analysis and Allocation in Systems Engineering (INCOSE, 2015) and the International Standard 'ISO/IEC/IEEE 15288' for Systems and Software Engineering (IEEE, 2015). This section focuses on activities relevant to steps presented in the stakeholder-centric CBA framework for transport infrastructure projects.

Step 1: Understand the problem situation of the investment project

This step focuses on clarifying difficulties practitioners face with a CBA in making the investment decision. The situational problem is to make an investment decision that can be based on consensus among key stakeholders of the project. Because different stakeholders have different interests and levels of power, and, based on their worldview, may have different ways to interpret the CBA, this may create conflicts regarding project costs and benefits. Thus, it is essential to do a stakeholder analysis at this stage, then build a rich picture of the initial situation of problematic project investment. The CATWOE technique, proposed by Checkland and Poulter (2006), can be applied to identify a problematic situation (see Appendix G). In general, the Inputs-Activities-Outputs (IAO) diagram for Step 1 is depicted in Figure 4.10.

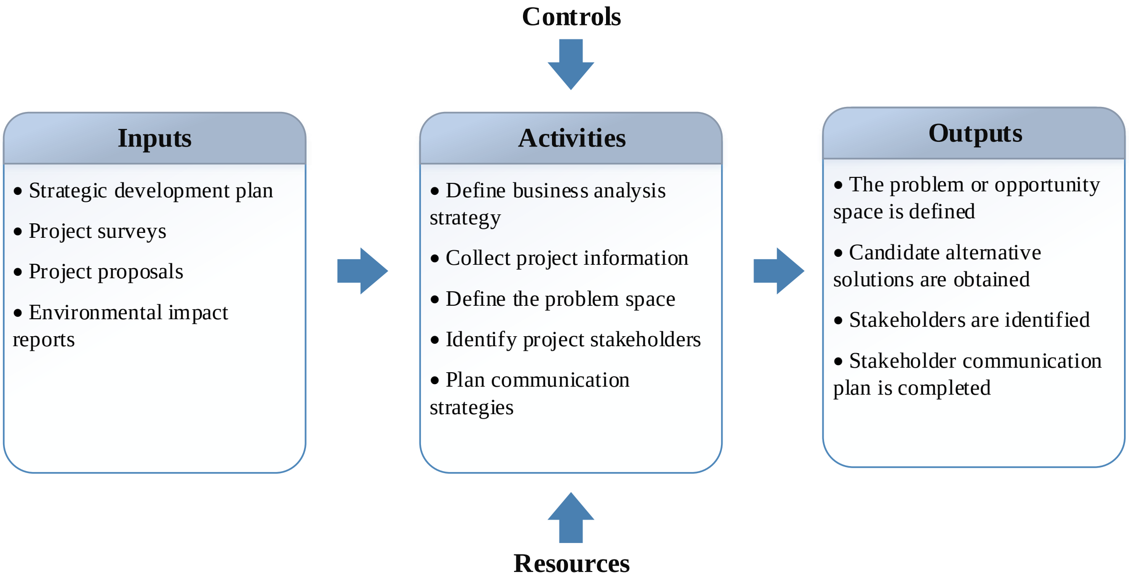


Figure 4.10. IAO diagram for problem situation identification

Step 2: Carry out informal cost-benefit debate

This step aims to create an open space for discussions between key stakeholders and the evaluation team. It provides initial opportunities for stakeholders to express their concerns and to discuss the significant issues of the investment project. Thus, no debate rules are applied, and no decisions are made at this step. This step empowers stakeholders to raise questions with other stakeholder groups and allows them to recognise the differences in evaluation viewpoints. In general, the IAO diagram for Step 2 is depicted in Figure 4.11.

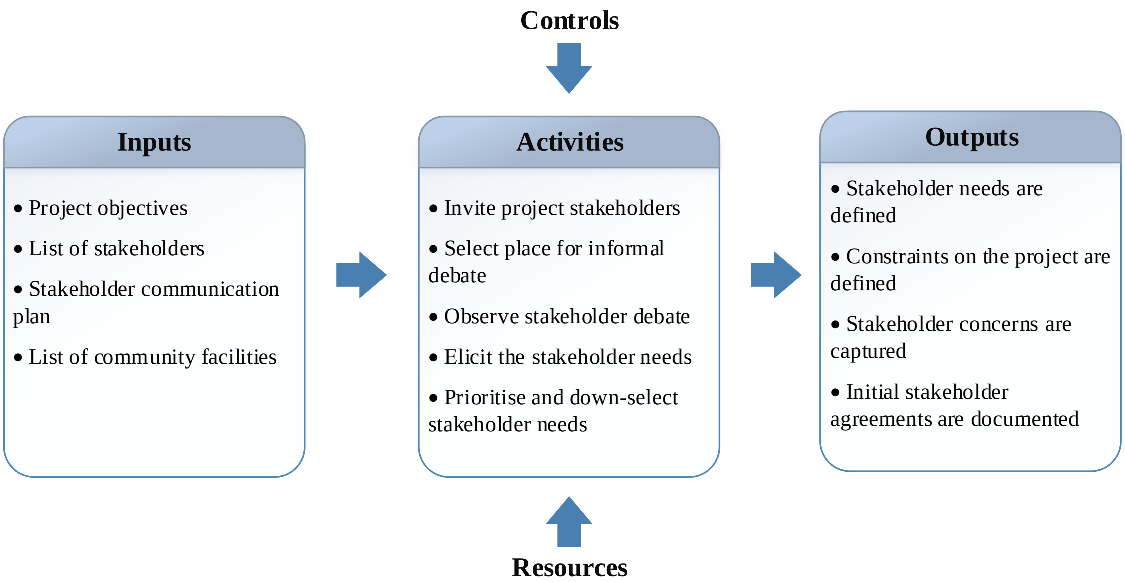


Figure 4.11. IAO diagram for informal cost-benefit debate

The evaluation team needs to be involved in this step to ensure that they have an opportunity to investigate barriers that may prevent stakeholders' consensus. The evaluation team can interact face-to-face with stakeholders to capture the actual needs of key stakeholders to be used for quantitative assessment. The outcome of the 'informal' debate provides insights into the stakeholder need analysis and allows the evaluation team to build up trust between them and stakeholder groups.

Step 3: Quantitative assessment by the evaluation team

This step focuses on translating stakeholder needs into specific requirements that can be identified and measured by the hard CBA system. As a result, the information generated from the 'hard' CBA system can be used as solid evidence for the 'formal' cost-benefit debate step of the stakeholder-centric CBA framework. In general, the IAO diagram for Step 3 is depicted in Figure 4.12.

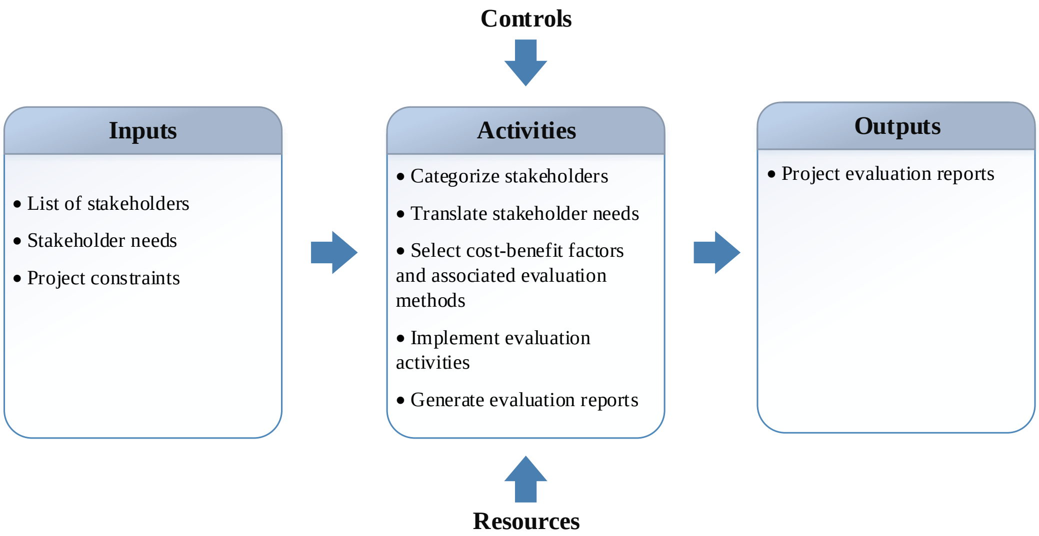


Figure 4.12. IAO diagram for quantitative assessment

In this study, the whole process of generating supplementary information for the CBA is carried out via the CBAFS software developed by the author. The details of CBAFS are presented in Chapter 5.

Step 4: Carry out formal cost-benefit debate

The formal debate is a vital part of the stakeholder-centric CBA framework which aims to provide a constructive dialogue between key parties about the need for project investment. In general, the IAO diagram for Step 4 is depicted in Figure 4.13.

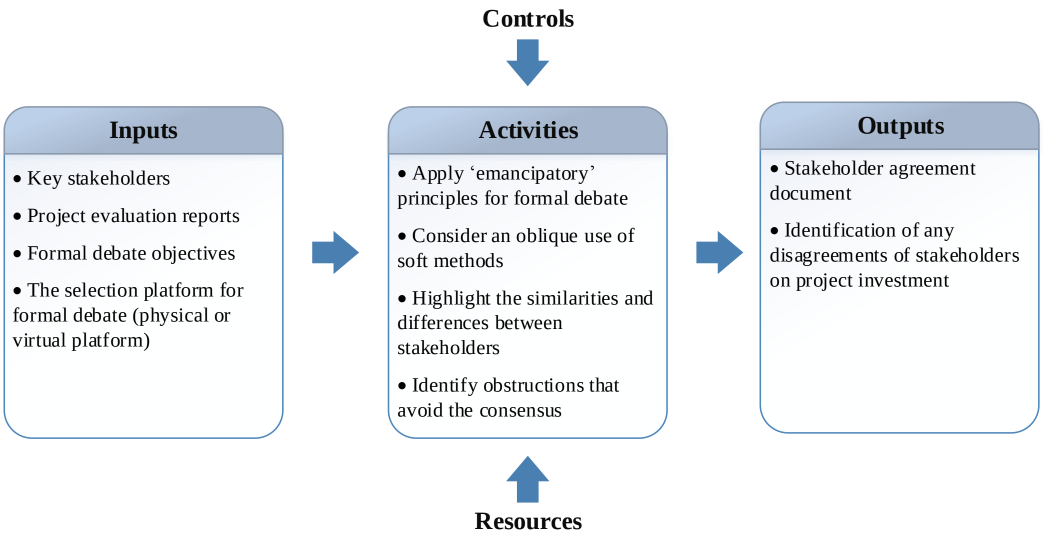


Figure 4.13. IAO diagram for formal cost-benefit debate

If the formal debate is to be held in person, Figure 4.14 presents five steps for this process.

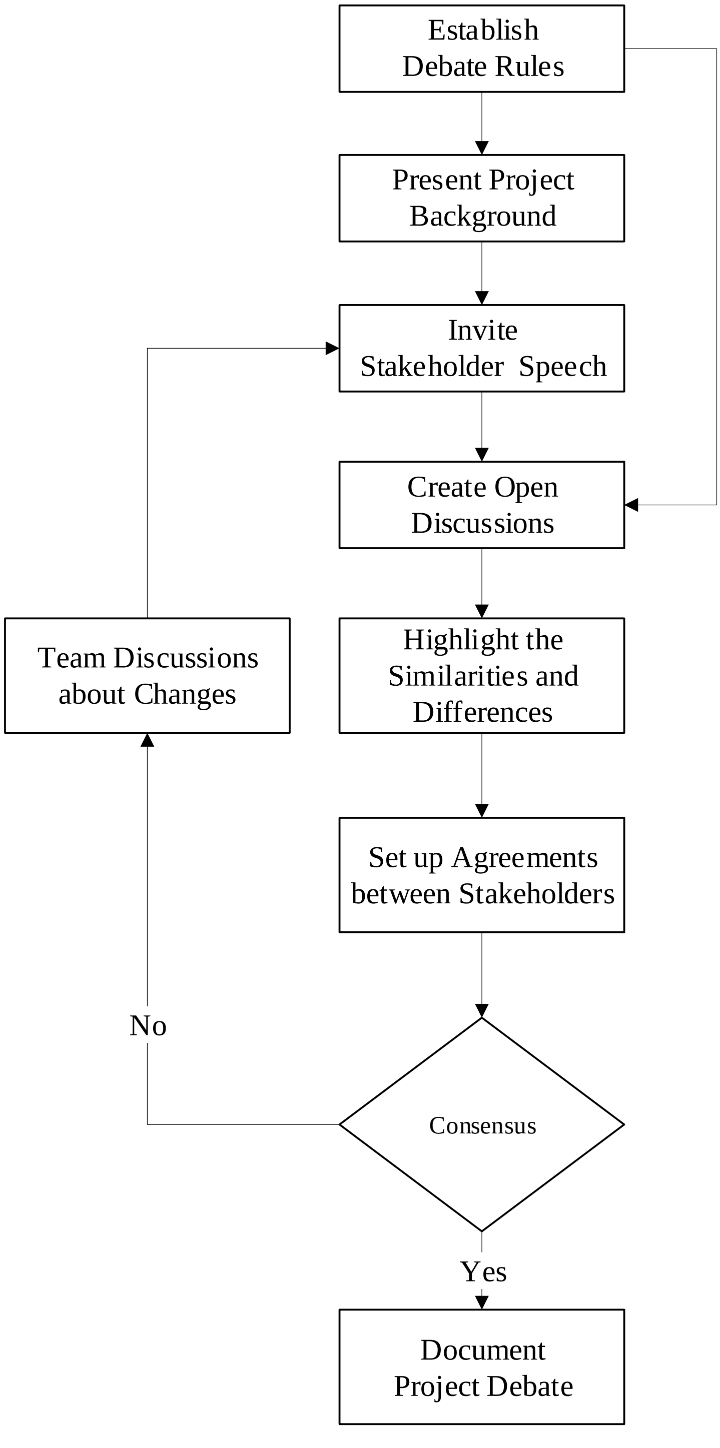


Figure 4.14. The flowchart of formal cost-benefit debate

To better understand and anticipate conflicts between stakeholder groups in construction projects, Yang et al. (2009) reviewed stakeholder theory and distributed 654 questionnaires in Hong Kong. From their research, the authors extracted the main factors contributing to the success of stakeholder engagement, including:

- Explore stakeholder needs and constraints regarding projects;
- Communicate and engage stakeholders frequently and adequately;
- Understand the areas of stakeholder interest;
- Analyse conflicts and coalitions among stakeholders;
- Assess stakeholder attributes;
- Formulate appropriate strategies to manage stakeholders;
- Effectively resolve conflicts among stakeholders;
- Predict stakeholders' reactions to implementing strategies;
- Respond to stakeholders' behaviour.

Often the debate between stakeholder groups is carried out in a coercive environment where contentious viewpoints seem to be resisted by those in a position of power. Instead of using an emancipatory method to deal with issues in a context perceived to be coercive, Flood and Romm (1995) consider an oblique use of methods. Using a method in an oblique way means confronting a situation in which people may feel threatened from a less direct angle (not the direct angle which is usually employed). Each method was designed to serve its purpose, and therefore the use of a soft method to tackle issues of coercion directly could possibly fail.

Therefore, soft methods need to be shaped by an oblique use resulting in a slight modification of the basic approach. Using this approach, practitioners (decision-makers) can create an open space for those involved (and affected) so that they will become less defensive about their positions. At the same time, decision-makers may generate a shift in consciousness across stakeholder groups, so that the cost-benefit information of the project proposal may start to be reinterpreted in a way which is more comfortable for all affected groups. Midgley (1997) stated that coercion is usually characterised by closure of a debate, so it is important to empower people to challenge the situation in an open space. In this research, several options for an oblique use of soft methods are:

- Option 1: An oblique use of soft methods at the beginning stage of the stakeholder debate. This option focuses on inviting stakeholders themselves to set up debate rules for their discussion. This approach repositions stakeholders at the centre of the decision-making process, and it allows stakeholders to interact proactively and to negotiate with others. This exercise is conducted first, so that solutions can be tested. In this case, stakeholders' viewpoints are acknowledged and appreciated, and the likelihood of understanding the differences in outcomes increases.

- Option 2: An oblique use of soft methods at the middle stage of the stakeholder debate. This option focuses on creating an open space for stakeholder discussion. Different stakeholders have different foci, including policymakers (scarcity of resources), the local community (lack of relevant knowledge), and business owners (loss of opportunity cost). People have a chance to approach the CBA from different angles, through methods such as brainstorming and scenario building, and thus the likelihood of understanding in evaluating perspectives is strong.

- Option 3: An oblique use of soft methods at the end stage of the stakeholder debate. This option focuses on setting up agreements between key stakeholders. The evaluation team should focus on the 'right' person who is representative of key stakeholder groups to communicate with the team. The typical technique for dealing with this problem is negotiation which aims to reach the benefits of cross-stakeholder collaboration. In other words, the outcome of the negotiation task needs to match the minimum requirements of critical groups, such as landowners, the local community and business owners.

Another option for the formal debate is to use a virtual debate website. The details of this option are presented in Chapter 6 with a real case study in South Australia.

Step 5: Cost-Benefit debate synthesis

A synthesis process is usually carried out after every debate. This process aims to summarise the results of the formal stakeholder debate. In general, the IAO diagram for Step 5 is depicted in Figure 4.15.

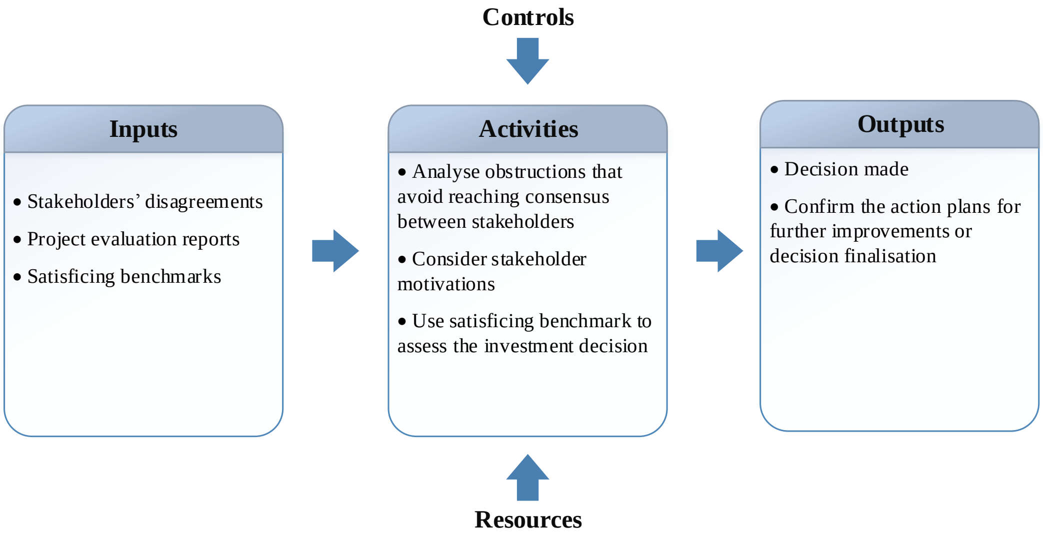


Figure 4.15. IAO diagram for cost-benefit debate synthesis

In practice, the cost-benefit debate is a complex process and there is no way to identify the 'best' option for decision-making (see Appendix Q). Thus, 'satisficing' benchmarks for decision-making are proposed. Satisficing is considered as a 'good enough' approach that permits satisfaction at a specified level of all needs (Simon, 1956). The unique features of the 'satisficing' approach are to provide a holistic viewpoint, with no clear causality, unknown solutions, non-linear interaction and bottom-up decision-making (Gorod, Nguyen & Hallo, 2017). Regarding transport infrastructure projects, a 'good' investment decision is defined as a decision that can reach a sufficient degree of consensus between critical stakeholders: thus, the degree of 'consensus' is a key principle in establishing 'satisficing' benchmarks for decision-making.

Table 4.7. Establishing a 'satisficing' benchmark for decision-making

Benchmark	Yes	No
1/ Address key stakeholder concerns.		
2/ Reflect stakeholder motivations.		
3/ Allow stakeholders to be involved in the analysis process.		
4/ Satisfy minimum technical requirements: • Urban Master Plan; • Design, Construction and Operation; • Traffic Forecast Volume; • NPV, IRR, and B/C.		
5/ Be feasible with resources allocation: • Cost; • Time; • Human Resources.		

The investment decision should only be made if the project proposal can satisfy all 'satisficing' benchmarks presented in Table 4.7. If the level of agreement is sufficient, consensus between key groups is achieved and the representatives of decision-makers can finalise their decision; otherwise, the evaluation team needs to have further discussions to clarify any obstacles which are impeding reaching an accommodation between stakeholders. Thus, the synthesis process in the stakeholder-centric CBA framework can lead to the following positive outcomes:

- Agreement on making the investment decision: This situation occurs when the stakeholder debate is fruitful. In other words, consensus between stakeholder groups is achieved. Stakeholder groups are aware of the difference in the evaluation perspective, and they are willing to accept a gap in views to set up formal agreements. The decision-makers (such as The Department of Transport Infrastructure and Planning) can rely on such agreements to finalise the investment decision on whether the project should be planned and executed. This situation is an ideal case where the cooperation between stakeholders is achieved in the first or second round of debate.

- Agreement about the need for further discussions about the changes: This case refers back to the problematic situation of decision-makers when stakeholders defend their positions and viewpoints during the cost-benefit debate. As a result, the occurrence of conflicts requires the evaluation team to review the situation and to establish action plans to rectify the differences, which are presented in Step 6.

Step 6: Establish action plans for improvements

Discussions about the changes refer to activities/tasks required to improve the decision regarding the investment project. In general, the IAO diagram for Step 6 is depicted in Figure 4.16.

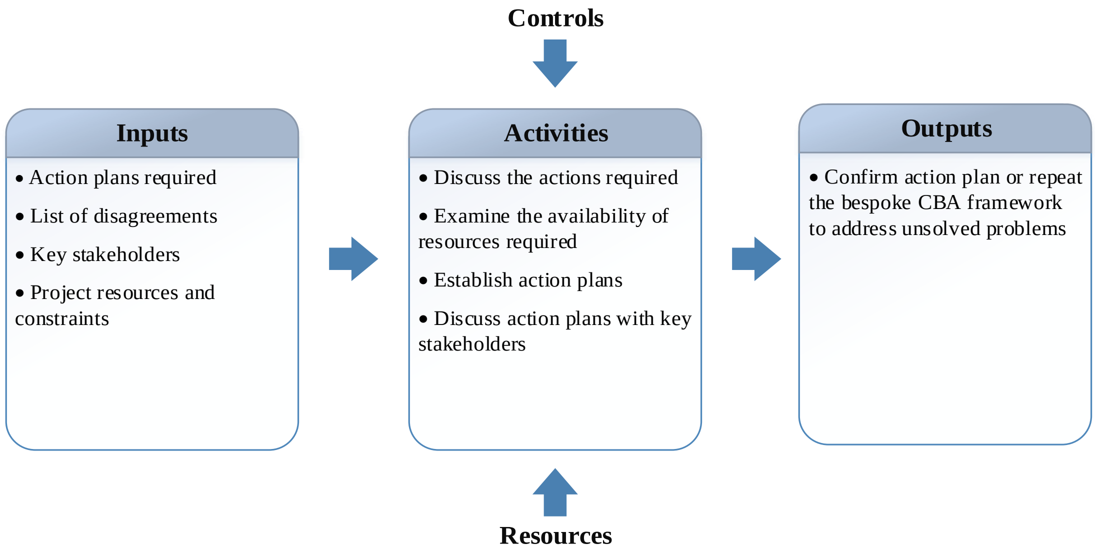


Figure 4.16. IAO diagram for establishing action plans

In some cases, when stakeholders have serious conflicts regarding project benefits and viewpoints, they may not reach consensus in the first or second round of debate. Figure 4.17 illustrates a typical example for building an action plan to improve the problematic situation of CBA interpretation.

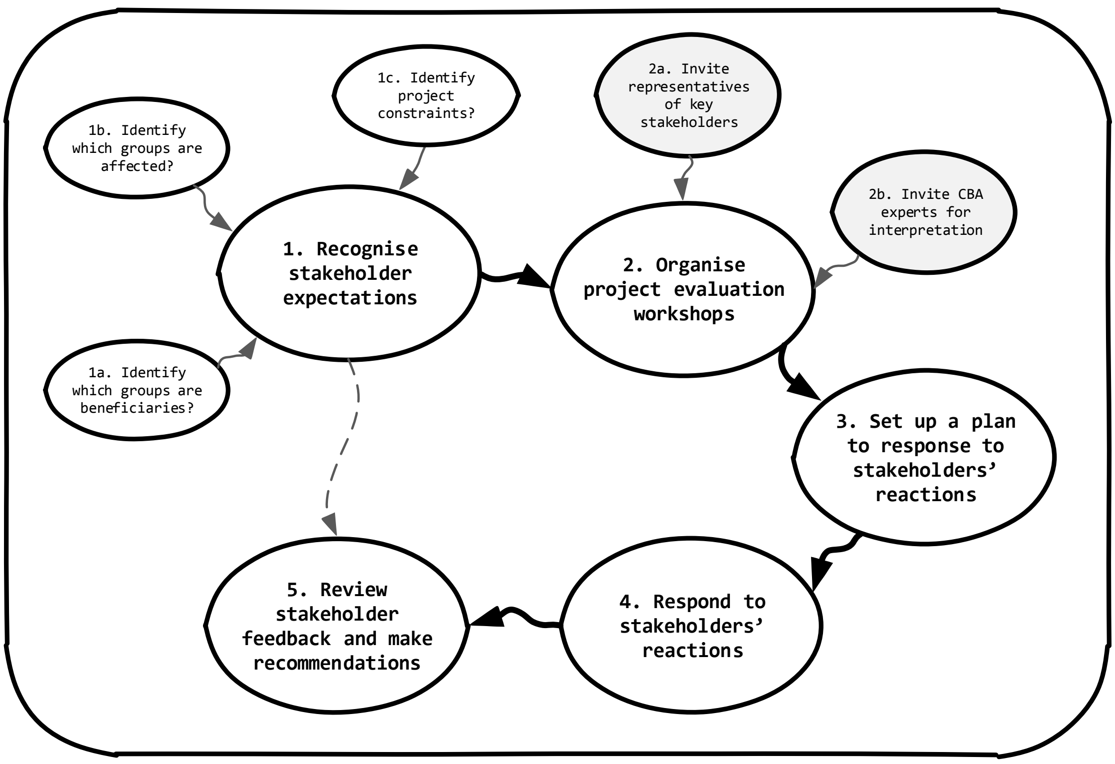


Figure 4.17. An example of an action plan for improvement

In this example, the assumed situation is based on the evaluation team determining that the main obstruction to reaching consensus is the lack of project information regarding the benefits of the investment. People tend to pay much more attention to their most salient aspect in interpreting the outcome of project investment. They may over emphasise project impacts without strong evidence used for justification. Hence, the evaluation team decides to set up an action plan to improve the problematic situation by providing additional information concerning the benefits.

Step 7: Implement action plans

The evaluation team starts to implement actions to improve the problematic situation of the CBA. In general, the IAO diagram for Step 7 is depicted in Figure 4.18.

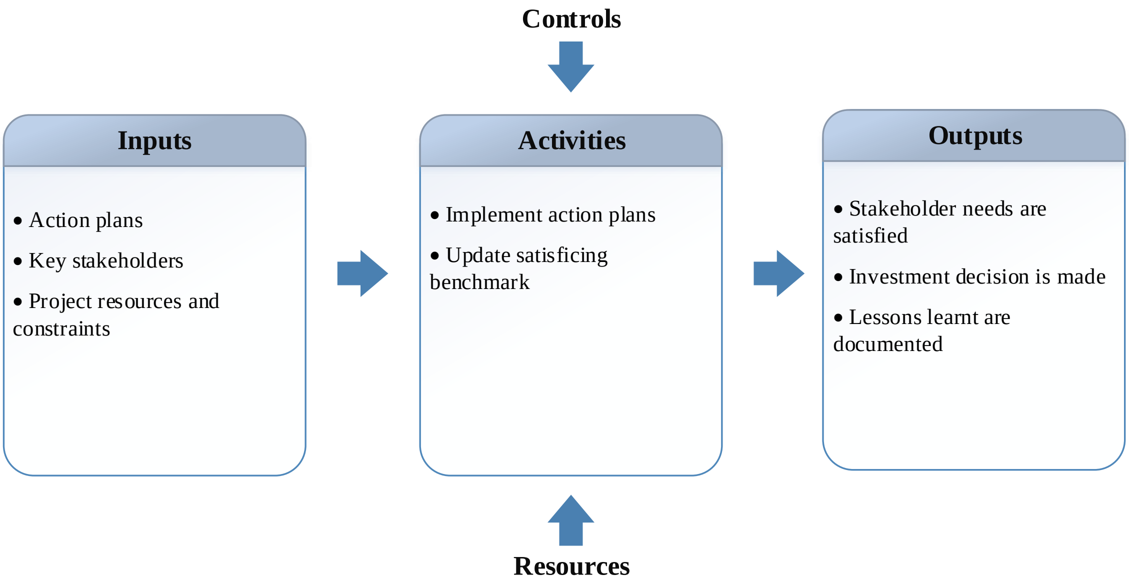


Figure 4.18. IAO diagram for implementing action plans

In accordance with the example presented in step 6, the team members carry out the following activities: firstly, they invite the representatives of key stakeholder groups to participate in a project evaluation workshop to provide them with basic concepts. Secondly, they provide evaluation reports to key stakeholders to obtain their feedback. Next, the team members establish a plan to respond to stakeholders' reactions via a range of channels such as public media, websites, and social workshops. In addition, the evaluation team reviews stakeholders' feedback to document their major concerns before making suggestions to decision-makers. As a result, the evaluation team is able to understand the differences between evaluation positions and to recognise obstructions (e.g. areas of conflicts) which prevent accommodation between the key parties.

The details of an action plan are described in Chapter 6 with a real case study in Australia.

4.7. Summary

Chapter 4 has focused on clarifying the difficulty in making investment decisions for transport infrastructure projects. The differences between viewpoints and ways of interpreting these significant issues can create barriers to reaching consensus among the key stakeholders of an investment project. This chapter discusses the problem of selecting methods and techniques for a CBA and then presents the Total Systems Intervention (TSI) approach as a way to tackle this issue. The rationale of the TSI selection is expressed via its philosophy. The stakeholder-centric CBA framework represents a combination of Soft Systems Methodology (SSM) and ‘hard’ CBA system approaches to deal with the difficulties of cost-benefit analysis for a specific project, considering the four main groups of factors: technical, financial, socio-economic and environmental. The implementation of the stakeholder-centric CBA framework requires seven steps: an understanding of the problematic situation, informal cost-benefit debate, ‘quantitative’ assessment, formal cost-benefit debate, synthesis, together with the selection of action plans for problem situation improvement. The backbone of the stakeholder-centric CBA framework is the project cost-benefit debate with stakeholders. The oblique use of soft methods during the cost-benefit debate process is carefully examined to ensure that stakeholders have opportunities to contribute their voices to the project proposal without the involvement of power being exercised. The steps for stakeholder-centric CBA framework implementation, as presented in this chapter, allow practitioners readily to establish their evaluation program. The next chapter focuses on software design for ‘hard’ CBA system. The case study, used to illustrate the applicability of the stakeholder-centric CBA framework follows, is presented in Chapter 6.

Chapter 5

A Supporting Tool for the Stakeholder-Centric CBA Framework

5.1. Introduction

Chapter 5 opens with a discussion about the need to develop a supporting tool for the stakeholder-centric CBA framework. It then focuses on describing the procedure applied to develop the supporting tool for a CBA to be used in transport infrastructure projects. This chapter continues with a full description of the fundamental steps to be applied for coding and testing. The next section provides details on the functions to be implemented and explains the utility of the software. The conclusion summarises the critical points discussed in this chapter and highlights the contributions of the supporting tool in assisting with the implementation of the stakeholder-centric CBA framework.

5.2. The Need to Develop the Supporting Tool

From the CBA literature, two main research problems have been identified: achieving stakeholder engagement and selecting evaluation methods for a CBA. The stakeholder-centric CBA framework (SCF), therefore, was proposed and presented in Chapter 4 to address these problems. The skeleton of the SCF relies mainly on two major components. The first component is a 'soft' system analysis which is built through the adoption of the SSM learning cycle to tackle the stakeholder engagement issue. The second part is the 'hard' system CBA analysis of the infrastructure project of interest that is constructed to provide supplementary information for the cost-benefit debate among stakeholders as presented in **Step 4** of the SCF. The combination of 'soft' and 'hard' systems approach in the proposed framework is intended not only to allow decision-makers to deal with stakeholder issues but also to improve the probability of success of the 'picking and mixing' strategy of methods and techniques used in CBA for transport infrastructure projects.

Traditionally, the 'hard' CBA system approach is the main approach utilised to provide quantitative information to support the decision-making process regarding investment projects. The 'hard' CBA system approach, in particular, is selected to provide a systematic procedure for analysis and associated assessments that can be documented in evaluation reports to investors. However, the role of the ‘hard’ CBA system in the SCF is significantly amended in this new approach. Practitioners use the ‘hard’ CBA system approach to provide supplementary information for stakeholder debate, rather than using it as a basis for making direct recommendations for investment decision-makers relying on their own judgements. In accordance with the functional design presented in Chapter 4 (see Figure 4.9), the hard CBA system within the proposed framework has four main functions: (A1) translate stakeholder needs into technical requirements, (A2) identify cost-benefit factors and associated evaluation methods, (A3) implement evaluation activities, and (A4) generate cost-benefit information. These four main functions were designed to be executed in sequential order to provide reliable information for the stakeholder debate.

In order to optimise the functional analysis of the ‘hard’ CBA system, the researcher has developed software that enables practitioners to reduce the complexity involved in the analysis and also to reduce the time needed for evaluation activities. The software application (Cost-Benefit Analysis Facility Software; CBAFS) enables non-expert evaluators to confidently calculate the CBA for transport infrastructure projects: for example, in terms of traffic forecast, debt service assessment, financial assessment, economic assessment, and risk evaluation. The unique advantage of CBAFS is that it allows users to select evaluation methods and implement these methods, a possibility which is not available in other software used in this domain. In addition, the CBAFS is designed to serve the purpose of simplifying the complicated ‘hard’ processes of the SCF and to reduce the time for implementation. Thus, its role is maximised when CBAFS is used in a collaborative way (rather than in a separate way) with the ‘soft’ aspect of the proposed framework for transport infrastructure projects.

Chapter 5 identifies that a supporting tool is needed to:

- Guide practitioners to select evaluation methods for CBA. Instead of simply using conventional methods (e.g. discounted cash flow techniques, residual value method, and shadow price method), practitioners are then able to identify and select a comprehensive set of methods that may provide useful information for the stakeholder debate step of the SCF.

- Support practitioners to investigate the sensitivity of input parameters to various assumptions associated with different project scenarios. In particular, analysts can establish project inputs based on stakeholder viewpoints to test whether a project is feasible or not.

- Generate supplementary information quickly for the cost-benefit debate. The use of the CBAFS as presented in this research enables users to:
    - promptly execute assessment functions
    - proactively report the evaluation outcome to decision-makers
    - provide the required information to the key stakeholders of transport infrastructure projects before the cost-benefit debate.

5.3. The Construction of Cost-Benefit Analysis Facility Software

The process used to develop CBAFS includes four stages: identifying software requirement(s), design, coding and debugging, and testing. These stages are carried out in sequential order as depicted in Figure 5.1 below.

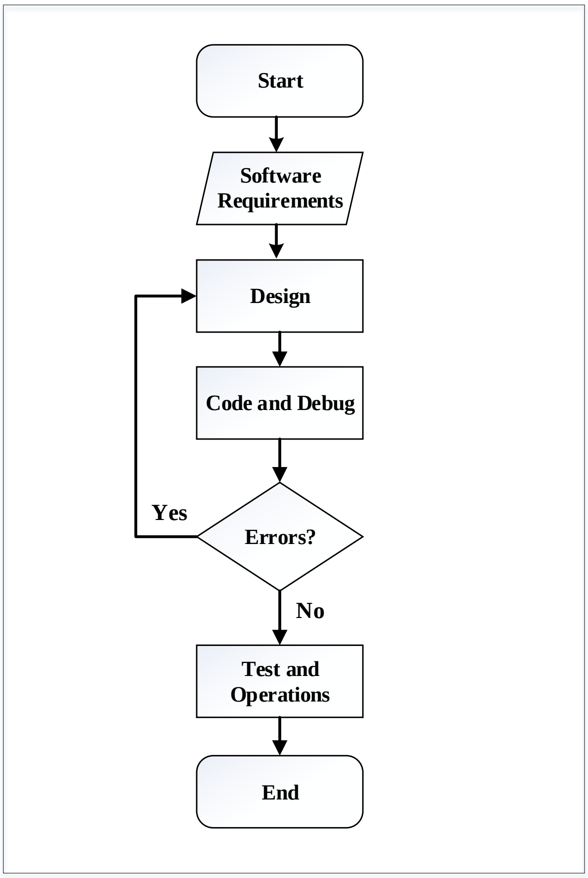


Figure 5.1. Software development process. Adopted from Boehm (1983)

From the identification of functional system requirements as presented in Chapter 4 for the 'hard' CBA system, the researcher has focused on defining the software requirements and associated features used for design.

5.3.1. Software requirements

A software requirement specification is a description of a software system which is to be developed (Sommerville & Sawyer, 1997). Software requirements consist of three distinct levels: business requirements, user requirements, and functional requirements. In addition to these three given software requirement types, every system has an assortment of non-functional requirements or constraints on the service of functions offered by the system: for example, reliability, total cost, and time.

Firstly, business requirements describe the benefits the organisation hopes to achieve (Wiegers & Beatty, 2013). In order to do so, the focus remains on the objectives laid out by the organisation itself and/or its customers who request the system. For CBAFS, the researcher's goals are analogous to business objectives. In particular, CBAFS is intended to reduce the time for establishing 'hard' CBA processes and calculations. It also reduces the cost of training in analytical skills for non-expert users. The implementation of CBAFS can improve the accuracy and effectiveness of evaluation activities, and this plays a vital role in providing evidence for stakeholder debate. Moreover, the use of CBAFS enables project evaluators to investigate the sensitivity of input parameters based on the given assumptions. In accordance with changes from inputs and outputs, identified project scenarios can provide insights into discussions between team members about the potential cost and benefit of an investment project. For example, any change in the project cost estimation can lead to a change in financial assessment outcome, therefore the evaluation team can set the input variance (e.g. +/-10%) to the total investment cost to observe the change of assessment results and make predictions.

Secondly, user requirements describe goals and/or tasks that users must be able to perform using the product to provide value to customers (Wiegers & Beatty, 2013). Typically, user requirements reflect the viewpoint of users, so readers with only general knowledge (rather than detailed information on subjects resulting from formal studies) should be able to read and understand the requirements outlined. In this study, the main user requirements for the CBAFS are that the software must have the capacity to support users, to assist with data acquisition and to establish connecting links, whilst performing evaluation functions. From the early stage of CBAFS design, it was determined that the intended users would be non-expert evaluators who have only basic computer skills and little experience in establishing evaluation programs. Thus, other basic user requirements relate to user interface, software performance, and data backup. This user interface requirement creates the need for a sophisticated interface with simplicity of use as depicted in Figure 5.2.

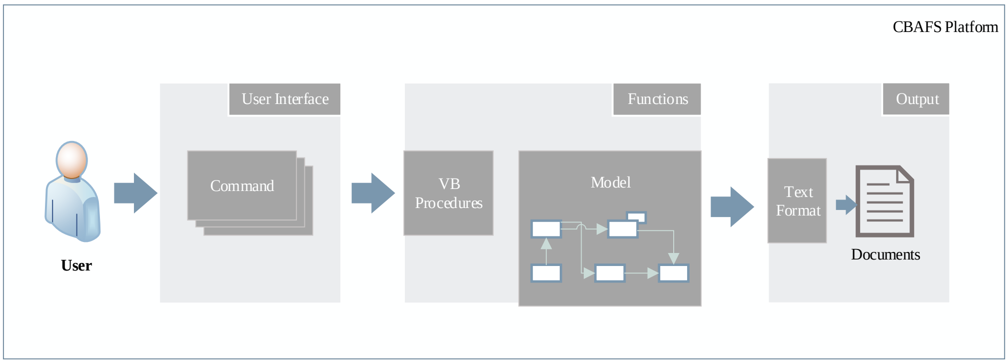


Figure 5.2. Overview of CBAFS platform

Figure 5.2 is a block diagram of the CBAFS that illustrates the connectivity between the user and the program. The CBAFS automatically creates the attribute data file and users can modify this file according to their needs. The operation of text generation relies on the data stored in the attribute data file to produce the final text report. CBAFS tasks are typically performed by different system functions such as running programs, importing data, and printing reports.

Thirdly, functional requirements specify the behaviour the product exhibits under a specific condition (Wiegers & Beatty, 2013). Functional requirements are described as details that the developer must implement to enable users to accomplish their tasks, thereby satisfying the business requirements. These functional requirements may involve calculations, technical details and processes that define what a system is intended to accomplish. In the case of CBAFS, the four main functions that need to be performed in the following sequence are: (A1) translate stakeholder needs into technical requirements, (A2) identify cost-benefit factors and associated methods, (A3) implement evaluation activities, and (A4) generate cost-benefit information. The specifications of behaviour between inputs and outputs for each of these functions are presented below in Figure 5.3

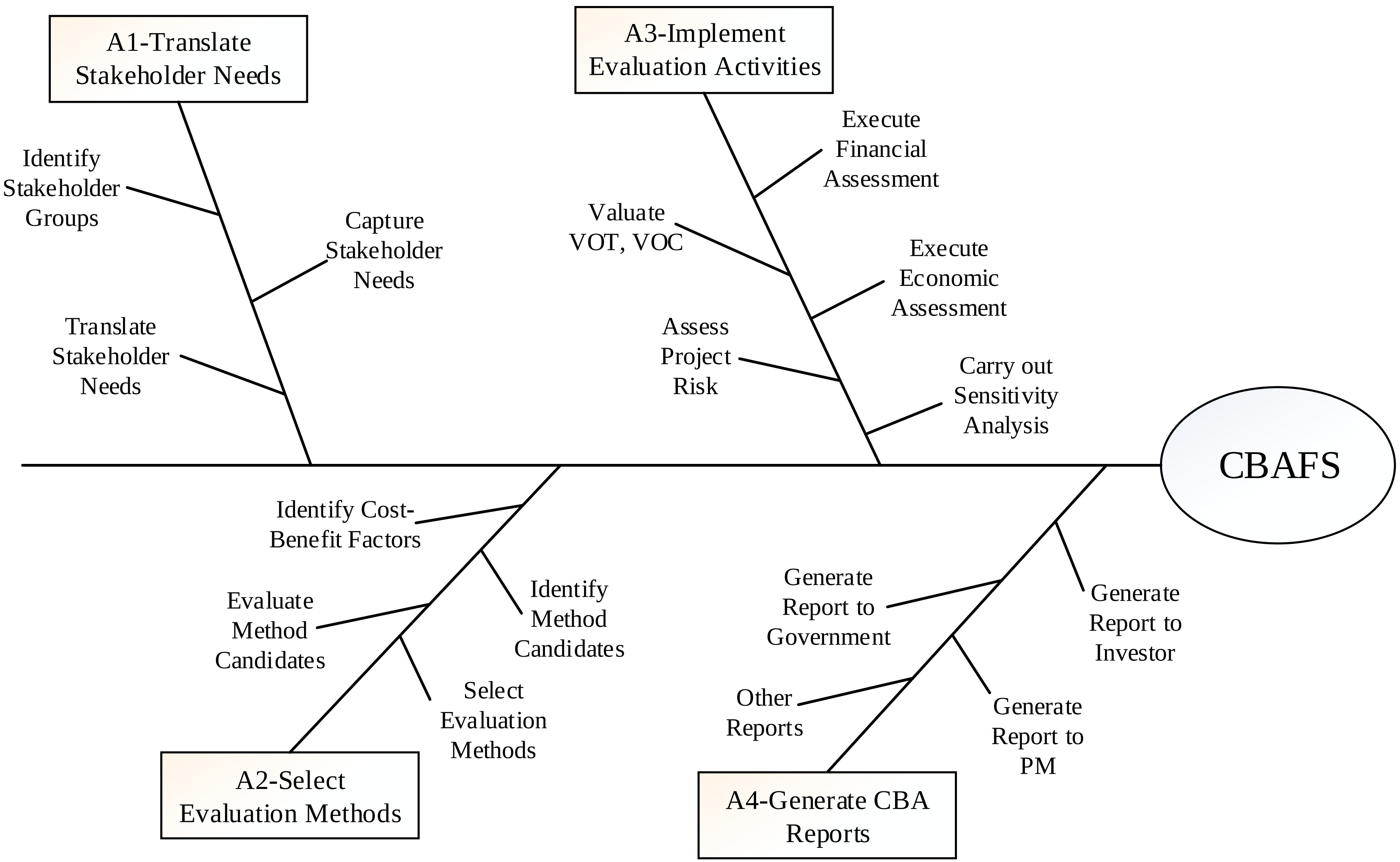


Figure 5.3. Partial feature tree for the CBAFS

The Feature Tree presented in Figure 5.3 is a hierarchical diagram that is used to depict the features of the four functions of the 'hard' CBA system. The main functions of the CBAFS are broken down into sub-functions to improve the readability and testability of the code. The details of sub-functional requirements are presented in Table 5.1 below, and these are used to specify the inputs and outputs of CBAFS.

Table 5.1. Software functional requirements

Translate Stakeholder Needs:	**Functional Requirement Descriptions**
Identify Stakeholders	The CBAFS shall display the list of potential project stakeholders for transport infrastructure projects. It allows users to select key groups that are relevant to their project context.
Capture Stakeholder Needs	For each selected group, the CBAFS shall display archetypal primary stakeholder needs (see Appendix D) and allow users to select stakeholder needs for project evaluation.
Translate Stakeholder Needs	The CBAFS shall display the direct link between stakeholder needs and technical interpretations. It shall allow the user to select measurement attributes associated with given stakeholder needs. It shall also prompt the user to confirm the attributes used for evaluation.
Select Evaluation Methods:	**Functional Requirement Descriptions**
Identify Cost-Benefit Factors	Based on the measurement attributes identified (e.g. transport cost savings, traffic accident rate, and number of generated jobs), the CBAFS shall show a list of relevant cost-benefit factors. It shall display the connection between measurement attributes and cost-benefit factors. It shall allow the user to select salient factors that should be incorporated into project evaluation.
Identify Associated Methods	Once cost-benefit factors are confirmed, the CBAFS shall automatically show a list of promising methods used for cost-benefit measurement. It shall notify the user to confirm the selection.
Evaluate Method Candidates	In order to specify methods used for evaluation, the CBAFS shall enable the user to rank methods in accordance with seven

	criteria: relevance, acceptability, cost, data requirements, execution time, efficiency, consistency, learnability and adaptability (see Appendix C). The CBAFS shall show the assessment results and notify the user to confirm their final selection.
Select Evaluation Methods	The CBAFS shall display the availability of methods that were designed in the current version of the software to support the user. For unavailable methods, the CBAFS shall notify the user to carry out supplementary evaluation activities for analysis.
Implement Evaluation Activities:	**Functional Requirement Descriptions**
Evaluate Travel Time Savings	The CBAFS shall display input parameters used for the evaluation of travel time. It shall notify the user to enter the required parameters for calculation. The CBAFS shall prompt the user to confirm, cancel or edit input parameters before generating the outcome.
Evaluate Operating Cost Savings	The CBAFS shall notify the user to enter the required input parameters for evaluating vehicle operating cost savings. Once the information is confirmed, the CBAFS shall show the status of information and generate evaluation results.
Execute Financial Assessment	The CBAFS shall display a list of input parameters for financial assessment, and it should allow the user to fill in the information required. Once the user finishes this task, it shall display a message to confirm input parameters for assessment. Results generated shall be displayed in the form of financial indicators.
Execute Economic Assessment	The CBAFS shall automatically link input parameters from the financial analysis (e.g., investment cost, operational cost, and maintenance cost) and display this information to the user for confirmation. Once the information is confirmed, the CBAFS shall show assessment results in the form of project economic indicators.
Assess Project Risks	The CBAFS shall display a list of common risks associated with CBA groups (technical, financial, socio-economic and environmental)

	and ask the user to select risk factors that may affect the project implementation outcome. Once the user assigns quantitative values (e.g. time and cost) for each risk factor, the CBAFS shall notify the user to confirm the information. The results generated from this sub-function shall display in the form of quantitative risk assessment (e.g. ISO 31000-2009).
Carry out Sensitivity analysis	The CBAFS shall display the main input parameters for the evaluation of an investment project (e.g. traffic growth rate, investment cost, operational cost, maintenance cost, etc.) and allow the user to set up the variance between the base case and various scenarios. Once the information is entered, the CBAFS shall prompt a message to the user for confirmation. The results generated from the CBAFS shall be displayed in the form of charts and performance indicators for comparison and analysis.
Generate CBA Information:	**Functional Requirement Descriptions**
Report to Investor	The CBAFS shall contain a generic outline of an evaluation report. It shall allow the user to edit the outline and add supplementary information in accordance with the need of the business owner. Once the outline is confirmed, the CBAFS shall automatically transfer evaluation results into the report and export the document in Microsoft Word format.
Report to Government	Similarly, the CBAFS shall permit the user to select the outline of a formal report for the government. The CBAFS shall prompt a message to the user for editing and confirmation. Once the report outline is confirmed, the CBAFS shall automatically export the evaluation report in the form of Microsoft Word.
Report to Project Manager	The report to the project manager covers all aspects of the project. Thus, the CBAFS shall notify the user to confirm the evaluation report outline and then export it to a Word document.

The final requirement refers to non-functional requirements, which are related to assumptions and dependencies of the CBAFS. First, the operating environment selected for running the software needs to ensure that the CBAFS can run on all computer systems. In this study, the operating system selected is Microsoft Windows; and Microsoft Excel is selected as the main platform for CBAFS execution. Second, the User Interface must be simple, convenient and securable. The User Interface Standard, proposed by Mayhew (1992), is selected to conform with the CBAFS screen display since it provides practical guidelines for developing a clear software interface, including dialog styles and organisation of functionality to support user tasks. Third, if any errors occur during calculation, the CBAFS shall enable the user to recover an incomplete worksheet and to continue working on it. Finally, the CBAFS should have a 'help' link shown on its main menu to provide specific guidelines to users for operation and testing.

5.3.2. Design and coding

The design and coding of CBAFS was directed by the following three design principles from Gulliksen et al. (2003), which consist of user focus, active user involvement and simple design representations. The details of these principles are stated below:

- User focus – the primary focus of the CBAFS is to support non-expert users to use 'hard' CBA systems approaches for project evaluation. CBAFS is intended to allow users to provide key project cost-benefit information to key stakeholders for their debate and to support decision-makers to finalise the investment decision.

- Active user involvement – during the CBAFS development process, feedback from colleagues was elicited to review the functionality of CBAFS and its features. Based on these comments, the researcher re-examined the CBAFS functionality and made some modifications to User Forms design.

- Simple design representations – the CBAFS design relies on the Microsoft Excel platform, so its design is quite simple and easy for users who have basic Excel skills (e.g. using simple functions like sum, average, max and min) to follow the instructions and carry out evaluation activities for project evaluation.

In this study, the researcher selected the Visual Basic (VB) programming language for coding CBAFS. VB is a third-generation event-driven programming language and integrated development environment (IDE) from Microsoft (Microsoft, 2018). The first version of VB was released in 1991 and it has been widely applied for developing Microsoft applications. The developer can simply create an application by using the existing components of VB (Plant & Murrell, 2007). Programs written in VB can use the Windows Application Programming Interface (API), which requires external function declarations. A dialect of Visual Basic, Visual Basic for Applications (VBA), is used as a macro or scripting language within Microsoft Office. Below is the rationale behind choosing Visual Basic programming language to develop the CBAFS:

- Firstly, VBA is already built into Excel, so users do not need to buy a separate program and spend time on installing it and learning complicated skills *plus* the user can run the software on any personal computer (PC) that has Microsoft Excel 365 installed. This reduces the incompatibility between CBAFS and other software installed and minimises user frustration.

- Secondly, VBA consists of many built-in functions (Sengupta, 2009) including many financial and statistical functions that can support developers to simplify the work associated with developing various models. These functions are similar to the functions that are built into MS Excel, which increases users' confidence in using the CBAFS framework. The CBAFS output is exported in the two Microsoft supported formats (Word document (.docx) and Excel sheets (.xlsx)) that allow the users to edit the evaluation report outline in line with the stakeholders' requirements.

Visual Basic has three types of module: the user form, the standard module, and the class module. The user form contains controls, such as buttons and text boxes. Users can code event-driven procedures that are invoked when a particular event occurs on a particular control, thereby creating a user interface. The standard module contains a collection of one or more procedures (subprogram between Sub and End Sub). The class module contains both data and procedures and acts as one object. Once created as a class module, the user can create any number of instances by naming each instance as an object variable.

In this study, the researcher followed three main steps in designing the CBAFS as shown in Figure 5.4 below: (1) calculation flowchart construction, (2) user form design and (3) coding for the standard module and the class module.

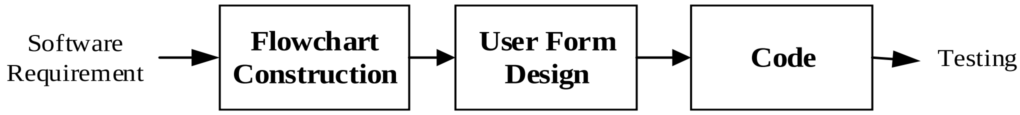


Figure 5.4. The main steps for CBAFS design

The first step focuses on establishing flowcharts for mathematical models (Figure 5.5 below) before moving to building conceptual models that work on the Excel platform. Examples of these include traffic forecast, financial assessment, economic assessment model, and risk assessment. The flowchart is a visual representation of data flow, and it is extremely useful in writing a program or algorithm. The flowchart can explain or spell out the logic behind a program **before** ever starting to **code** the process (Furey, Wilson, Hillier, Kent, & Haussler, 1973; LucidChart, 2018).

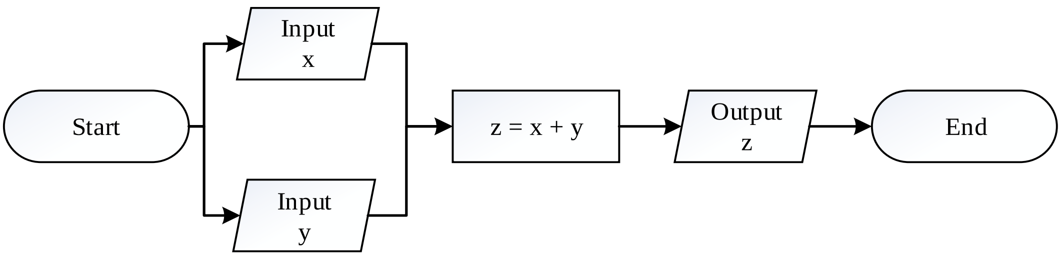
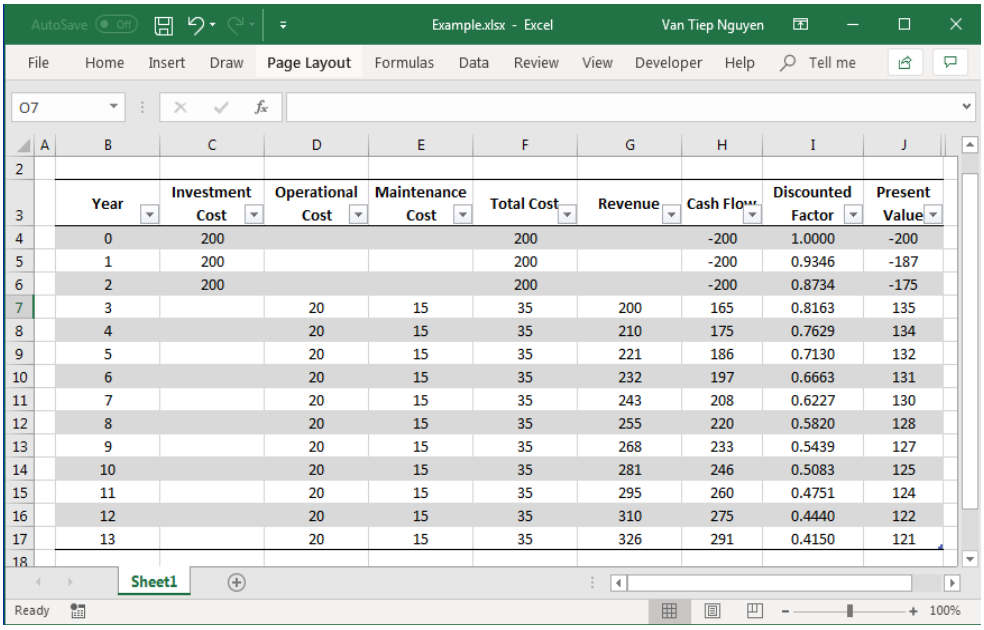


Figure 5.5. Basic flowchart for model building

Once the flowchart for the assessment models is built, the developer can specify input parameters as well as expected outputs for the required functions. Next, formulae and built-in Excel functions are used to construct the calculation models for the CBAFS. The researcher starts with simple models for analysis and investigates whether the model can still work under alternative parameter settings. A typical example of conceptual model building for project financial analysis is depicted in Figure 5.6 below.



Year	Investment Cost	Operational Cost	Maintenance Cost	Total Cost	Revenue	Cash Flow	Discounted Factor	Present Value
0	200			200		-200	1.0000	-200
1	200			200		-200	0.9346	-187
2	200			200		-200	0.8734	-175
3		20	15	35	200	165	0.8163	135
4		20	15	35	210	175	0.7629	134
5		20	15	35	221	186	0.7130	132
6		20	15	35	232	197	0.6663	131
7		20	15	35	243	208	0.6227	130
8		20	15	35	255	220	0.5820	128
9		20	15	35	268	233	0.5439	127
10		20	15	35	281	246	0.5083	125
11		20	15	35	295	260	0.4751	124
12		20	15	35	310	275	0.4440	122
13		20	15	35	326	291	0.4150	121

Figure 5.6. A typical example of financial conceptual model building

The second step is to use the toolbox provided by the VBA to design the user form. A toolbox in VB consist of Controls, Containers, Menu Options, Crystal Report Controls, Data Controls, Dialogs, Components, and Printing controls which can be integrated in a form to design the interfaces of an application (Microsoft, 2018). The toolbox provides a range of tools, such as frame, label, text box, comboBox, commandButton, optionButton, and image for user form design. An overview of the toolbox, together with the user form platform, is depicted in Figure 5.7 below.

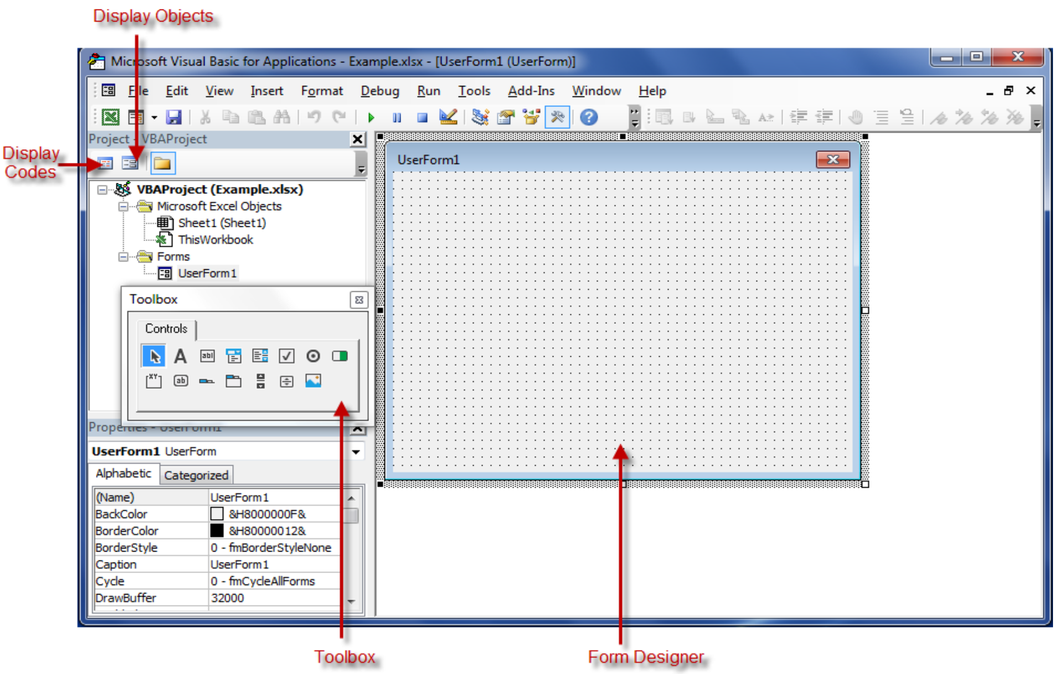


Figure 5.7. The initial screen of toolbox and the User Form in VBA

User Form is a dialog box used to collect input data from the user at the start of a macro that expands automatically into a set of instructions to perform the required tasks. The generated User Form often has a validation code that is added to ensure all required inputs are of the correct type. The User Form can be altered to make the design more attractive in appearance by both moving and resizing the controls (Microsoft, 2018). The design mainly depends on input data and on the developers' own experience. The User Form design should be simple and readable for setting the parameters to ensure that the user understands the information required. In addition, it should notify the user about errors occurring during the data entry process. The software may have a number of user forms, thus, the developer needs to ensure the consistency of user forms at the initial software design stage before moving on with further details. Figure 5.8 below illustrates the typical User Form designed for a project financial assessment model.

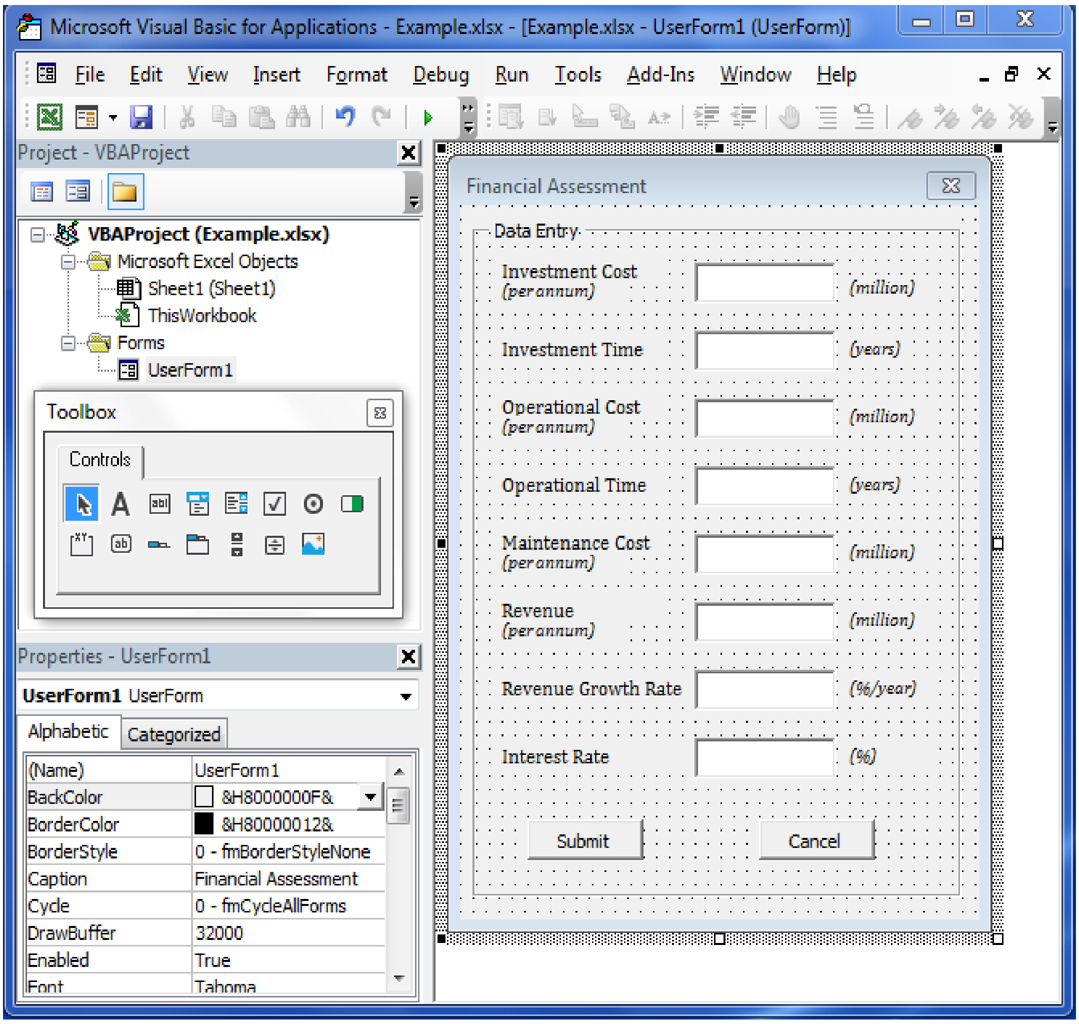


Figure 5.8. User Form for financial assessment model

In the next step, the researcher needs to model the function behaviour through the coding task. The compulsory requirements for the researcher are to understand the principles and fundamental components of VB, including the main procedures, statements, objects, classes, collections, methods, variables, constants, syntax, and data flow. In VBA, number, strings, and date are the three types of data that are usually used. VBA offers the users the choice of the following data types: Byte, Boolean, Integer, Long, Single, Double, Currency, Decimal, Date, Object, String, Variant and User-Defined. In order to illustrate the coding process, the statement below is a typical example of VBA Code for financial assessment:

```
Private Sub Command Button Click ()
'1/Set Financial Table Titles
With Sheets("Financial Analysis")
        .Range("C3").Value = "Project Financial Analysis"
        .Range("C3").Font.Name = "Cambria"
        .Range("C3").Font.Size = 25
End With
'1.1/Set the Calculation Worksheet
With Sheets("Financial Analysis")
        .Range("C5").Value = "Years"
        .Range("D5").Value = "Land Cost"
        .Range("E5").Value = "Construction Cost"
        .Range("F5").Value = "Maintenance Cost"
        .Range("G5").Value = "Operational Cost"
        .Range("H5").Value = "Interest"
        .Range("I5").Value = "Total Cost"
        .Range("J5").Value = "Traffic Forecast"
        .Range("K5").Value = "Toll Rate"
        .Range("L5").Value = "Revenues"
        .Range("M5").Value = "Cash Flow (CF)"
        .Range("N5").Value = "Discounted Factor"
        .Range("O5").Value = "Present Value(PV)"
        .Range("P5").Value = "Cumulated Present Value"
```

```
End With
'1.2/Set the Number Format
Dim I, j As Long
j = CLng(CoB_constructTime.Value) + CLng(CoB_operateTime.Value)
For i = 6 To j + 6
  With Sheets("Financial Analysis")
          .Range("C" & i).Value = i - 6
          .Range("D" & i).NumberFormat = "$#,##0"
          .Range("E" & i).NumberFormat = "$#,##0"
          .Range("F" & i).NumberFormat = "$#,##0"
          .Range("G" & i).NumberFormat = "$#,##0"
          .Range("H" & i).NumberFormat = "$#,##0"
          .Range("I" & i).NumberFormat = "#,##0"
          .Range("J" & i).NumberFormat = "###,###"
          .Range("K" & i).NumberFormat = "$#,##0"
          .Range("L" & i).NumberFormat = "$#,##0"
          .Range("M" & i).NumberFormat = "$#,##0"
          .Range("N" & i).NumberFormat = "#,##0.0000"
          .Range("O" & i).NumberFormat = "$#,##0"
          .Range("P" & i).NumberFormat = "$#,##0"
End With
Next i
'1.3/Set the Initial Values
Dim tConstruct As Long
tConstruct = CLng(CoB_constructTime.Value)
'1.4/Add Maintenance cost and Operational cost
With Sheets("Financial Analysis")
   For i = tConstruct + 7 To j + 6
      .Range("F" & i).Value = CoB_maintainCost.Value * 1000000
      .Range("G" & i).Value = CoB_operateCost.Value * 1000000
   Next i
End With
```

...

'1.14/Group Columns

```
Sheets("Financial Analysis").Range(Cells(5, 3), Cells(j + 6, 16)).HorizontalAlignment = xlHAlignCenter
Sheets("Financial Analysis").Columns("D:H").Select
Selection.Columns.Group
Sheets("Financial Analysis").Columns("J:N").Select
Selection.Columns.Group
'1.15/Hidden the User Form
A413_financialAnalysis.Hide
End Sub
```

A snapshot of the VBA code is depicted in Figure 5.9 below, based upon the design of User Form as depicted in Figure 5.8 earlier.

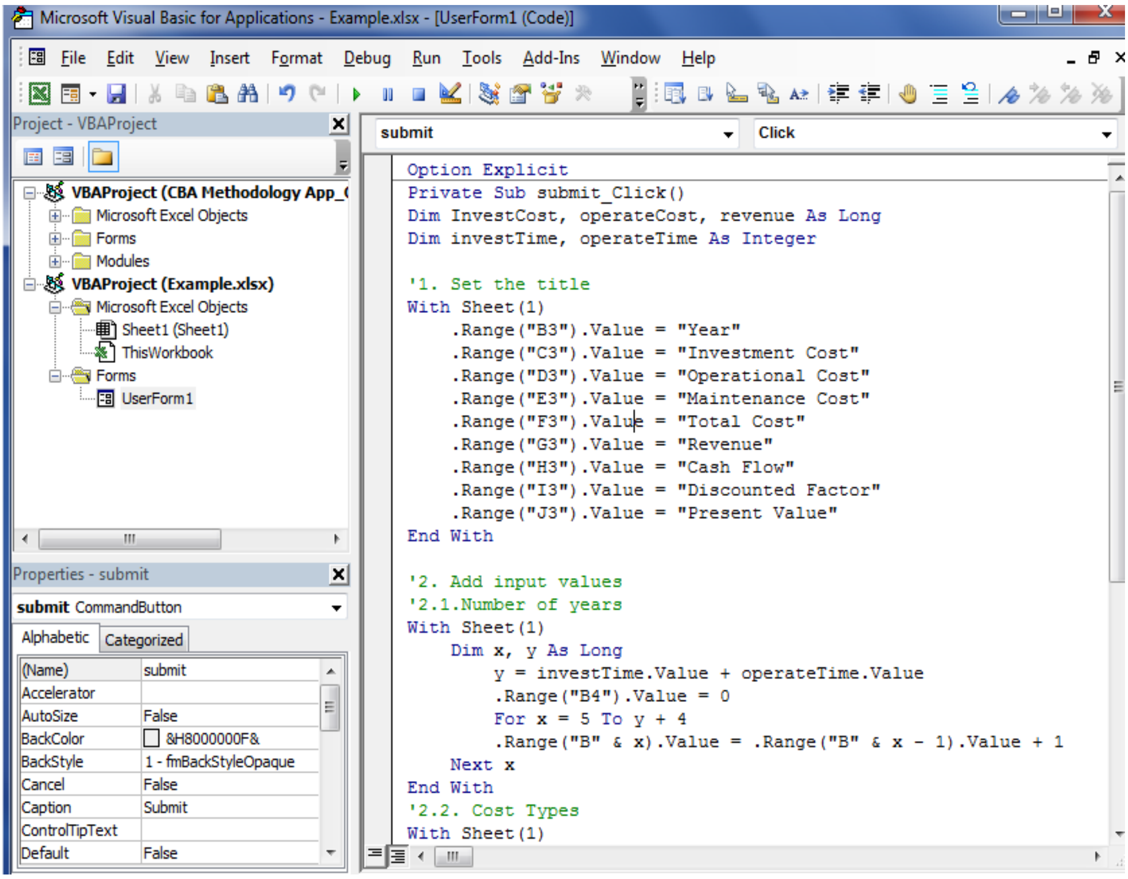


Figure 5.9. Code window for a standard module

During the coding process, several rules are applied to maximise the outcome of programming, such as establishing a naming convention for entities, variable declaration, methods verification (arguments), consistency in style, formatting, and error handling. In addition, VBA is widely applied in application development, so the code library provides useful information sources for research such as Functions (e.g. Ifs, Fors and Loops used for the execution of typical codes as many times as needed), Numbers, Dates and Times.

5.3.3. Testing and operation

According to the ANSI/IEEE 1059 Standard**,** testing is the process of analysing a software item to detect differences between existing and required conditions (i.e., defects) and to evaluate the features of the software item (P. Mathur, 2008). Testing is required to ensure that the functions behave as required under specific conditions as coded in the software. Testing is the most time-consuming part of any VBA project. During the project development period, developers often use 20% of their time for analysing and designing, 15% for programming, and 65% for testing an application (Leclerc, 2018). In the testing phase, the developer concentrates on correcting bugs, typos and logical errors to ensure the application is fully functional and runs smoothly. More importantly, during the testing phase, the developer can improve the original project, fine tune it, and/or discover better ways for coding an application (Leclerc, 2018).

In general, there are five methods used to debug VBA code, as follows:

- Stepping Through Code: This method supports the programmer to check the VBA code line-by-line in order to detect minor errors such as spelling, typing and grammatical rules. The developer needs to put the cursor on the first line of code to be analysed and to press ‘F8’ or choose to ‘Step Into’ on the Debug menu. The next line of code to be executed will be displayed using a black font against a yellow background. If the code calls another procedure, stepping through the code with F8 will cause execution to enter the called procedure in a line-by-line.

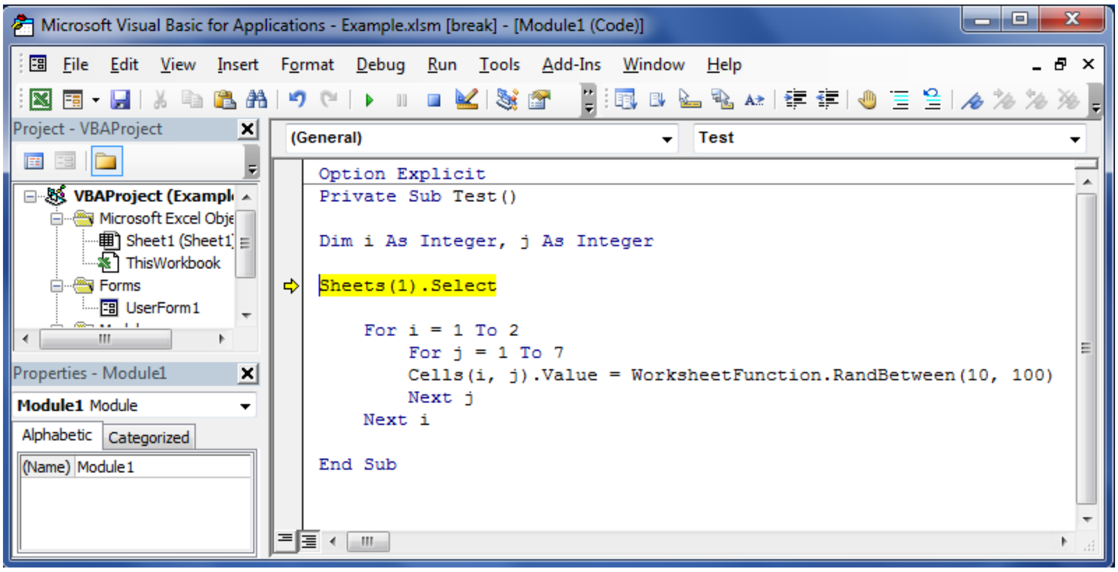


Figure 5.10. The illustration of stepping through code

- Break Points and The Stop Command: this method allows the developer to run parts of code that are bug-free while pausing the execution of the macro at the area that needs further investigation and testing. A break point is a marker placed on a line of code that causes execution to pause immediately before executing that line. When the developer runs the code, the execution will pause immediately before the line of code with the break point and will display it against a yellow background.

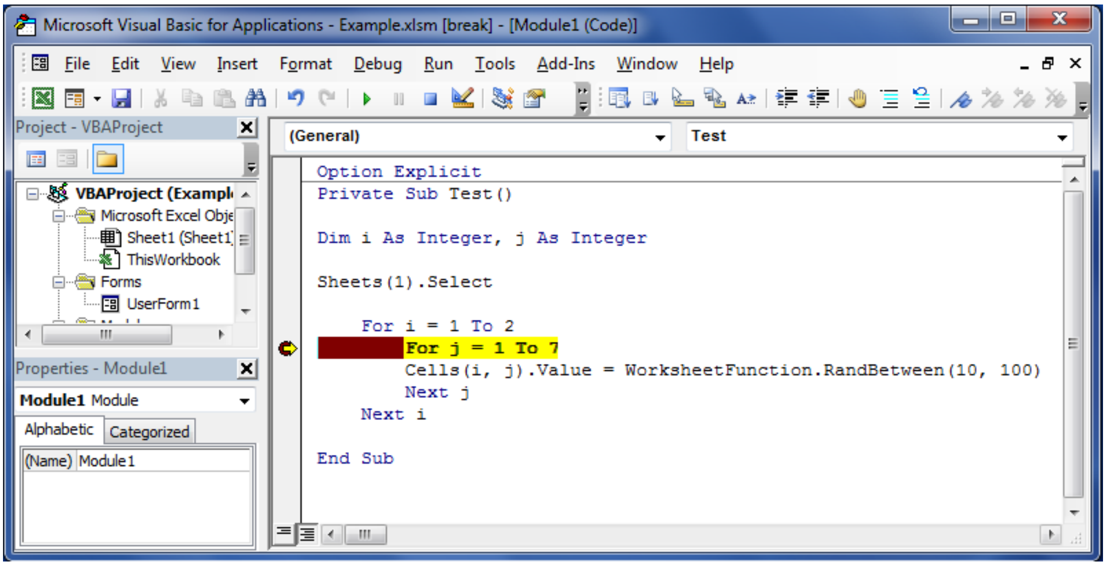


Figure 5.11. The illustration of break points

- The Debug Command: VBA provides a Debug object with two properties: Print and Assert. The developer can use both of these properties to display a variable's value and to control the program flow. 'Debug.Print' will write what follows to the immediate window and this is useful for the developer who wants to see the value of a variable in a certain line without storing the variable in a message box.

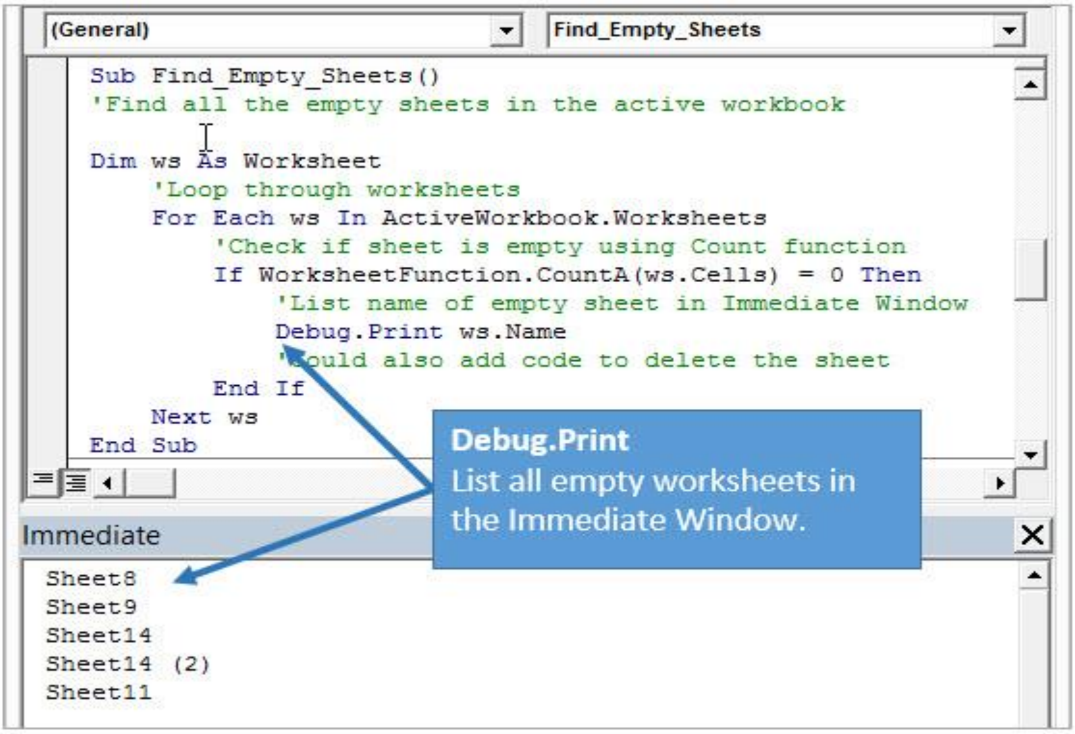


Figure 5.12. The illustration of Debug.Print

- The Locals Window: this allows the developer to view the value of all the variables in a procedure when the developer is stepping through the procedure. The use of the Locals Window will display variable values, and this is easier than examining the value from the immediate window. For simple variable types (e.g., Long and String variables), the value can be displayed on one line, while for complex types or objects (e.g., a Range variable), its properties are displayed in a tree structure.

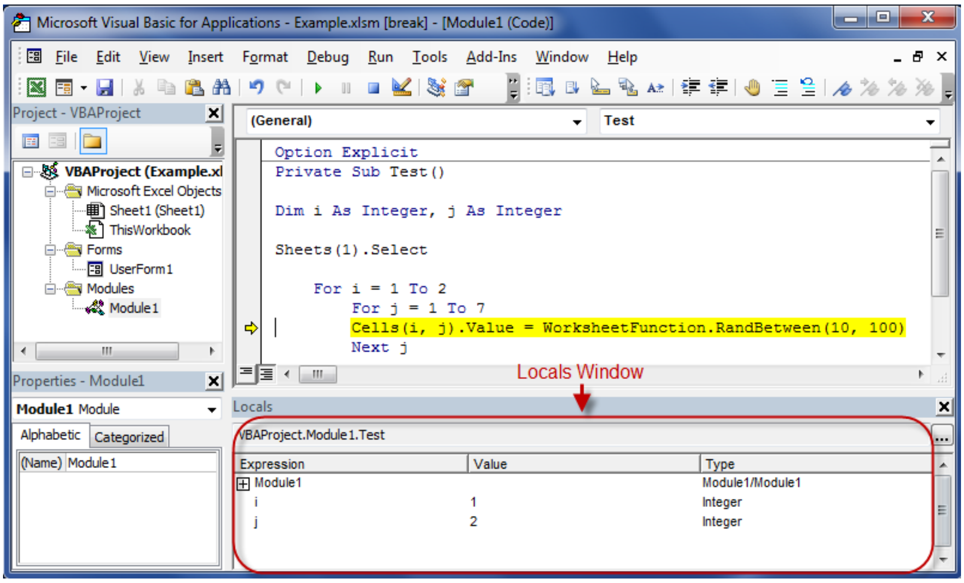


Figure 5.13. The illustration of Locals window

- The Call Stack: this is a data structure maintained by VBA that tracks procedures that call another procedure. For example, if procedure X calls procedure Y which calls Z, the Call Stack window will display the list of procedures starting with the most recent procedure in descending order to get to the current position. This is useful to track the flow of execution that ended up in the current location.

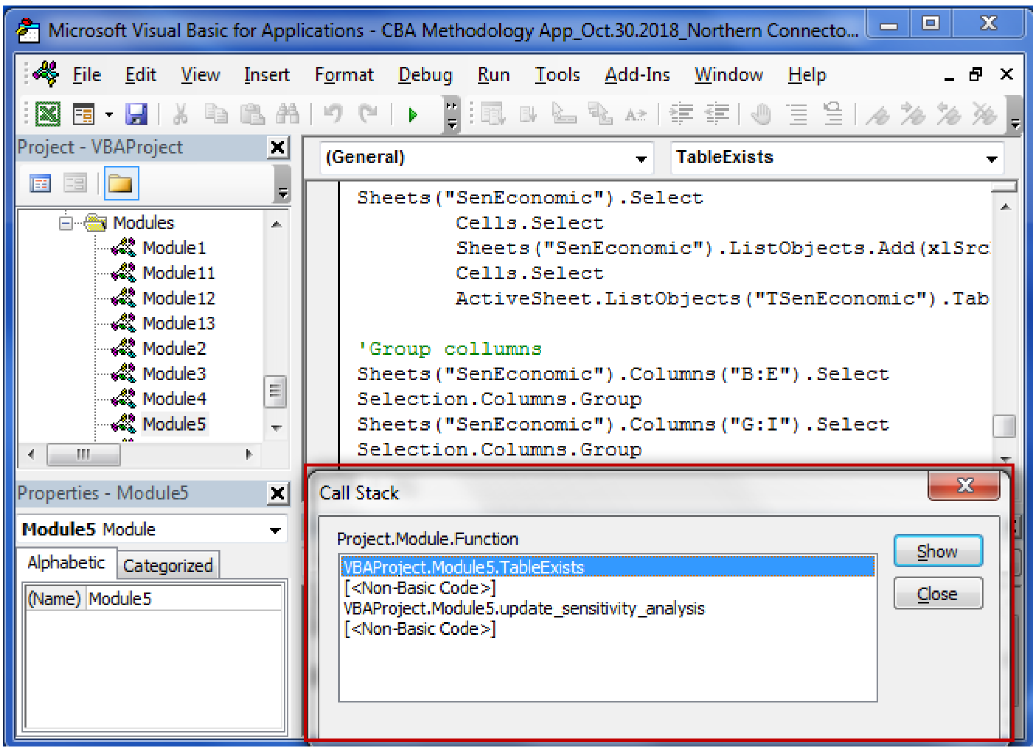


Figure 5.14. The illustration of Call Stack

In a VBA project, the testing must be carried out during the coding stage. It often starts with a simple function with several modules to ensure that coding lines work well before moving to complex functions. The developer, depending on the complexity of a function, needs to break down the main testing tasks into smaller tasks for control. In this research, the researcher has attempted to use the manual testing type with the three levels: unit testing, integration testing, and system testing to ensure the correct functionality of the CBAFS software. The five testing methods presented above were mainly used to test the code scripts of the program. Due to time limitations, some features of the software may need further upgrade and testing in the future.

5.4.Using the Cost-Benefit Analysis Facility Software

5.4.1. Information entry

A brief overview of the functional flow diagram of CBAFS is depicted in Figure 5.15.

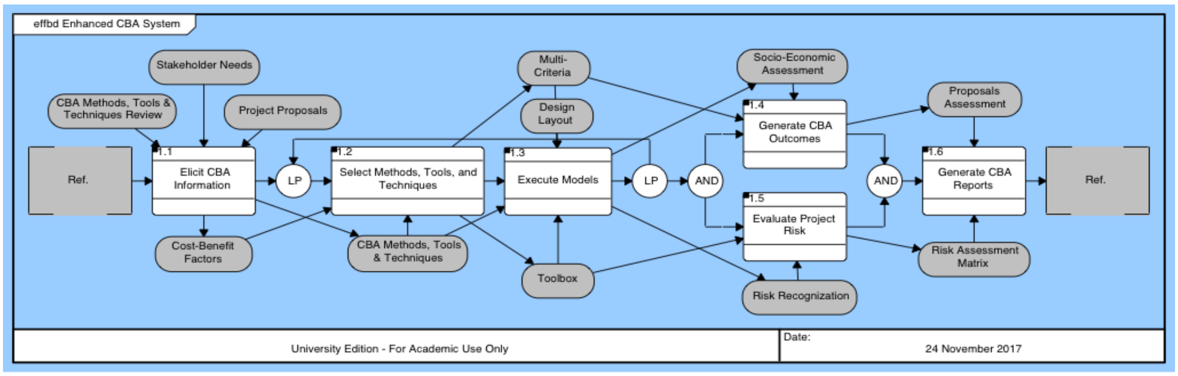


Figure 5.15. The functional flow diagram of hard CBA system. Adapted from Nguyen, Cook, Ireland, and Gunawan (2017)

To start the CBAFS, the user is required to first download the application and store it in a drive of a PC and/or a Laptop (see Appendix P). When the user double-clicks the CBAFS file, the initial screen of CBAFS will show the main stages that are used by CBAFS to perform a CBA (Figure 5.16). Four basic buttons located at the bottom of a CBAFS screen allow the user to start the evaluation program and/or reset the program. The Sheet Manager Button is used to control worksheets within the program, including hidden worksheets that contain parameters and default constants set for an evaluation program.

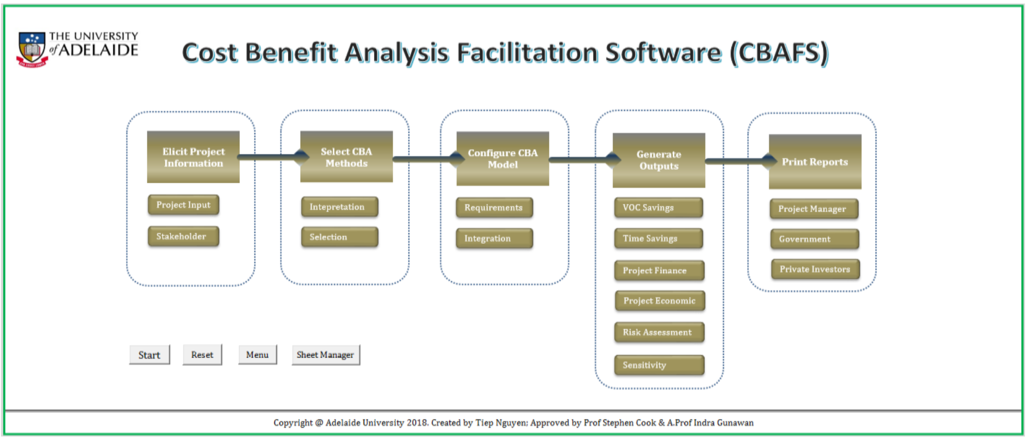


Figure 5.16. The initial screen of CBAFS produced from the Microsoft Excel platform[4]

Once the user clicks on the 'Start' button, the menu of the program will appear as depicted in Figure 5.17. The first page of the menu shows the information entry that is required, while the second and the third pages of the program menu allow the user to execute the main functions of the program related to stakeholder need translation, evaluation method selection and execution. The last page of the menu enables the user to generate evaluation reports in a Microsoft Word format. In particular, for the first page of the CBAFS menu, the user is required to enter basic information related to the transport infrastructure project of interest, including construction time, construction cost, operational time and operational cost per annum.

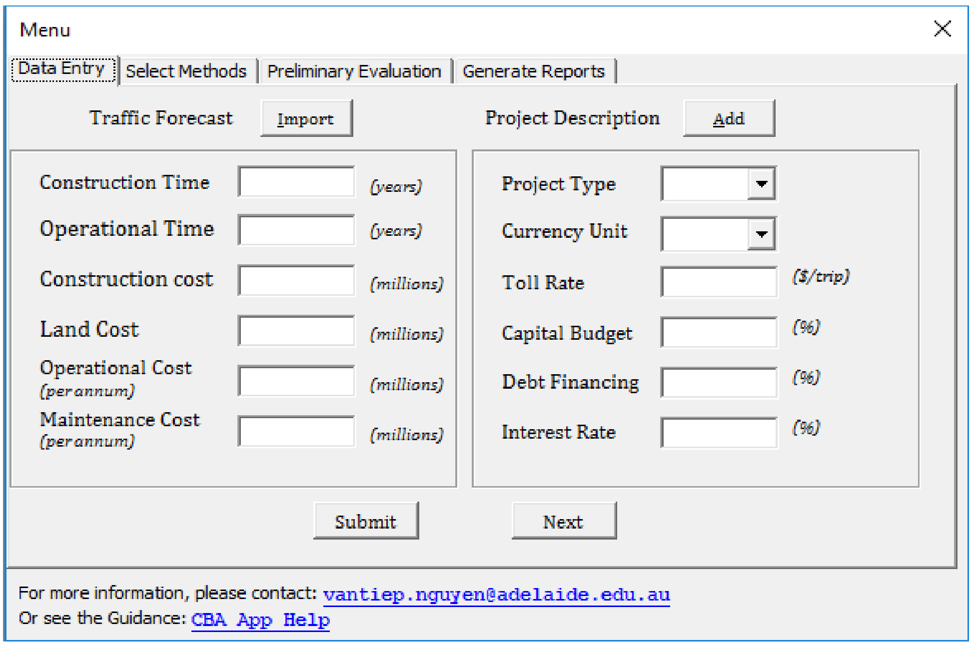


Figure 5.17. Information entry dialogue box for CBAFS

[4] For a brief overview of the CBAFS software, please see the video link: https://youtu.be/nUtwYR6h2-w

The main purpose of the information entry page is to elicit input parameters for the financial and economic assessments of a transport infrastructure project. The user may wish to correct errors in information entry and it therefore remains possible to re-enter project inputs or to go directly to the Excel worksheet for modification (see the User Guide in Appendix P). Once this step is complete, another dialogue box appears to ask users to confirm the input parameters for their evaluation program, before moving towards CBAFS functions.

5.4.2. Software functions

The CBAFS has three main functions: stakeholder need translation, evaluation method selection, and evaluation execution. The implementation of the first two functions requires the main activities of mapping stakeholder groups, translating stakeholder needs, identifying cost-benefit factors and associated methods, assessing method candidates, selecting evaluation methods and identifying their execution conditions, before scheduling the method implementation. These activities have a dependent relationship and need to be carried out in the correct sequential order. Therefore, activities of two given functions (stakeholder need translation and evaluation method selection) are arranged on the same page of the program menu to show the analytical, logical flow which is depicted in Figure 5.18.

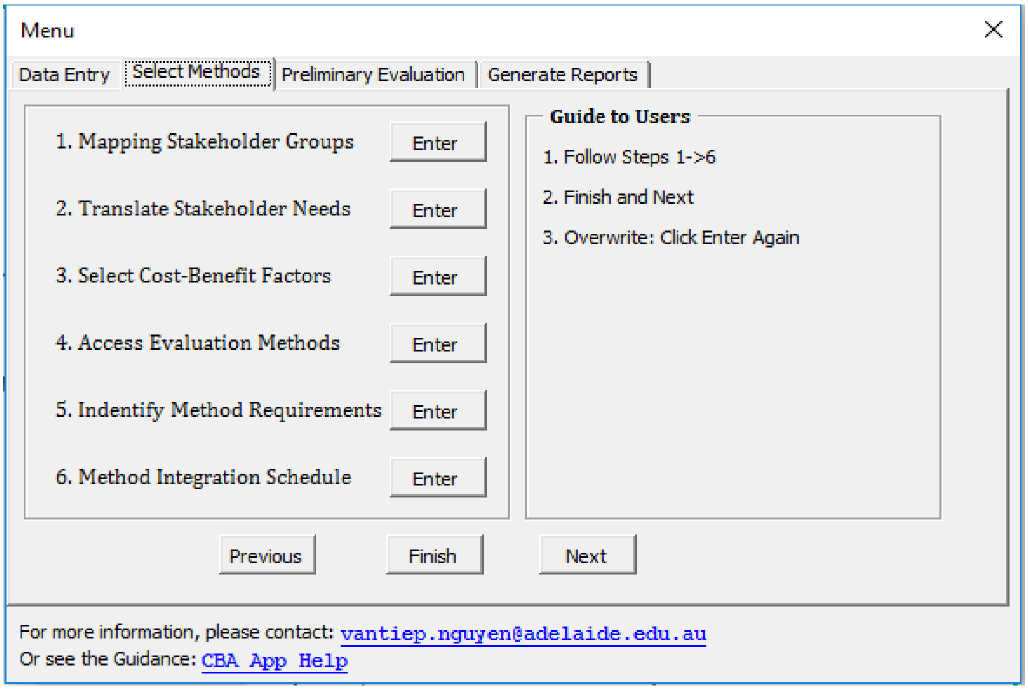


Figure 5.18. Second menu page of CBAFS

Typically, inputs for stakeholder mapping and stakeholder need translation are collected after the informal cost-benefit debate step of the SCF (see Chapter 4). This is a necessary step to ensure that the evaluation team can better capture the values of the input parameters. In other words, the informal debate among stakeholders enables the evaluation team to identify key stakeholder groups and to elicit their actual needs before quantitative assessments. Based on the exchange of information from the informal debate step, an evaluation team member can use CBAFS to map stakeholders and to translate their needs into measurable attributes, which would then be used for the identification of evaluation methods. In this study, the researcher conducted a literature survey and reviewed project evaluation reports to generate the archetypal list of possible needs for stakeholder groups (see Appendix D). The House of Quality technique was then employed to identify associated technical requirements. The CBAFS was designed to support users by automatically creating a link between the stakeholder needs and technical requirements. Non-expert users, based on the list of technical requirements provided, can select the relevant requirements to particular stakeholder group for their assessment before clicking on the Submit Button to confirm the selection (Figure 5.19).

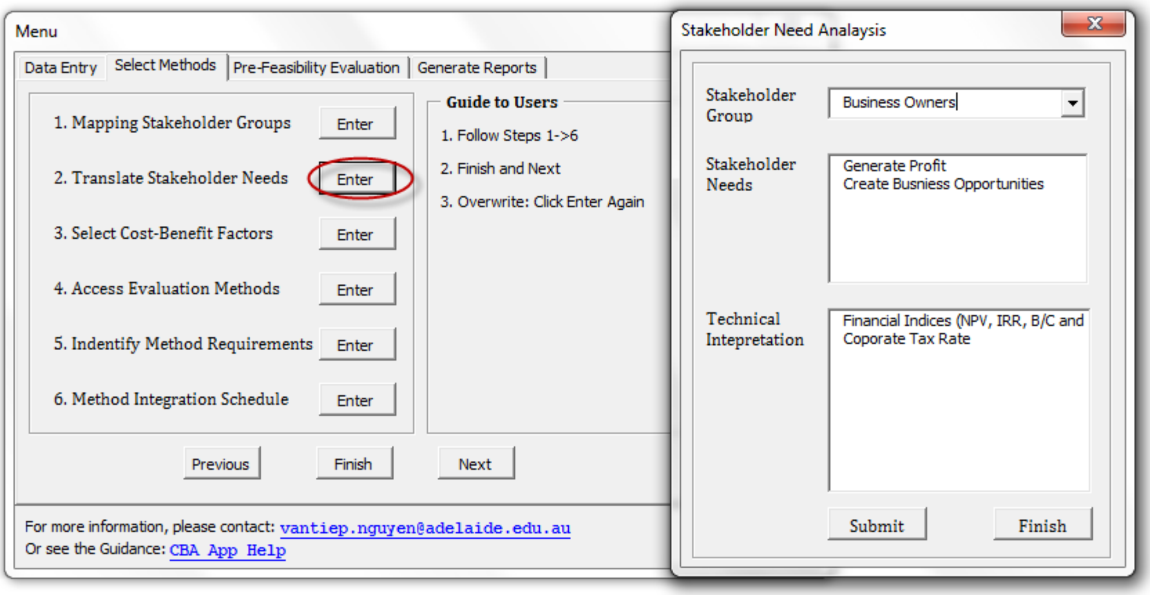
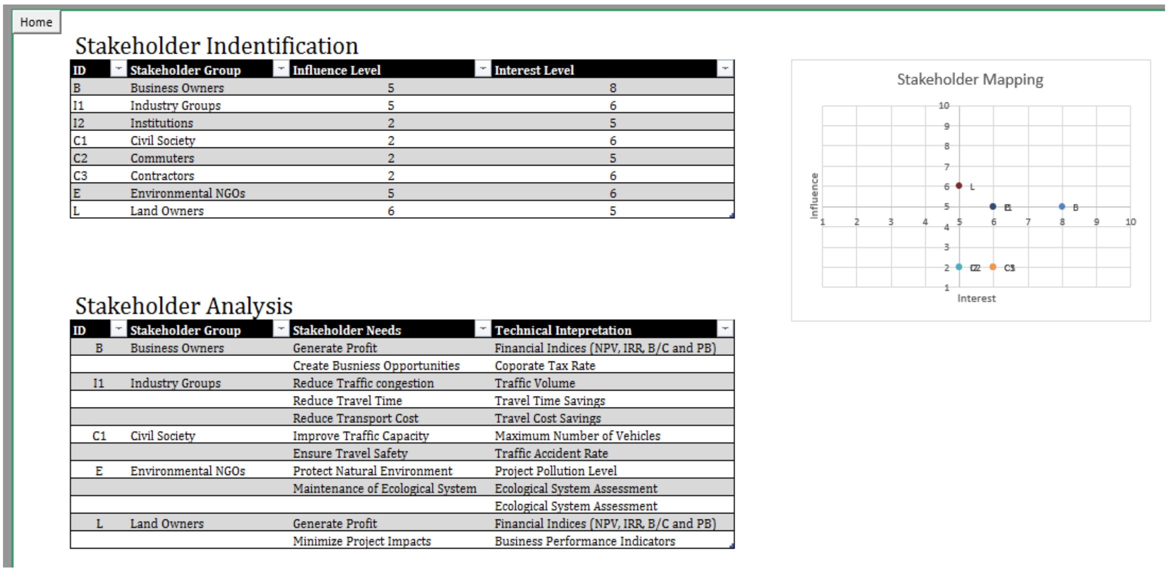


Figure 5.19. Stakeholder needs translation

The list of needs and technical requirements will automatically appear for selection in accordance with each stakeholder group identified. The user needs to repeat the selection task for key groups. Once this task is completed, the user can click the Finish Button to extract the results, which are represented in Figure 5.20.



Home

Stakeholder Indentification

ID	Stakeholder Group	Influence Level	Interest Level
B	Business Owners	5	8
I1	Industry Groups	5	6
I2	Institutions	2	5
C1	Civil Society	2	6
C2	Commuters	2	5
C3	Contractors	2	6
E	Environmental NGOs	5	6
L	Land Owners	6	5

Stakeholder Analysis

ID	Stakeholder Group	Stakeholder Needs	Technical Intepretation
B	Business Owners	Generate Profit	Financial Indices (NPV, IRR, B/C and PB)
		Create Busniess Opportunities	Coporate Tax Rate
I1	Industry Groups	Reduce Traffic congestion	Traffic Volume
		Reduce Travel Time	Travel Time Savings
		Reduce Transport Cost	Travel Cost Savings
C1	Civil Society	Improve Traffic Capacity	Maximum Number of Vehicles
		Ensure Travel Safety	Traffic Accident Rate
E	Environmental NGOs	Protect Natural Environment	Project Pollution Level
		Maintenance of Ecological System	Ecological System Assessment
			Ecological System Assessment
L	Land Owners	Generate Profit	Financial Indices (NPV, IRR, B/C and PB)
		Minimize Project Impacts	Business Performance Indicators

Figure 5.20. Stakeholder analysis worksheet

From the perspective of identified technical requirements, the next step is to identify cost-benefit factors and associated methods that were used for evaluation. In this study, the list of inherent cost-benefit factors and associated methods arose from the CBA literature survey presented in Chapter 2 (see Appendix E). The researcher used these relationships to design a sub-function that automatically matches requirements to cost-benefit factors and associated evaluation methods. The user simply needs to select the specific technical requirements for assessment then CBAFS can provide cost-benefit factors and associated methods.

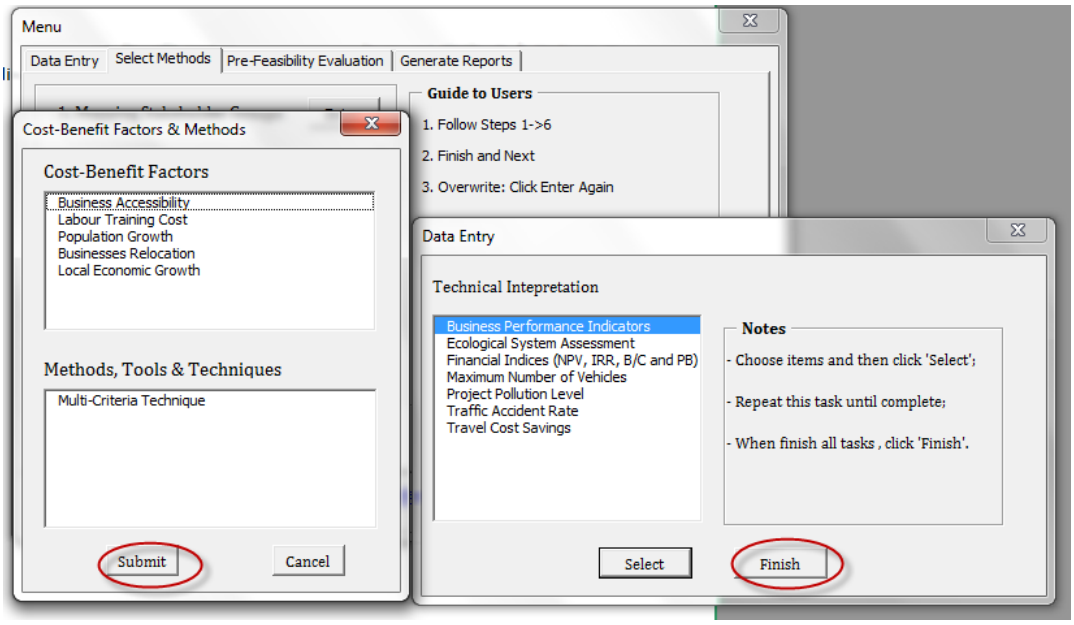


Figure 5.21. Cost-Benefit factors and associated methods

Next, the program will automatically filter methods from the previous step for selection. Some attributes for method selection are: relevance, acceptability, cost, data requirement, execution time, efficiency, consistency, learnability, and adaptability (see Appendix C for more detail). In order to assign the values required, the user needs to hold a discussion with evaluation team members to assign the value for these attributes.

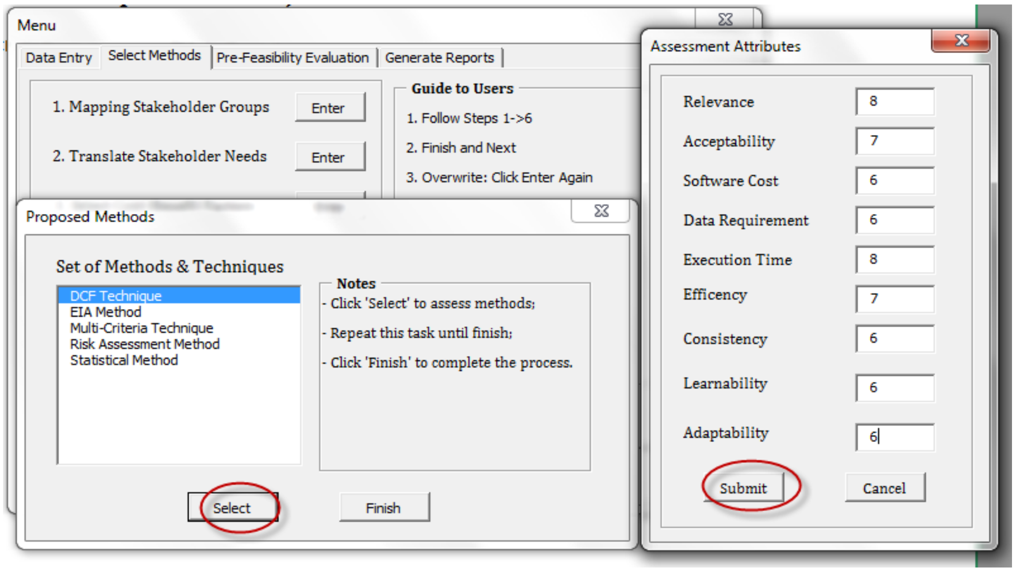
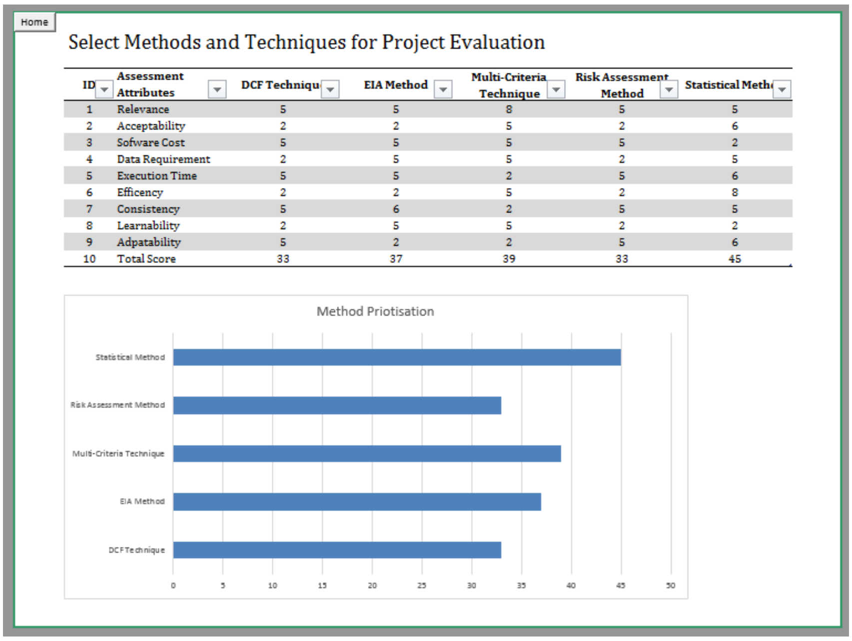


Figure 5.22. Score sections for method evaluation

It should be noted that the score for each given attribute must be greater than one and less than ten, and the value assigned must be in numerical format. Based on the total score of attributes assigned for evaluation methods, the prioritisation of the proposed methods is automatically generated for selection as shown in Figure 5.23.


Select Methods and Techniques for Project Evaluation

ID	Assessment Attributes	DCF Techniqu	EIA Method	Multi-Criteria Technique	Risk Assessment Method	Statistical Meth
1	Relevance	5	5	8	5	5
2	Acceptability	2	2	5	2	6
3	Sofware Cost	5	5	5	5	2
4	Data Requirement	2	5	5	2	5
5	Execution Time	5	5	2	5	6
6	Efficency	2	2	5	2	8
7	Consistency	5	6	2	5	5
8	Learnability	2	5	5	2	2
9	Adpatability	5	2	2	5	6
10	Total Score	33	37	39	33	45

Figure 5.23. Method prioritisation

CBAFS supports the user to execute some typical methods, including the valuation of time savings, the valuation of transport cost savings, financial assessment, economic assessment, risk evaluation, and project sensitivity analysis. For those methods that are not available in the current version of the CBAFS (see Appendix E), the dialogue box will appear to notify the user about methods which are currently available and unavailable (Figure 5.24).

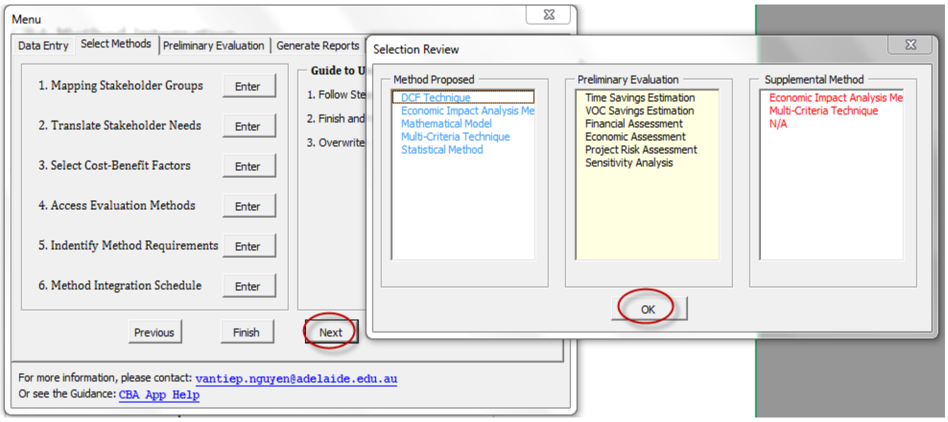


Figure 5.24. Method selection review

In accordance with the list of evaluation methods provided, sub-functions were designed to execute the selected methods as shown in Figure 5.25.

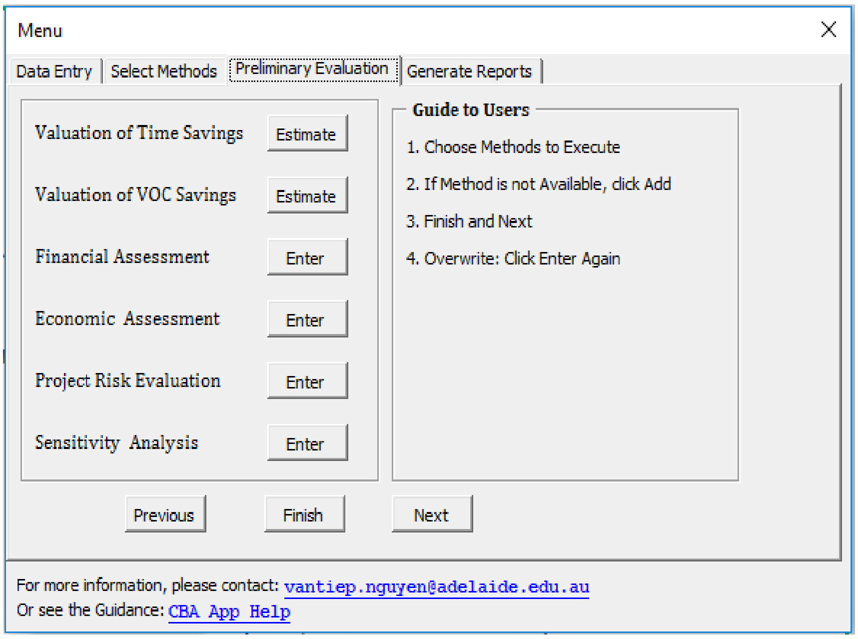


Figure 5.25. CBAFS preliminary evaluation

In this chapter, the researcher described two sub-functions from the list provided, including the valuation of time savings and project financial analysis. The first function is carried out to evaluate the value of saving travel time for each type of vehicle (e.g. car, light truck and rigid) per trip. The value of saving travel time also depends on travelling purpose, such as work or entertainment. In the Input Form, the user needs to enter the required values and then click the Submit Button for assessment, as illustrated in Figure 5.26.

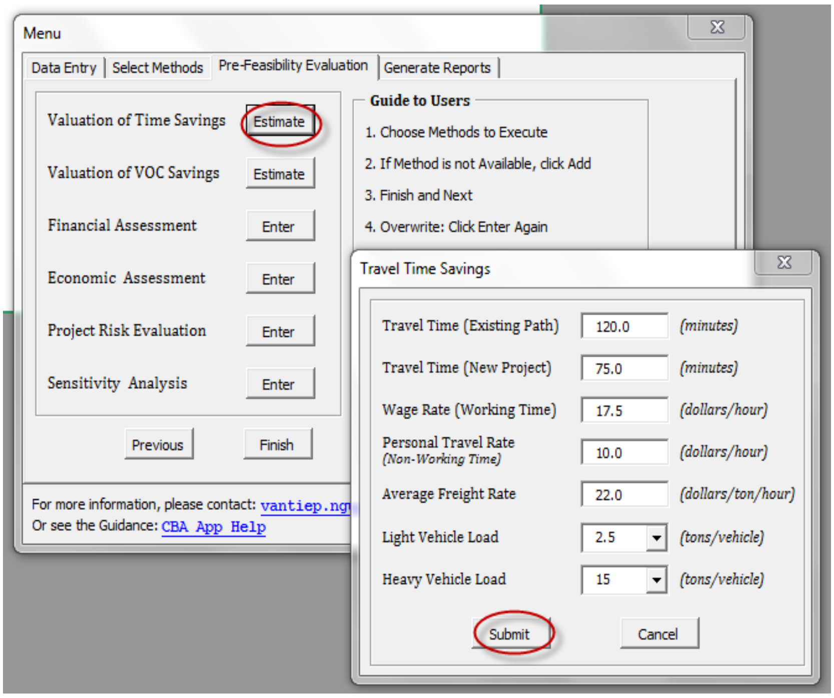


Figure 5.26. Input form for travel time cost savings

Once input parameters are entered, the user can click the Submit Button to extract the results shown in the Excel worksheet (Figure 5.27). In this example, assumed values are the distribution percentage for vehicle types travelling on the new road (e.g. 40% car, 30% light truck, 15% rigid and 15% bus). The assumed values can be changed in accordance with the purpose of the user at the beginning stage of the evaluation program.

Home

Travel Time Cost Savings

List	Cost Components	Car (40%)	Light Vehicle (30%)	Rigid(15%)	Bus(15%)
1	Travel Time Savings (l	0.75	0.75	0.75	0.75
2	Wage Rate ($/hour)	17			
3	Personal Travel Rate ($/hour)				10
4	Light Vehicle Load (tons/vehicle)		2.5		
5	Heavy Vehicle Load (tons/vehicle)			15	
6	Freight Rate per Ton per Hour		22	22	
7	Total Saving Cost per 1	12.75	41.25	247.5	7.5

Figure 5.27. Travel cost savings example

In terms of the financial assessment sub-function, it is necessary to select input parameters for calculation, such as construction time, operational time, construction cost, operational cost, and land cost. Typically, the CBAFS program automatically links the financial analysis User Form with the project information entry identified at the beginning stage, so the user only needs to click the Submit Button to generate the analytical results (Figure 5.28). The CBAFS program automatically generates the outcome of the project financial assessment within an Excel worksheet (Figure 5.29) in which the user can observe the cash flow of project finance as well as identifying indicators used for project evaluation.

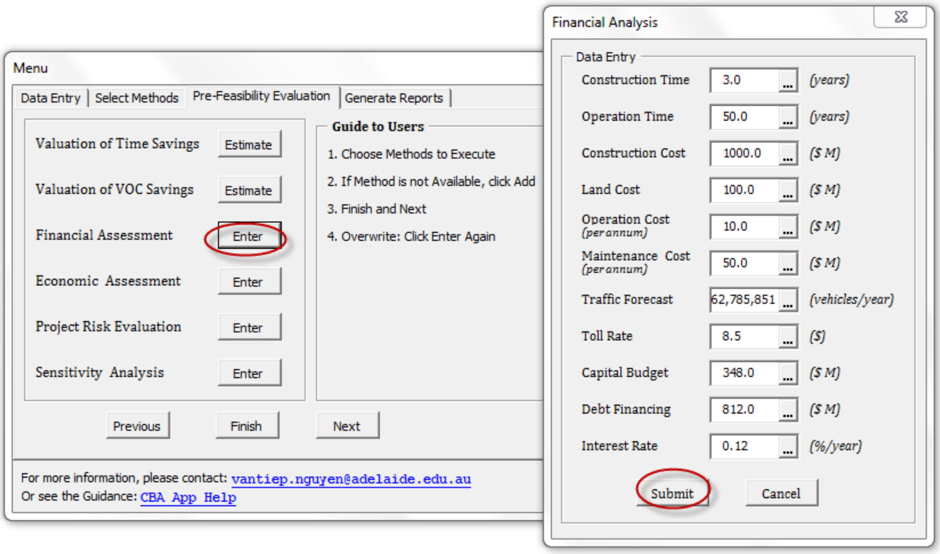


Figure 5.28. Financial analysis input form

In this example, the financial indices used for evaluation are Net Present Value, Internal Rate of Ratio and Benefit-Cost ratio and these are shown in the CBAFS Dashboard.

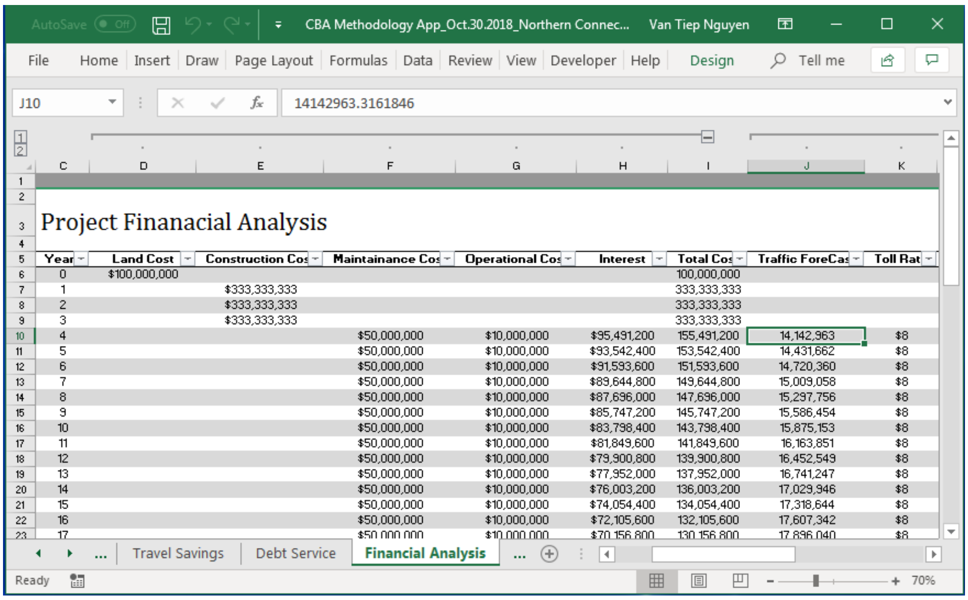


Figure 5.29. Financial analysis worksheet

The current version of CBAFS is limited to six typical methods and techniques (traffic forecast model, mathematical models for VOT and VOC, financial assessment technique, economic assessment technique, risk assessment method, and project sensitivity analysis technique). However, its upgrade version is expected to include additional methods (such as environmental impact assessment method) which are not mentioned in this thesis. Since the main purpose of CBAFS is to provide supplementary information (as evidence) for the formal cost-benefit debate step of a SCF, the additional methods can be executed separately by the evaluation team to provide extra information for specific stakeholder groups.

5.4.3. Text generation

Text generation is performed by selecting the appropriate option on the last page in the CBAFS main menu as depicted in Figure 5.30. This process comprises merging evaluation results from Excel worksheets which contain charts and tables with stored paragraphs to form the evaluation report. The output of this program is a text file in Microsoft Word document (.docx) format.

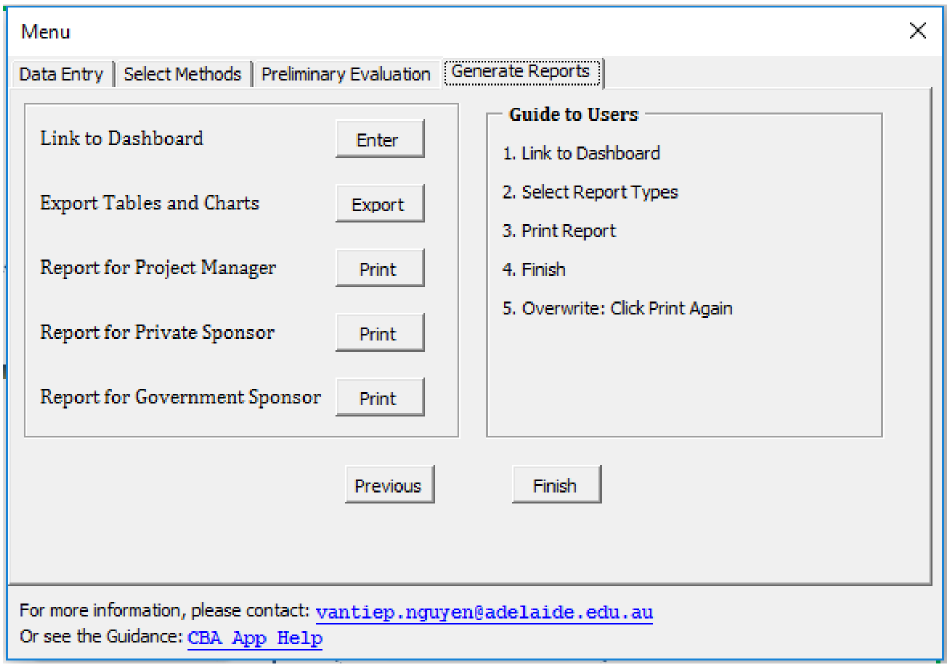


Figure 5.30. Text generation function

Technically, the program provides evaluation report templates and the user can choose the outline format for their report including page length, column width, paragraph indentation and headers and footers. For different stakeholders, the required information may well be different. Thus, the user is able to review the report file and manually modify and make the necessary changes for the final version of their project report.

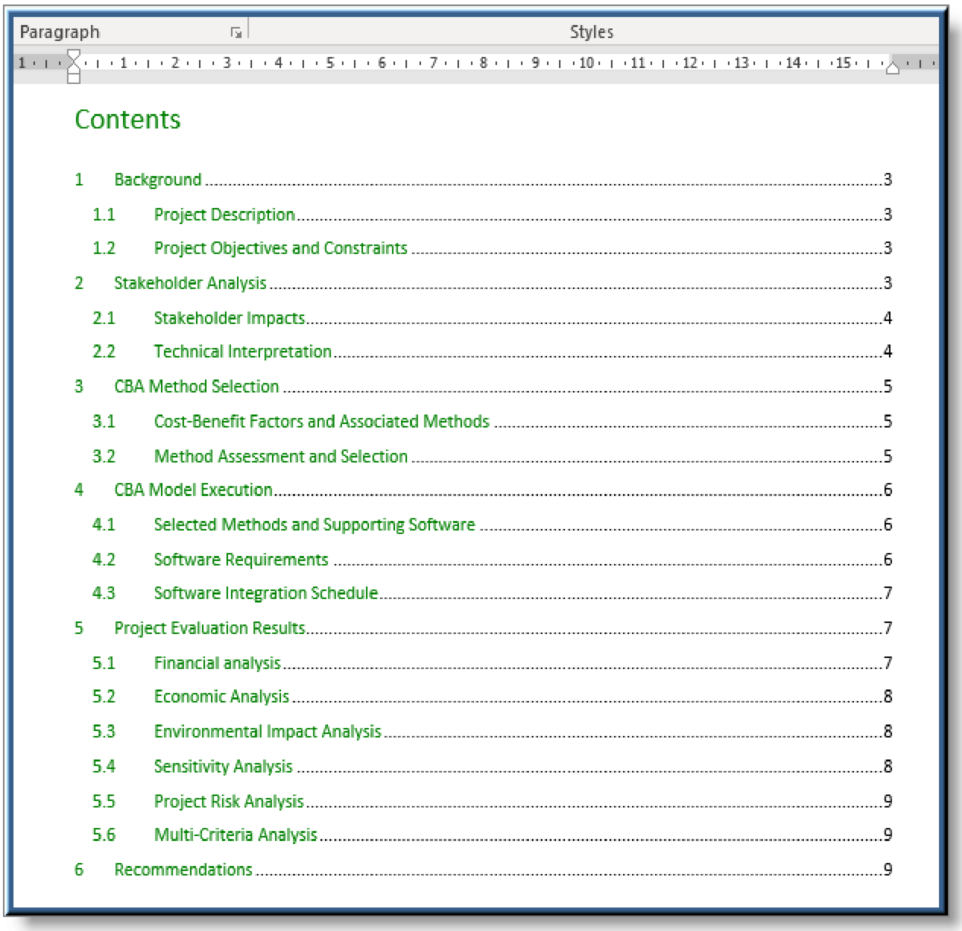

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Figure 5.31. Project evaluation report template

The assessment of the hard aspect of the SCF is time-consuming and challenging. This CBAFS app provides a significant shortcut for practitioners in undertaking this quantitative assessment process. The user, instead of manually following the complicated functional analysis process of CBA, can simply use the CBAFS software to carry out necessary evaluation activities. The CBAFS considerably reduces the time needed for technical analyses and improves user confidence in carrying out evaluation activities for the hard aspect of the SCF. In this thesis, assisting practitioners with undertaking the 'quantitative' assessment is only the first part of the contribution. Practitioners, having successfully completed the assessment using the app, are now in a strong position to use the supporting information to bolster the key step of conducting the formal stakeholders' debate of a SCF. Solid evidence generated from using CBAFS is a crucial factor contributing to the success of the debate as well as to the sustainability of investment decisions made for transport infrastructure projects.

5.5. Summary

To summarise, the hard CBA system approach plays a vital role in quantitatively measuring impacts of an infrastructure investment project. The 'hard' CBA system is a principal component of the SCF that provides fundamental cost-benefit information for a formal cost-benefit debate among key stakeholders. In order to support users to follow the functional analysis processes of the hard system, the application entitled 'CBAFS' was designed for implementation. The CBAFS functions, presented in this chapter, are the result of a design process, including the identification of system requirements, software design, coding and testing. The Visual Basic programming language enables users to make use of the available functions of CBAFS based on the Excel platform. The CBAFS does not require complicated installation or guidelines for operation, and thus, it can be used easily by both individuals and organisations. The use of CBAFS not only provides key information for a stakeholder debate, but also enables decision-makers to recognise significant factors in the CBA that could obstruct the achievement of consensus among key stakeholders in the decision regarding investment in transport infrastructure projects. In the following chapter (Chapter 6), the researcher has selected a specific case study within the Australian context to demonstrate the utility of the SCF and its supporting tool (CBAFS). Due to time constraints, the researcher has built a 'trial' version of the CBAFS but plans to develop a commercial version of CBAFS in the near future with Visual Basic.Net.

Chapter 6

A Case Study and Research Discussion

6.1. Introduction

The objective of the following chapter is to illustrate the utility of the new stakeholder-centric CBA framework and to validate its applicability for transport infrastructure projects. It opens with a brief discussion of the differences between the proposed framework and the traditional framework. This chapter then introduces a case study for applied analysis: the Northern Connector road project in Adelaide, South Australia. The researcher uses secondary data and information collected regarding the Northern Connector to illustrate the analysis processes of both the traditional framework and the stakeholder-centric CBA framework. The findings of this application are used to clarify the pros and cons of each framework as applied in the Australian context, as well as to highlight unique points of the proposed CBA framework. Next, seven in-depth interviews were conducted to assess the utility and applicability of the stakeholder-centric CBA framework for transport infrastructure projects. The chapter ends with a detailed summary of experts' suggestions to improve the utility of the stakeholder-centric CBA framework.

6.2. Background

The conventional CBA for transport infrastructure is a hard, top-down approach (Aaltonen, 2011) that tends to focus on a specific group of factors to present solutions. The 'top-down' approach to a CBA is suitable when problems are well-defined (Gorod, Hallo, & Nguyen, 2018; Nonaka, 1988), but this approach has many limitations when applied to the complex environment of transport infrastructure projects. In particular, socio-economic issues, including stakeholder conflicts and environmental issues related to the CBA, in most cases, are difficult to identify and quantify (Feng & Wang, 2007). Even though scholars have attempted to upgrade (or extend) features of the conventional framework to cope with complex issues, obstacles remain to a complete solution for resolving critical CBA problems, especially regarding stakeholder engagement and subsequent evaluation method selection. The stakeholder-centric CBA framework, in contrast, is a 'bottom-up' approach that focuses on eliciting the perceptions of key stakeholders (individuals) needed to clarify the major issues which arise in a CBA for a particular transport infrastructure project, and in identifying the root causes leading to conflicting viewpoints regarding the investment decisions which need to be made. The development of the stakeholder-centric CBA framework relies on the three strong philosophical positions underpinning Total System Intervention (complementarism, sociological awareness and human well-being and emancipation). Thus, it enables analysts to seek 'holistic' solutions to the major CBA issues that need to be addressed.

In order to clarify the major differences between the stakeholder-centric CBA framework and the traditional framework, the Northern Connector Project within South Australia has been selected as a case study for analysis. The primary reason for this selection is that the Northern Connector Project is a complex project which has many issues encompassing the four main groups of CBA factors (technical, financial, socio-economic and environmental); and the investment decision-making process on the Northern Connector project was carried out with the involvement of multiple stakeholders across various industries, local government, non-organisations and communities. Another reason for the Northern Connector selection is that the project implementation is being executed under the supervision of the Government of South Australia (State Level) which matches the boundary conditions of applying a stakeholder-centric CBA for a specific project, as presented in Chapter 2.

It should be noted that this study focuses on the specific processes of both a traditional framework and a stakeholder-centric CBA framework to provide detailed critiques on the strengths and weaknesses of the approaches adopted. The outcome of this work is to provide insights into the utility and efficacy of the new proposed framework and to highlight the pros and cons of its implementation.

6.3.Northern Connector Project: A Case Study

The Northern Connector is a 15.5-kilometre-long expressway which is proposed to connect the North-South Motorway (National Highway M2) at Wingfield to the Northern Expressway (M2). The Northern Connector is considered as a key part of infrastructure networks between Old Noarlunga and Nuriootpa known as the North-South Corridor (DTEI, 2011a). The Northern Connector with three-lanes in each direction is currently being constructed and the operation of Northern Connector project is expected to provide a much faster, safer and less congested route over the section of the North-South Corridor between South Road and the Northern Expressway. The starting point of the Northern

Connector is the Southern interchange and the endpoint of the project is the Northern interchange; see Figure 6.1.

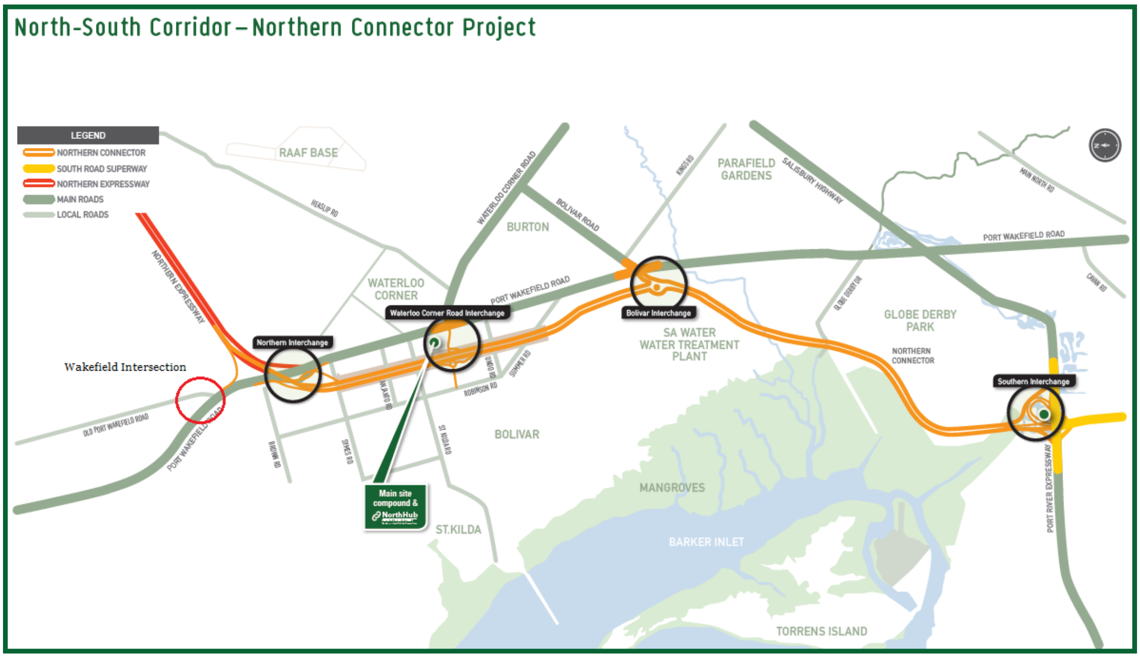

Figure 6.1. Northern Connector project overview. Adapted from the South Australia Government (2015)

The Northern Connector project has been developed in response to South Australia's Strategic Plan and the 30-Year Plan for Greater Adelaide (DTEI, 2011a). According to this strategic plan, the population growth rate of northern Adelaide will increase significantly and this will lead to increased road traffic. The Northern Connector project aims to improve the system-wide accessibility that supports major economic activities in the northern and western regions. The Northern Connector project is considered to be a critical part of Adelaide's North-South Corridor, extending from Gawler to Old Noarlunga (DTEI, 2011c). The Australian Government has committed $708 million to the project, with $177 million contributed by the South Australian Government. Critical information on the Northern Connector project is presented in Table 6.1.

Table 6.1. Key parameters of the Northern Connector project

List	Project Information	Parameters	Notes
1	Total road length	15.6 km	Three lanes in each direction
2	Construction Time	3 Years	(1/2016-12/2019)
3	Operational Time	30 Years	2020-2050
4	Construction Cost	$600 Million	Estimated
5	Land Compensation Cost	$85 Million	Estimated
6	Operational Cost	$5.5 million/year	Estimated
7	Maintenance Cost	$5.7 million/year	Estimated
8	Toll rate	$5.0/trip	Estimated
9	Total Budget	$885 Million	$708 million from the Australian Government and $177 million from the South Australian Government
10	Traffic Forecast	25,000-35,500 (vehicles/day)	Estimated

Transport statistics from the S.A Department of Transport, Energy and Infrastructure (DTEI) indicate that traffic volumes on Port Wakefield Road and the Salisbury Highway are increasing significantly, leading to traffic congestion, road crashes and a reduction in efficiency for freight transport (DTEI, 2011a). Thus, the implementation of the Northern Connector project is expected to bring many potential benefits to the local economy and residents, including the following:

- Improved freight connection between Port Adelaide and the Riverland, the Barossa Valley regions to the east, Perth to the west, and Darwin and Olympic Dam to the north (DTEI, 2011a). This project will provide a faster road to critical destinations within South Australia such as Adelaide Airport, sporting venues, businesses and beaches in the southern and western suburbs. In addition, the operation of the Northern Connector will reduce travel time for commuters travelling to and from the northern suburbs.

- Improved safety for road users by reducing conflicts between vehicles at grade intersections, particularly from Port Wakefield Road (DTEI, 2011a). The operation of the Northern Connector project will also improve traffic conditions and access for road users and local communities, indirectly reducing crashes which often occur on the existing routes.

- Support for local industries in the Northern Adelaide region: for example, agribusiness, manufacturing, automotive, defence, transport and storage, mining and energy production. In addition, the project implementation will create approximately 1662 jobs per year during the construction period from 2016 to 2019 (DTEI, 2011a).

- Improved amenity and environmental sustainability (DTEI, 2011a). The reduction in traffic congestion will directly lead to reduced travel time and fuel use savings, which will also create a positive influence on the air quality and noise pollution in suburbs close to Port Wakefield Road, including Paralowie and Parafield Gardens.

At the same time, the Northern Connector is a substantial project that will absorb a significant amount of South Australia's financial resources and its implementation can be expected to have certain negative impacts on local communities and the natural environment. Major problems associated with the Northern Connector project implementation include the following:

- During the execution stage of the project, construction noise and vibration may have an impact on local communities in areas close to the Northern Connector (DTEI, 2011a). In particular, truck movements on local roads and the installation of equipment for construction may affect the daily life of local people. Moreover, there may be some vibration effects on buildings close to the works.

- The project area is located in the native title areas claimed by the Kaurna People, so there may be disturbance to or interference with Aboriginal sites (DTEI, 2011a). The Aboriginal Heritage Committee is greatly concerned about these problems and has required a heritage survey to determine affected locations.

- The main drainage systems and surface waterbodies are potentially impacted during project implementation and operation. In particular, storm-water systems (e.g. Helps Road drain and Dry Creek), constructed wetlands (e.g. Barker Inlet north and south wetlands), and natural surface water (e.g. Little Para River, North Arm Creek, and Magazine Creek) may be affected during the construction stage of the Northern Connector Project (DTEI, 2011a).

- The major concerns of local communities include the socio-economic impacts of property acquisition, changes in local road access, safety in a multiple transport corridor, the potential effects of project implementation on property values and the possibility of community severance (DTEI, 2011a).

- The impacts of project implementation on vegetation and fauna in the project area have also received attention from environmental organisations (DTEI, 2011a). It is essential to determine whether the effects of the Northern Connector project on local fauna, especially on bird species and their habitats, are as significant as conservation groups warn.

From the analyses above, it can be seen that it is crucial to carry out appropriate evaluation activities to examine the feasibility of the project proposal. Both the traditional CBA framework and the stakeholder-centric CBA framework are used to provide analysis processes for evaluation and comparison. It should be noted that *instead of focusing on the desired outcome of the CBA, the researcher is focusing on the analysis procedure employed in each framework to clarify the degree of transparency of each framework.*

6.4.Conventional CBA Framework Implementation

There is wide recognition that CBA is the most appropriate tool when considering and comparing costs and benefits of a wide variety of projects and policies, including infrastructure projects. The various levels of Australian governments provide guidelines for the use of CBA. For example: NSW Treasury, Victorian Department of Treasury and Finance, and Building Queensland (Infrastructure Australia, 2018) and all have their own guidelines. Similarly, the use of CBA for infrastructure investment evaluation is supported by many international agencies such as The World Bank (Independent

Evaluation Group, 2010), The European Commission (2008), and The OECD (Pearce, Atkinson, & Mourato, 2018). Generally, some key features of a conventional CBA approach include the following, as listed below:

- CBA is a procedure that is designed to support decision-makers in making the investment decision about whether the project should be undertaken. CBA is used to evaluate economic and social values of project investment options (i.e. increase in social welfare) over the entire period of the project proposed.

- Within CBA, an advance in well-being is measured by assessing how much an individual is willing to pay (WTP) to secure that gain, or how much they are willing to accept (WTA) in compensation, in order to forgo that gain (Infrastructure Australia, 2018).

- During a project lifecycle, project benefits and costs occur at different points of time, so this variation needs to be explicitly incorporated into the analysis (Commonwealth of Australia, 2006). In financial analysis, project benefits and costs are 'discounted' over time in order to assess present value; thus, the CBA is considered as a type of discounted cash flow analysis.

- If the present value of project benefits is greater than the present value of estimated costs, then the project proposal can be considered worthwhile. In some cases, there may be other better project proposals, and thus these proposals should be ranked in accordance with given objectives and budget constraints (Commonwealth of Australia, 2006).

Typically, the traditional CBA framework for transport infrastructure projects has five main steps, which are depicted in Figure 6.2, as follows: (1) the development of the base case; (2) the identification of cost-benefit factors; (3) the quantification of cost-benefit factors; (4) the performance of sensitivity analysis; and (5) the reporting of the results of the CBA.

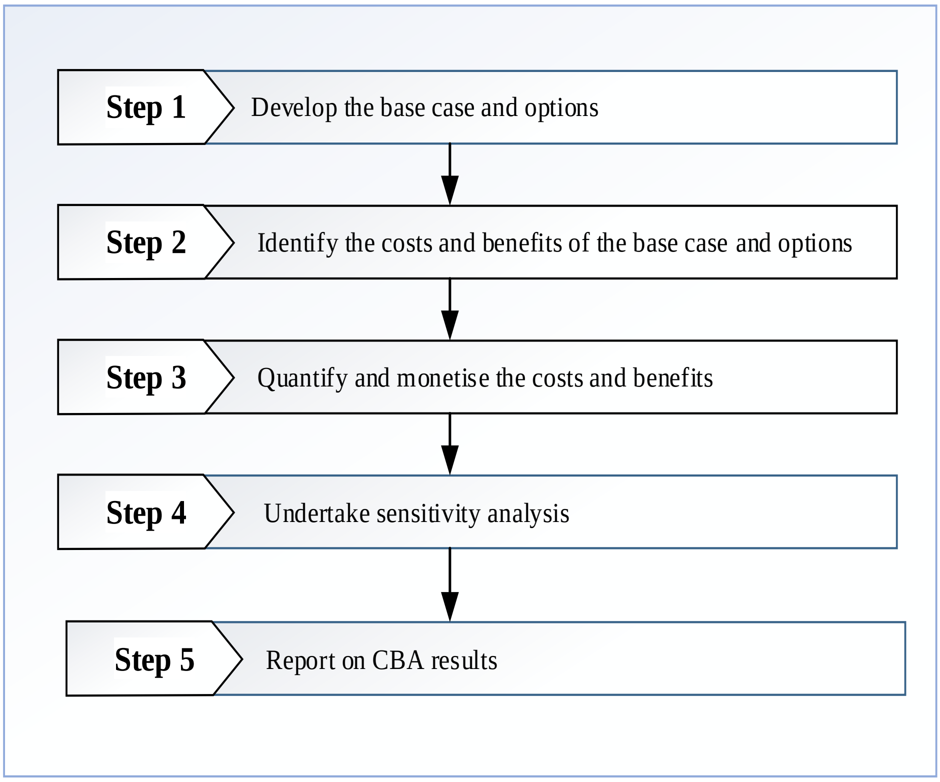

Figure 6.2. Key steps in a Cost-Benefit Analysis (CBA) for Infrastructure Projects. Adopted from Infrastructure Australia (2018)

There can be slight differences between traditional frameworks presented in CBA guidelines provided by international agencies reflecting their objectives and application context. In this study, the researcher focuses on the context of Australia to illustrate the implementation of a traditional framework. Thus, cost-benefit guidelines provided by The Australian Department of Finance (Commonwealth of Australia, 2006) and The European Commission (2014) were selected to provide methods and techniques used for analysis and assessment.

Step 1: The development of the base case and options

The **base case** was constructed with the scenario of not implementing the project while the **project case** was associated with the scenario of Northern Connector project approval. Two options for the project case are the implementation of a *freeway* or a *toll road*.

Step 2: The identification of cost-benefit factors

In the base case, a range of costs have been identified, as follows: traffic congestion, traffic delays, traffic accidents, and greenhouse gas emissions caused by overcapacity of existing routes in next ten-years (DTEI, 2011b). Table 6.2 provides brief descriptions of common factors associated with the scenario of not making the investment in the Northern Connector project.

Table 6.2. The identification of cost factors for the Base Case
(not making the investment)

List	Cost Factors	Descriptions	Base Case
1	Traffic delays	This is a direct cost to both travellers and vehicle owners caused by the additional travel time due to traffic congestion.	Defined
2	Traffic accidents	Indirect costs that are caused by the over capacity of existing roads that leads to collisions between vehicles.	Defined
3	Logistics costs	Indirect costs as a result of an increase in travel time and vehicle operating costs.	Defined
4	Air pollution	Costs related to gas emissions caused by traffic congestion on existing routes, especially at Port Wakefield Road intersections.	Defined
5	Business Opportunities	This is an indirect cost which relates to the level of business accessibility to local industries in South Australia.	Non-defined

Technical surveys have identified challenges to upgrading existing roads resulting from the impact on the local community (DTEI, 2011b). Thus, it is crucial to consider constructing a new road that directly connects the Southern interchange to the Northern interchange. In this case, the list of possible cost factors for project investment is presented in Table 6.3.

Table 6.3. The identification of cost factors for the Northern Connector project (for both freeway and toll road options)

List	Project Cost Factors	Descriptions	Freeway option	Toll Road option
1	Planning & design cost	Costs used for survey, design, preparation and planning.	Defined	Defined
2	Land cost	Costs used for land compensation and project site clearance.	Defined	Defined
3	Construction Cost	Direct costs in the execution stage, including project management cost.	Defined	Defined
4	System operation & maintenance cost	All the costs used to operate and maintain the new service.	Defined	Defined
5	Plant and machinery cost	Costs related to installation and operation of machinery systems and plant for the Northern Connector.	Defined	Defined
6	Air pollution/emissions (carbon dioxide, NOx, SO_2)	Environmental costs regarding air pollution during project execution stage.	Defined	Defined
7	Noise pollution	Environmental costs regarding noise pollution during project execution.	Defined	Defined
8	Chemical waste, polluted soil and water pollution	Environmental costs regarding waste pollution during project construction stage.	Defined	Defined
9	Unemployment rate	Social costs related to business relocation that leads to loss of jobs	Defined	Defined
10	Traffic delays during project construction	Intangible costs as a result of Northern Connector project implementation.	Non-Defined	Non-Defined
11	Loss of cultural, historic, recreational and natural resources and loss of open space.	Indirect costs as a result of changes to a place of cultural significance and to natural resources.	Non-Defined	Non-Defined
12	Impacts on ecosystems and biodiversity	Indirect costs as a result of damaging the ecosystems within the investment area.	Non-Defined	Non-Defined

Table 6.3 shows that most cost factors related to the financial and technical aspects of project investment can be well-defined, while some factors related to social and cultural aspects are difficult to quantify.

In addition to the cost factors addressed above, the implementation of the Northern Connector project would bring benefits to South Australia's economy, especially for core businesses such as the agricultural sector and related services (DTEI, 2011a). The operation of the Northern Connector would directly solve critical issues regarding traffic congestion and traffic accidents at the Wakefield intersection (DTEI, 2011a). The details of project benefits are presented in Table 6.4.

Table 6.4. The identification of benefit factors for the Northern Connector project (for both freeway and toll road options)

List	Project Benefit Factors	Descriptions	Freeway Option	Toll Road Option
1	Traffic congestion reduction	Indirect benefits regarding traffic congestion reduction.	Defined	Defined
2	Travel time savings	Travel-time savings for business people, commuters, and other travellers.	Defined	Defined
3	Vehicle operating cost savings	The cost savings to the owner of vehicles such as cars, light trucks and heavy trucks.	Defined	Defined
4	Traffic accident reduction	Social benefits regarding traffic accident reduction (e.g. vehicle damage, injuries and deaths).	Defined	Defined
5	Accessibility benefits for business trips	The increase in accessibility level would bring intangible benefits to business owners and local industries.	Non-Defined	Non-Defined
6	Agriculture development	Economic benefits as a result of infrastructure improvements.	Non-Defined	Non-Defined
7	Trade logistics improvement	Indirect benefits arising from saving time and cost in logistics activities.	Defined	Defined
8	Taxes and fees paid by vehicle owners.	Because of an increase in number of vehicles, taxes and fees are indirect benefits contributing to local budget.	N/A	Defined
9	Unemployment rate	Social benefits regarding labour market development in the locality, especially for jobs created during project construction stages.	Non-Defined	Non-Defined
10	Environmental protection	This factor is an indirect benefit of project operation because of the reduction in traffic delays and congestion.	Defined	Defined

Even though the information presented in Table 6.3 and Table 6.4 provides a clear picture regarding the costs and benefits of the project proposal, the identification of cost-benefit factors depends on the experience of evaluators involved in the CBA activity. As a result, there is a high possibility of subjective judgements being used to assess project costs and benefits, and this may prevent the inclusion of hidden additional factors that significantly affect the performance of the investment decision made.

Step 3: The quantification and monetisation of cost-benefit factors

a. Project Financial Analysis

It is apparent that the base case for a scenario of not undertaking the project investment does not affect the financial aspects (under investor's perspective), so the researcher focuses on the project case with two options (freeway and toll road) for analysis. From Table 6.3, defined cost-benefit factors are selected for financial evaluation, including land cost, planning and design cost, operation cost, maintenance cost and revenue generated from project operation. The Bottom-Up Budgeting technique, proposed by the Project Management Institute (2013), is used to identify the construction cost and the total investment cost of the Northern Connector project.

Table 6.5. Construction cost estimation of the Northern Connector project (for both freeway and toll road options)

List	Cost Components	Label	Formula	Total Cost (AUD)
1	Direct costs	A	B+C+D+E	$495,320,000
1.1	Material	B		$156,000,000
1.2	Machinery	C		$187,000,000
1.3	Labour	D		$145,000,000
1.4	Others	E	1.5%*(B+C+D)	$7,320,000
2	Indirect costs (*Administration*)	F	6%*A	$29,719,200
3	Expected profits	G	5.5%*(A+F)	$28,877,156.00
4	Construction cost before tax	H	A+F+G	$553,916,356
5	Tax	K	10%*H	$55,391,636
6	Total construction cost after tax	L	H+K	$609,307,992

Table 6.6. The total investment cost of the Northern Connector project
(for both freeway and toll road options)

List	Cost Components	Label	Formula	Total Cost (AUD)
1	Construction cost	L	Table 6.5	$609,307,992
2	Land compensation	M	Market Price	$100,000,000
3	Management cost	N	1.19%*L	$7,250,765
4	Consultation cost	O	1.45%*L	$8,834,966
5	Total cost baseline	P	L+M+N++O	$725,393,723
6	Allowance	Q	10%*P	$72,539,372
7	Contingency	R	8%*P	$58,031,497.81
8	Total estimated cost	S	P+Q+R	$855,964,593

In addition to cost components, traffic forecasting is the most important parameter used for calculating the projected revenue during the operation stage. Typically, the project revenue for the toll road option is determined based on the multiplication of the traffic forecast and the toll rate applied. From statistical data and traffic surveys carried out by The Department for Transport, Energy and Infrastructure (DTEI, 2011c), the traffic forecast for the Northern Connector at major interchanges is presented in Table 6.7.

Table 6.7. Traffic forecast for the Northern Connector project
(number of vehicles/day)

Project Locations	2010 (Existing Route)	2031 (Forecast)	
		With Northern Connector	Without Northern Connector
North of Northern Expressway	15,900	32,500	33,000
Northern Expressway to Waterloo Corner	30,900	22,500	52,000
Waterloo Corner road to Bolivar Road	38,700	20,000	53,000
Bolivar Road to Ryans Road	49,000	25,000	60,000
Ryans Road to Globe Derby Drive	47,600	29,100	69,100
Globe Derby to Salisbury Highway	56,100	25,000	67,500
Average Daily Traffic Volume	39,700	25,683	55,766

This table shows that the operation of the Northern Connector road will significantly reduce the pressure of traffic volume on the existing routes, especially for Bolivar Road, Ryans Road, and the Salisbury Highway. Based on project costs and traffic forecasts identified above, the Discounted Cash Flow technique is applied for project financial analysis. Typically, cost and benefit components occurring during the project lifecycle are discounted with a fixed interest rate to identify the present value of costs and benefits before comparison. The detail of financial analysis is presented in Appendix M. The main results of project financial analysis are shown in Table 6.8.

Table 6.8. Project financial analysis
(for both freeway and toll road options)

Financial Indicators	**Freeway**	**Toll Road**	**Note**
Investment Cost	$855,964,593	$870,964,593	Equipment costs for Toll Road option ($15.0 million)
System Operation (*per annum*)	$ 5,500,000	$ 5,600,000	The difference between two options is insignificant.
Maintenance Cost	$5,700,000/year $30,755,000/5-year	$5,700,000/year $30,755,000/5-year	
Construction Time	3 years	3 years	
Traffic Forecast	25,683 vehicles/day	17,978 vehicles/day	
Operational Time	30 years	30 years	
Toll Rate	N/A	$5/vehicle/trip	
Financial Net Present Value (FNPV)	N/A	$ 401.3 million	
Financial Benefit-Cost Ratio (FB/FC)	N/A	1.36	
Financial Payback Period (FPP)	N/A	28.7 years	

Table 6.6, Table 6.7 and Table 6.8 provide detailed calculations on project cost estimation and traffic forecasts, but in fact, most infrastructure projects suffer cost overrun and delays. Flyvbjerg (2007) pointed out that for rail, an average cost overrun of 44.7% is combined with an average traffic shortfall of 51.4 %; and for roads, an average cost overrun of 20.4% is combined with a fifty-fifty chance that the traffic forecast is also

incorrect by more than 20%. The main cause for this problem arises from an optimism bias of analysts who intend to overestimate the benefits and underestimate costs (Flyvbjerg, 2007). In addition, the accuracy of financial assessments depends on the acceptance of parameter inputs and the assumptions used for calculation. A small change in project inputs may lead to a significant change in the outcome of project evaluation (Jones et al., 2014), so the supervision role of independent organisations (or professional stakeholders) should be considered in the CBA framework to enhance the accuracy level of value assigned to the input parameters selected.

b. Project Economic Analysis

Without project investment (the base case), the traffic capacity of the existing route from the Southern interchange to the Northern interchange will be overloaded (DTEI, 2011a) and this will lead to traffic congestion and associated consequences such as an increase in travel time, travel cost and the number of traffic accidents. In contrast, the implementation of the Northern Connector is expected to bring potential benefits, not only covering investment costs but also avoiding social costs caused by traffic congestion occurring in the base case. It is clear that the potential costs identified for the base case (e.g. traffic congestion) are the reverse of potential benefits of the project case (e.g. solving traffic congestion): thus, the researcher selected the project case option for economic analysis.

From the identification of cost-benefit factors presented in Step 2 (see Table 6.3 and Table 6.4), typical factors are travel time savings, travel cost savings, the reduction in number of traffic accidents and other costs associated with the investment. These factors are critical components of project economic analysis. According to the guidelines proposed by The European Commission (2008), three stages are proposed for economic analysis: (1) conversion from market to shadow price (2) evaluation of non-market impacts and (3) the calculation of project economic performance. The purpose of the first stage is to convert the investment costs from the market price into a shadow price for economic analysis. Next, the second stage focuses on measuring non-market impacts under monetary terms. Finally, the third stage is a synthesis step, which classifies cost-benefit components before calculation.

- *Conversion of market to shadow price*

Typically, the shadow price is referred to as a monetary value assigned to currently unknowable or difficult-to-calculate costs (Georgi, 1973). When the market price does not reflect the opportunity cost of inputs and outputs, multiple conversion factors are used to convert them into a shadow price for analysis (Little & Mirrlees, 1990). The calculation of standard conversion factors is based on the CBA guide of The European Commission (2008). There are many ‘minor’ items in project inputs that need to be adjusted for calculation: for example, cost of labour force, raw materials, machinery, energy, land acquisitions, maintenance, management, and consultants. The details of calculating conversion factors for project inputs from the social opportunity cost perspective, are presented in Appendix L. The conversion factors addressed are then applied to convert the investment cost (market price) of the Northern Connector Project into the shadow price. The basic formula applied for this task is shown in Equation 6.1.

$$v_i = k_i \, p_i \qquad \text{(Equation 6.1)}$$

where k_i are the conversion factors

p_i are market prices for project inputs

v_i are shadow prices for the same project inputs

The detail of conversion from market price of Northern Connector project into shadow price is presented in Table 6.9.

Table 6.9. Conversion from market price to shadow price for project inputs
(For both freeway and toll road options)

List	Cost Components	Market Price	Conversion Factors	Shadow Price
1	Construction cost	$609,307,992	0.86	$524,004,873
2	Land compensation	$100,000,000	1.00	$100,000,000
3	Management cost	$7,250,765	0.98	$7,105,750
4	Consultation cost	$8,834,966	0.98	$8,658,267
5	Total cost baseline	$725,393,723	-	$639,768,889
6	Allowance	$72,539,372	0.98	$71,088,584.81
7	Contingency	$58,031,497.81	0.98	$56,870,868
8	Total estimated cost	$855,964,593	-	$767,728,342
9	Operational Cost	$5,500,000	0.91	$4,983,000
10	Maintenance Cost • Every year • Every 5-year	 $5,700,000 $30,700,000	 0.936 0.936	 $5,300,000 $28,755,000

- *The evaluation of non-market impacts.*

The implementation of the Northern Connector project will bring significant benefits to users who will travel on the new road, including travel time savings, vehicle operating cost savings and a reduction in traffic accidents. In addition, the operation of the Northern Connector will resolve the traffic congestion issue at intersections such as the Wakefield interchange, the Southern interchange, the Bolivar interchange, the Waterloo Corner interchange and the Northern interchange. Generally, the main costs and benefits of the Northern Connector include some principal components as described below:

- Consumer's surplus refers to the difference between the consumer's willingness-to-pay and the real costs spent on the new route (Bohm, 1979). The consumers' surplus typically refers to the value of perceived operating costs (VOC) and value of time (VOT) for passengers and freight travelling on the new road.

- Gross producer's surplus refers to the projected revenue resulting from operating the toll road (Jenkins, 1999). If the Connector Northern project is operated as a freeway without a toll rate, the figure for the gross producer's surplus will be zero.

- Environmental impact measurement refers to the amount of carbon emissions generated from activities during the construction stage of the Northern Connector and from vehicles travelling on the new road (operation stage).

In order to calculate the major benefit components of the Northern Connector project, several assumptions related to fuel price and time savings are used for assessment. The details of VOC and VOT assessment are presented in Tables 6.10 and 6.11.

Table 6.10. The value of travel time saving

List	VOT Components	Estimation	Notes
1	Travel time on existing road (minutes)	40.0	45km/h with Traffic Delays
2	Travel time on Northern Connector (minutes)	10.0	100 km/h without Traffic Delays
3	Travel Time Savings (hour/trip)	0.5	
4	Average Wage Rate ($/hour)	35.4	70% Travel for Working ($43/hour) and 30% Travel for Non-Working ($17/hour)
5	Average Freight Rate ($/hour/ton)	15.0	10 tons/truck in average
6	**VOT Savings ($/vehicle)**	**34.9**	70% Car and 30% Truck

Table 6.11. The value of operating cost savings for vehicles
(For both freeway and toll road options)

List	VOC Components	Existing Path with speed of 55-60 km/h (20 km in total length)	Northern Connector with speed of 96-103 km/h (15.5 km in total length)
1	Fuel cost (cents/km)	41.7	32.1
2	Oil cost (cents/km)	0.10	0.10
3	Tyres cost (cents/km)	50.05	49.55
4	Repairs & Maintenance cost (cents/km)	24.93	24.93
5	Depreciation cost (cents/km)	54.00	54.00
6	Total Cost (cents)	**170.8**	**160.7**
7	**VOC Savings (cents/vehicle)**	nil	**925**

In addition, the operation of the Northern Connector project is predicted to reduce greenhouse gas emission by 37 kilotons of CO_2 every year, compared to the base case (without the Northern Connector) (DTEI, 2011a). Greenhouse gas emission savings are related to the fact that due to the more favourable alignment, the distance travelled for most traffic will be reduced and vehicles will not need to stop for junctions nor idle in congested traffic. In addition, the traffic flow remaining on the existing road will be smoother. The assumed unit cost is AUD 23 per tonne of CO_2, with an annual growth of AUD 1.0 (Jotzo, 2012). The total greenhouse gas emissions for the Northern Connector is presented in Table 6.12.

Table 6.12. Greenhouse gas emission (kt CO_2-e). Adapted from DTEI (2011a)
(for both freeway and toll road options)

Project Phase	Greenhouse Gas Emission
GHG emission during construction stage	+187 (increase)
30-year GHG emission during operation stage	-2,409 (savings)
GHG Emissions caused by maintenance activities	+222.6 (increase)
Total GHG emission savings	+1,999.4 (saving)

Moreover, accident cost savings can be estimated through statistical surveys of The S.A. Department for Transport, Energy and Infrastructure. Analysis of comparative safety levels reveals that the traffic fatality risk for the base case is 192 crashes from 2005 to 2010 (two fatalities, 69 injuries and 121 cases of property damage), while the predicted figure for the Northern Connector project is fewer than 90 crashes (DTEI, 2011c). With the assumed unit cost being \$ 14,183 per minor crash and \$397,000 per serious crash respectively (Connelly & Supangan, 2006), the implementation of the Northern Connector project will save an estimated AUD \$1.0 million every year during its operation stage, representing a significant saving.

- *The project economic performance*

Based on the project costs and benefits addressed above, the Discounted Cash Flow technique is applied again for project economic analysis. The detail of the economic analysis is presented in Appendix N. Table 6.13 shows the main results of the Northern Connector project economic analysis.

Table 6.13. Project economic analysis
(for both freeway and toll road options)

Indicators	Freeway	Toll road
Investment Cost	$767,728,342	$782,728,342
Operational Cost	$4,983,000	$5,096,000
Maintenance Cost	$5,300,000/year $28,755,000/5-year	$5,300,000/year $28,755,000/5-year
Traffic Forecast	25,683 vehicles/day	17,978 vehicles/day
Travel Time Savings	$34.9/vehicle	$29.9/vehicle
VOC Savings	$9.25/vehicle	$9.25/vehicle
Accident reduction	$50,000/crash	$50,000/crash
CO_2 Emission Saving	+37 kilotons CO_2	+37 kilotons CO_2
Economic Net Present Value (ENPV)	$7,233 million	$4,130 million
Economic Benefit-Cost Ratio (EB/EC)	8.28	5.09
Economic Payback Period (EPP)	6.5 years	9.1 years

It is clear that Table 6.13 provides specific indicators used for comparison and project proposal selection. However, this approach has limitations because it mainly relies on the **economic** approach to monetise cost-benefit factors (Hansjürgens, 2004). This approach only reflects the viewpoint of the economists with its use of conventional methods and it does not allow key stakeholders to be involved in the CBA process. Even though several economic aspects of the project such as travel time savings, transport cost savings, carbon emission savings and traffic accident reduction are included in this assessment, many factors of the project investment which are major concerns of stakeholders are not fully considered: for example, traffic disruption, land compensation, business opportunities. These factors should be perceived from the viewpoint of stakeholder groups that are directly affected and measured by supplementary methods (see Appendix E).

Step 4: Sensitivity analysis

The sensitivity analysis aims to study the uncertainty present in the output of the assessment models used for measuring the impact of the Northern Connector Project when the analyst changes assumptions and input parameters for evaluation. In this case, six main inputs to the project: investment cost, traffic forecast, operational and maintenance cost, VOT, VOC, accident savings, and the amount of CO_2 savings are selected for adjustment (see Appendix O). The changes in investment cost and traffic forecast inputs are shown in Table 6.14.

Table 6. 14. Project sensitivity analysis

Variable tested	Freeway		Toll Road		Notes
	FNPV	ENPV	FNPV	ENPV	
Investment cost (+20%) Traffic forecast (-20%)	N/A	-24%	-161%	-32%	FNPV and ENPV stand for Financial and Economic Net Present Value.
Investment cost (+15%) Traffic forecast (-15%)	N/A	-18%	-119%	-24%	
Investment cost (+10%) Traffic forecast (-10%)	N/A	-12%	78%	-16%	
Investment cost (+0%) Traffic forecast (-10%)	N/A	-10%	-38%	-12%	
Investment cost (+0%) Traffic forecast (-15%)	N/A	-14%	-57%	-19%	
Investment cost (+0%) Traffic forecast (-20%)	N/A	-19%	-75%	-25%	

Table 6.14 shows that the outcome of financial analysis is highly sensitive to changes in the investment cost and traffic forecast. Sensitivity analysis in this case is useful for outcome predictions but it still has limitations because the number of input variables tested depends on the analyst's viewpoint, rather than stakeholder viewpoints. Other variables which should be considered relate to project risks such as capital cost, technology cost, project delays, and environmental conditions. In addition, the variance between project inputs and outputs not only depends on the changes in input parameters, but also depends on analysis techniques and processes applied for calculation. A typical example is the selection of project lifecycle for cash flow analysis. The selection of the operational time (e.g. 30-year or 50-year) often leads to a significant change in the outcome of both project financial and project economic assessment. Thus, it would be recommended that sensitivity analysis should be executed with a range of variances under stakeholder perspectives and tested by different methods and techniques. This will help the analyst to recognise potential risks, as well as to examine the feasibility of the project proposal via scenarios examined.

Step 5: Project CBA report

Overall, financial analysis for toll road option shows certain positive indicators with a financial net present value of the project case of $401.3 million (see Table 6.8) and a Benefit-Cost ratio of 1.36. These indicators are significantly low compared with those for project economic analysis. The result of the economic analysis shows that the economic net present values (ENPV) for the toll road and freeway are $ 4,130 million and $ 7,233 million respectively; and the Benefit-Cost ratios for the toll road and freeway are 5.09 and 8.28 respectively (see Table 6.13). Thus, the investment in the Northern Connector with the freeway option is recommended.

It is apparent that the recommendations produced from the traditional approach are not convincing due to several limitations. Firstly, the transparency of input parameters is poor because the selection of project inputs lacks transparency, input and influence from independent groups. Secondly, many cost-benefit factors of importance to certain stakeholder groups may not have been captured and mentioned in the traditional project evaluation reports. Thirdly, the selection of evaluation methods is limited by the analysts' worldview and their experience. Thus, the evaluation team, instead of putting the 'best' reports on the table, need to take a new approach to CBA that gives an opportunity for stakeholders to be involved in the cost-benefit analysis process. The new approach also needs to improve the likelihood of picking and mixing the most appropriate evaluation methods for incorporation into the CBA program. Such an approach would improve the transparency of CBA processes and thereby, the investment decisions made and would be more likely to engender consensus among key parties, which would contribute to the feasibility and sustainability of the resulting project.

6.5.Stakeholder-Centric CBA Framework Implementation

The stakeholder-centric CBA framework has the following seven main steps: the identification of the problematical situation, 'informal' cost-benefit debate, quantitative assessment, 'formal' cost-benefit debate, synthesis, discussions about the changes needed, and action plan implementation.

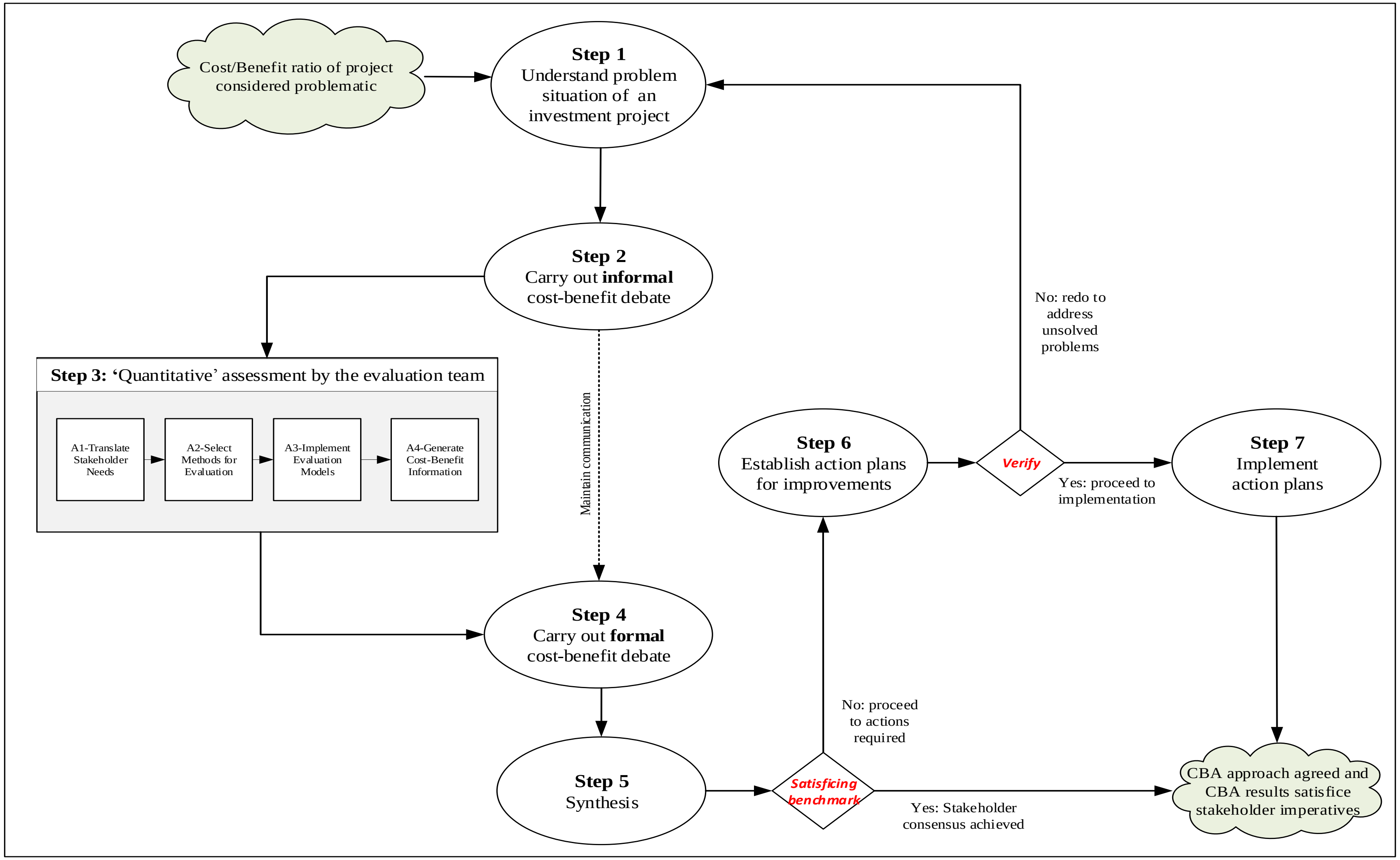

Figure 6.3. Stakeholder-centric CBA framework

Step 1: Understand problematic situation of the Northern Connector project

This step focuses on overcoming difficulties that practitioners may experience in using the CBA to make an investment decision that achieves consensus between key stakeholders. This study, instead of carrying project surveys, considers evaluation reports provided by The Department of Transport, Energy and Infrastructure of the Government of South Australia, to present detailed analyses. In the case of the Northern Connector project, stakeholders have different interests in the implementation of the project and, not surprisingly, they tend to focus on their 'preferred' interests and, therefore, raise different questions. For this project, the key stakeholder groups are listed below:

- The residents, who are people who live in areas close to the construction works. In this case that included residents in the City of Playford, City of Salisbury, City of Port Adelaide, in particular the suburbs of Virginia, Waterloo Corner, St Kilda, Bolivar, Globe Derby Park, Dry Creek, Wingfield and Gilman (DTEI, 2011a). These people may have had some serious concerns regarding the socio-economic impacts of property acquisitions as well as safety in a multiple-use transport corridor. In addition, air pollution and noise pollution during the construction stage may also be a major concern for the local community.

- Industry groups, including business owners, contractors and logistics suppliers in the Southern and Northern areas of Adelaide. These groups on the whole may have a positive orientation towards the implementation of the Northern Connector project which will significantly reduce travel time and transport costs between the Southern and Northern interchanges (DTEI, 2011a). In addition, the implementation of the Northern Connector will also create business opportunities for major contractors and sub-contractors, especially those involved in the construction industry in South Australia.

- The State Government is a primary sponsor of the Northern Connector project, and anticipates that the implementation of the project will attract ongoing investment into industry and business in the following areas: the Outer Harbour, the Osborne Maritime precinct, the inner harbour region, the north-west industrial crescent, Wingfield Industrial region, and the Greater Edinburgh Parks Industrial and Technology Park (DTEI, 2011a). In addition, the Northern Connector will contribute to the achievement of SA policies such as the 30-year Plan for Greater Adelaide, the Housing Plan for South Australia, and the Adelaide Urban Corridor Strategy.

- The SA Engineering Society is concerned with the impacts of project investment on the main drainage systems and surface water bodies in specific areas, including Helps Road Drain, Dry Creek, Barker Inlet North, Little Para River, North Arm Creek and Magazine Creek (DTEI, 2011a). Additionally, the SA Engineering Society Group has also had input into the selection of a preferred route for the Northern Connector road.

- Non-Government Organisations (NGO) focus on project impacts on the environment and the biosphere of ecosystems in several areas. People in these organisations are technical specialists from environmental and engineering consultancies, including, for instance, a wetlands designer and a flora and fauna expert (DTEI, 2011e). These people have major concerns about the increase in greenhouse gas, unsustainability and climate change caused by the construction of the Northern Connector project.

- The Aboriginal Heritage Committee is concerned with the impacts of the project on local heritage and the possible disturbance or interference by construction with Aboriginal sites and objects (DTEI, 2011d). The committee has asked for heritage assessment to determine the possible locations and sites affected.

- The travelling public refers to users who intend to select the Northern Connector road for their travelling in the future. The major interest of this group is the comfort and convenience of travelling on the Northern Connector road. In addition. the operational options (e.g. freeway or toll road) proposed for Northern Connector project received great attention from people in this group.

- Media groups often focus on controversial project topics to investigate social issues. This group is interested in analysing the impacts of Northern Connector project to highlight key information that may receive great interest from the public.

Based on the initial analysis mentioned above, a rich picture is built up to help the analyst to explore the problematical situation and express it through a diagram which can show the relationships and interactions between key stakeholders. Figure 6.4 illustrates the problem situation of the decision-maker in identifying potential costs and benefits of Northern Connector project.

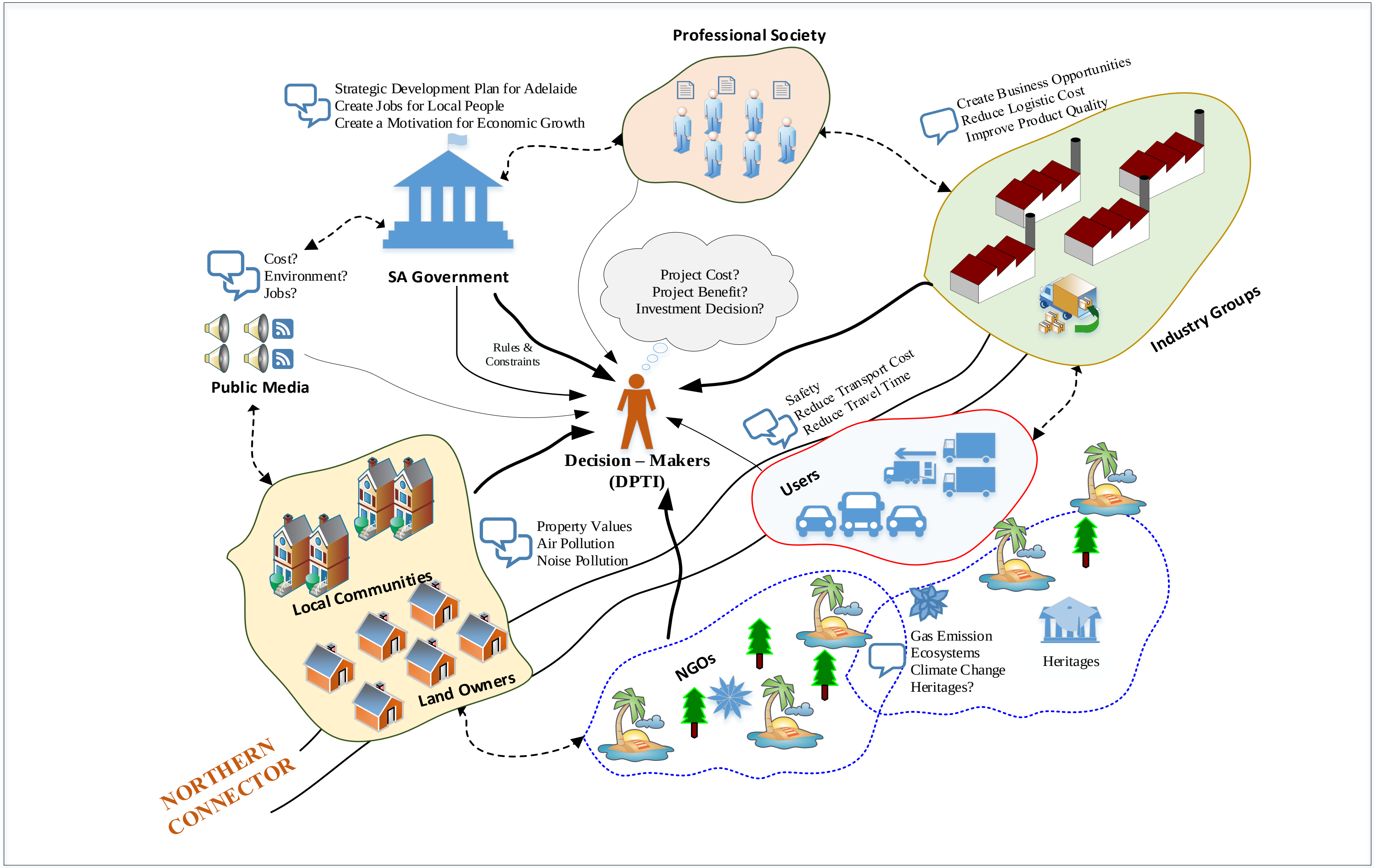

Figure 6.4. Rich picture of Northern Connector project

In Figure 6.4, the problem faced by decision-makers is one of how to make an investment decision that can reach an acceptable level of consensus between key stakeholders under the rules and constraints of The South Australian Government. In this case, it is crucial to understand the actual needs of stakeholders. Thus, the CATWOE technique presented in Chapter 4 is applied to recognise the difference between distinct worldviews regarding the investment in the Northern Connector project. From the rich picture above, the components of CATWOE analysis are addressed via these different worldviews.

Table 6.15. CATWOE components for Northern Connector project

Government of South Australia	Worldview	The implementation of the Northern Connector project can help the SA government to achieve their strategic development policy and hence improve the State's transport infrastructure.
	Transformation	The construction of Northern Connector project will improve the reputation of the State government and get support of multiple parties.
	Customers	Travellers, residents, and industry groups.
	Actors	Department of Planning, Transport and Infrastructure
	Owners	Government of South Australia.
	Environment	Strategic planning for Adelaide; the rules and regulations applied for construction projects; environmental groups.
Transport Users	Worldview	The construction of the Northern Connector project can provide a reliable route for travelling.
	Transformation	To construct a new road that can improve safety and accessibility as well as protect natural environment.
	Customers	People who are going to travel on the new road.
	Actors	Department of Planning, Transport and Infrastructure
	Owners	Government of South Australia.
	Environment	Strategic planning for Adelaide; and rules and regulations applied for construction projects.
	Worldview	The investment of Northern Connector project directly negatively affects local business, especially farms and primary-industry jobs.

Landowners	Transformation	To construct a new road which can improve the competitive advantage for local business, but it needs to provide trade-offs for land compensation.
	Customers	Industry groups and travellers.
	Actors	Department of Planning, Transport and Infrastructure
	Owners	Government of South Australia.
	Environment	Strategic planning for Adelaide; and rules and regulations applied for construction projects
Residents near construction sites	Worldview	The construction of Northern Connector project negatively affects the living environment: for examples, noise pollution, air pollution and traffic disruption, especially in local business areas.
	Transformation	To construct a new road which can improve safety and accessibility and minimise project impacts on the local community during construction stage.
	Customers	Industry groups and travellers.
	Actors	Department of Planning, Transport and Infrastructure
	Owners	Government of South Australia.
	Environment	Strategic planning for Adelaide; and rules and regulations applied for construction projects.
Industry Groups	Worldview	The approval of Northern Connector implementation can create great opportunities for contractors and related industries.
	Transformation	To construct a new road with the involvement of numerous contractors and sub-contractors.
	Customers	Travellers; contractors and logistics companies.
	Actors	Department of Planning, Transport and Infrastructure; industry associations.
	Owners	Government of South Australia.
	Environment	Strategic planning for Adelaide; and rules and regulations applied for construction projects.
	Worldview	The construction of the Northern Connector project has significant impacts on the biosphere of ecosystems and the sustainability of natural environment.

NGOs	Transformation	To construct a new road that can satisfy environmental protection requirements, which contributes to the sustainable development of South Australia.
	Customers	Affected groups.
	Actors	Department of Planning, Transport and Infrastructure; environmental groups; anti-development political actors.
	Owners	Government of South Australia.
	Environment	Strategic planning for Adelaide; and rules and regulations applied for construction projects.
SA Engineering Society	Worldview	The implementation of the Northern Connector has impacts on the main drainage systems and surface water bodies in areas closed the project.
	Transformation	To construct a new road which can satisfy technical standard and minimise the impacts of project construction on the existing drainage systems and surface water bodies.
	Customers	Industry groups, residents and travellers.
	Actors	Department of Planning, Transport and Infrastructure
	Owners	Government of South Australia.
	Environment	Strategic planning for Adelaide; and rules and regulations applied for construction projects.
Public Media	Worldview	The implementation of the Northern Connector project creates a motivation for local economic growth, but project construction also affects the natural environment.
	Transformation	To construct a new road with the involvement of multiple stakeholders including local community and social media.
	Customers	Travellers and residents.
	Actors	Department of Planning, Transport and Infrastructure
	Owners	Government of South Australia.
	Environment	Strategic planning for Adelaide; and rules and regulations applied for construction projects.

From the CATWOE components presented in Table 6.15, it can be seen that the major similarities between stakeholders are in terms of actors, owners and environmental constraints of the Northern Connector project. The major differences in stakeholder perspectives are their worldviews and their perceptions of the customers of the Northern Connector project. The identification of CATWOE factors as presented in Table 6.15 enables the analyst to recognise the main causes leading to the differences in perspective, as follows:

- Worldview: while the SA Government focuses on the strategic plan for economic development, other groups focus on the potential costs and benefits of project implementation. In particular, residents have more concerns about jobs and safety; industry groups are interested in construction contracts and logistics costs in the future; NGOs are concerned about environmental consequences; landowners have concerns regarding the value of their properties.

- Customers: stakeholders, depending on their worldview, have a tendency to consider beneficiaries (or victims) as the main customers of the project proposal. For example, the worldview of government sees as customers as industry groups and travellers, while the worldview of NGOs sees customers as negatively affected groups such as landowners and local communities.

In addition to the diversity of stakeholders' perspectives, these same stakeholders have different interests and levels of power regarding the investment decisions made in this project. The analysts can use the four attributes proposed by Mitchell, Agle, and Wood (1997) to identify critical stakeholders who can potentially create significant influences on the project success. The four proposed attributes presented here are Power, Legitimacy, Urgency and Involvement. Power refers to the ability to get other stakeholders to do something they would not otherwise do. Legitimacy is a generalised perception of the appropriateness of the stakeholder to influence the given project, including societal norms, values and beliefs. Urgency is the degree to which stakeholders can gain immediate attention on project matters. Involvement relates to the frequency of stakeholder project participation.

Table 6.16. Stakeholder assessment matrix for the Northern Connector project[5]

Stakeholders	Power	Legitimacy	Urgency	Involvement
SA Government	*****	****	*****	**
Residents	***	**	*	**
Industry Groups	**	**	*	***
NGOs	***	***	****	**
Land Owners	***	*	***	*
Engineering Societies	*	**	*	*
Public Media	****	***	**	**

The number of stars in the above diagram indicates the relative scoring of attributes for each stakeholder group of the project. As Table 6.16 shows, the government has maximal scores for power, legitimacy and urgency but minimal scores for involvement. This means that the local government can have a significant influence on the outcome of project investment decisions, but its involvement during project stages is limited. Similarly, the assessment of residents shows that they have some power, but their ability to have any influence on the project is limited. From the stakeholder analysis presented, the differences between these groups regarding their perspectives and motivations are highlighted to set up appropriate communication channels between the evaluation team and key stakeholders involved in the decision-making process. A range of techniques for stakeholder communication can be used, including telephone calls, email, website, one to one meeting with landowners, community forums, letters and feedback forms, and meetings with local and state government agencies.

[5]The number of stars for each stakeholder group are assumptions made by the author, in line with the CATWOE analysis above.

Table 6.17. An example of stakeholder communication strategies

Stakeholder	Important Level	Communication Types	Communication Frequency
SA Government	Important	Face-to-Face, Email, Letter and Phone	Always
Residents	Medium	Face-to-Face and Social Media	Often
Industry Groups	Medium	Workshops and Interviews	Often
NGOs	Medium	Workshops and Interviews	Often
Landowners	Important	Face-to-Face and Workshops	Always
Public Media	Medium	Phone and Workshops	Often
Others (E.g. Engineering Societies and Urban Planners)	Medium	Workshops and Interviews	Often

Once the evaluation team gains the acceptance of stakeholders of their participation, the 'informal' cost-benefit debate will be carried out to recognise the obstructions which may hinder stakeholders in their understanding of the investment decisions for the Northern Connector project.

Step 2: Carry out informal Cost-benefit debate

This step aims to create an open space for discussions between key stakeholders and the evaluation team. It provides opportunities for stakeholders to express their concerns and to discuss the significant issues of the investment project, as they see them. In the 'informal' debate, the main objective is to understand stakeholder needs (rather than seeking consensus between them), so all stakeholders are encouraged to discuss and to contribute their voices to the project evaluation plan. The ideal place for 'informal' debate could be a community facility where invited stakeholders are able to interact with others and freely discuss issues concerning the investment project. Essentially, the evaluation team is the organiser of this informal discussion and its team members need to summarise stakeholder's concerns at the end of the program. For the Northern Connector project, major concerns of key stakeholders are categorised in the following four main groups:

- The financial group, whose major concern is the costs spent on land compensation and construction (DTEI, 2011b). The Northern Connector is a complex project, so any change in project design can lead to changes in the scope and this will be a main cause of cost overrun.

- The technical group, where the major concern is safety in a multiple use transport corridor and changes to local road access (DTEI, 2011e). In addition, the accuracy level of traffic forecast for the Northern Connector project depends on many hidden factors such as population growth rate and traffic forecast models applied, and so people may be mistrustful of the forecast.

- The socio-economic group, where the major concerns of local residents are property acquisition and effects on property values in their areas (DTEI, 2011d). In addition, people living in the investment area may be concerned about local jobs which could be lost due to business relocation.

- The environmental group where the major concerns of NGOs are the consequences of project implementation for the natural environment: for example, air pollution, noise pollution and chemical waste during the construction stage (DTEI, 2011d) and ultimately when in use. Many questions raised may also emphasise the sustainability of ecosystems within the investment area.

The involvement of the evaluation team allows its members to better understand and capture actual stakeholder needs which are presented in Table 6.18.

Table 6.18. Stakeholder needs for the investment in the Northern Connector project

List	Stakeholder Group	Needs
1	SA Government	+ Reduce Traffic Congestion + Reduce Traffic Accident + Create Jobs for local people + Improve the competitive advantage of local industries + Minimise the financial risk + Contribute to the local budget
2	Residents Users	+ Have a safe and efficient road + Protect the natural environment + Increase the value of the property
3	Industry Groups	+ Reduce the traffic congestion + Save travel time for vehicles + Create opportunities for contractors
4	Environmental Activists	+ Protect the natural environment + Ensure the sustainability of ecosystems + Reduce green gas emissions
5	Landowners	+ Receive suitable compensation for their land + Plan for business relocation
6	Public Media	+ Gain the attention of the local community + Improve the ratings for media programs + Spread project information to the public
7	Others	+ Satisfy technical standards for construction + Minimise project effects on local businesses

The appreciation of stakeholder needs is a crucial step to ensure that the subjective judgements of the evaluation team are minimised and that the team operates from a more accurate understanding before moving toward the next step for quantitative assessment.

Step 3: Quantitative assessment by the evaluation team.

Once the main stakeholder groups and their associated needs are clearly identified, this step focuses on translating stakeholder needs into specific requirements that can be measured by the hard CBA system via the CBAFS software. The assessment results generated from the ‘hard’ CBA system would be used as evidence for discussions between stakeholders in the ongoing debate. In the case of the Northern Connector project, the translation from stakeholder needs into engineering requirements is presented in Table 6.19.

Table 6.19. The translation from stakeholder needs into technical requirements

Stakeholder needs (What?)	Technical interpretation (How?)
SA Government	
+ Reduce Traffic Congestion	+ Traffic rate
	+ Transport cost savings
	+ Transport time savings
+ Reduce Traffic Accident	+ Traffic accident rate
+ Create Jobs for local people	+ Number of generated jobs
+ Improve the competitive advantage for local industries	+ Industrial development
+ Minimise the financial risk	+ Project financial indices
+ Contribute to local budget	+ Tax contribution per year
Residents	
+ Have a safe and efficient road	+ Design standards
+ Protect the natural environment	+ Air pollution level
	+ Noise pollution level
+ Increase the value of the property	+ The real estate price
Industry Groups	
+ Reduce the traffic congestion	+ Traffic rate
	+ Travel cost savings
+ Save travel time for vehicles	+ Travel time savings
+ Create jobs for local people	+ Number of jobs created
NGOs	
+ Protect the natural environment	+ Air pollution level
	+ Noise pollution level
	+ Chemical waste level
+ Reduce green gas emission	+ Carbon dioxide emission level
+ Ensure the sustainability of ecosystems	+ The identification of ecosystems
Landowners	
+ Receive suitable compensation for their land	+ Compensation fee
+ Plan for business relocation	+ Plan for relocation
Public Media	
+ Gain attention of local community	+ Public opinion measurement
+ Improve the rating for social programs	+ Users' feedback

The translation from stakeholder needs into measurable attributes can be performed by the CBAFS software. The evaluation team needs to follow the CBAFS Guide (see Appendix P) to carry out sequential activities that are depicted in Figure 6.5.

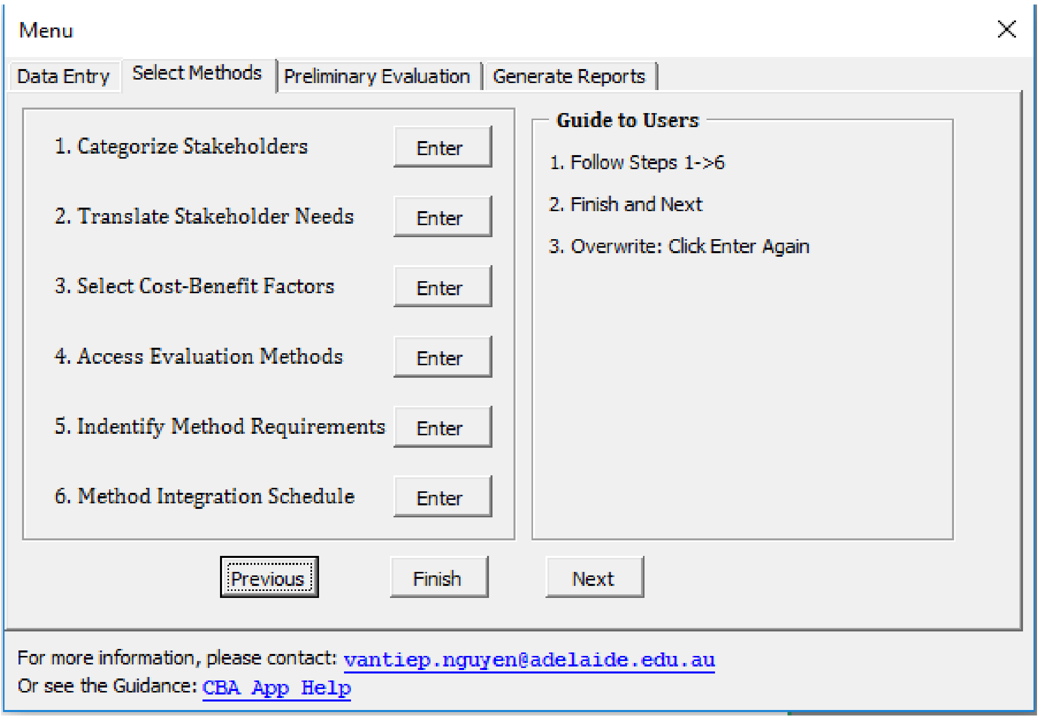

Figure 6.5. Select methods for project evaluation

In the following illustrated example, the list of needs and technical requirements will automatically appear for selection in accordance with each stakeholder group identified. The user needs to choose key groups and then select appropriate technical interpretations, which are demonstrated in Figure 6.6 and Figure 6.7 respectively.

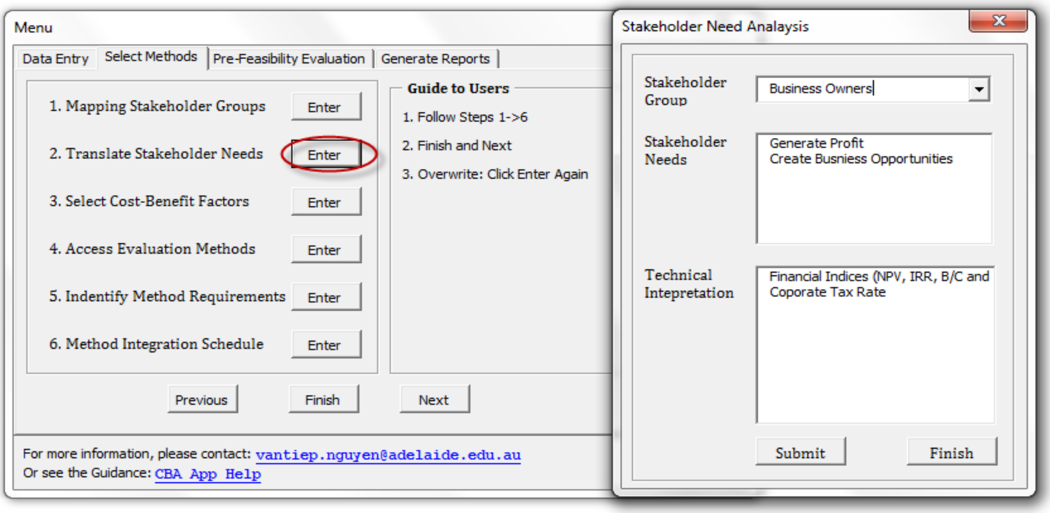

Figure 6.6. Stakeholder need translation

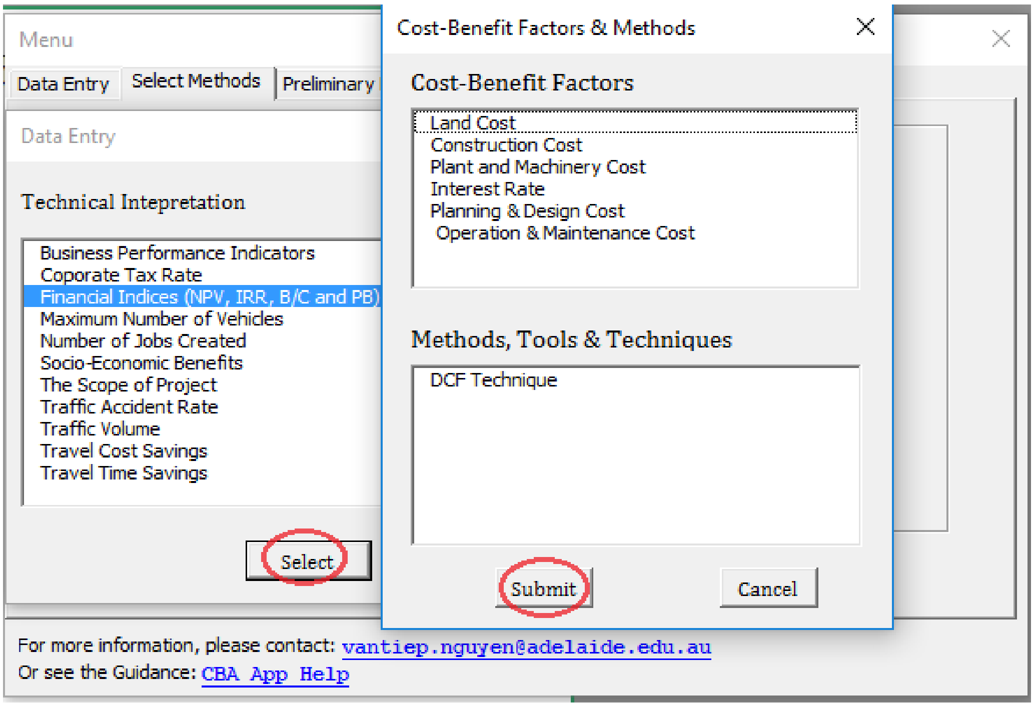

Figure 6.7. Cost-benefit factors and associated methods

In this study, the CBAFS was designed to execute assessment functions related to traffic forecast, VOT estimation, VOC estimation, financial analysis, economic analysis, risk evaluation and sensitivity analysis.

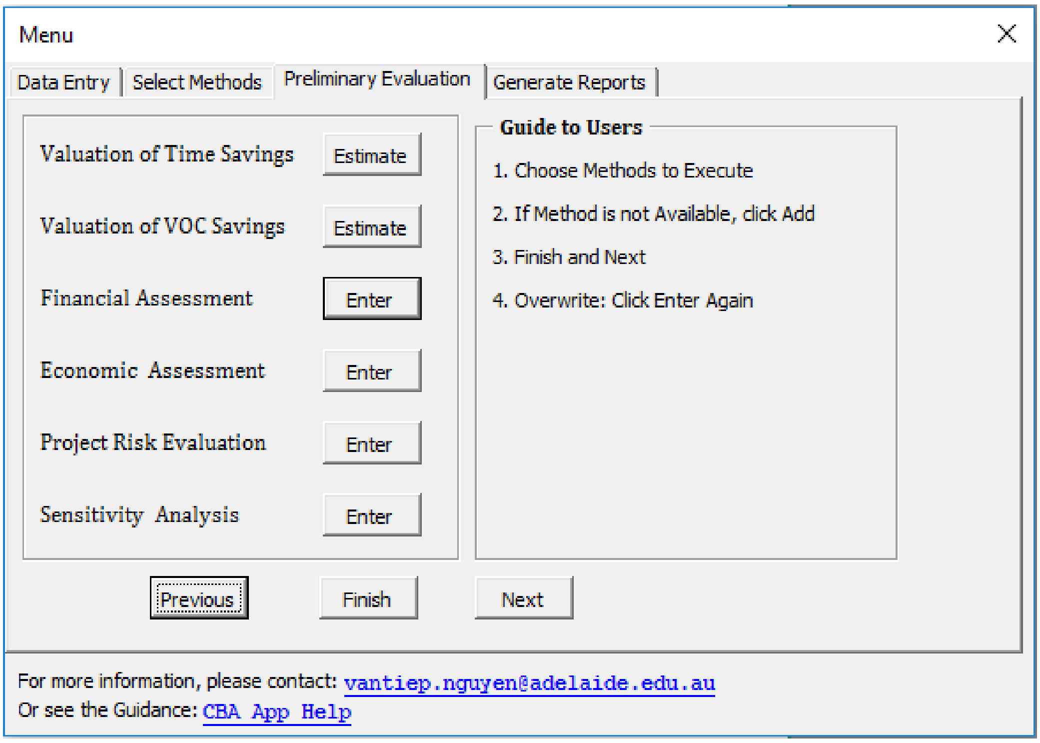

Figure 6.8. Preliminary evaluation of Northern Connector project

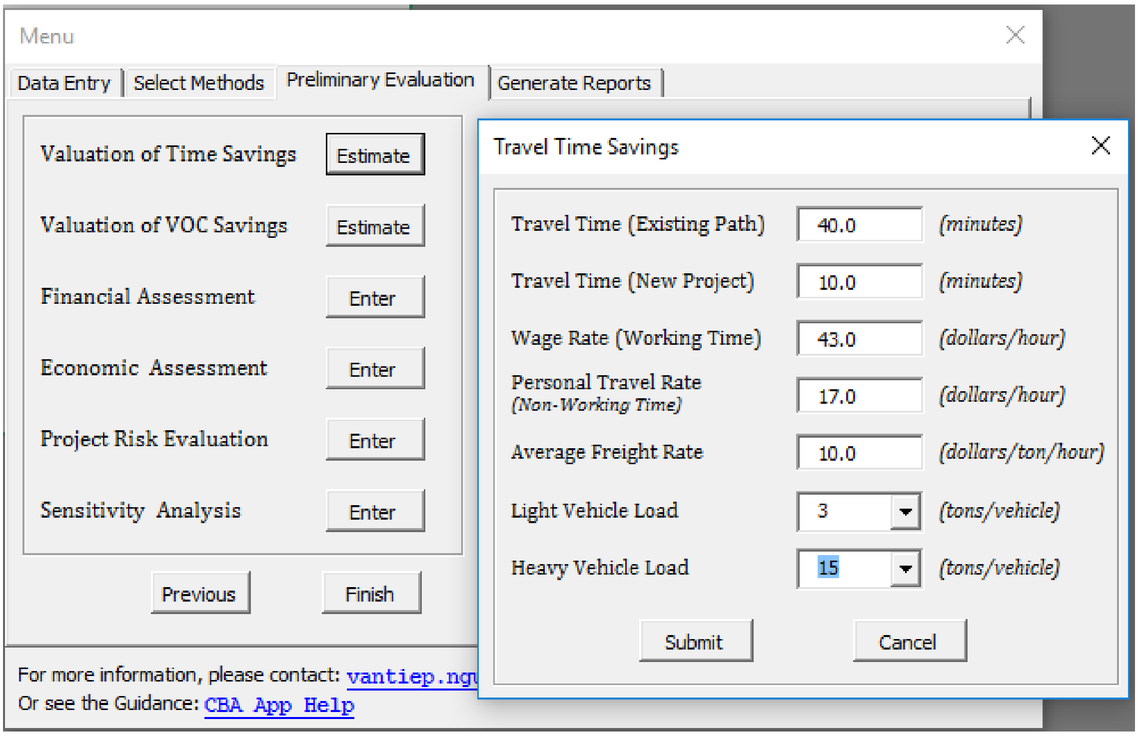

Figure 6.9. Valuation of travel time savings

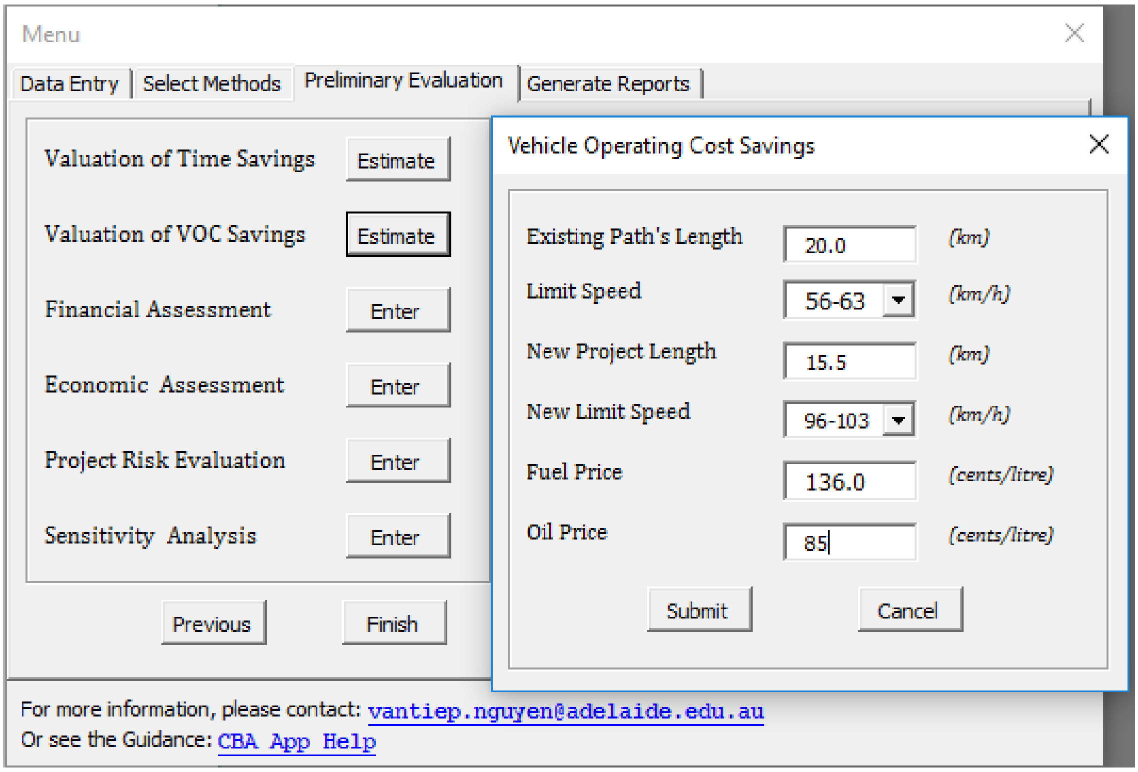

Figure 6.10. Valuation of transport cost savings

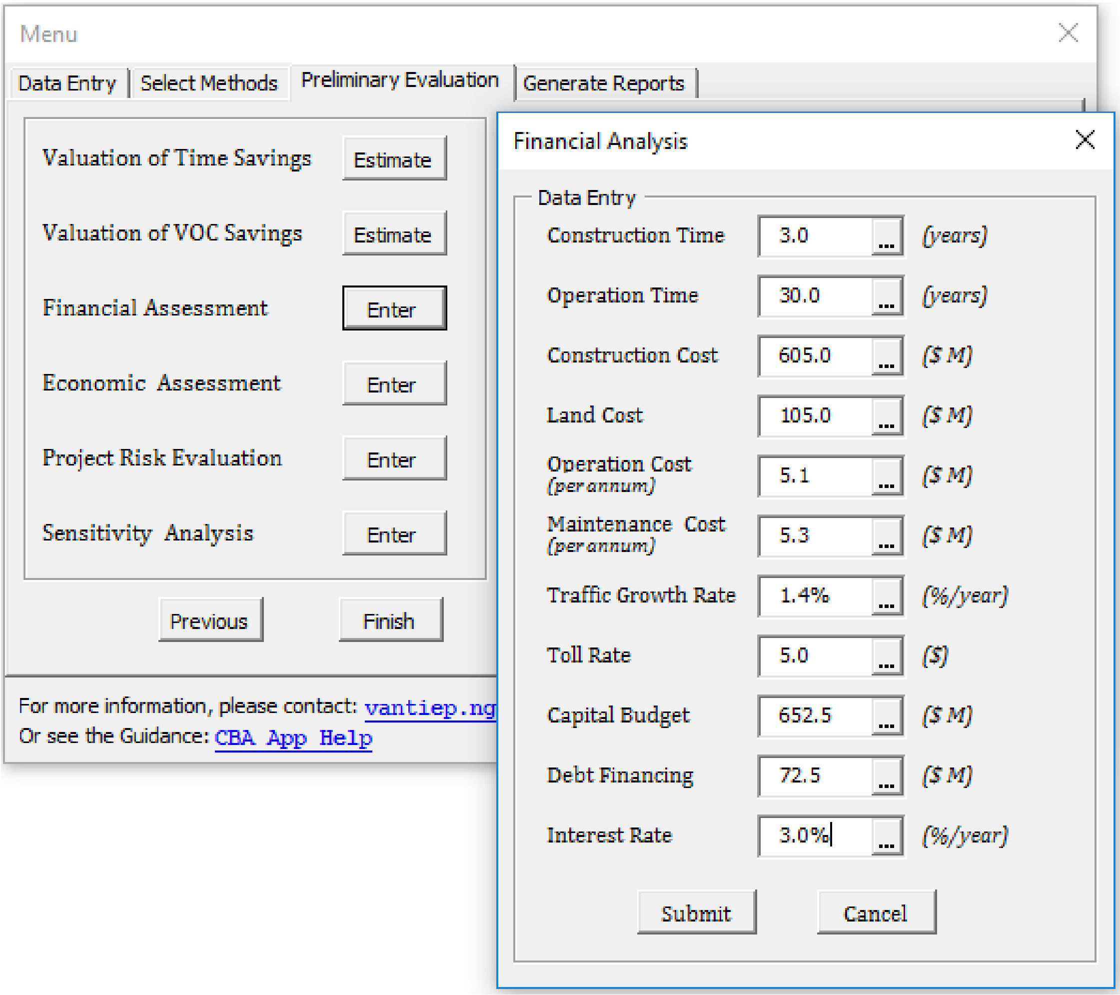

Figure 6.11. Project financial analysis

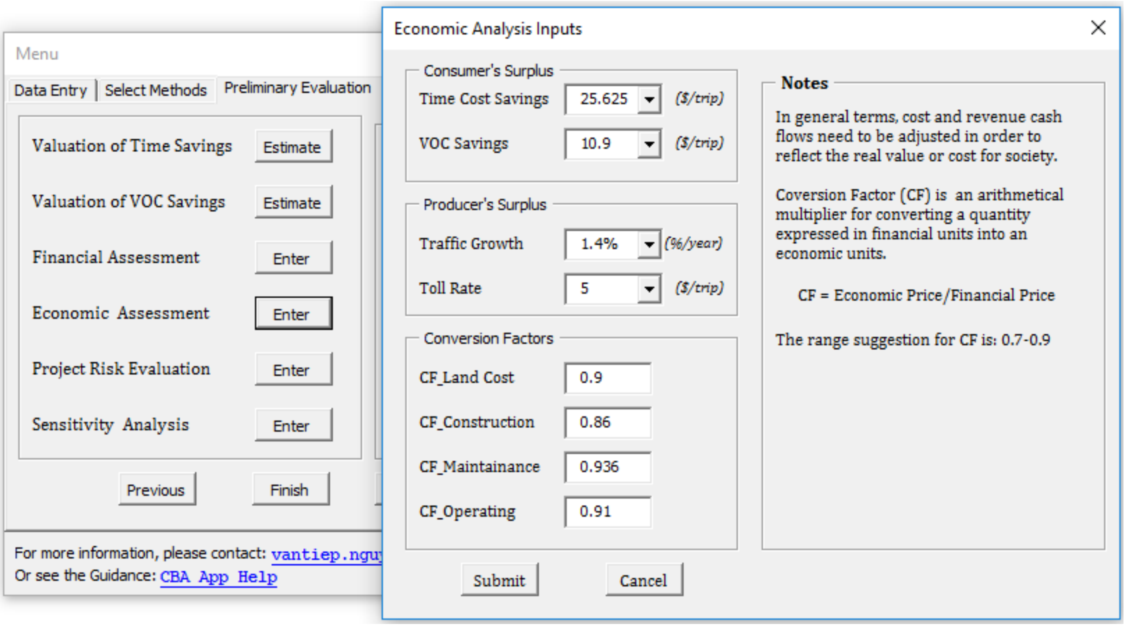

Figure 6.12. Project economic analysis

The CBAFS software has been used to carry out a range of evaluation activities for the Northern Connector project, including: VOT estimation, VOC estimation, financial assessment, economic assessment, risk assessment and sensitivity analysis. This software produces an accurate result quickly, without significant expertise required and it is, therefore, a valuable tool for practitioners. The details of the evaluation of the project are presented in Appendix M, Appendix N and Appendix O. In some cases, the evaluation team needs to consider using supplementary methods that are not currently available in the CBAFS to provide additional information for key stakeholders. Overall, the main indicators of the Northern Connector project are summarised in Table 6.20.

Table 6.20. Main assessment indicators of the Northern Connector project

Indicators	Freeway	Toll Road
Investment Cost	$855,964,593	$870,964,593
System Operation (*per annum*)	$ 5,500,000	$ 5,600,000
Maintenance Cost	$5,700,000/year $30,755,000/year	$5,700,000/year $30,755,000/year
Construction Time	3 years	3 years
Traffic Forecast	25,683 vehicles/day	17,978 vehicles/day
Operational Time	30 years	30 years
Toll Rate	N/A	$5/vehicle/trip
Financial Net Present Value (FNPV)	N/A	$401.3 million
Financial Benefit-Cost Ratio (FB/FC)	N/A	1.36
Financial Payback Period (FPP)	N/A	28.7 years
Time Savings	$34.9/vehicle	$29.9/vehicle
VOC Savings	$9.25/vehicle	$9.25/vehicle
Accident reduction	$50,000/crash	$50,000/crash
CO2 Emission Saving	+37 kilotons CO2	+37 kilotons CO2
Economic Net Present Value (ENPV)	$7,233 million	$4,130 million
Economic Benefit-Cost Ratio (EB/EC)	8.28	5.09
Economic Payback Period (EPP)	6.5 years	9.1 years

It is important to note that the information generated from the CBAFS is used as supplementary information for the formal stakeholder debate. The evaluation team can select key information to include in the evaluation report to key stakeholder groups that is aligned with their interests. For example, local communities have major concerns about the impacts of the project on their daily activities. Thus, they may expect to see such information as travel time, cost savings and environmental impact assessment. Once representatives of stakeholder groups receive the evaluation reports and accept the debate invitation, the ‘formal’ cost-benefit debate will be carried out to highlight the obstructions preventing the achievement of consensus among key parties.

Step 4: Formal cost-benefit debate

The main objectives of the second-round cost-benefit debate are to create an open space for stakeholder discussions and to establish some basic understandings between the different groups. Because the exercise of power in the interaction process is a primary inhibitor to open and free discussion, the evaluation team would set up the debate based on the ‘emancipatory’ principles of Total Systems Intervention to establish discussion in the main following stages.

Firstly, the evaluation team invites stakeholders to participate by utilising software that supports anonymous debating (e.g. DebateIsland and Debate Forum) designed for the formal debate. The representatives of the various stakeholder groups will have an ID (without personal information) to enter the virtual debate room. This ensures that all participants have freedom in discussions and can confidently show their major concerns regarding the investment in the Northern Connector project. In other words, the purpose of this activity is to avoid the exercise of power in the stakeholder debate process.

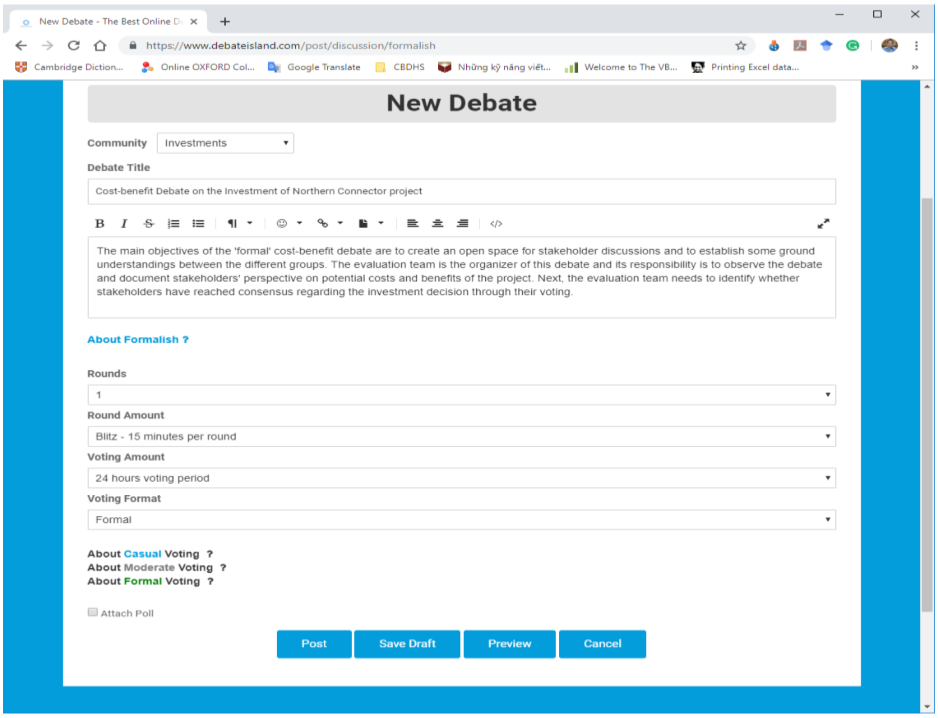

Figure 6.13. The 'formal' cost-benefit debate established for the Northern Connector project. Adopted from DebateIsland (2019)

Secondly, the evaluation team uses information generated from the 'hard' CBA system as evidence for the cost-benefit debate. Technically, outputs of the hard CBA system are linked and stored within the debate system which enables stakeholders to rapidly select relevant information for their arguments. In addition, a range of virtual tools from the webpage allows stakeholders to show their interest in, as well as to contribute their voice on the project proposal: for example, emotional symbols, voting and quotes (Figure 6.14). People have opportunities to approach the CBA from different angles, and thus the likelihood of understanding and accepting the differences in evaluation perspectives is greater.

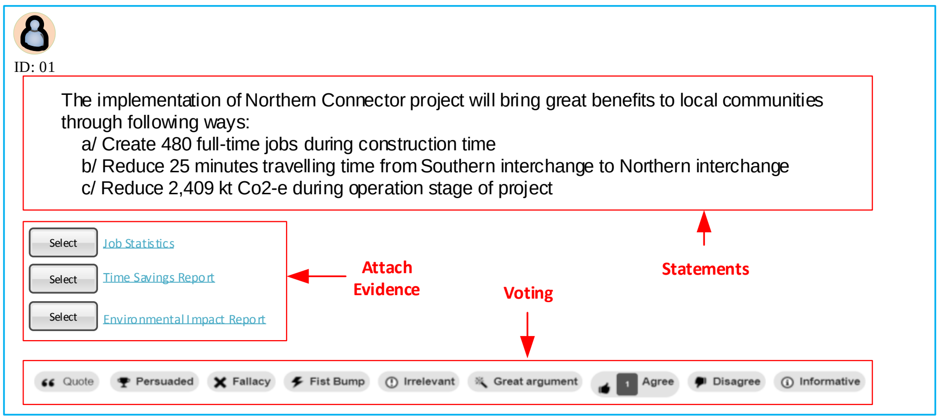

Figure 6.14. Stakeholder debate voting

The format of the debate is set up at the beginning and announced to participants to ensure that all understand and follow the rules: for example, those from a Lincoln-Douglash Debate, a Formalish Debate, or a Traditional Debate (DebateIsland, 2019). The number of participants in the 'formal' debate will depend on the complexity of the project and the identification of stakeholders in the first step of the stakeholder-centric CBA framework. The time frame can be established in accordance with the stakeholder requirement (e.g. 24-hours or 48-hours), to ensure that all stakeholders have a chance to read comments and present their arguments. Once the formal debate is finished, the evaluation team needs to identify whether stakeholders have reached consensus regarding the investment decision through their voting. Technically, the evaluation team can manually summarise findings from the formal debate, together with using statistical results generated from the data analysis system, which is a part of the analysis website (Figure 6.15).

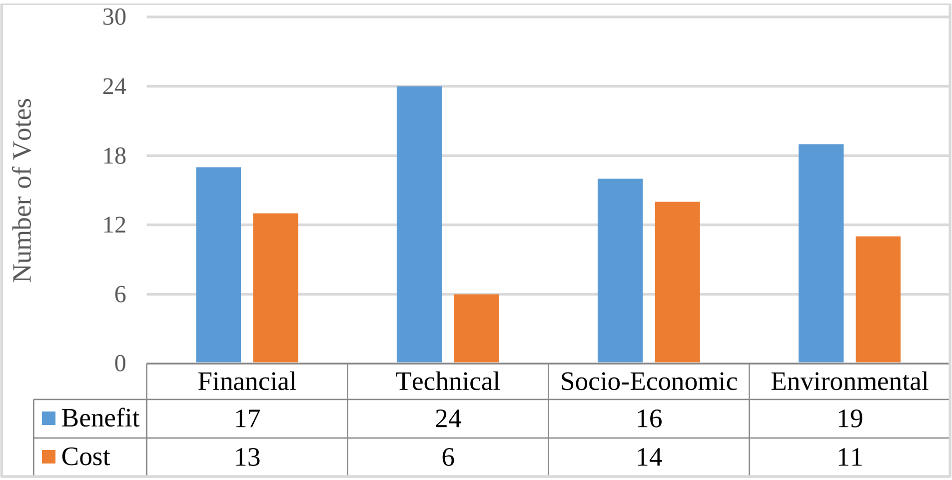

Figure 6.15. Statistical results from stakeholder debate

Figure 6.15 indicates that there is a slight difference between socio-economic costs and benefits. In other words, many people believe that the implementation of the Northern Connector will have negative impacts on the local economy and social values of South Australia. In some cases, some stakeholders may try to defend their position without rational arguments, so the evaluation team may need to use 'satisficing' benchmarks for debate assessment and for making the final decision, which is presented in the Synthesis Step.

Step 5: Cost-Benefit debate synthesis

Traditionally, an 'optimising' approach is used to produce the best results considering all the options. However, a cost-benefit debate is a complex process and there is no way to identify the 'best' option for decision-making (see Appendix Q). Thus, 'satisficing' benchmarks are used to assess whether the investment decision for Northern Connector project should be made. 'Satisficing' is considered as a 'good enough' approach that permits satisfaction at a specified level of need (Simon 1956). In this case, the evaluation team examines whether the outcome of the stakeholder debate matches the 'satisficing' benchmark (Table 6.21). In the example below, landowners have not reached consensus.

Table 6.21. 'Satisficing' benchmark for decision-making of Northern Connector project[6]

Satisficing Benchmark	Yes	No	Notes
1/ Address key stakeholder concerns			
+ Government of South Australia	✓		
+ Landowners	✓		
+ Local Community	✓		
+ Industry Groups	✓		
+ Environmental Organisations	✓		
+ Public Media	✓		
2/ Reflect stakeholder motivations			
+ Government of South Australia	✓		
+ Land owners		✗	
+ Local Community	✓		
+ Industry Groups	✓		
+ Environmental Organisations	✓		
+ Public Media	✓		
3/ Allow stakeholder to be involved in the analysis process	✓		
4/ Satisfy minimum financial and technical requirements for an infrastructure project			
+ Urban Master Plan	✓		
+ Design, Construction and Operation	✓		
+ Traffic Forecast Volume	✓		

[6] Main benchmarks can be divided into sub-benchmarks in accordance with a particular circumstance.

+ NPV, IRR, and B/C	✓		
5/ Be feasible with resources allocation			
+ Budget	✓		
+ Time	✓		
+ Human Resources	✓		

In this assumed situation, the researcher presents a possible scenario related to landowners and residents who live in the investment area. During the cost-benefit debate, landowners may believe that the implementation of the Northern Connector will significantly reduce their property value and they may therefore not agree with the current plan for project investment. In this case, machine learning, together with natural language processing, designed and integrated into the 'formal' debate system, are used to analyse various aspects of landowners' arguments.

The evaluation team discovers that the major issue for landowners is not the proposed price for land compensation because most landowners are in fact concerned about negative impacts of the project on their future business: for example, closing down several farming areas, re-planning the land usage, and replanting of native deep-rooted perennials. Consequently, the cost-benefit debate ends without the agreement of these key stakeholders. Thus, members of the evaluation team have closed discussions to take account of stakeholders' motivations. The evaluation team, based on statistical analysis from the 'formal' debate system, addresses the main cause leading to this problem, which is lack of a realistic plan for landowners' business relocation. Next, the evaluation team carries out Step 6 to establish action plans for problem solving.

Step 6: Establish action plan for improvement

This step refers to activities or tasks required to remove roadblocks in the CBA debate process. The evaluation team needs to establish action plans to resolve the problems related to landowners' concerns regarding the Northern Connector project. In this case, the evaluation team suggests an action plan including the following activities: (1) business relocation plan for landowners, (2) workshops to explain the action and (3) field trips for landowners in Playford, Port Adelaide Enfield and Salisbury to visit alternative locations.

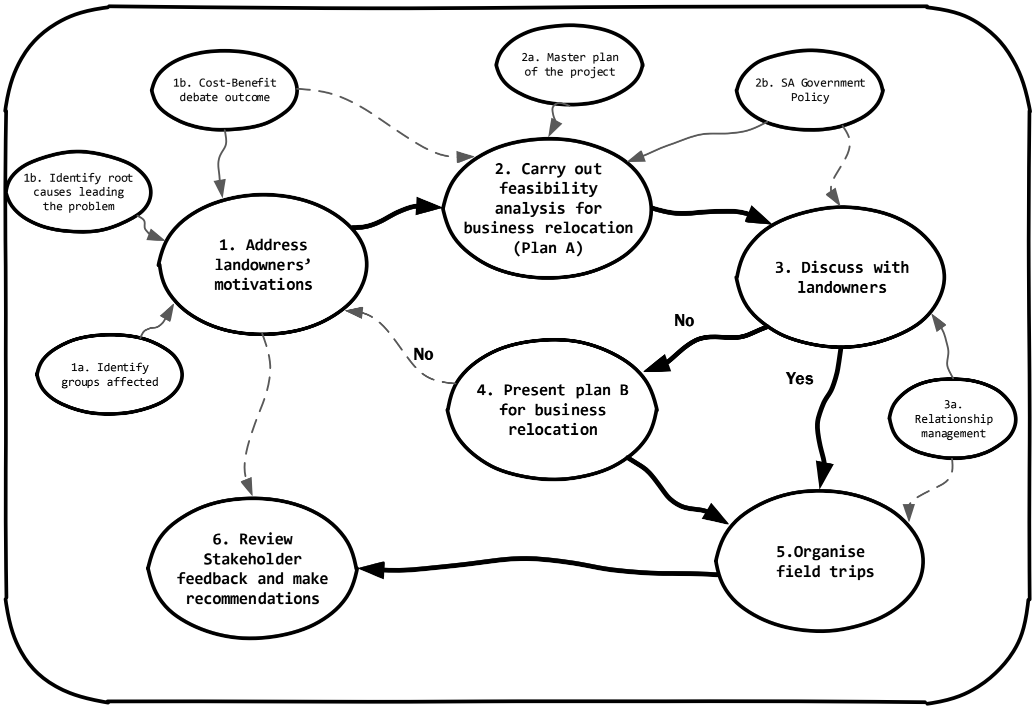

Figure 6.16. The action plan for landowner group of the Northern Connector project following the formal debate

In this situation, Plan A is constructed with the scenario that landowners in the investment area will move to new locations proposed by the government, together with financial support for business relocation. Plan B is constructed with the scenario that landowners will propose their own preferred locations and the government will then examine whether these locations are feasible. The negotiation process is then carried out and the outcome is that landowners accept Plan A with an increase of 30% in the total financial budget for property relocation and business launch in the first of three years (which equals with the time they would be affected during Northern Connector construction stage). Based on the agreement made between the Government of South Australia and the landowners, action plan A is carried out.

Step 7: Implement action plans

The evaluation team collaborates with departments of the South Australian government to implement action plan A. As a result, the outcome of actions is positive when landowners are happy with the supporting plan for business relocation. The outcome of stakeholder debate is documented and signed off by the parties involved. Next, decision makers and team members review the 'satisficing' benchmark to ensure the feasibility of the project proposal.

Table 6.22. 'Satisficing' benchmark review[7]

Benchmark	Yes	No
1/ Address key stakeholder concerns	✓	
2/ Reflect stakeholder motivations + Landowners' motivations relate to future business + Other stakeholder groups	✓	
3/ Allow stakeholder to be involved in the analysis process	✓	
4/ Satisfy minimum technical requirements	✓	
5/ Be feasible with resources allocation	✓	

The project investment should only be approved when it satisfies all 'satisficing' benchmarks, as above.

6.6.Research Discussion and Validation

6.6.1. CBA framework strengths and weaknesses

The conventional cost-benefit analysis approach is often carried out in a hierarchical fashion. This somewhat mechanical approach to project evaluation is premised on the view of a 'simple' system as being stable, rational and controllable (Gorod et al., 2018). This view has been the dominant paradigm within management for many decades, with the decision-maker using the formal process of analysis, evaluation and review of project feasibility toward the achievement of goals. In other words, the CBA analysis process is straightforward and rarely takes into consideration the dynamic nature of the infrastructure project environment. From the analysis of the given case study (the Northern Connector road), the strengths and weaknesses of the conventional CBA framework are identified and presented in Table 6.23.

[7] The assessment matrix based on the author's assumption.

Table 6.23. The strengths and weaknesses of the conventional CBA framework

Strengths	Weaknesses
+ It provides a clear evaluation structure with specific steps (Næss, 2006). The analysts can follow the framework to carry out evaluation activities for their project. + The framework has been widely applied by governmental organisations for public projects (Infrastructure Australia, 2018). Stakeholders who are involved in transport infrastructure projects can understand basic concepts presented in the framework such as traffic forecast, financial analysis, environmental impacts. + The framework has been applied for the evaluation of many projects, so the analyst can review evaluation reports of case studies to clarify framework aspects that are not clear or difficult for them. By following evaluation steps presented in real cases, people have more confidence with framework implementation. + The framework suggests many techniques used for measuring non-market impacts of transport infrastructure projects (Independent Evaluation Group, 2010; MacKie, 2010; The European Commission, 2008), so the analysists can select suitable methods (techniques) for their evaluation program.	- Even though the framework has listed specific steps for a comprehensive evaluation program, it focuses strongly on financial analysis and economic analysis to make recommendations for decision makers. - The framework does not leave space for project stakeholder involvement, so the results of framework application often reflect the viewpoint of analysts. This creates difficulties in understanding the diversity in evaluation perspectives. - It does not provide justification for the selection of methods and techniques used for evaluation. The method selection seems to mainly rely on the financial and economic schools of thought to propose analysis techniques such as discounted cash flow (DCF) and microeconomic analysis. - The application of the framework in practice is unclear. It is difficult to include the views of critical stakeholders who are involved in the CBA process and who can have a significant influence on the success of the evaluation program.

Transport infrastructure projects have, however, become more complex and interconnected than ever before and the decision-making process is complicated with the involvement of a range of stakeholders from the government through to the public. Although many authors have argued that practitioners should consider the diversity of CBA perspectives, they still face obstacles in selecting evaluation methods and seeking consensus among project key stakeholders. The stakeholder-centric CBA framework was developed to resolve these problems. It provides a specific guide for practitioners in recognising the problematic situation and establishing the necessary evaluation activities before making the final investment decision. From the analysis of the case study, the strengths and weaknesses of the stakeholder-centric CBA framework are presented in Table 6.24.

Table 6.24. The strengths and weaknesses of the stakeholder-centric CBA framework

Strengths	Weaknesses
+ It provides a 'soft' approach that allows the stakeholder to be involved in the analysis process and contribute their voice to the final investment decision of transport infrastructure projects. + The framework provides specific steps and processes that enable the analyst to fully capture the wide range of concerns of an investment project and to select suitable methods and techniques used for problem solving from a broader range. + The framework development is based on three philosophical positions of Total Systems Intervention, so it provides strong arguments on the selection of methods and techniques for evaluation and implementation. +The results of the framework application provide not only suggestions but also action plans to improve the problematical situation of the investment project.	- The framework is a new proposal for CBA, so users need to learn new analysis skills: for example, building a rich picture, using the CATWOE technique and running the CBAFS for quantitative assessments. - The implementation of the framework requires the involvement of many stakeholders so that it may take time and cost for stakeholder participation and engagement. - The framework also requires evaluation team members to have basic skills for using the CBAFS software, so it may take time for training activities.

The conventional framework provides a clear and simple structure for CBA, but its approach is too 'hard' and does not provide a 'holistic' solution. In comparison with the conventional CBA framework, the outstanding contributions of the stakeholder-centric CBA framework are as follows:

- The stakeholder-centric CBA framework enables practitioners to capture stakeholder needs and to recognise their motivations before carrying out evaluation activities. From the stakeholder analysis, practitioners can clearly identify specific project requirements that may prevent major risks during the project implementation stage.

- The stakeholder-centric CBA framework allows stakeholders to be involved in the CBA process. In other words, the stakeholder-centric CBA framework focuses on 'actions' to improve the transparency of CBA, while the traditional approach focuses on the 'analysis' process to make recommendations. The implementation of the stakeholder-centric CBA framework can improve the supervision role of stakeholders based on the accuracy of CBA.

- The stakeholder-centric CBA framework enables practitioners to build trust between the evaluation team and key stakeholders via communication strategies. The stakeholder-centric CBA framework uses a 'soft' approach where both decision-makers and stakeholders have opportunities for face-to-face communications and collaboration.

- The learning cycle of the stakeholder-centric CBA framework is a feedback loop for continuous improvements. Thus, the more feedback from stakeholders in the CBA, the greater the likelihood of recognising the root causes leading to stakeholder conflicts on the investment decision made.

- The stakeholder-centric CBA framework uses 'satisficing' benchmarks for assessment, instead of using 'optimising' criteria provided by the conventional framework. The 'satisficing' criteria are established based on the acceptance level of consensus among key stakeholders, and therefore the investment decision made becomes feasible in the case of continuing disagreement.

From the contributions highlighted above, it is clear that the implementation of the stakeholder-centric CBA framework can provide solid evidence for making investment decisions that are informed by all salient factors and are inclusive of the views of key stakeholders. As a result, the investment decision made becomes feasible and sustainable and this is a key factor contributing to the success of a transport infrastructure project.

6.6.2. Stakeholder-centric CBA framework validation

In Constructive Research, Kasanen et al. (1993) proposed market-based validation as the means of validating managerial constructions. In this research, the researcher focuses on the investment decision-makers for transport infrastructure projects; thus, the validation test falls into the first level of market test, which is "the manager is willing to use the construct for problem-solving and decision-making". The validation test has two parts: empirical validation and subjective matter expert (SME) validation.

- Firstly, a case study was selected to demonstrate how the stakeholder-centric CBA framework can be applied for project proposal selection. Due to time limitation and legal requirements, secondary data of the Northern Connector project was selected to demonstrate the main steps of both the conventional and the stakeholder-centric CBA frameworks. The primary purpose of this task is to address the strengths and weaknesses of the stakeholder-centric CBA framework and to highlight the major differences between the proposed framework and the traditional framework.

- Secondly, interviews with practitioners were conducted to gather their feedback on the utility and efficacy of the stakeholder-centric CBA framework. Expert feedback is crucial for framework refinement, and the findings of the interviews can be used to validate the applicability the stakeholder-centric CBA framework.

In this research, the researcher designed a 60-minute interview with participants to receive their feedback. Seven in-depth interviews with infrastructure evaluation experts in South Australia were carried out from February to March 2019. Six were individual interviews while the last comprised a group of two people who wished to be interviewed in the same group and same time. (The only purpose of carrying out the group interview was to save time and there was no difference between the content of group interviews and individual interviews.) The interview procedure included two steps: (1) Case Study Presentation and (2) Interview to obtain data on the value of the methodology and associated tool. Participants in this project have different backgrounds including civil engineering, project management, technology management, architecture and built environment; and most of them have rich experience in project evaluation and decision-making for investment projects in Australia. The NVivo software was used to synthesize experts' answers and then code main points for analysis. The list of interview questions and the ethics approval number granted for the process are attached in Appendix A and Appendix B. The findings of the expert interviews on the efficiency and efficacy of the stakeholder-centric CBA framework are attached in Appendix R. To summarise, the main findings of interviews are presented in Table 6.25.

Table 6.25.Advantages and challenges of stakeholder-centric CBA framework implementation

Advantages	**Challenges**
The framework allows the evaluation team to shift away from just focusing on the pure financial perspective to socio-economic and environmental aspects.	Many stakeholders are involved in the decision-making process. Thus, having all of them involved in the evaluation procedure for the proposed framework can be a bit challenging.
Stakeholders get an opportunity not only to express themselves fully but also to realize whether their needs and requirements are feasible or not.	The effectiveness of the framework proposed depends on the people that are using it. Thus, it would be difficult to select the 'right' people for the evaluation team to ensure that they can implement the framework well.
The framework expands the thinking of stakeholders on the things that they want (or expect) from the project investment compared with things that can be achieved with the approval of local government.	Communication becomes complicated when many stakeholders are involved in the analysis process, so it would be difficult for the evaluation team to establish an effective communication strategy.
The framework reduces the risk and increases the opportunity of selecting the 'right' project for implementation.	Every initiative comes with a cost so there may be need for extra resources.
Because the traditional framework is often applied in a rushed way, the evaluation team tends not to spend enough time in investigating complicated issues related to stakeholder engagement. The stakeholder-centric CBA framework provides great chances for communication between the evaluation team and key stakeholders; and thus, this will positively affect the investment decision made.	- It may take time to train people who are involved in the analysis process to ensure the framework is implemented well. - Some experts raised concerns about the applicability of the stakeholder-centric CBA framework, since the conventional framework is widely applied, and many government rules and regulations may become invisible barriers for stakeholder-centric implementation.

In terms of skills needed for the stakeholder-centric CBA framework implementation, most experts agreed that people in the project evaluation team need to have a wide range of skills, especially leadership, negotiation and mathematical skills. Table 6.26 presents details of the individual skills required for stakeholder-centric CBA framework implementation.

Table 6.26. Skills required for stakeholder-centric CBA framework implementation

List	Skill	Description
1	Leadership Skill	This skill reflects the ability of the team leader in delegating, inspiring, and communicating with other members with a different background (e.g. technical, financial, economic and environmental). This skill supports the team leader in resolving conflicts between team members and making thoughtful decisions.
2	Technical Skill	The evaluation team needs to have people who have technical skills. Technical skills allow team members to use their professional knowledge related to design, construction and operation to examine the feasibility of the project from a technical perspective.
3	Financial Skill	Basic financial skill is a major requirement for team members. This skill ensures that members are good enough in calculating and estimating project components used for evaluation.
4	Communication Skill	This skill includes ability in verbal, nonverbal and written communication with stakeholders. This is a basic skill required for all members of the evaluation team.
5	Negotiation Skill	Negotiation skill is also crucial part of the framework used to seek agreement between stakeholders. During the informal debate, this skill supports the evaluation team to seek mutual benefits and maintain their relationship with key stakeholders.
6	Teamwork Skill	Teamwork skill ensures all people in the evaluation team can understand the differences between members (e.g. background and culture) in order to work well together and provide constructive feedback to others.
7	CATWOE Analysis skills	CATWOE analysis skills are used to identify the investment objectives, the problem areas, and stakeholder perspectives that may affect the decision-making process.
8	Action-Planning Skill	This skill reflects the ability of team members to establish action plans or strategies to accomplish the given goals. This skill is a crucial part presented in Step 5 of the stakeholder-centric CBA framework.
9	Presentation and Debate Skills	Presentation and debate skills allows the evaluation team to engage with a variety of audiences (stakeholders) and establish strategies for informal debate.

From the findings extracted from interviews, most experts would be willing to apply the stakeholder-centric CBA framework. They also made some suggestions for improvements:

- The stakeholder-centric CBA framework should be incorporated into the planning stage of transport infrastructure projects along with the initial involvement of stakeholders. This may help practitioners save time and costs of implementation.

- Skills for framework implementation should be addressed at the initial stage, to ensure that evaluation team members have sufficient understanding of its usefulness.

- Organise the evaluation team with people who can work in a full-time position rather than building the project evaluation team with members who join temporarily from other organisations. This ensures the consistency in implementing evaluation activities.

- Extend the sensitivity analysis with a range of input variances to show the probability of investment scenarios that may provide rich information for key stakeholders in discussions on potential costs and benefits of project proposals.

- Several experts focused on clarifying the 'satisficing' benchmark for making the final investment decision and they required extra information to understand the details of benchmark selected.

Based on expert recommendations, the researcher has reviewed and refined some sub-processes of the stakeholder-centric CBA framework to improve its applicability in practice.

6.7.Summary

Through the selection of the case study applied for framework analysis, it is clear that the traditional CBA framework provides a clear and simple structure for analysis and assessment, but the result of evaluation activities using this framework mainly reflects the viewpoint of analysts and does not reflect the diversity of stakeholder viewpoints. In addition, the conventional framework focuses on financial and economic aspects to justify feasibility, while other aspects are not fully considered.

On the other hand, the stakeholder-centric CBA framework is a result of combining 'soft' and 'hard' systems approaches to provide a 'holistic' approach to both the technical and social issues of CBA. The new proposed framework provides seven steps that enable practitioners to readily establish a comprehensive CBA program for their project. The 'soft' aspect of the stakeholder-centric CBA framework allows practitioners to capture the actual needs of key stakeholders and to recognise the differences in evaluation perspectives. The 'hard' aspect of the proposed framework allows practitioners to translate stakeholder needs into measurable attributes before identifying cost-benefit factors and associated evaluation methods. The implementation of the stakeholder-centric CBA framework relies on the 'emancipatory' principles of Total Systems Intervention, so the involvement of stakeholders in the analysis process is encouraged and this can significantly increase the likelihood of achieving consensus on the ultimate investment decision. The unique point of the stakeholder-centric CBA framework is that instead of using optimising criteria, it applies 'satisficing' benchmarks for assessment and decision-making. This change ensures that the investment decision made is feasible and sustainable.

The stakeholder-centric CBA framework is more flexible compared with the traditional framework but this flexibility comes at the cost of the time required for planning and framework implementation. In addition, the stakeholder-centric CBA framework not only requires practitioners to have technical skills but also to have interpersonal skills (soft aspect) to deal with stakeholder engagement issues. This may create difficulties for people who are not familiar with soft systems analysis skills, thus it is essential to provide training courses for evaluation team members to ensure that they are able to follow the instructions of the proposed framework. From the key findings extracted from interviews with experts, it is recommended that the stakeholder-centric CBA framework be incorporated early into the planning stage of the project with the initial involvement of stakeholders. This will help analysts to save time and ensures the consistency of communication strategies applied as well as increasing the transparency of CBA for transport infrastructure projects. It is clear that the new approach proposed by this thesis, supported by the software designed, brings many advantages for practitioners in making truly rational decisions for transport investment, potentially saving very significant resources.

Chapter 7

Research Conclusion

7.1. Introduction

The objective of this chapter is to review the findings of the research program and to examine its achievements. This chapter begins with a brief description of the research processes used, before summarising answers to the research questions outlined in Chapter 1. The focus then moves to making clear the original contribution of the research to the body of knowledge on cost-benefit analysis for transport infrastructure projects. From the main findings of the research program, several recommendations are then proposed to decision-makers to support them in implementing the stakeholder-centric CBA framework in practice. The chapter ends with the identification of the research limitations regarding both soft and hard aspects of the proposed framework, and also proposes directions for further research.

7.2. Review of the Research Program

7.2.1. Research motivation

According to Newswire (2019, p. 1), Harvard Business School Professor and Palladium Thought Leader George Serafeim noted at the World Economic Forum that:

> "It is critical to accelerate the practice of considering social and environmental factors alongside financial performance in corporate management and investment decision-making".

This point aligns with the purpose of this research program which considers the incorporation of various socio-economic and environmental factors into a stakeholder-centric CBA framework (SCF) for transport infrastructure projects. This also recalls the strong motivation behind the decision to carry out this study arising from the practical experience of the researcher and his previous Master's degree studies. The researcher has reviewed the CBA literature and discussed the matter with experts in the project evaluation area and identified the following critical issues with contemporary CBA practices as summarised below:

- CBA is widely used for the evaluation of transport infrastructure investment, but the traditional approach to CBA relies mainly on the financial and economic foundations for establishing the evaluation program (see Chapter 2). In addition, the traditional approach does not fully allow the analyst to capture relevant cost-benefit factors used for project evaluation, especially for factors arising from the socio-economic and environmental groups in transport infrastructure projects.

- The traditional approach to CBA provides a clear structure for evaluation implementation, but the transparency of cost-benefit analysis applied for evaluation is not adequate (Priemus et al., 2008). In particular, the outcome of the traditional CBA approach reflects the viewpoint of the analyst, and it does not reflect the diversity of stakeholders' viewpoints and hence neither does it reflect their needs and motivations.

- The traditional approaches to CBA provide solutions which work in principle but their application in practice remain unclear. In other words, many studies have been carried out to provide improvements to CBA practice, but these solutions have tended towards a theoretical approach and are less applicable to the real world. Therefore, there is a crucial need to develop a new approach to CBA in order to best solve relevant practical problems.

- The view of key stakeholders involved in the CBA process is not properly addressed in the traditional approach (Priemus et al., 2008). The involvement of stakeholders during the traditional CBA process is limited, and therefore investment decisions arising from traditional CBA frameworks do not reflect a sufficient level of consensus among the views of key stakeholders. This is a major shortcoming.

From the recognition of the difficulties addressed above, the researcher had a strong motivation to seek a more holistic approach to CBA for transport infrastructure projects.

7.2.2. Research challenges

At the commencement of the PhD research program, the researcher tried to upgrade the traditional framework to resolve the CBA issues identified above. Even though the researcher applied functional design principles to the CBA framework development, the utility of the proposed framework was questioned by experts and practitioners because it was seen to be too narrow and limited to a functionalist worldview.

The researcher then decided to investigate the philosophical underpinnings of the traditional CBA framework and recognised that the traditional approach represents 'hard' systems thinking that draws on the hard, scientific worldview from Science, Mathematics, Engineering and Scientific Management in the design of approaches for analysis and evaluation. While the hard systems approach provides optimal solutions for well-defined problems (Checkland & Scholes, 1990; Lane, 2000), it does not adequately interpret the worldview of the stakeholders who are concerned with softer issues such as environmental, societal, economic and political impacts (Aaltonen & Kujala, 2010; Mok et al., 2015). The researcher, therefore, decided to formulate a new CBA framework that uses a multi-methodological approach to include interpretive and critical methods, as well as functionalist methods. Indeed, the resulting framework can be considered truly stakeholder-centric, supported by quantitative methods.

In addition, the researcher recognises that non-expert users often face difficulties in following complicated functional analysis processes adopted from the hard system approach, so it is valuable to develop an application that allows users to accelerate the progress of executing functional analysis activities. However, the translation process from technical language into a programming language is a complicated process that requires programming skills: for example, formulating concepts, learning algorithms, writing codes and testing. Thus, the researcher participated in training courses provided by Microsoft and then undertook much self-practice to overcome the programming language barrier. The supporting tool of the stakeholder centric CBA framework, entitled CBAFS, was the result of learning and experimenting over a long time period.

7.3. Summary of Research Findings

This research entitled 'Designing a stakeholder-centric framework for Cost-Benefit Analysis of transport infrastructure projects' was conducted by formulating and addressing four research questions presented in Chapter 1. In this chapter, responses to these research questions are presented as follows:

RQ1: What factors need to be included in a CBA for a transport infrastructure project?

Chapter 2 provides a set of thirty-five cost-benefit factors that should be considered in project evaluation. The categorisation of cost-benefit factors into four main groups, (technical, financial, socio-economic and environmental) allows practitioners to focus on key factors in building an effective evaluation program. The findings of the literature review show that the selection of cost-benefit factors for an evaluation program should be based on stakeholder needs. In particular, as different stakeholders may have different interpretations of the CBA for transport infrastructure projects, the project evaluation team needs to focus on critical stakeholder groups to elicit their actual needs and then identify associated cost-benefit factors (see Appendix D and Appendix E) to be used for the evaluation. In addition, cost-benefit factors selected should be ranked in accordance with the prioritisation made by key stakeholders at the 'informal' debate stage of the SCF. This ensures that the cost-benefit factors selected are aligned with the views of key stakeholders. These stakeholders are, therefore, directly involved in the CBA process and have a significant impact on the quality of the advice provided for the investment decision.

RQ2 & RQ3: How can the various components, including financial costs and social benefits of the CBA system, be incorporated? and what approaches are best suited to produce the CBA outputs?

The findings of the literature review show that the perceived relationship between cost and benefit factors depends on the worldviews of project stakeholders (Byrne, 2005). The relationships between these factors are nonlinear and there are no universal agreements for establishing such a relationship. In this study, cost-benefit factors are identified and integrated in the stakeholder-centric CBA framework to carry out activities, including:

- Starting with interpretive work to understand the culture, worldview, values, societal and environmental concerns of the stakeholders.

- Working with stakeholders to help them to understand the broader systemic goals of a project and to translate their positions into inputs for an overall project objective function.

- In addition, undertaking the quantified functionalist attributes of the project to complete a quantitative assessment.

- Re-engaging the stakeholder group to debate the findings of the assessment and producing recommendations on the way forward, including their preferred options.

The combination of soft system and hard system approaches to CBA produces a desirable outcome for decision-making. The stakeholder-centric CBA framework, as the result of such a combination, provides a specific procedure of seven steps in order to combine hard and soft systems approaches. In the proposed framework, the learning cycle of Soft Systems Methodology is adopted to identify stakeholder engagement issues, while tools and techniques from the hard system approach are selected to provide quantitative cost-benefit information used for more informed stakeholder debate and decision making.

The quantitative information provided allows critical stakeholders to improve their understanding of the project impacts before debate, thus increasing the likelihood of achieving an acceptable level of consensus. In this study, a range of factors (e.g. financial, social and environmental) can be addressed and analysed through the use of the CBAFS application designed by the researcher (see Appendix P). Results generated from the CBAFS can be used as solid evidence for the cost-benefit debate among key stakeholders and provide reliable indicators incorporated in a *satisficing* benchmark, that is, a level of satisfaction that may be less than perfect, but one which all stakeholders are prepared to accept and use for collective decision-making.

RQ4: How can the results of a CBA designed and executed for a specific project be validated?

In the SCF, results generated from hard CBA methods (techniques) are used as supplementary information (e.g. evidence) for stakeholder debate, so the acceptability level of information depends on the self-judgement of professional groups. Notably, professional stakeholders can be experts or practitioners in many disciplines, such as construction contractors, design experts, financiers, economists, and environmentalists; and these people play a role in commenting upon the results provided by the evaluation team. The evaluation team may be required to review their assessment (e.g. clarifying assumptions and constraints applied for analysis and checking input parameters) and this will likely increase the transparency of CBA for a particular transport infrastructure project. It is clear that this study has proposed a considerable change in the manner of validating CBA itself. The validation process, instead of being carrying out solely by the evaluation team, is now executed through cooperation between the evaluation team and professional stakeholders. This enables the project evaluation team to better capture the values of the input parameters and to more thoughtfully interpret the CBA evaluation. This proposed change also provides opportunities for experts and practitioners to contribute their voice to the validation process of CBA for a specific project.

7.4. Research Contributions to Knowledge

This study adds to the body of knowledge through structuring CBA schools of thought, formulating a list of cost-benefit factors for project evaluation, redefining the boundary of CBA application, proposing a new CBA framework, and creating a link between theoretical and practical aspects of CBA for transport infrastructure projects. The research program has made original contributions to the advancement of the CBA discipline, as outlined below:

- ***Structuring the CBA schools of thought and recognising CBA strengths and weaknesses.*** This contribution creates a unique point of difference for this research program compared with other studies. Even though many studies have focused on making clear the role of CBA and identifying CBA issues as well as providing solutions, none has presented a clear structure of CBA schools of thought in the domain of transport infrastructure projects. In this study, the researcher captures the philosophical positions of scholars during four specific periods from 1844 until the present. These schools of thought are clearly described and discussed, including the formation of CBA (1844-1958), macro-micro economic approaches (1958-1990), socio-economic approaches (1990-2010) and stakeholder-driven CBA approaches (2010-2018). This categorisation provides additional insights into the nature of CBA for transport infrastructure projects. It also allows researchers to better recognise the strengths and weaknesses of the different approaches to CBA: for example, viewpoints, assumptions, and constraints used for establishing project evaluation programs. In accordance with these different schools of thought, researchers can develop solutions based on a wider range of alternatives, and this is obviously an advantage.

- ***Formulating a list of cost-benefit factors that can be incorporated into an evaluation program for a specific transport infrastructure project***. The main purpose of listing cost-benefit factors is to help practitioners to be aware of these factors and then select important factors for their evaluation program. In this study, the list of thirty-five cost-benefit factors were categorised into four main groups of technical, financial, socio-economic, and environmental. In accordance with the cost-benefit factors listed, the study presents associated existing evaluation methods for selection and implementation (see Appendix E). This provides clear advice to practitioners in recognising formerly unappreciated factors (e.g. socioeconomic factors and environmental factors) and seeking appropriate evaluation methods.

- ***Redefining the boundary of CBA application in the domain of transport project infrastructure projects***. This is a unique contribution of this research compared with other studies. Even though a limited number of studies have emphasised the important role of clarifying the CBA boundary before implementation, none has provided in-depth discussions of this boundary issue. In this study, the researcher has provided detailed discussions to make clear the boundary of CBA application. The discussions presented in Chapter 2 helps practitioners to recognise the difference between CBA for transport infrastructure networks and CBA for specific transport infrastructure projects. To simplify, CBA for transport infrastructure networks focuses on macroeconomic goals of the higher government, whereas CBA for a single project focuses on specific aspects such as technical, financial, socio-economic and environmental aspects for the individual project. By understanding the boundary of CBA application, practitioners can identify the appropriate activities and keep their focus on the main aspects of their evaluation program.

- ***Proposing a stakeholder-centric CBA framework that can combine soft systems approaches and hard systems approaches to deal with both technical and social issues in CBA***. The proposed framework can guide practitioners to establish a comprehensive evaluation program for a transport infrastructure project. It allows project stakeholders to be involved in the CBA process, thus providing these stakeholders with opportunities to contribute their voice to the project proposal implementation plan. The core aspect of the stakeholder-centric CBA framework (SCF) is the cost-benefit debate among stakeholders which enables the project evaluation team to capture the actual needs of stakeholders from debate, rather than from analysis of project documentation and from discussion within the project team, as occurs when using the traditional framework. In addition, the role of professional stakeholder group commentary is improved through the interaction process between the evaluation team and professional stakeholders (e.g. construction contractors, financiers, economists, and environmentalists). The SCF also provides a specific procedure to select 'appropriate' evaluation methods through its hard system approach. The functional analysis process applied allows evaluators to translate stakeholder needs into measurable attributes and then to seek cost-benefit factors and associated evaluation methods. Moreover, the SCF considers the actions required for tackling the stakeholder engagement issue, so this feature enables the evaluation team to be proactive in dealing with changes arising from key stakeholders' requirements. The final investment decision made from the SCF's implementation is based on a *satisficing* concept which adequately reflects stakeholders' concerns and motivations, so that the investment decision made is feasible and sustainable.

- ***Linking theoretical aspects of CBA to practical aspects in project evaluation.*** The production of the SCF with its strong philosophical foundation, together with its application and expert feedback, has shown a clear link between theoretical and practical aspects of CBA, including the following:
    - Makes contributions to theory as described above.
    - The practical problems identified are based on a strong academic foundation and the researcher's experience.

- The systems approaches to management can be used to derive a solid approach to stakeholder-centric CBA for specific transport infrastructure projects.
- Solutions designed for problem-solving in this study are both practical and theoretical in nature, which contributes greatly to the advancement of the CBA discipline.

7.5. Recommendations to Decision-Makers

This research highlights that there is an urgent need to develop a new CBA framework for transport infrastructure projects that allows stakeholders to be centrally involved in the analysis and decision-making process. As a result, the SCF was designed and proposed for practical implementation. In order to improve the effectiveness and efficiency of the proposed framework, the following recommendations have been made for decision-makers and their evaluation team:

- Incorporate the SCF into the early planning stage of a transport infrastructure development. The involvement of stakeholders at this stage ensures the consistency of communication strategies employed during project stages (e.g. business case analysis, detailed evaluation and implementation), which is one of the key factors contributing to project success. In addition, the project evaluation team will offer strong opportunities to build trust between themselves and key stakeholders prior to the cost-benefit debate step. As a result, the evaluation team is able to maximise the likelihood of reaching consensus among key stakeholders regarding the project investment decision.

- Select people for the evaluation team who have different backgrounds and rich experience in project evaluation. This ensures the diversity of the project team with people who have expertise in technical, financial, economic and environmental aspects of transport infrastructure projects. In addition, the project team members should span the requisite skill set such as analysis skills, technical skills, problem-solving skills, and communication skills. Well-developed communication competencies should be one of the priorities for selecting members of the evaluation team as this will help decision-makers to employ stakeholder communication strategies. The SCF also requires specific skills for the application of soft systems methods such as CATWOE and rich picture analysis and also debate moderation. Therefore, it is crucial to provide training courses for team members to ensure they are able to cope with foreseeable difficulties in conducting activities which include both technical and social aspects.

- Encourage evaluation team members to apply ‘emancipatory’ principles for cost-benefit debate such as allowing stakeholders to set up rules for their debate, minimising the exercise of power in discussions, and presenting the interpretation of the CBA in a way which is suitable to the sensitivities of stakeholders. In addition, it could be useful to provide evaluation workshops at the beginning for key stakeholder groups to increase their awareness of the status of project proposals, the evaluation framework which will be applied, as well as to encourage their participation in and contribution to the CBA process. Finally, the lessons learnt from cost-benefit debates should be documented and used to support future project teams with information that can increase the effectiveness and efficiency of the implementation of future SCF.

7.6. Thesis Limitations

There are several limitations related to the initial conditions of the research program, including time spent on developing the application for hard aspects of the framework, the cooperation between the researchers and practitioners during the research program, and legal conditions required for applying the proposed framework to public projects sponsored by local governments. The details of these limitations are presented as follows:

- Due to the limited time available for application development, the current version of CBAFS does not include some evaluation methods such as environmental impact assessment and statistical methods. In addition, it should be noted that the functional analysis process of the hard CBA system approach should be optimised to ensure that all processes are logical and fit with the purpose of providing supplementary information for the cost-benefit debate step of the SCF. There are design features of the CBAFS which are not totally completed, including User Form design and coding; these features will be upgraded in the near future. Moreover, the CBAFS will be more powerful and convenient for users if it can be designed as a web-based application to be used for online surveys, data acquisition, and rapid assessment.

- The cooperation between researchers and practitioners during the research program had several limitations. First, the practitioners selected for interview have different backgrounds (e.g. technical, social-science, financial and economic, and environmental), and not surprisingly tended to focus on their ‘favourite’ or familiar aspects to make suggestions. In addition, the interaction process between the researcher and practitioners was limited due to the short time frame available (e.g. participants’ time commitment, the researcher’s time spent on interviews), so some soft aspects have not been fully explored in the interviews. Even though the interviews were undertaken with the intention of validating the utility of the SCF, it is possible that some judgements from participants are less relevant to the purpose of the interview.

- Even though the experts interviewed would be willing to apply the SCF for the evaluation of transport infrastructure projects, several challenges for framework implementation were identified in the interviews. First, there are several legal conditions required for applying an evaluation framework to public transport projects sponsored by local governments and these conditions are complicated and need time for any changes or modifications. Second, planning transport infrastructure projects depends on cooperation among departments of the local government, so it would be necessary to get the approval of parties who are involved or responsible for framework implementation. Third, members working in the government sector are often familiar with the traditional CBA framework (e.g. the evaluation procedure and analysis skills), so there may be a need to allocate resources for training activities and implementation.

7.7. Suggestions for Further Work

This study has identified several research limitations that can be addressed and resolved in the near future. In particular, future work needs to include the development of the CBAFS application guidelines, the allocation of resources for ongoing CBAFS upgrades, and a collection of action plans. The details of future developments are presented below:

- Develop a detailed application guideline for SCF's implementation. The main purpose of this guideline is to support the evaluation team in establishing 'soft' and 'hard' processes for a CBA program. The guideline will provide fundamental concepts of CBA for transport infrastructure projects and describe the SCF for transport infrastructure projects in detail. The guideline will also include a demonstration of the proposed framework implementation through applying the proposed framework to typical case studies (e.g. road projects, bridge projects and railway projects). The SCF guideline is considered to be a formal document, and thus, the evaluation team is able to readily establish its evaluation program by following the steps presented in the guideline. It is also expected that the guideline will be updated over time and will incorporate lessons learnt for SCF's implementation in future projects as they become available.

- Provide an upgraded version of the CBAFS software. This will bring many benefits for users. First, new evaluation methods will be designed and incorporated in the CBAFS to provide more options for users in selecting evaluation methods. Second, the researcher would consider upgrading the design of the software interface (e.g. Input Form, Output Form, and Command Button) to optimise the interface which support interactions between users and software. In addition, the CBAFS will be further developed to become a web-based application for project appraisal. This change allows multiple users to be working at the same time, and, therefore, sharing project data with others in a safe and convenient way. The web-based application would also enable users to provide evaluation reports to key stakeholders and to gather their feedback quickly.

- Carry out studies that concentrate on building a library of action plan templates for implementation. This work focuses on supporting the evaluation team to react to the changes arising from stakeholders' requirements. It provides blueprints for the evaluation team to seek solutions for solving problems related to stakeholder engagement during the decision-making process of transport infrastructure projects. Based on the availability of action plan templates, evaluation teams will proactively edit and establish their own action plans for their evaluation program, and this will improve the likelihood of achieving consensus between key stakeholders for project investment.

- Investigate cultural factors that may significantly affect stakeholder involvement during the planning stage. Depending on project context (e.g. cultural background and traditions), the project team may need to have different communication strategies to ensure that they can capture stakeholders' concerns and their motivations. Thus, cultural factors should be examined in real case studies in the future to improve the outcome of the SCF.

7.8. Conclusion

To conclude, this study has provided detailed answers to the research questions identified at the beginning of the research program. First, the findings from literature review surveys provided a list of thirty-five cost-benefit factors that should be considered in an evaluation program. Second, the study established that the relationship between cost-benefit factors that should be considered in terms of the way stakeholders perceive and interpret them, to identify key factors for evaluation. Third, the findings of this study show that the combination of 'soft' systems and 'hard' systems approaches provides 'real' solutions for tackling the stakeholder engagement issue and for solving problems of evaluation method selection. As a result, SCF is an application product of the research program that enables decision-makers to make fully informed decisions in seeking a sustainable solution for infrastructure project investment programs.

The original contributions of this study are in structuring CBA schools of thought, exploring cost-benefit factors, proposing the SCF and linking theoretical aspects to practical aspects in the evaluation of transport infrastructure projects.

The study also makes three main recommendations for both decision-makers and practitioners to improve the effectiveness of the proposed framework. These include incorporating the SCF into the planning stage of transport infrastructure projects, selecting members that have specialist knowledge and necessary experience for SCF's implementation and encouraging the evaluation team to apply emancipatory principles for open discussions.

In conclusion, the conventional approach to CBA for transport infrastructure projects has long historical roots in professional practice but its application has many limitations.

Practitioners can overcome the weaknesses associated with conventional CBA approaches through wrapping soft systems approaches around a comprehensive quantitative CBA analysis engine and planning for several stakeholder debates and workshops designed in the SCF. The comprehensive and appropriate assessment of stakeholders' differing perceptions, as presented in the SCF, will dismiss speculation through more accurate cost estimation, provide a better understanding of the potential benefits in relation to stakeholders' perceptions, and also reduce conflict and resistance which could seriously impede project performance. Therefore, there is clearly an urgent need to embrace and execute this broader technique for investment decision-making to achieve significant practical benefits going forward. In this way, the efficiency of allocating scarce resources for transport infrastructure development will be enhanced.

Finally, the framework designed in this applied research is at the beginning of a long journey of implementation and further refinement in light of the actual experience of practitioners. In that sense, further discussions about CBA are suitably extended through implementation of the proposed framework and practical lessons learnt.

List of Appendices

Appendix A: Ethics Approval Granted

THE UNIVERSITY of ADELAIDE

Our reference 33414

26 February 2019

RESEARCH SERVICES
OFFICE OF RESEARCH ETHICS, COMPLIANCE AND INTEGRITY
THE UNIVERSITY OF ADELAIDE

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CRICOS Provider Number 00123M

Professor Stephen Cook
Entrepreneurship, Commercialisation and Innovation Centre

Dear Professor Cook

ETHICS APPROVAL No: H-2019-027

PROJECT TITLE: The cost-benefit analysis for the evaluation of specific transport infrastructure projects

The ethics application for the above project has been reviewed by the Low Risk Human Research Ethics Review Group (Faculty of Arts and Faculty of the Professions) and is deemed to meet the requirements of the *National Statement on Ethical Conduct in Human Research 2007 (Updated 2018)* involving no more than low risk for research participants.

You are authorised to commence your research on: 26/02/2019
The ethics expiry date for this project is: 28/02/2022

NAMED INVESTIGATORS:

Chief Investigator:	Professor Stephen Cook
Student - Postgraduate Doctorate by Research (PhD):	Mr Van Tiep Nguyen
Associate Investigator:	Associate Professor Indra Gunawan

CONDITIONS OF APPROVAL: Thank you for your considered responses to the matters raised. The revised application provided on 18/02/19 has been approved.

Ethics approval is granted for three years and is subject to satisfactory annual reporting. The form titled Annual Report on Project Status is to be used when reporting annual progress and project completion and can be downloaded at http://www.adelaide.edu.au/research-services/oreci/human/reporting/. Prior to expiry, ethics approval may be extended for a further period.

Participants in the study are to be given a copy of the information sheet and the signed consent form to retain. It is also a condition of approval that you immediately report anything which might warrant review of ethical approval including:

- serious or unexpected adverse effects on participants,
- previously unforeseen events which might affect continued ethical acceptability of the project,
- proposed changes to the protocol or project investigators; and
- the project is discontinued before the expected date of completion.

Yours sincerely,
Dr Anna Olijnyk
Convenor
Associate Professor John Tibby
Convenor
The University of Adelaide

Appendix B: Expert Interview Questions

Background information

- How long have you been working in infrastructure projects?
- Do you often get involved in processes of project evaluation?
- What is the highest level of formal position you have achieved in your work?

Understandings about issues in project appraisal

- What are the tools and techniques used for the evaluation of your project?
- What are the strengths and limitations of these tools?
- What aspects of project evaluation do you think should be improved?

Stakeholder-centric CBA framework justifications

- What do you like about this framework?
- What challenges do you think you would face when applying this framework in practice?
- What aspects of the framework do you think need improvements?

Skills required for stakeholder-centric CBA framework implementation

- What skills would you need to have to apply this framework?
- How long do you think it would take to learn these skills?
- If you had your own choice, would you apply this framework?

In general, do you want to suggest this framework to others for proposals assessment?

Appendix C: Attributes to select methods, tools and techniques for CBA

List	Value Attribute	Appropriateness	Referred by
1	Relevance	The ease with which method allows us to answer important questions or focus on the key issues of project evaluation.	(Befani, 2016; Forestry Department, 1996; Patricia et al., 2015)
2	Acceptability	The ease with which the method is accepted as a standard instrument in the particular context	(Forestry Department, 1996)
3	Cost	The amount of resources needed to understand and apply new methods, tools and techniques.	(Forestry Department, 1996; Patricia et al., 2015)
4	Data requirement	The ease with which methods allow analysts to collect needed data for input.	(Befani, 2016; Forestry Department, 1996)
5	Installation & execution time	The time required to establish the new methods, tools, & techniques, including software installation and training time.	(Lutters et al., 2014; Patricia et al., 2015)
6	Efficiency	The capability of a method to achieve results with the minimum expenditure of time and effort.	(Cook et al., 2015)
7	Consistency	The degree of consistency of information presented.	(Cook et al., 2015)
8	Learnability	The ease with which users are able to learn the new method and perform activities.	(Cook et al., 2015; Forestry Department, 1996)
9	Adaptability	The ease with which the method can be adapted for use in different situations.	(Cook et al., 2015; Smolander, Tahvanainen, & Lyytinen, 1990)

Appendix D: Typical Stakeholder Needs

List	Stakeholder Groups	Stakeholder Needs	References
1	State Government	Achieve development goals	(De Langen, 2006; Li, Ng, & Skitmore, 2013; Rangarajan, Long, Tobias, & Keister, 2013)
		Reduce traffic congestion	
		Reduce travel time	
		Reduce transport cost	
		Ensure traffic safety	
		Extend the transport network	
		Contribute to regional tax income	
2	Business Owners	Generate profit	(Haezendonck, 2008; Li et al., 2013; Rangarajan et al., 2013)
		Create business opportunities	
3	Industry Groups	Improve logistics system	(De Langen, 2006)
		Reduce travel time	
		Reduce transport cost	
		Contracts rewarded for contractors	
4	Commuters	Reduce traffic congestion	(De Langen, 2006; Li et al., 2013)
		Reduce travel time	
		Minimise traffic interruption	
		Ensure travel safety	
		Create jobs for local people	
5	Landowners	Generate profit	(De Langen, 2006; Li et al., 2013)
		Minimise project impacts	
6	Environmental NGOs	Protect natural environment	(De Langen, 2006)
		Maintenance of ecological system	
7	Academic Institutions	Improve the transport system	
		Protect natural environment	
		Contribute the voice to the proposal	
8	Professional Society	Improve traffic capacity	(Amekudzi, Herabat, Wang, & Lancaster, 2002)
		Ensure travel safety	
		Provide a better transport system	

List	Stakeholder Groups	Stakeholder Needs (*Continue*)	References
9	Contractors	Generate profit	(Davis, 2014)
		Create business opportunities	
		Create jobs for local people	
10	Pressure Groups	Identify potential risk	(Li et al., 2013)
		Be against project implementation	
		Protect conservation of local cultural and historical heritage	
11	Users (Travellers)	Reduce travel congestion	(Haezendonck, 2008; Li et al., 2013)
		Ensure project safety	
		Improve comfort	
12	Media	Improve public service	(Elias, Cavana, & Jackson, 2001; Rangarajan et al., 2013)
		Protect natural environment	
		Create jobs for local place	
14	Transport Advocacy Groups	Encourage new investments in transport infrastructure domain	(Rangarajan et al., 2013)
		Support the development of the construction sector	
15	Urban Planners	Follow the master plan of the city	(Rangarajan et al., 2013)
		Extend transport network	
		Ensure sustainable development	

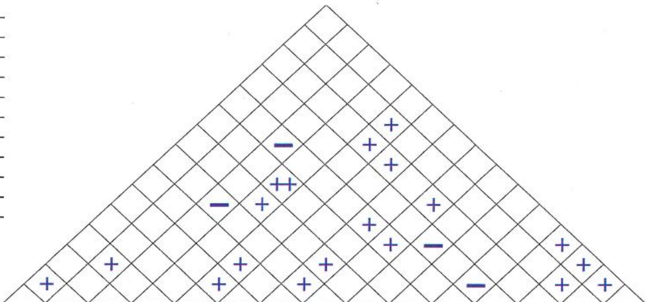
Appendix E: Cost-Benefit Factors and Associated Methods

List	Cost-benefit factors	Group	Typical Methods
1	**Capital costs**		
1.1	Land cost	Finance	Stated Preference Method, Hedonic Pricing Technique
1.2	Construction cost	Finance	Bottom-up Cost Estimation Technique and Market Survey Technique
1.3	Plant and machinery cost	Finance	Market Survey Technique
1.4	Labour training	Finance	Market Survey Technique
1.5	Interest payments	Finance	Financial Sustainability Analysis Technique
2	**Planning & design cost**	Finance	Market Survey Technique
3	**System operation & maintenance cost**	Finance	Discounted Cash Flow, Terminal Value (TV)
4	**User costs and benefits**		
4.1	Capital cost	Finance	Market Survey Technique
4.2	Ticket fares	Finance	Market Survey Technique
4.3	Vehicle operating cost savings	Finance	Mathematical Models
4.4	Traffic congestion reduction	Socio-Economic	Stated Preference Method, Contingent Valuation Method
4.5	Travel time savings	Socio-Economic	Mathematical Models
4.6	Traffic accident reduction	Socio-Economic	Statistical models
4.7	Accessibility benefits for business trips	Socio-Economic	Stated Preference Method, The Dose-Response Technique
5	**Non-user costs and benefits**		
5.1	Saving in foreign exchange	Socio-Economic	Statistical models
5.2	Traffic administration service	Socio-Economic	The Shadow Price Method
5.3	Taxes and fees paid by vehicle owners.	Socio-Economic	Discounted Cash Flow Technique, CBA-DK Model
5.4	An increase in traffic	Socio-Economic	Statistical models, The Dose-Response Technique

List	**Cost-benefit factors** (*Continue*)	Group	Typical Methods
5.5	Trade logistics improvement	Socio-Economic	The Dose-Response Technique
5.6	Air pollution/emissions (carbon dioxide, NOx, SO_2)	Environmental	Contingent Valuation Method, Environmental Impact Assessment (EIA)
5.7	Noise pollution	Environmental	Environmental Impact Assessment (EIA), Hedonic Pricing Technique
5.8	Chemical waste, polluted soil and water pollution	Environmental	Environmental Impact Assessment (EIA), Hedonic Pricing Technique
5.9	Unemployment rate	Socio-Economic	Statistical models, The Dose-Response Technique
5.10	Businesses relocation, and traffic delays during project construction	Socio-Economic	Contingent Valuation Method, Stated Preference Method
5.11	Population growth	Socio-Economic	Statistical models
5.12	Public services include education and health care	Socio-Economic	Contingent Valuation Method
5.13	Real estate market development	Socio-Economic	The Dose-Response Technique
5.14	Tourism industry development	Socio-Economic	The Dose-Response Technique
5.15	Agriculture development	Socio-Economic	The Dose-Response Technique

Appendix F: House of Quality (HOQ)

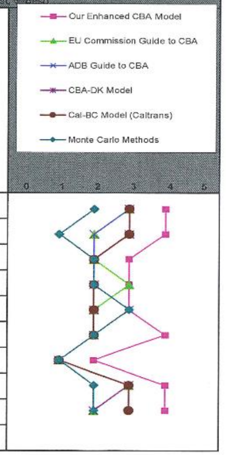
Title: Stakeholder needs analysis
Author: Authors
Date: 1/11/2017
Notes:



Legend

Θ	Strong Relationship	9
O	Moderate Relationship	3
▲	Weak Relationship	1
++	Strong Positive Correlation	
+	Positive Correlation	
−	Negative Correlation	
▼	Strong Negative Correlation	
▼	Objective Is To Minimize	
▲	Objective Is To Maximize	
X	Objective Is To Hit Target	

Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	Demanded Quality (a.k.a. "Customer Requirements" or "Whats") / Quality Characteristics (a.k.a. "Functional Requirements" or "Hows")	Transport cost savings	Transport time savings	Project financial indices	Number of generated jobs	Online manual platform	Database storage system	Feedback control system	Risk assessment matrix	Public opinion measurement	Business opportunity assessment	Environment assessment matrix	Political attitude surveys	Generic evaluation framework	Project evaluation standards	Structure of the evaluation report	Our Enhanced CBA Model	EU Commission Guide to CBA	ADB Guide to CBA	CBA-DK Model	Cal-BC Model (Caltrans)	Monte Carlo Methods
				Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Competitive Analysis (0=Worst, 5=Best)					
				Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x)	▼	▼	X	▲	X	▲	▲	X	X	X	X	X	X	▲	X						
1	9	15.0	15.0	Rank project proposal priority	Θ	Θ	Θ	Θ	▲		▲	Θ	O	▲	▲	▲	Θ	O	Θ	4	3	3	3	3	2
2	9	15.0	15.0	Need an interface that allows users to select methods, tools, techniques and procedures	▲	▲	O	O	Θ	▲	▲	▲					▲	▲	O	4	2	2	3	3	1
3	9	5.0	5.0	Trace project information sources			▲		▲	Θ	▲		O				▲		O	3	2	2	2	2	2
4	9	12.0	12.0	Stakeholders are able to communicate with users					O		Θ	▲	▲		▲	▲	O	▲		3	3	2	2	2	2
5	9	13.0	13.0	Recognize potential risk of project proposals			O		▲			Θ	▲	▲	O	▲	Θ	▲		3	2	3	2	2	3
6	3	15.0	15.0	Recognize indirect effects of project investment					▲				▲	▲	O		O			4	2	2	2	2	2
7	9	10.0	10.0	Investigate political attitudes			▲	▲	▲		▲	▲				Θ	▲			2	1	1	1	1	1
8	9	10.0	10.0	A guidance for project proposal selection	O	O	O	▲	▲		▲	O	▲	▲	▲	▲	Θ	Θ	Θ	4	3	3	3	3	2
9	9	5.0	5.0	A concise report	▲	▲	O	▲				▲			▲		Θ	Θ	Θ	4	2	2	2	3	2
10																									
				Target or Limit Value	Max	Max	N/A	Max	Simple	Max	Flexible	N/A	N/A	N/A	N/A	N/A	Simple	Max	Simple						
				Difficulty (0=Easy to Accomplish, 10=Extremely Difficult)	5	5	5	5	3	5	3	8	7	5	5	6	7	7	5						
				Max Relationship Value in Column	9	9	9	9	9	9	9	9	3	1	3	9	9	9	9						
				Weight / Importance	185.0	185.0	279.0	205.0	239.0	60.0	163.0	324.0	110.0	53.0	126.0	140.0	498.0	220.0	330.0						
				Relative Weight	5.9	5.9	9.0	6.6	7.7	1.9	5.2	10.4	3.5	1.7	4.0	4.5	16.0	7.1	10.6						



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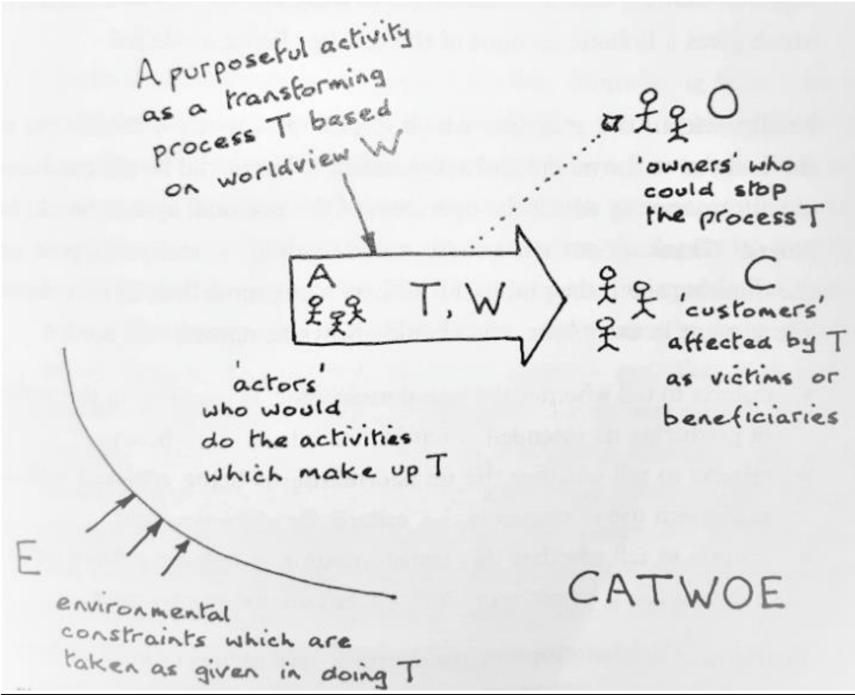
Appendix G: CATWOE Technique

CATWOE analysis technique was proposed by Smyth and Checkland (1976) which is a crucial part of Soft Systems Methodology (SSM). The CATWOE is a useful technique to approach the problem from different stakeholders' perspectives. This technique enables the analysts to appreciate the difference in evaluation viewpoints before making recommendations. The generic model of CATWOE and its associated components are depicted in the Figure below.



C – Customers: The purpose of this step to identify the customers and understand how the system influences them.

A – Actors: They are people who are responsible to carry out activities and be involved with the implementation of changes in the system.

T – Transformation Process: Transformation is the core process in which inputs are transformed by actors into outputs.

W – World view: This reflects the underlying worldview for the transformation.

O – Owners: This refers to stakeholders who have the authority to control the system. These stakeholders usually are the owner, entrepreneur or investor of an organisation, who can decide whether a project should start or stop.

E – Environmental Constraints: This is about the actual environmental elements that may influence or restrict the system. These can be rules surrounding the system.

Appendix H: List of Common Project Risks[8]

ID	Risk Description	Risk Category
1	Degraded visual amenity	Environmental
2	Dust generated through excavation works and traffic movement	Environmental
3	Temporary elevated noise emissions	Environmental
4	Traffic disruption	Technical
5	Inefficient use of resources	Technical
6	Discharge of dirty water	Environmental
7	Discharge of contaminant laden runoff	Environmental
8	Contamination of soil, surface water and groundwater	Environmental
9	Localized contaminated material	Environmental
10	Construction labour safety	Technical
11	Impact to any item of historic importance during construction	Socio-Economic
12	Insufficient allocation of counterpart funds	Financial
13	Delays in land acquisition and resentment	Technical
14	Delays in commencement of civil works	Technical
15	Delays in completion of civil works	Technical
16	Unsatisfactory performance of supervision	Technical
17	Traffic volume is lower than the initial estimate	Financial
18	Improper O&M of the project	Technical
19	Soft soil conditions worse than the initial estimate	Technical
20	Inappropriate selection of sub-contractors	Technical
21	Civil works cost increase caused by the inaccuracy of work estimation	Financial
22	Material cost increase caused by construction market	Financial
23	Local business disruption caused by project construction	Socio-Economic
24	Bureaucracy of government	Socio-Economic
25	Project cost increase due to design variations	Financial

[8] Adopted from Nguyen, Cook, and Ireland (2017)

Appendix I: Typical Vehicle Oil Consumption Cost[9]

Car (Existing Path)	24-31	32-39	40-47	48-55	56-63
Oil Price (cents/litre)	85	85	85	85	85
dtopcf	1.5	1.5	1.5	1.5	1.5
Pdies	1	1	1	1	1
Oilcons	0.63	0.65	0.67	0.7	0.73
Gear	1.1	1.1	1.1	1.1	1.1
Total	88.358	91.163	93.968	98.175	102.383
Oil Cost/km	0.09	0.09	0.09	0.10	0.10

Car (New Path)	**24-31**	**32-39**	**40-47**	**48-55**	**56-63**
Oil Price (cents/litre)	85	85	85	85	85
dtopcf	1.5	1.5	1.5	1.5	1.5
Pdies	1	1	1	1	1
Oilcons	0.53	0.55	0.57	0.6	0.63
Gear	1.1	1.1	1.1	1.1	1.1
Total	74.333	77.138	79.943	84.150	88.358
Oil Cost/km	0.07	0.08	0.08	0.08	0.09

Car (Existing Path)	**64-71**	**72-79**	**80-87**	**88-95**	**96-103**
Oil Price (cents/litre)	85	85	85	85	85
dtopcf	1.5	1.5	1.5	1.5	1.5
Pdies	1	1	1	1	1
Oilcons	0.75	0.77	0.79	0.81	0.84
Gear	1.1	1.1	1.1	1.1	1.1
Total	105.188	107.993	110.798	113.603	117.810
Oil Cost/km	0.11	0.11	0.11	0.11	0.12

Car (New Path)	**64-71**	**72-79**	**80-87**	**88-95**	**96-103**
Oil Price (cents/litre)	85	85	85	85	85
dtopcf	1.5	1.5	1.5	1.5	1.5
Pdies	1	1	1	1	1
Oilcons	0.65	0.67	0.69	0.71	0.74
Gear	1.1	1.1	1.1	1.1	1.1
Total	91.163	93.968	96.773	99.578	103.785
Oil Cost/km	0.09	0.09	0.10	0.10	0.10

Legends

- Dtopcf: petrol to diesel vehicle conversion ratio (model variable = 1.5)
- Pdies: proportion of vehicles which are diesel powered
- Oilcons: basic engine oil consumption speed relationship per vehicle
- Gear: factor relating total oil consumption to engine oil use (model variable = 1.1)

[9] Adopted from Department of Transport and Main Roads (2011)

Appendix J: Vehicle Fuel Consumption Cost[10]

Car (Existing Path)	**24-31**	**32-39**	**40-47**	**48-55**	**56-63**
Fuel cost per litre	136	136	136	136	136
Basic Fuel Consumption (litre/km)	0.134	0.132	0.129	0.127	0.124
Fuel Efficiency	1.1	1.1	1.1	1.1	1.1
Road Gradient	0.015	0.022	0.031	0.043	0.043
Road Curvature	0.1	0.1	0.1	0.1	0.1
Congestion	0.0161	0.0161	0.0161	0.0161	0.0161
Roughness of the Road	0.1407	0.1470	0.1617	0.1827	0.2100
Fuel Consumption Cost per km	43.35	42.74	42.32	42.06	41.70

Car (New Road)	**24-31**	**32-39**	**40-47**	**48-55**	**56-63**
Fuel cost per litre	136	136	136	136	136
Basic Fuel Consumption (litre/km)	0.117	0.115	0.112	0.110	0.108
Fuel Efficiency	1.1	1.1	1.1	1.1	1.1
Road Gradient	0.015	0.022	0.031	0.043	0.043
Road Curvature	0.1	0.1	0.1	0.1	0.1
Congestion	0.014	0.014	0.014	0.014	0.014
Roughness of the Road	0.1173	0.1225	0.1348	0.1523	0.1750
Fuel Consumption Cost per km	37.29	36.75	36.36	36.09	35.71

Car (Existing Path)	**64-71**	**72-79**	**80-87**	**88-95**	**96-103**
Fuel cost per litre	136	136	136	136	136
Basic Fuel Consumption (litre/km)	0.122	0.119	0.117	0.115	0.112
Fuel Efficiency	1.1	1.1	1.1	1.1	1.1
Road Gradient	0.043	0.043	0.043	0.043	0.043
Road Curvature	0.1	0.1	0.1	0.1	0.1
Congestion	0.0161	0.0161	0.0161	0.0161	0.0161
Roughness of the Road	0.2163	0.1890	0.1890	0.1890	0.1890
Fuel Consumption Cost per km	40.98	39.74	38.96	38.19	37.44

Car (New Road)	**64-71**	**72-79**	**80-87**	**88-95**	**96-103**
Fuel cost per litre	136	136	136	136	136
Basic Fuel Consumption (litre/km)	0.106	0.104	0.102	0.100	0.098
Fuel Efficiency	1.1	1.1	1.1	1.1	1.1
Road Gradient	0.043	0.043	0.043	0.043	0.043
Road Curvature	0.1	0.1	0.1	0.1	0.1
Congestion	0.014	0.014	0.014	0.014	0.014
Roughness of the Road	0.1803	0.1575	0.1575	0.1575	0.1575
Fuel Consumption Cost per km	35.09	34.08	33.41	32.76	32.11

[10] Adopted from Department of Transport and Main Roads (2011)

Appendix K: Typical Vehicle Tyre Cost[11]

Cars (Existing Path)	24-31	32-39	40-47	48-55	56-63
TreadCost	55.07	55.07	55.07	55.07	55.07
Btw (VT)	115.87	115.87	115.87	115.87	115.87
Cong (VT)	0.086	0.082	0.078	0.076	0.074
Curve (VT)	6.5	6.5	6.5	6.5	6.5
Rough (VT)	0.25	0.25	0.25	0.25	0.25
Grad (VT)	0.02	0.02	0.02	0.02	0.02
Total	50129	50103	50078	50065	50052
Tyre Cost/Km	50.13	50.10	50.08	50.07	50.05

Cars (New Project)	24-31	32-39	40-47	48-55	56-63
TreadCost	55.07	55.07	55.07	55.07	55.07
Btw (VT)	115.87	115.87	115.87	115.87	115.87
Cong (VT)	0.046	0.046	0.046	0.046	0.046
Curv(VT)	6.5	6.5	6.5	6.5	6.5
Rough (VT)	0.2	0.2	0.2	0.2	0.2
Grad (VT)	0.02	0.02	0.02	0.02	0.02
Total	49555	49555	49555	49555	49555
Tyre Cost/km	49.55	49.55	49.55	49.55	49.55

Cars (Existing Path)	64-71	72-79	80-87	88-95	96-103
TreadCost	55.07	55.07	55.07	55.07	55.07
Btw (VT)	115.87	115.87	115.87	115.87	115.87
Cong (VT)	0.072	0.07	0.067	0.062	0.058
Curve (VT)	6.5	6.5	6.5	6.5	6.5
Rough (VT)	0.25	0.25	0.25	0.25	0.25
Grad (VT)	0.02	0.02	0.02	0.02	0.02
Total	50039	50027	50008	49976	49950
Tyre Cost/km	50.04	50.03	50.01	49.98	49.95

Cars (New Project)	64-71	72-79	80-87	88-95	96-103
TreadCost	55.07	55.07	55.07	55.07	55.07
Btw (VT)	115.87	115.87	115.87	115.87	115.87
Cong (VT)	0.046	0.046	0.046	0.046	0.046
Curve (VT)	6.5	6.5	6.5	6.5	6.5
Rough (VT)	0.2	0.2	0.2	0.2	0.2
Grad (VT)	0.02	0.02	0.02	0.02	0.02
Total	49555	49555	49555	49555	49555
Tyre Cost/km	49.55	49.55	49.55	49.55	49.55

Legends:

- Btw (VT): basic tyre wear
- Cong (VT): Congestion adjustment
- Curve (VT): Curvature adjustment
- Rough (VT): Roughness adjustment
- Grad (VT): Gradient adjustment

[11] Adopted from Department of Transport and Main Roads (2011)

Appendix L: The Calculation of Conversion Factors from Market Price to Shadow Price[12]

Type of cost	Conversion factors	Descriptions
Blue-collar labour	0.80	Many young people without professional skills from the investment area seek jobs, so the rate of unemployment in this area is quite high.
Skilled labour	1.00	There is an assumption that the labour market price is competitive, so conversion factor applied for skilled labour (e.g. engineers, consultants and manager) is 1.00.
Raw material	0.98	No significant distortions
Equipment	1.00	Imported without taxes and tariffs
Electricity	0.49	Net of excise taxes
Water	0.48	Use recycled water
Construction cost	0.86	These are following assumptions: ○ 26.5% of non-skilled workforce (CF=0.8); ○ 8% of skilled labour (CF=1.00); ○ 30% 0f materials (CF=0.98); ○ 15% of equipment (CF=1.00); ○ 5% of energy (CF=0.49) ○ 5% of water (CF=0.48) ○ 10% of tax (CF=1.00) The conversion factor for construction cost is calculated: 0.265*0.7)+(0.08*1)+(0.3*0.98)+(0.15*1)+(0.05*0.49)+(0.05*48)+(0.1*1)+(0.055*0) = 0.86
Management cost	0.98	Making an assumption: ○ 5 % of non-skilled workforce (CF=0.8); ○ 70% of skilled labour (CF=1.00); ○ 10% 0f materials (CF=0.98); ○ 15% of equipment (CF=1.00); The conversion factor for management cost is calculated: (0.05*0.8)+(0.7*1)+(0.1*0.98) +(0.15*1)= 0.98

[12] Adopted from The European Commission (2008)

Type of cost	Conversion factors	Descriptions *(continue)*
Consultation cost	0.98	Making an assumption: ○ 5 % of non-skilled workforce (CF=0.80); ○ 70% of skilled labour (CF=1.00); ○ 10% of materials (CF=0.98); ○ 15% of equipment (CF=1.00). The conversion factor for consultant cost is calculated (0.05*0.8) + (0.7*1) + (0.1*0.98) +(0.15*1) = 0.98
Costs of land compensation	1.00	Making an assumption that the SA Government pays the compensation fee for property owners at the price that is equal with the real estate market price in the investment area.
Allowance	0.98	The standard conversion factor
Contingency	0.98	The standard conversion factor
Maintenance cost	0.906	Making an assumption: ○ 30% of blue-collar worker (CF=0.8); ○ 20% of white-collar worker (CF=1.00); ○ 20% of materials (CF=0.98); ○ 30% of equipment (CF=1.00). The conversion factor for maintenance cost is calculated (0.3*0.8)+(0.2*1)+(0.2*0.98) +(0.3*1) = 0.906
Operating cost	0.936	Making an assumption: ○ 20% of non-skilled workforce (CF=0.8); ○ 30% of skilled labour (CF=1.00); ○ 20% of materials (CF =0.98); ○ 30% of equipment (CF=1.00). The conversion factor for operational cost is calculated (0.2*0.8) + (0.3*1) + (0.2*0.98) + (0.3*1) = 0.936

Appendix M: Project Financial Assessment

Years	Investment Cost ($Mil)	Maintenance Cost ($Mil)	Operational Cost ($Mil)	Total Cost ($Mil)	Traffic Forecast (Mil)	Toll Rate ($/trip)	Revenues ($ Mil)	Cash Flow (CF)	Discounted Factor	Present Value (PV)	Cumulated Present Value
0	100.0			100.0				-100.0	1.0000	-100.0	-100.0
1	252.0			252.0				-252.0	0.9709	-244.6	-344.6
2	252.0			252.0				-252.0	0.9426	-237.5	-582.2
3	267.0			267.0				-267.0	0.9151	-244.3	-826.5
4		5.7	5.6	11.3	3.7	5.0	18.3	7.0	0.8885	6.2	-820.3
5		5.7	5.6	11.3	3.8	5.2	19.8	8.5	0.8626	7.3	-813.0
6		5.7	5.6	11.3	4.0	5.4	21.8	10.5	0.8375	8.8	-804.2
7		5.7	5.6	11.3	4.2	5.7	24.0	12.7	0.8131	10.3	-793.9
8		30.7	5.6	36.3	4.4	6.0	26.5	-9.8	0.7894	-7.8	-801.6
9		5.7	5.6	11.3	4.7	6.3	29.2	17.9	0.7664	13.7	-787.9
10		5.7	5.6	11.3	4.9	6.6	32.2	20.9	0.7441	15.5	-772.4
11		5.7	5.6	11.3	5.1	6.9	35.5	24.2	0.7224	17.5	-754.9
12		5.7	5.6	11.3	5.4	7.2	39.1	27.8	0.7014	19.5	-735.4
13		30.7	5.6	36.3	5.7	7.6	43.1	6.8	0.6810	4.7	-730.8
14		5.7	5.6	11.3	6.0	8.0	47.6	36.3	0.6611	24.0	-706.8
15		5.7	5.6	11.3	6.2	8.4	52.4	41.1	0.6419	26.4	-680.4
16		5.7	5.6	11.3	6.6	8.8	57.8	46.5	0.6232	29.0	-651.4
17		5.7	5.6	11.3	6.9	9.2	63.7	52.4	0.6050	31.7	-619.7
18		30.7	5.6	36.3	7.2	9.7	70.3	34.0	0.5874	19.9	-599.8

Years	Investment Cost ($Mil)	Maintenance Cost ($Mil)	Operational Cost ($Mil)	Total Cost ($Mil)	Traffic Forecast (Mil)	Toll Rate ($/trip)	Revenues ($ Mil)	Cash Flow (CF)	Discounted Factor	Present Value (PV)	Cumulated Present Value
19		5.7	5.6	11.3	7.6	10.2	77.5	66.2	0.5703	37.7	-562.0
20		5.7	5.6	11.3	8.0	10.7	85.4	74.1	0.5537	41.0	-521.0
21		5.7	5.6	11.3	8.4	11.2	94.1	82.8	0.5375	44.5	-476.5
22		5.7	5.6	11.3	8.8	11.8	103.8	92.5	0.5219	48.3	-428.2
23		30.7	5.6	36.3	9.2	12.4	114.4	78.1	0.5067	39.6	-388.6
24		5.7	5.6	11.3	9.7	13.0	126.2	114.9	0.4919	56.5	-332.1
25		5.7	5.6	11.3	10.2	13.7	139.1	127.8	0.4776	61.0	-271.0
26		5.7	5.6	11.3	10.7	14.3	153.4	142.1	0.4637	65.9	-205.2
27		5.7	5.6	11.3	11.2	15.1	169.1	157.8	0.4502	71.0	-134.1
28		30.7	5.6	36.3	11.8	15.8	186.4	150.1	0.4371	65.6	-68.5
29		5.7	5.6	11.3	12.4	16.6	205.5	194.2	0.4243	82.4	13.9
30		5.7	5.6	11.3	13.0	17.4	226.6	215.3	0.4120	88.7	102.6
31		5.7	5.6	11.3	13.6	18.3	249.8	238.5	0.4000	95.4	198.0
32		5.7	5.6	11.3	14.3	19.2	275.4	264.1	0.3883	102.6	300.5
33		30.7	5.6	36.3	15.0	20.2	303.6	267.3	0.3770	100.8	**401.3**

Appendix N: Project Economic Assessment

1) Toll Road Option

Years	Investment Cost ($Mil)	Maintenance Cost ($Mil)	Operational Cost ($Mil)	Total Cost ($Mil)	VOC Savings ($Mil)	VOT Savings ($Mil)	CO2 Emission Savings ($Mil)	Accident savings ($Mil)	Total Benefits ($Mil)	Cash Flow (CF)	Discounted Factor	Present Value (PV)	Cumulated Present Value
0	100.0			100.0						-100.0	1.0000	-100.0	-100.0
1	$222			222.3			-1.9		-1.9	-224.2	0.9709	-217.7	-317.7
2	$222			222.3			-1.9		-1.9	-224.2	0.9426	-211.3	-529.0
3	$237			237.3			-1.9		-1.9	-239.2	0.9151	-218.9	-747.9
4		5.3	5.1	10.4	33.8	109.2	1.1	1.0	145.1	134.7	0.8885	119.6	-628.3
5		5.3	5.1	10.4	35.5	114.6	1.1	1.0	152.2	141.8	0.8626	122.3	-505.9
6		5.3	5.1	10.4	37.3	120.3	1.1	1.0	159.7	149.3	0.8375	125.0	-380.9
7		5.3	5.1	10.4	39.1	126.4	1.1	1.0	167.6	157.2	0.8131	127.8	-253.1
8		28.7	5.1	33.8	41.1	132.7	1.1	1.0	175.9	142.1	0.7894	112.1	-140.9
9		5.3	5.1	10.4	43.1	139.3	1.1	1.0	184.6	174.2	0.7664	133.5	-7.5
10		5.3	5.1	10.4	45.3	146.3	1.1	1.0	193.7	183.3	0.7441	136.4	128.9
11		5.3	5.1	10.4	47.5	153.6	1.1	1.0	203.3	192.9	0.7224	139.3	268.2
12		5.3	5.1	10.4	49.9	161.3	1.1	1.0	213.3	202.9	0.7014	142.3	410.6
13		28.7	5.1	33.8	52.4	169.3	1.1	1.0	223.9	190.1	0.6810	129.4	540.0
14		5.3	5.1	10.4	55.0	177.8	1.1	1.0	235.0	224.6	0.6611	148.5	688.4
15		5.3	5.1	10.4	57.8	186.7	1.1	1.0	246.6	236.2	0.6419	151.6	840.1
16		5.3	5.1	10.4	60.7	196.0	1.1	1.0	258.9	248.4	0.6232	154.8	994.9
17		5.3	5.1	10.4	63.7	205.8	1.1	1.0	271.7	261.3	0.6050	158.1	1,152.9
18		28.7	5.1	33.8	66.9	216.1	1.1	1.0	285.2	251.3	0.5874	147.6	1,300.6
19		5.3	5.1	10.4	70.3	226.9	1.1	1.0	299.3	288.9	0.5703	164.7	1,465.3
20		5.3	5.1	10.4	73.8	238.3	1.1	1.0	314.2	303.7	0.5537	168.2	1,633.5
21		5.3	5.1	10.4	77.5	250.2	1.1	1.0	329.8	319.4	0.5375	171.7	1,805.2
22		5.3	5.1	10.4	81.3	262.7	1.1	1.0	346.2	335.7	0.5219	175.2	1,980.4
23		28.7	5.1	33.8	85.4	275.8	1.1	1.0	363.4	329.5	0.5067	167.0	2,147.4

Years	Investment Cost ($Mil)	Maintenance Cost ($Mil)	Operational Cost ($Mil)	Total Cost ($Mil)	VOC Savings ($Mil)	VOT Savings ($Mil)	CO2 Emission Savings ($Mil)	Accident savings ($Mil)	Total Benefits ($Mil)	Cash Flow (CF)	Discounted Factor	Present Value (PV)	Cumulated Present Value
24		5.3	5.1	10.4	89.7	289.6	1.1	1.0	381.4	371.0	0.4919	182.5	2,329.9
25		5.3	5.1	10.4	94.1	304.1	1.1	1.0	400.4	390.0	0.4776	186.2	2,516.1
26		5.3	5.1	10.4	98.9	319.3	1.1	1.0	420.3	409.9	0.4637	190.1	2,706.2
27		5.3	5.1	10.4	103.8	335.3	1.1	1.0	441.2	430.8	0.4502	193.9	2,900.1
28		28.7	5.1	33.8	109.0	352.0	1.1	1.0	463.2	429.3	0.4371	187.7	3,087.7
29		5.3	5.1	10.4	114.4	369.6	1.1	1.0	486.2	475.8	0.4243	201.9	3,289.6
30		5.3	5.1	10.4	120.2	388.1	1.1	1.0	510.4	500.0	0.4120	206.0	3,495.6
31		5.3	5.1	10.4	126.2	407.5	1.1	1.0	535.8	525.4	0.4000	210.2	3,705.8
32		5.3	5.1	10.4	132.5	427.9	1.1	1.0	562.5	552.1	0.3883	214.4	3,920.2
33		28.7	5.1	33.8	139.1	449.3	1.1	1.0	590.5	556.7	0.3770	209.9	**4,130.1**

2) Freeway Option

Years	Investment Cost ($Mil)	Maintenance Cost ($Mil)	Operational Cost ($Mil)	Total Cost ($Mil)	VOC Savings ($Mil)	VOT Savings ($Mil)	CO2 Emission Savings ($Mil)	Accident savings ($Mil)	Total Benefits ($Mil)	Cash Flow (CF)	Discounted Factor	Present Value (PV)	Cumulated Present Value
0	100.0			100.0						-100.0	1.0000	-100.0	-100.0
1	222.6			222.6			-1.9		-1.9	-224.4	0.9709	-217.9	-317.9
2	222.6			222.6			-1.9		-1.9	-224.4	0.9426	-211.6	-529.5
3	222.6			222.6			-1.9		-1.9	-224.4	0.9151	-205.4	-734.8
4		5.3	5.0	10.3	48.1	181.3	1.1	1.0	231.6	221.2	0.8885	196.6	-538.3
5		5.3	5.0	10.3	50.5	190.4	1.1	1.0	243.0	232.7	0.8626	200.7	-337.5
6		5.3	5.0	10.3	53.0	199.9	1.1	1.0	255.1	244.8	0.8375	205.0	-132.6
7		5.3	5.0	10.3	55.7	209.9	1.1	1.0	267.7	257.4	0.8131	209.3	76.7
8		28.7	5.0	33.7	58.5	220.4	1.1	1.0	281.0	247.3	0.7894	195.2	271.9
9		5.3	5.0	10.3	61.4	231.4	1.1	1.0	295.0	284.6	0.7664	218.1	490.1
10		5.3	5.0	10.3	64.4	243.0	1.1	1.0	309.6	299.3	0.7441	222.7	712.7

Years	Investment Cost ($Mil)	Maintenance Cost ($Mil)	Operational Cost ($Mil)	Total Cost ($Mil)	VOC Savings ($Mil)	VOT Savings ($Mil)	CO2 Emission Savings ($Mil)	Accident savings ($Mil)	Total Benefits ($Mil)	Cash Flow (CF)	Discounted Factor	Present Value (PV)	Cumulated Present Value
11		5.3	5.0	10.3	67.7	255.2	1.1	1.0	325.0	314.6	0.7224	227.3	940.0
12		5.3	5.0	10.3	71.1	267.9	1.1	1.0	341.1	330.8	0.7014	232.0	1,172.0
13		28.7	5.0	33.7	74.6	281.3	1.1	1.0	358.1	324.3	0.6810	220.8	1,392.9
14		5.3	5.0	10.3	78.3	295.4	1.1	1.0	375.9	365.5	0.6611	241.7	1,634.5
15		5.3	5.0	10.3	82.3	310.1	1.1	1.0	394.5	384.2	0.6419	246.6	1,881.1
16		5.3	5.0	10.3	86.4	325.7	1.1	1.0	414.2	403.8	0.6232	251.7	2,132.8
17		5.3	5.0	10.3	90.7	341.9	1.1	1.0	434.8	424.4	0.6050	256.8	2,389.6
18		28.7	5.0	33.7	95.2	359.0	1.1	1.0	456.4	422.7	0.5874	248.3	2,637.8
19		5.3	5.0	10.3	100.0	377.0	1.1	1.0	479.1	468.8	0.5703	267.3	2,905.2
20		5.3	5.0	10.3	105.0	395.8	1.1	1.0	503.0	492.6	0.5537	272.8	3,177.9
21		5.3	5.0	10.3	110.2	415.6	1.1	1.0	528.0	517.7	0.5375	278.3	3,456.2
22		5.3	5.0	10.3	115.7	436.4	1.1	1.0	554.3	544.0	0.5219	283.9	3,740.1
23		28.7	5.0	33.7	121.5	458.2	1.1	1.0	581.9	548.2	0.5067	277.7	4,017.8
24		5.3	5.0	10.3	127.6	481.1	1.1	1.0	610.9	600.5	0.4919	295.4	4,313.3
25		5.3	5.0	10.3	134.0	505.2	1.1	1.0	641.3	631.0	0.4776	301.4	4,614.6
26		5.3	5.0	10.3	140.7	530.5	1.1	1.0	673.3	662.9	0.4637	307.4	4,922.0
27		5.3	5.0	10.3	147.7	557.0	1.1	1.0	706.8	696.5	0.4502	313.6	5,235.6
28		28.7	5.0	33.7	155.1	584.8	1.1	1.0	742.1	708.3	0.4371	309.6	5,545.2
29		5.3	5.0	10.3	162.9	614.1	1.1	1.0	779.1	768.7	0.4243	326.2	5,871.4
30		5.3	5.0	10.3	171.0	644.8	1.1	1.0	817.9	807.6	0.4120	332.7	6,204.1
31		5.3	5.0	10.3	179.5	677.0	1.1	1.0	858.7	848.4	0.4000	339.3	6,543.4
32		5.3	5.0	10.3	188.5	710.9	1.1	1.0	901.5	891.2	0.3883	346.1	6,889.5
33		28.7	5.0	33.7	197.9	746.4	1.1	1.0	946.5	912.8	0.3770	344.1	**7,233.6**

Appendix O: Project Sensitivity Analysis

1) Financial Sensitivity Analysis with Toll Road Option

FNPV	Traffic Forecast Variable Tested									
		80%	85%	90%	95%	100%	105%	110%	115%	120%
Investment Cost Variable Tested	80%	-8%	11%	29%	48%	67%	86%	105%	124%	143%
	85%	-24%	-5%	14%	33%	52%	71%	90%	109%	127%
	90%	-40%	-21%	-2%	17%	36%	55%	73%	92%	111%
	95%	-57%	-38%	-19%	0%	18%	37%	56%	75%	94%
	100%	-75%	-57%	-38%	-19%	0%	19%	38%	57%	75%
	105%	-95%	-76%	-57%	-38%	-20%	-1%	18%	37%	56%
	110%	-116%	-97%	-78%	-59%	-40%	-22%	-3%	16%	35%
	115%	-138%	-119%	-100%	-81%	-62%	-44%	-25%	-6%	13%
	120%	-161%	-142%	-123%	-105%	-86%	-67%	-48%	-29%	-10%

2) Economic Sensitivity Analysis with Toll Road option

ENPV	Traffic Forecast Variable Tested									
		80%	85%	90%	95%	100%	105%	110%	115%	120%
Investment Cost Variable Tested	80%	-19%	-13%	-7%	0%	6%	12%	18%	24%	31%
	85%	-20%	-14%	-8%	-2%	5%	11%	17%	23%	29%
	90%	-22%	-15%	-9%	-3%	3%	9%	15%	22%	28%
	95%	-23%	-17%	-11%	-5%	2%	8%	14%	20%	26%
	100%	-25%	-19%	-12%	-6%	0%	6%	12%	19%	25%
	105%	-26%	-20%	-14%	-8%	-2%	4%	11%	17%	23%
	110%	-28%	-22%	-16%	-10%	-3%	3%	9%	15%	21%
	115%	-30%	-24%	-18%	-12%	-5%	1%	7%	13%	19%
	120%	-32%	-26%	-20%	-14%	-7%	-1%	5%	11%	17%

ENPV	VOT Variable Tested									
		80%	85%	90%	95%	100%	105%	110%	115%	120%
Investment Cost Variable Tested	80%	-16%	-11%	-5%	0%	6%	11%	17%	22%	28%
	85%	-18%	-12%	-7%	-1%	5%	10%	16%	21%	27%
	90%	-19%	-13%	-8%	-2%	3%	9%	14%	20%	25%
	95%	-20%	-15%	-9%	-4%	2%	7%	13%	18%	24%
	100%	-22%	-17%	-11%	-6%	0%	6%	11%	17%	22%
	105%	-24%	-18%	-13%	-7%	-2%	4%	9%	15%	20%
	110%	-26%	-20%	-15%	-9%	-3%	2%	8%	13%	19%
	115%	-27%	-22%	-16%	-11%	-5%	0%	6%	11%	17%
	120%	-29%	-24%	-18%	-13%	-7%	-2%	4%	9%	15%

ENPV	VOC Variable Tested									
		80%	85%	90%	95%	100%	105%	110%	115%	120%
Investment Cost Variable Tested	80%	0%	1%	3%	4%	6%	7%	9%	10%	12%
	85%	-1%	0%	2%	3%	5%	6%	7%	9%	10%
	90%	-3%	-1%	0%	2%	3%	5%	6%	7%	9%
	95%	-4%	-3%	-1%	0%	2%	3%	5%	6%	7%
	100%	-6%	-4%	-3%	-1%	0%	1%	3%	4%	6%
	105%	-8%	-6%	-5%	-3%	-2%	0%	1%	3%	4%
	110%	-9%	-8%	-6%	-5%	-3%	-2%	-1%	1%	2%
	115%	-11%	-10%	-8%	-7%	-5%	-4%	-2%	-1%	0%
	120%	-13%	-12%	-10%	-9%	-7%	-6%	-4%	-3%	-2%

3) Economic Sensitivity Analysis with Freeway option

ENPV	Traffic Forecast Variable Tested									
		80%	85%	90%	95%	100%	105%	110%	115%	120%
Investment Cost Variable Tested	80%	-19%	-14%	-8%	-2%	3%	9%	15%	20%	26%
	85%	-20%	-14%	-9%	-3%	3%	8%	14%	20%	25%
	90%	-21%	-15%	-10%	-4%	2%	7%	13%	19%	24%
	95%	-22%	-16%	-10%	-5%	1%	7%	12%	18%	24%
	100%	-23%	-17%	-11%	-6%	0%	6%	11%	17%	23%
	105%	-24%	-18%	-12%	-7%	-1%	5%	10%	16%	22%
	110%	-25%	-19%	-13%	-8%	-2%	4%	9%	15%	21%
	115%	-26%	-20%	-14%	-9%	-3%	3%	8%	14%	20%
	120%	-27%	-21%	-16%	-10%	-4%	1%	7%	13%	18%

ENPV	VOT Variable Tested									
		80%	85%	90%	95%	100%	105%	110%	115%	120%
Investment Cost Variable Tested	80%	-15%	-10%	-6%	-1%	3%	8%	12%	17%	21%
	85%	-15%	-11%	-6%	-2%	3%	7%	12%	16%	20%
	90%	-16%	-12%	-7%	-3%	2%	6%	11%	15%	20%
	95%	-17%	-13%	-8%	-4%	1%	5%	10%	14%	19%
	100%	-18%	-13%	-9%	-4%	0%	4%	9%	13%	18%
	105%	-19%	-14%	-10%	-5%	-1%	4%	8%	12%	17%
	110%	-20%	-15%	-11%	-6%	-2%	2%	7%	11%	16%
	115%	-21%	-16%	-12%	-8%	-3%	1%	6%	10%	15%
	120%	-22%	-18%	-13%	-9%	-4%	0%	5%	9%	14%

Front Cover

Name of Product

Transport Infrastructure Project
Cost Benefit Analysis Facilitation Software

User Manual

Version 0.1a

CBAFS

Contents

Contents

Minimum Requirements:

- Operating System: Microsoft Window 7 and later.
- Office 2016, MS Office 365 and later

Abbreviations

- CBA: Cost- Benefit Analysis
- MCA: Multi-Criteria Analysis
- VOC: Vehicle Operating Cost
- EIA: Environmental Impact Assessment
- SEA: Socio-Economic analysis
- DCF: Discounted Cash Flow
- NPV: Net Present Value
- IRR: The Rate of Return
- B/C: Benefit/Cost
- PB: Pay-back Period

1. CBAFS Introduction

CBAFS is an evaluation program for transport infrastructure projects. It focuses on translating stakeholder needs into technical requirements and then uses this information to seek cost-benefit factors and associated methods used for evaluation. This software also allows users to carry out a preliminary evaluation program for transport projects with four main aspects; technical, financial, socio-economic and environmental. Moreover, CBAFS supports users to generate reports for different types of business owner; project managers, private investors and local government.

CBAFS takes the data entered by the user about the project-of-interest and uses this to produce cost-benefit analysis information with the following forms:

- Traffic forecast
- Project input
- Stakeholder identification
- Stakeholder need analysis
- Technical Interpretation
- Method assessment and selection
- Method execution conditions
- Method planning and scheduling
- Travel time cost savings
- Vehicle operating cost savings
- Project financial assessment
- Project economic assessment
- Risk assessment (Technical, Financial, Socio-Economic & Environmental)
- Sensitivity analysis

In order to produce this CBA information, CBAFS requires a significant amount of information about the project-of-interest. This is input in two ways: manual entry as prompted by dialog windows and the importing a structured comma, separated variable file in the prescribed CBAFS format (see Appendix X) for traffic history information. Once input, project data files can be saved for later use.

Since CBAFS is based on the Visual Basic Language for programming, the output format of CBAFS are Excel worksheets and Word documents. Users are able to observe evaluation results via separate Excel worksheets and generate a full project report. The final report is a Word document that contains the main forms of the evaluation program that can be edited. The structure of the final report depends on the interest of main audiences, so CBAFS automatically sets up the report structure types based on audience interest.

Users can download the CBAFS file from the Web (www.CBAFS.com) or ask providers for a USB drive for installation. The main requirement of using CBAFS is that users need to install Microsoft Office 2016 or Microsoft Office 365 (www.products.office.com/en-au/home) before carrying out the main steps of an evaluation program. The details of carrying out CBAFS are presented in Section 2 (CBAFS Implementation).

2. CBAFS Implementation

2.1 Set up Project Inputs

Step 1: Download the CBAFS file and double click on this file to start the evaluation program.

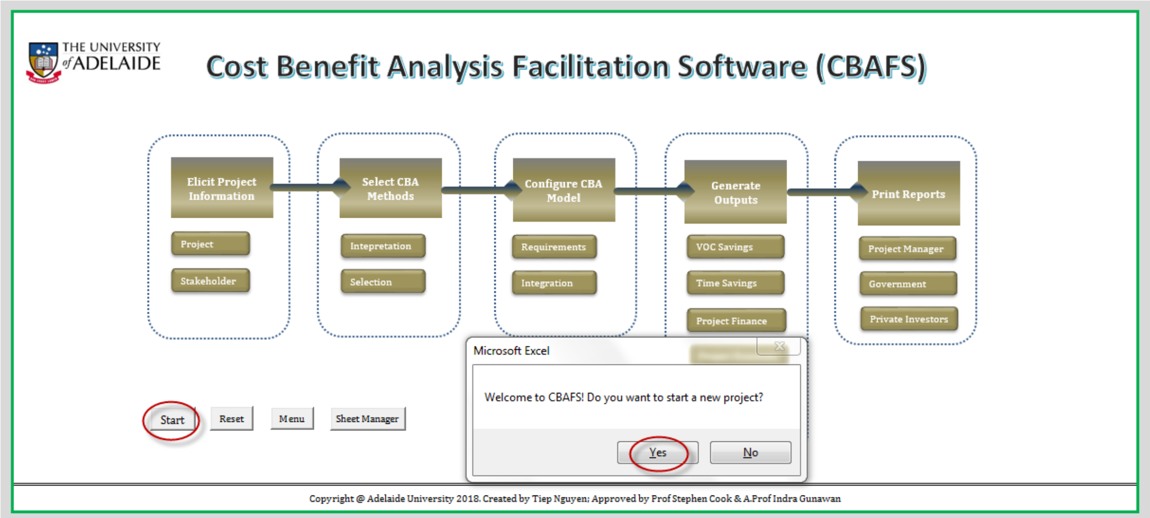


Figure 2.1. CBAFS Overview

Next, click **Start** button to begin the evaluation program. You need to fill in basic information of your project including name, project description, and author name; and specify the file path for data storage. When you finish this task, click submit to confirm your provided information.

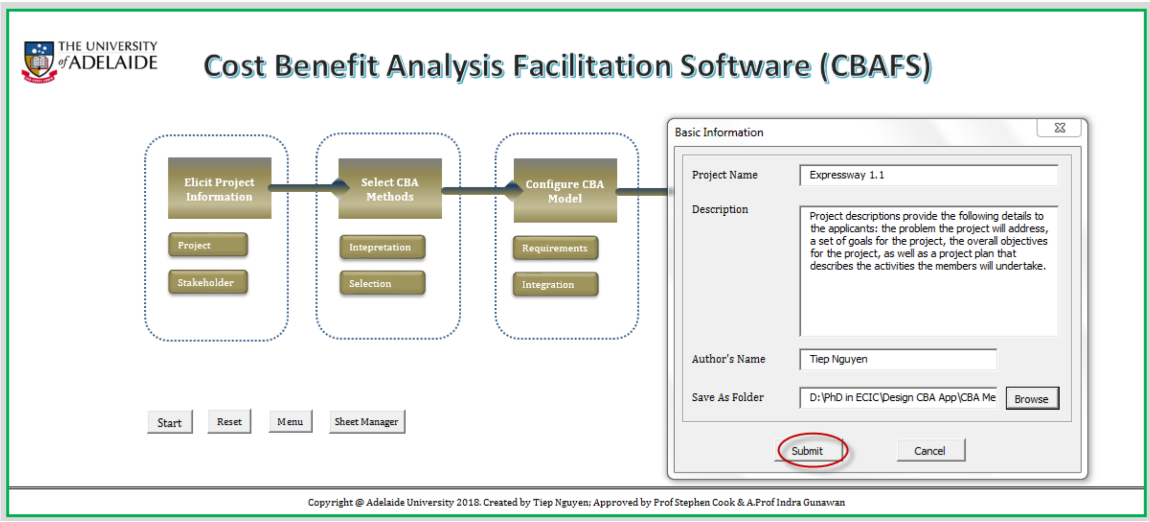


Figure 2.2. Data Entry Page

Step 2: Set traffic forecast by clicking the **Import** button and chose the separated variable file in the prescribed CBAFS format (see Appendix X) for traffic history information.

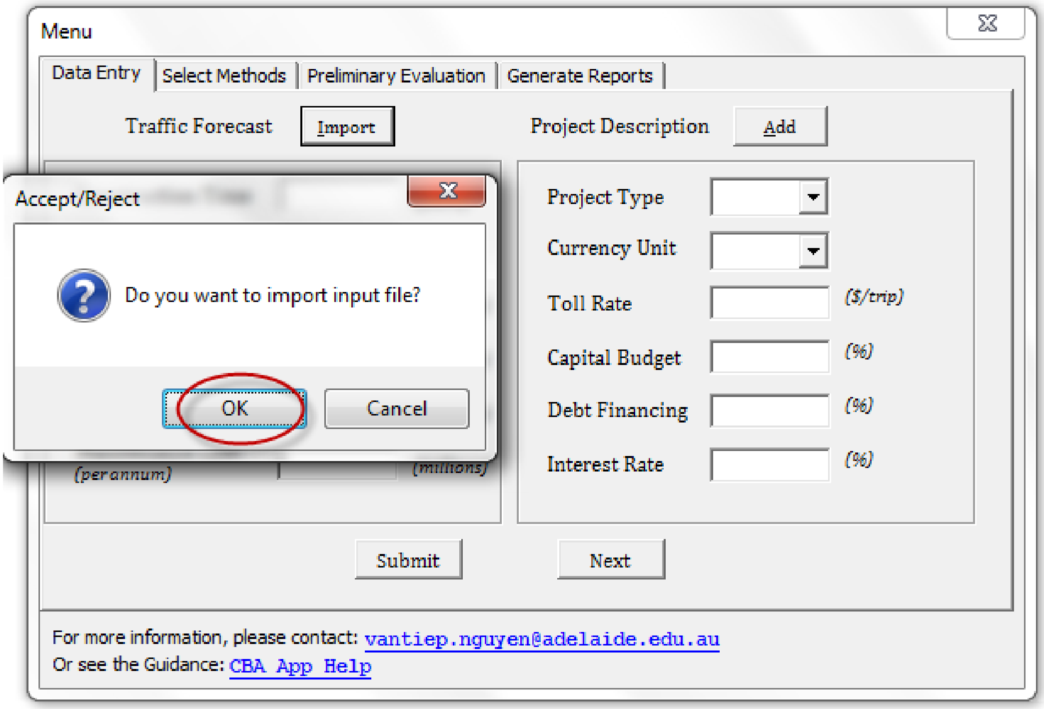


Figure 2.3. Traffic Forecast

The CBA App automatically uses the historical data of your project to fill in the number of vehicles including Cars, Light Good Vehicles (LGV), Heavy Vehicles (Rigid), and Public Service Vehicles (PSV). When you finish this task, click the **OK** button to generate a Traffic Forecast worksheet. You can close the Menu form to observe the results. If you want to go back to the menu, click Ctrl-Shift-M.

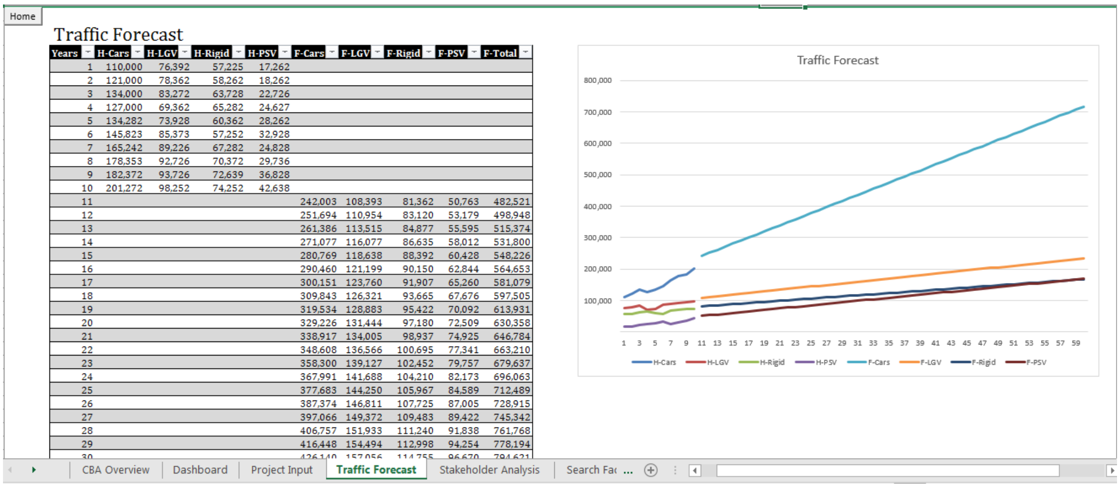


Figure 2.4. Traffic Forecast Worksheet

Step 3: To get back to the Entry Page (Ctrl-Shift-M), you need to set up your project inputs, including:

- Project Description: Click **Add** button to add general information about your project.
- Construction Time: The required time to construct your project, e.g. 2 years.
- Operational time: The time for operating your projects after construction stage, e.g. 30-50 years.

- Land cost: The total cost for compensation and site clearance.
- Operational cost: The amount of money used for hiring staff and buying facilities to operate the project during the operational time.
- Maintenance cost: The costs associated with the maintenance of any facility, equipment or asset of project.
- Project type: Select the type of your project such as Road or Bridge
- Toll Rate: Set the toll rate for each trip, such as 12$/trip.
- Capital Budget: The percentage of capital investment for project implementation
- Debt Financing: The percentage of project loan against the total cost.
- Interest rate: The rate of interest for the project loan.

When you finish this task, click the **Submit** button and then click the **Next** button to move to the **Select Methods** page.

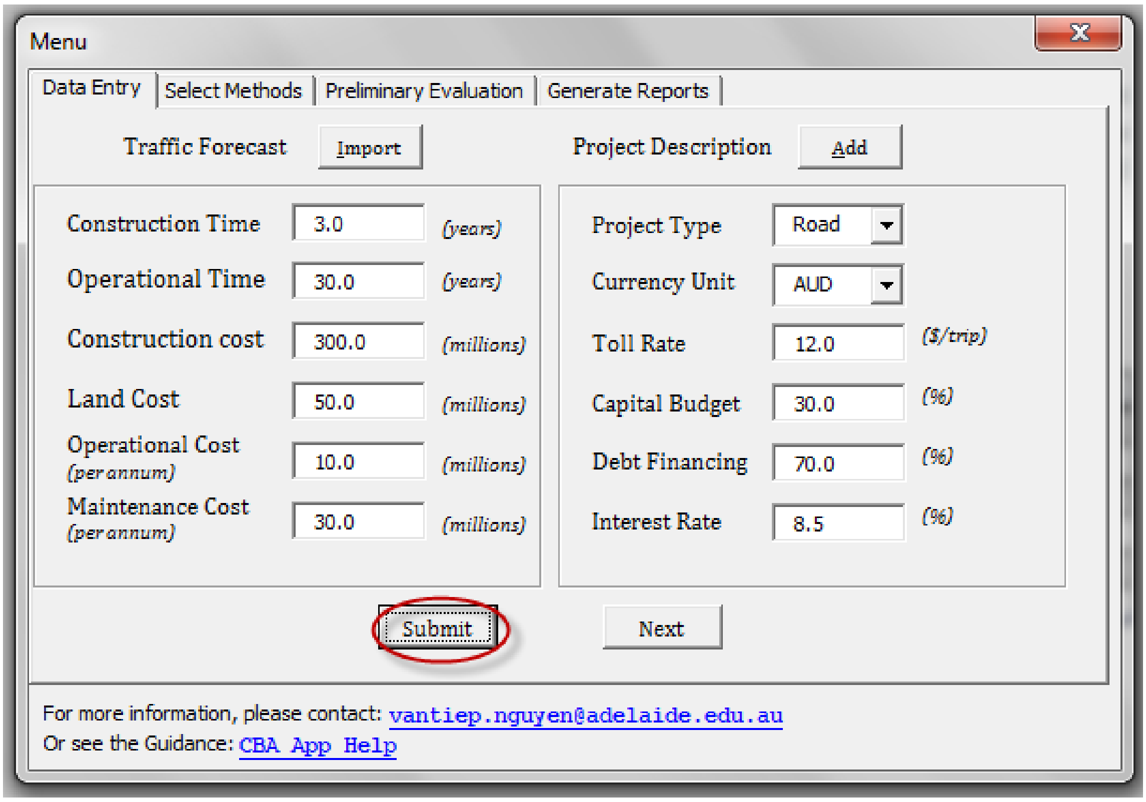


Figure 2.5. Set up Project Input

2.2 Select Evaluation Methods

Step 1: Mapping Stakeholder Groups

Click the **Enter** button for stakeholder mapping and then identify the influence and interest of each group associated with the context of your project.

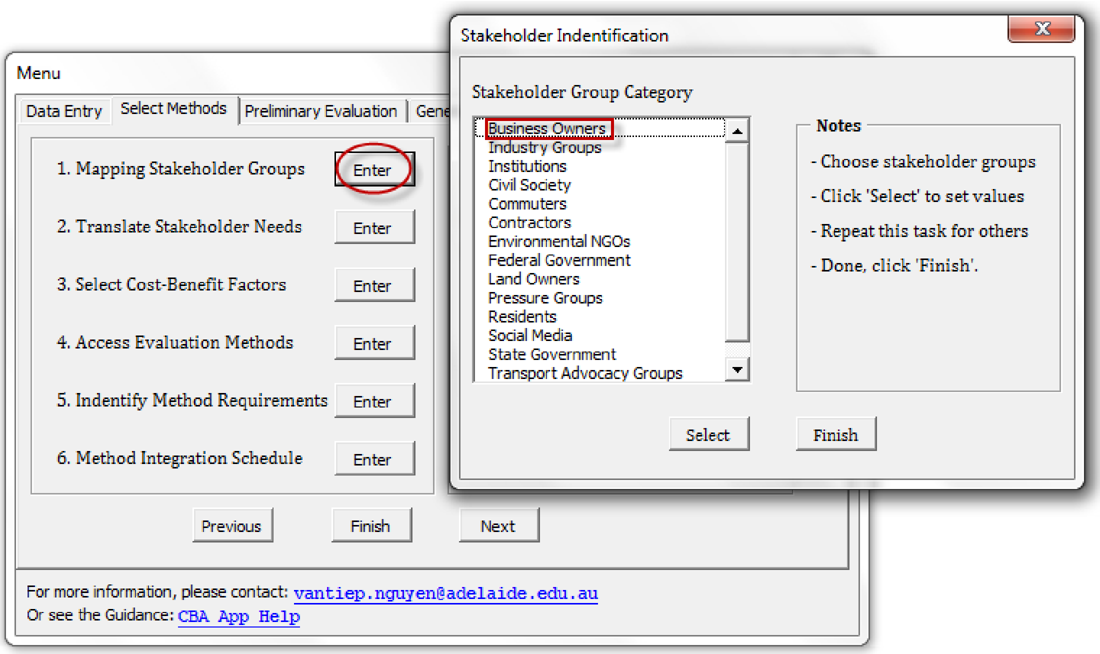


Figure 2.6. Stakeholder Mapping

For each group, you need to score for influence and interest (Figure 2.7). Please remember the score should be less than 10 for both the interest and influence level of stakeholder groups. When you finish your assignment, click the **Submit** button to generate an influence-interest grid and move to the next step.

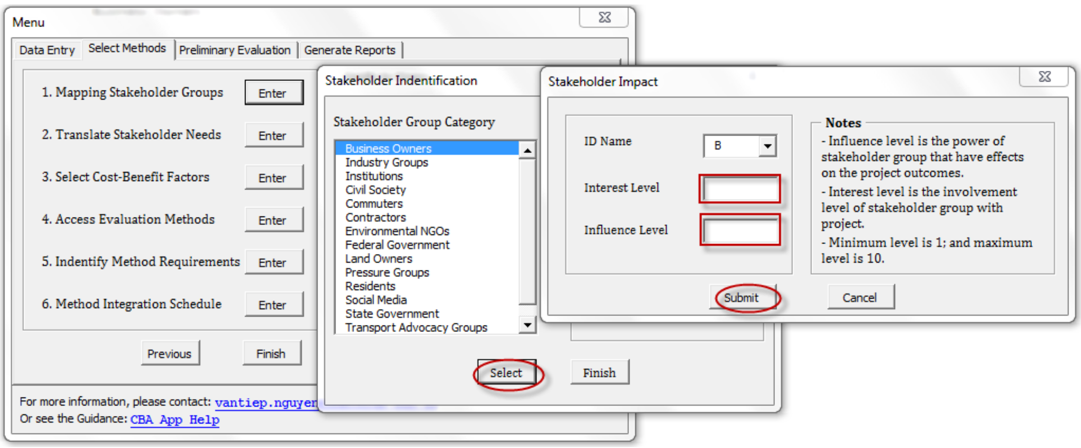


Figure 2.7. Set up Score for Stakeholder Groups

For more information, please see:
https://www.mindtools.com/pages/article/newPPM_07.htm

Step 2: Translate Stakeholder Needs

It is important to translate stakeholder needs into technical requirements, so the program supports users by creating a link between the stakeholder needs and technical requirements. You need to select the stakeholder group (see Figure 2.8) and then click the Submit button. You need to repeat this task for other groups.

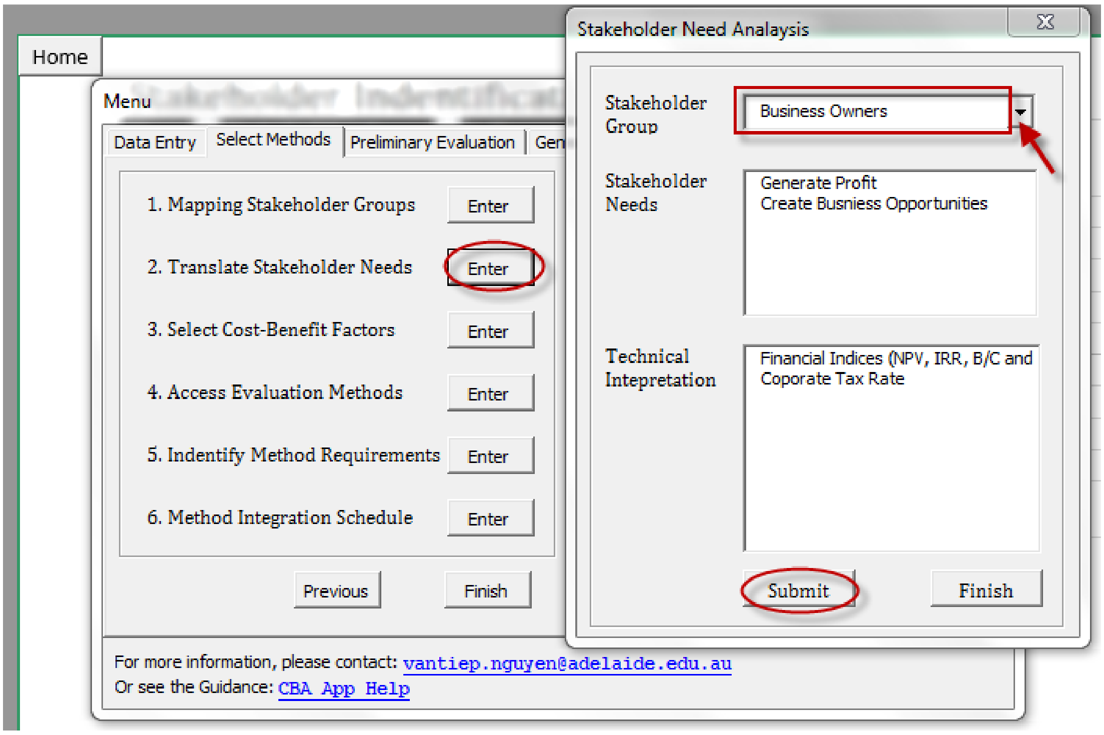


Figure 2.8. Stakeholder Needs Translation

When you finish this task for all groups, click the **Finish** button to observe the results (Figure 2.9).

Stakeholder Indentification

ID	Stakeholder Group	Influence Level	Interest Level
B	Business Owners	8	7
I1	Industry Groups	4	7
I2	Institutions	4	3
C2	Commuters	7	5
C3	Contractors	4	7
F	Federal Government	4	6
P	Pressure Groups	4	5

Stakeholder Analysis

ID	Stakeholder Group	Stakeholder Needs	Technical Intepretation
B	Business Owners	Generate Profit	Financial Indices (NPV, IRR, B/C and PB)
		Create Busniess Opportunities	Coporate Tax Rate
I1	Industry Groups	Reduce Traffic congestion	Traffic Volume
		Reduce Travel Time	Travel Time Savings
		Reduce Transport Cost	Travel Cost Savings
I2	Institutions	Ensure the Feasibility of Project	Financial Indices (NPV, IRR, B/C and PB)
			Socio-Economic Benefits
			Business Performance Indicators
C2	Commuters	Reduce traffic congestion	Traffic Volume
		Reduce Travel Time	Travel Time Savings
		Reduce Transport Cost	Travel Cost Savings
		Ensure Travel Safety	
C3	Contractors	Generate profit	Financial Indices (NPV, IRR, B/C and PB)
		Create Busniess Opportunities	Coporate Tax Rate
		Create Jobs for Local Place	Number of Jobs Created
F	Federal Government	Extend Transport Network	The Scope of Project
		Improve Public Service	Travel Cost Savings
			Travel Time Savings

Figure 2.9. Stakeholder Analysis Worksheet

Step 3: Select Cost-Benefit Factors and Associated Methods

The purpose of this step is to link technical requirements with cost-benefit factors and associated methods. Click the **Enter** button to start this task.

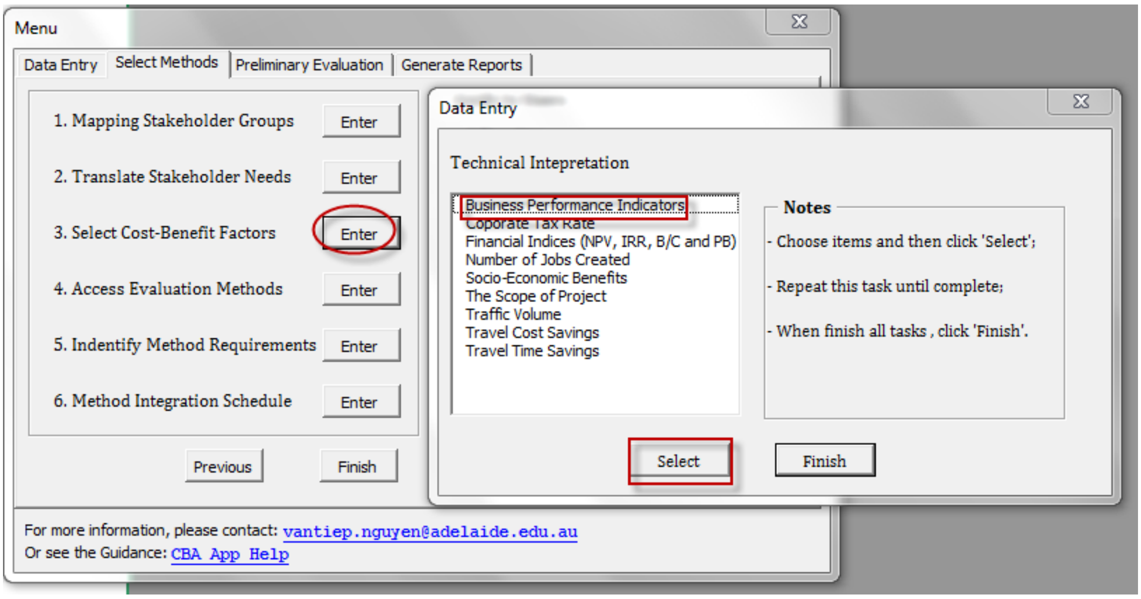


Figure 2.10. Technical Interpretation

Next, choose appropriate interpretations and then click the **Select** button. For each interpretation, you can select multiple cost-benefit factors and then click the **Submit** button (Figure 2.11).

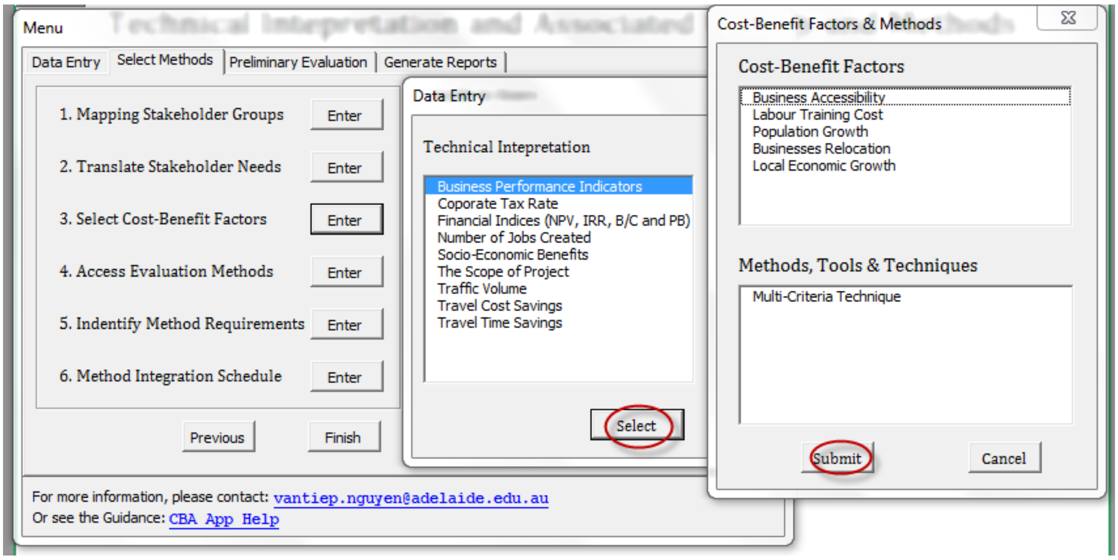
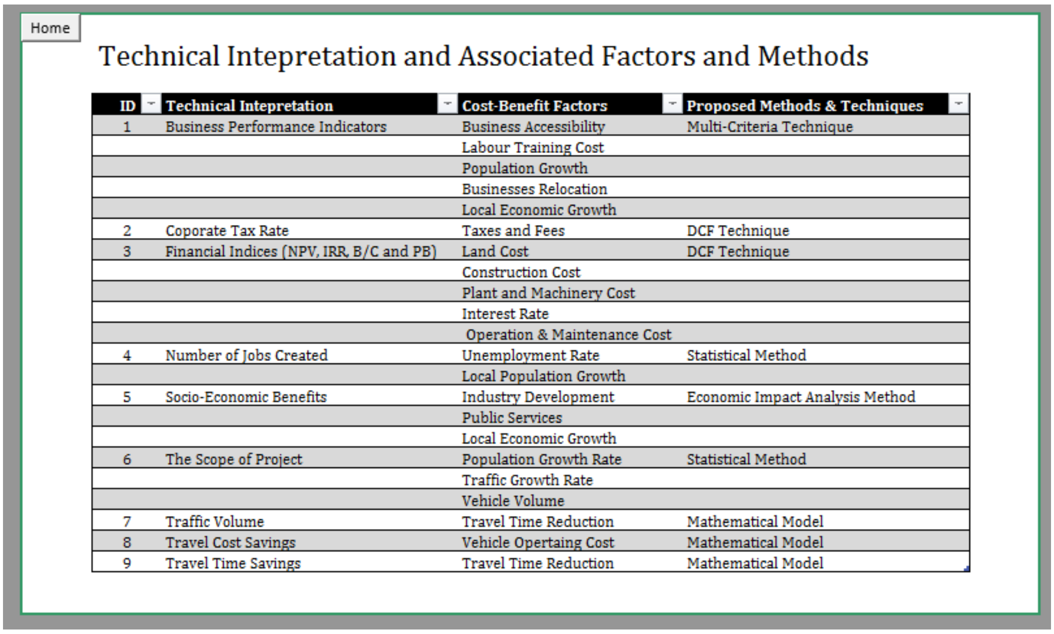


Figure 2.11. Cost-Benefit Factors and Associated Methods

When you finish this task, click **Finish** to observe the results (Figure 2.12). The list of candidate methods is based on the findings of the author's thesis (see Appendix Y).



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Technical Intepretation and Associated Factors and Methods

ID	Technical Intepretation	Cost-Benefit Factors	Proposed Methods & Techniques
1	Business Performance Indicators	Business Accessibility	Multi-Criteria Technique
		Labour Training Cost	
		Population Growth	
		Businesses Relocation	
		Local Economic Growth	
2	Coporate Tax Rate	Taxes and Fees	DCF Technique
3	Financial Indices (NPV, IRR, B/C and PB)	Land Cost	DCF Technique
		Construction Cost	
		Plant and Machinery Cost	
		Interest Rate	
		Operation & Maintenance Cost	
4	Number of Jobs Created	Unemployment Rate	Statistical Method
		Local Population Growth	
5	Socio-Economic Benefits	Industry Development	Economic Impact Analysis Method
		Public Services	
		Local Economic Growth	
6	The Scope of Project	Population Growth Rate	Statistical Method
		Traffic Growth Rate	
		Vehicle Volume	
7	Traffic Volume	Travel Time Reduction	Mathematical Model
8	Travel Cost Savings	Vehicle Opertaing Cost	Mathematical Model
9	Travel Time Savings	Travel Time Reduction	Mathematical Model

Figure 2.12. Technical Interpretation Worksheet

Step 4: Access Evaluation Methods

This step focuses on seeking promising methods for evaluation. Click the **Enter** button to start this process. The program will automatically filter methods from the previous step for your evaluation. For each method, click the **Select** button to carry out this process (Figure 2.13). Some attributes for assessment are: Relevance, Acceptability, Software Cost, Data Requirement, Execution Time, Efficiency, Consistency, Learnability, and Adaptability. You need to discuss with other team members to assign a score for each section and the score must be less than 10.

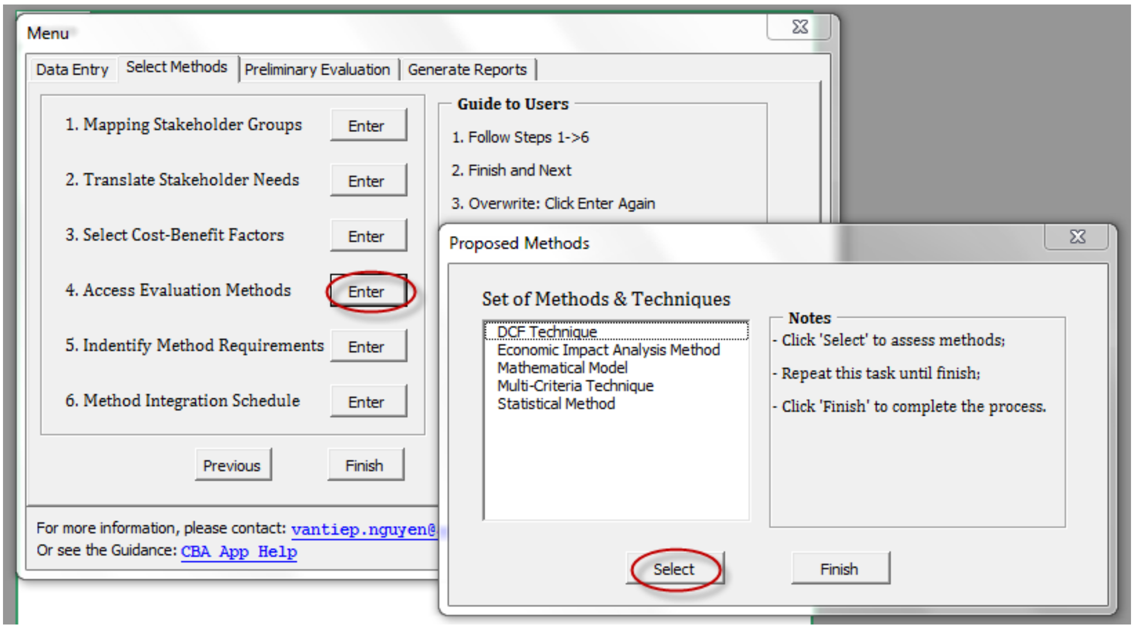


Figure 2.13. Method Evaluation Page

For each method, please click the **Select** button to assess the feasibility for each one. You need to repeat this process for other methods and when you complete this task, please click the **Finish** button to observe the results. To go back the Menu, click **Ctrl-Shift-M.**

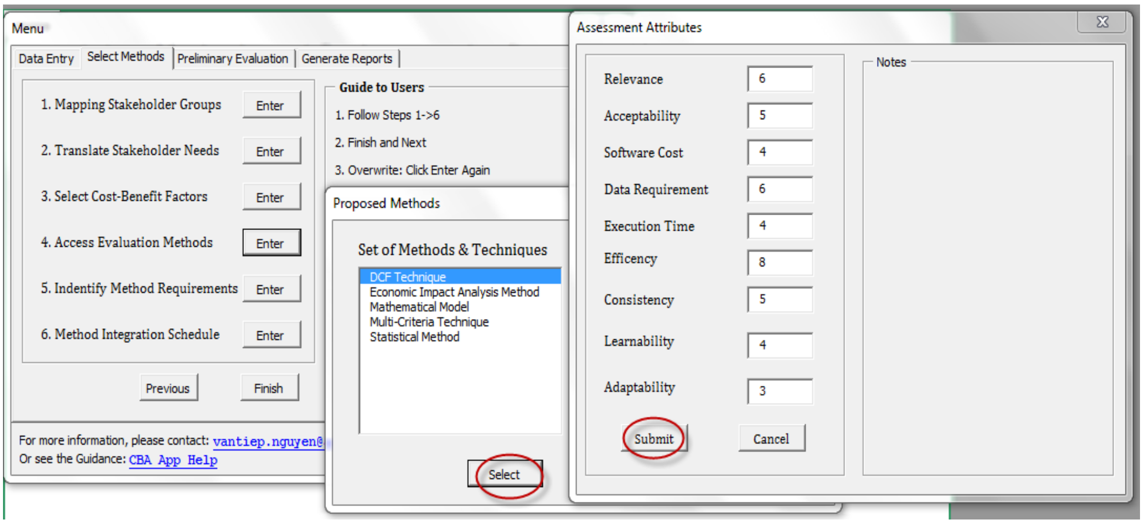
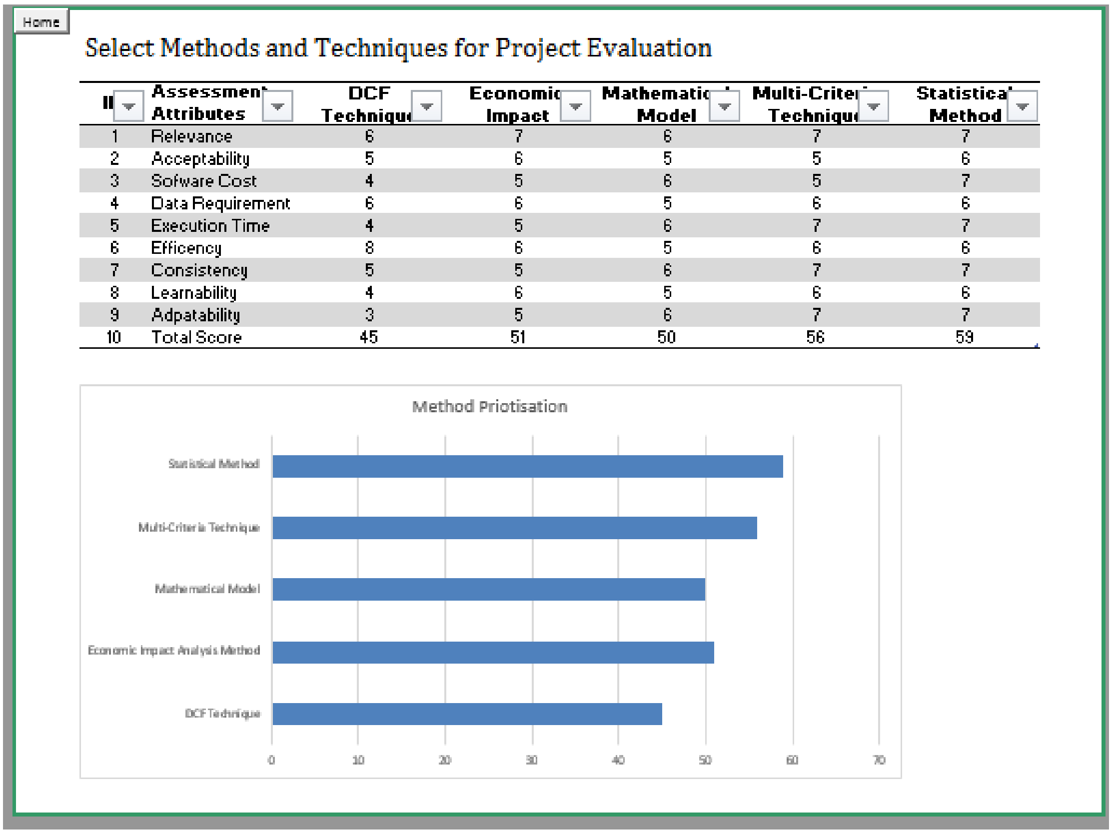


Figure 2.14. Score Sections for Method Evaluation

Please remember the score for each given attribute must be less than 10. Based on the total score of attributes, the prioritisation of proposed methods is automatically generated (Figure 2.15).



ID	Assessment Attributes	DCF Technique	Economic Impact	Mathematical Model	Multi-Criteria Technique	Statistical Method
1	Relevance	6	7	6	7	7
2	Acceptability	5	6	5	5	6
3	Sofware Cost	4	5	6	5	7
4	Data Requirement	6	6	5	6	6
5	Execution Time	4	5	6	7	7
6	Efficency	8	6	5	6	6
7	Consistency	5	5	6	7	7
8	Learnability	4	6	5	6	6
9	Adpatability	3	5	6	7	7
10	Total Score	45	51	50	56	59

Figure 2.15. Method Prioritisation

Step5: Identify Method Requirements

Because, each method may have some compulsory requirements for implementation, the purpose of this step is to highlight the main requirements of selected methods for implementation. Click the **Enter** button to carry out this process for proposed methods.

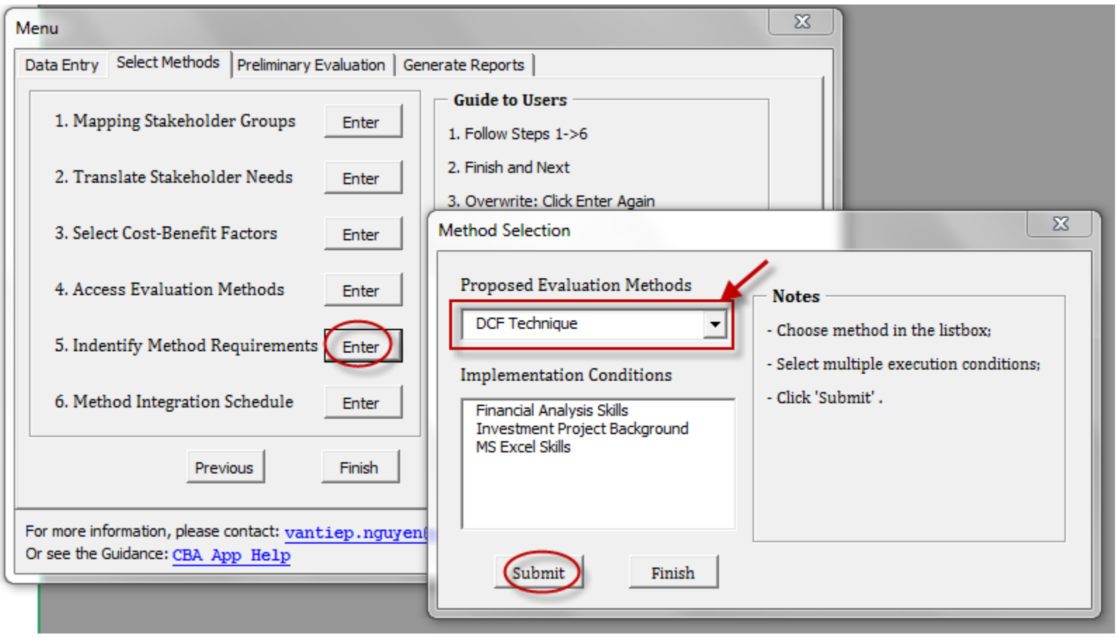


Figure 2.16. Method Requirement Page

Repeated this process for the remaining methods. When your assignment is completed, click **Finish** to review the main requirements (Figure 2.17).

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Method Execution Conditions

ID	Selected Methods	Method Execution Conditions
1	DCF Technique	Financial Analysis Skills
		Investment Project Background
		MS Excel Skills
2	Economic Impact Analysis Method	Economic Impact Analysis Skill
		Macro & Micro Economic Background
		Planning Skills
3	Mathematical Model	Basic Caculation Skills
		Mathematical Background
		Modelling Skills
4	Multi-Criteria Technique	Decision-Making Skills
		MS Excel Skills
		Multi-criteria Analysis Skills
5	Statistical Method	MS Excel Skills
		Ms Word Skills
		Statistics Background

Figure 2.17. Method Execution Conditions

Step 6: Method Integration Schedule

This step supports users to establish the schedule for implementing the evaluation program. Click the **Enter** button to start this process.

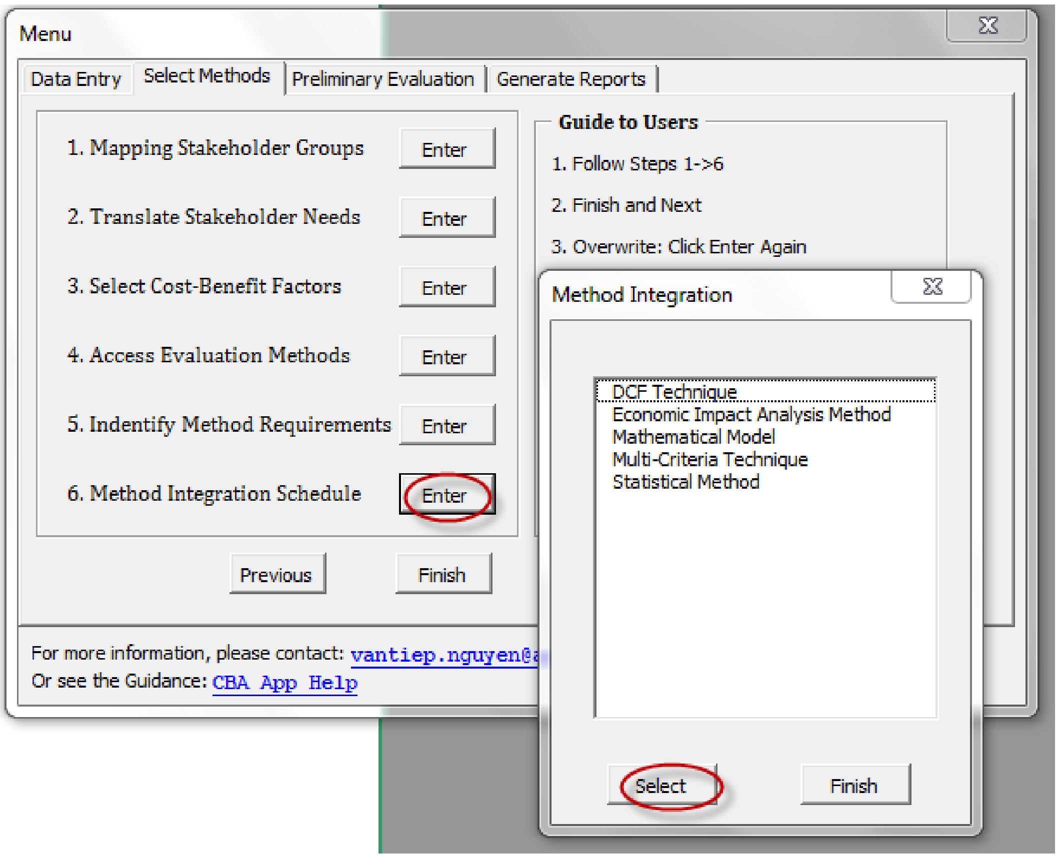


Figure 2.18. Method Integration Page

For each method, you need to identify evaluation layers, start time and finish time. The time format should be "dd/mm/yy**,** so please review this before your submission (Figure 2.19).

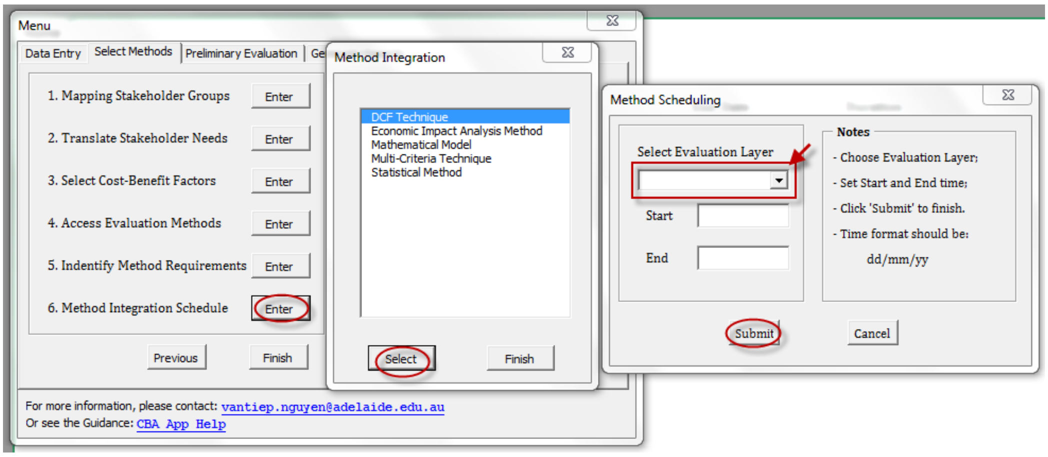


Figure 2.19. Method Schedule

The Gantt chart is automatically generated in accordance with the given time (Figure 2.20).

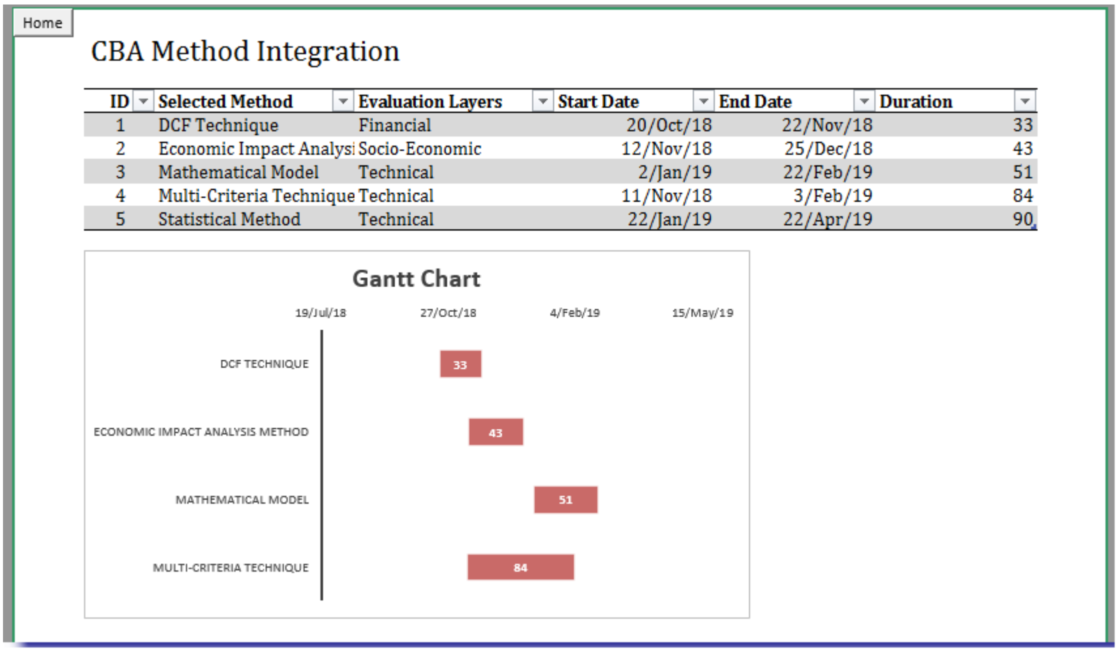


Figure 2.20. Gantt Chart for Method Integration

To move two the preliminary evaluation, click the Next button to review the selection (Figure 2.21). The Method Proposed section lists the proposed methods from your evaluation. The Preliminary Evaluation section presents main aspects of a program evaluation that will be carried out immediately. Supplemental methods are methods that need to be supplemented in a full evaluation program. You can add the results of supplemental methods to the report later.

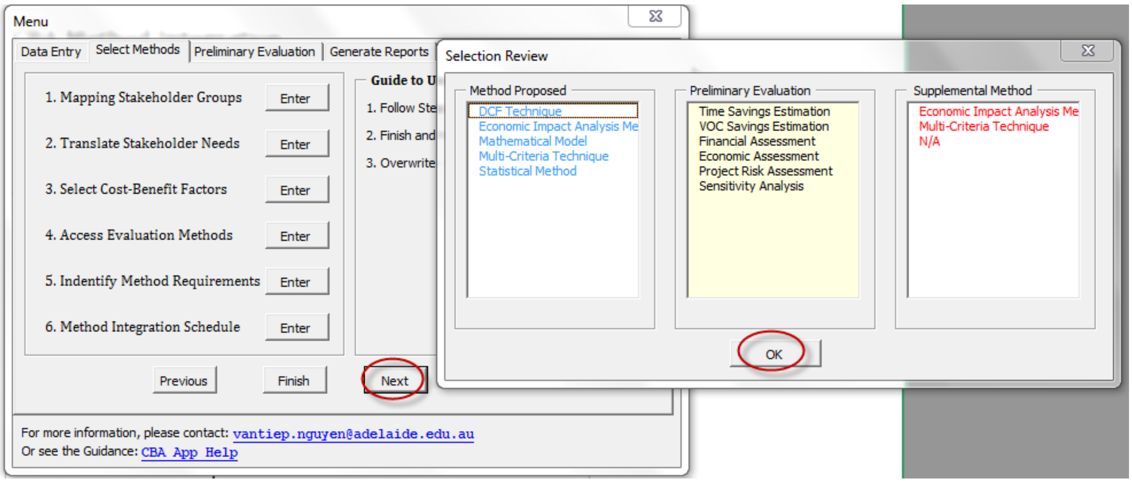


Figure 2.21. Method Selection Review

2.3 Execute Preliminary Evaluation

Step 1: Travel Time Cost Savings

Travel time cost savings is the amount of money saved for each vehicle per trip. This depends on vehicle type and the willingness to pay principle of travellers. Click the **Estimate** button to set up the inputs for calculation (Figure 2.22).

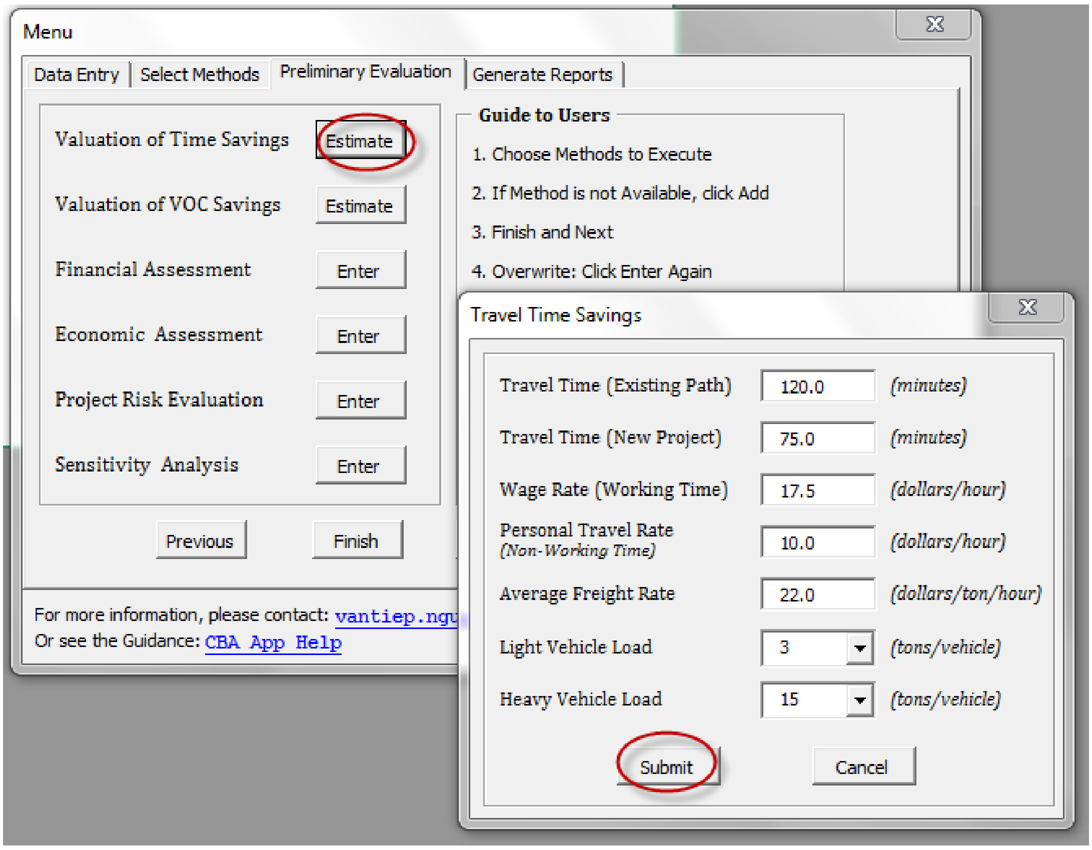
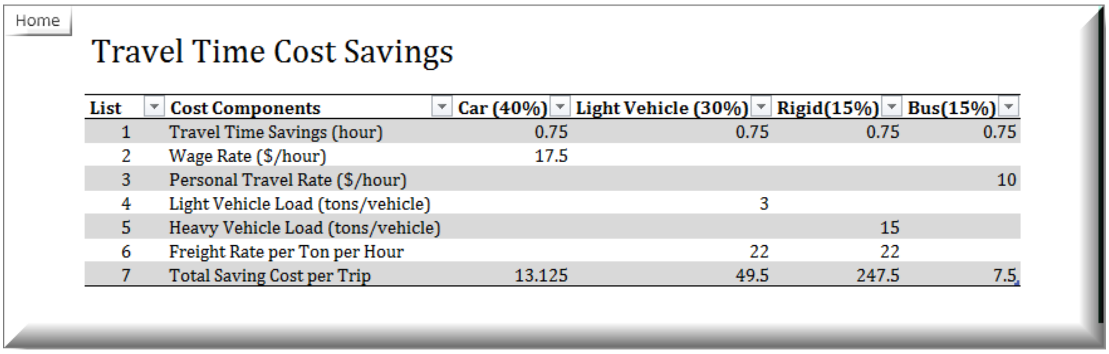


Figure 2.22. Travel Time Cost Savings Page

When you finish this task, click the **Submit** button to observe the results (Figure 2.23).


Home

Travel Time Cost Savings

List	Cost Components	Car (40%)	Light Vehicle (30%)	Rigid(15%)	Bus(15%)
1	Travel Time Savings (hour)	0.75	0.75	0.75	0.75
2	Wage Rate ($/hour)	17.5			
3	Personal Travel Rate ($/hour)				10
4	Light Vehicle Load (tons/vehicle)		3		
5	Heavy Vehicle Load (tons/vehicle)			15	
6	Freight Rate per Ton per Hour		22	22	
7	Total Saving Cost per Trip	13.125	49.5	247.5	7.5

Figure 2.23. Travel Cost Savings

Step 2: Vehicle Operating Cost (VOC) Savings

Vehicle operating cost savings is the amount of money saved for each vehicle per trip. This can be calculated by the comparison of that VoC under the condition of existing road and new road. Click the **Estimate** button to carry out this process (Figure 2.24).

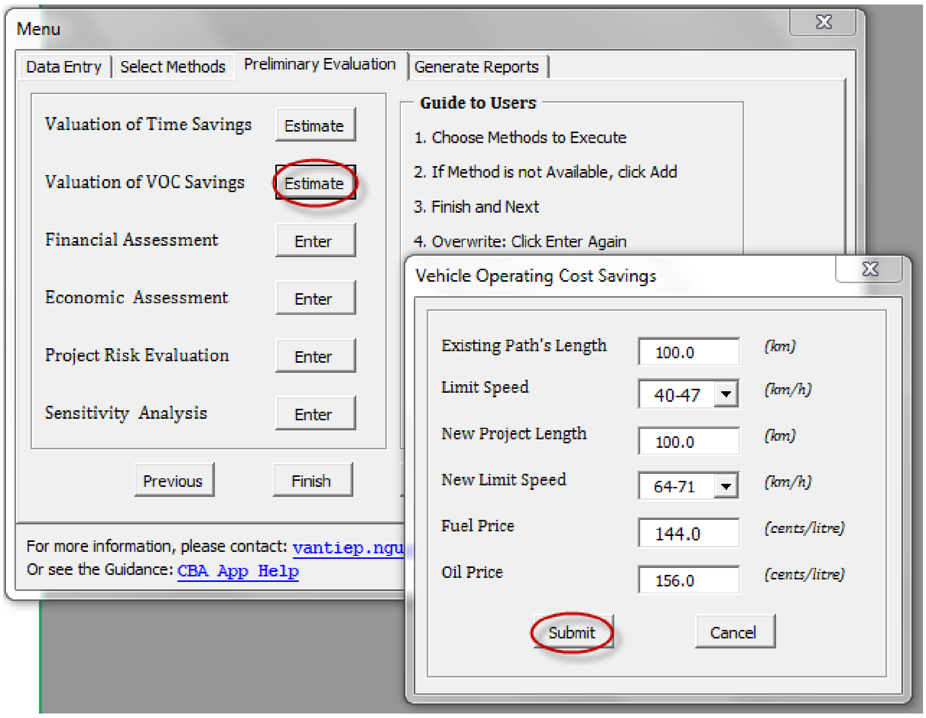
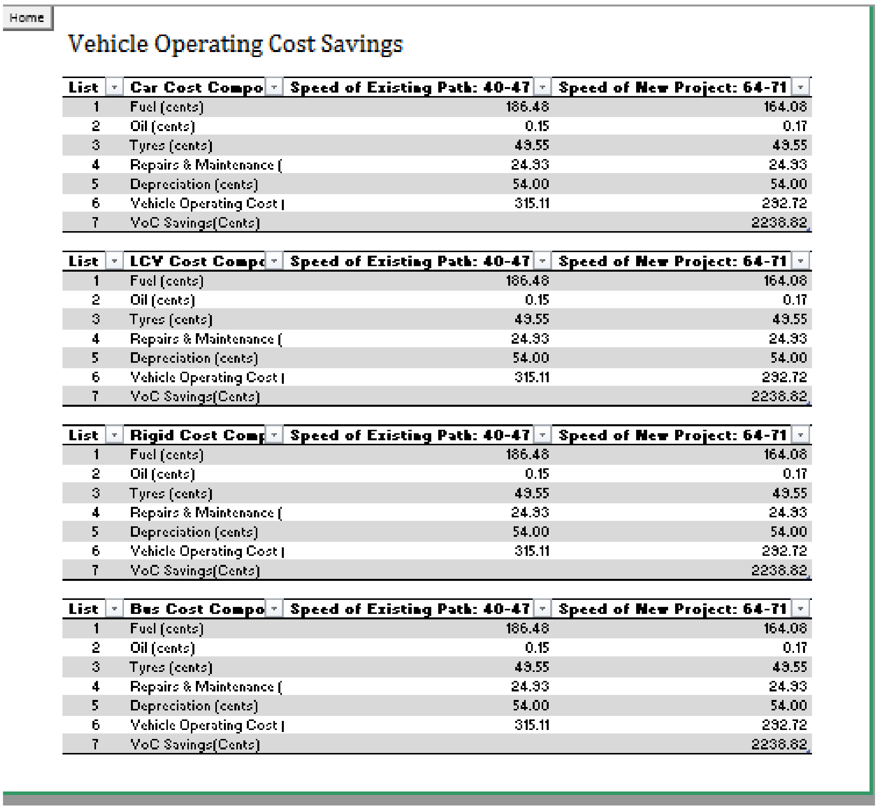


Figure 2.24. VOC Savings Page

When you finish this task, click the **Submit** button to observe the results (Figure 2.25)



Home

Vehicle Operating Cost Savings

List	Car Cost Compo	Speed of Existing Path: 40-47	Speed of New Project: 64-71
1	Fuel (cents)	186.48	164.08
2	Oil (cents)	0.15	0.17
3	Tyres (cents)	49.55	49.55
4	Repairs & Maintenance (	24.93	24.93
5	Depreciation (cents)	54.00	54.00
6	Vehicle Operating Cost (	315.11	292.72
7	VoC Savings(Cents)		2238.82

List	LCV Cost Compo	Speed of Existing Path: 40-47	Speed of New Project: 64-71
1	Fuel (cents)	186.48	164.08
2	Oil (cents)	0.15	0.17
3	Tyres (cents)	49.55	49.55
4	Repairs & Maintenance (	24.93	24.93
5	Depreciation (cents)	54.00	54.00
6	Vehicle Operating Cost (	315.11	292.72
7	VoC Savings(Cents)		2238.82

List	Rigid Cost Comp	Speed of Existing Path: 40-47	Speed of New Project: 64-71
1	Fuel (cents)	186.48	164.08
2	Oil (cents)	0.15	0.17
3	Tyres (cents)	49.55	49.55
4	Repairs & Maintenance (	24.93	24.93
5	Depreciation (cents)	54.00	54.00
6	Vehicle Operating Cost (	315.11	292.72
7	VoC Savings(Cents)		2238.82

List	Bus Cost Compo	Speed of Existing Path: 40-47	Speed of New Project: 64-71
1	Fuel (cents)	186.48	164.08
2	Oil (cents)	0.15	0.17
3	Tyres (cents)	49.55	49.55
4	Repairs & Maintenance (	24.93	24.93
5	Depreciation (cents)	54.00	54.00
6	Vehicle Operating Cost (	315.11	292.72
7	VoC Savings(Cents)		2238.82

Figure 2.25. VOC Savings Worksheet

Step 3: Project Financial Analysis

Click the **Enter** button to set up inputs for financial analysis. The program automatically links with the Project Input worksheet, so you just need to click the **Submit** button to generate the results (Figure 2.26).

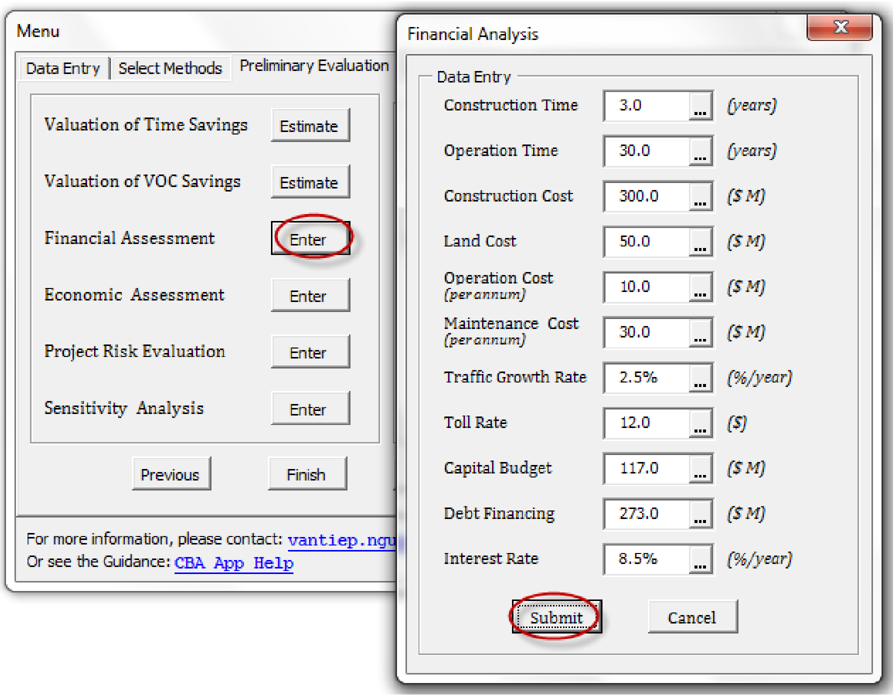


Figure 2.26. Financial Analysis Form

Step 4: Project Economic Analysis

Click the **Enter** button to execute the process of financial analysis. Conversion Factors for major costs need to be justified. The purpose of conversion factors is to convert financial inputs into economic inputs (please see the CBA Guide of EU Commission 2012).

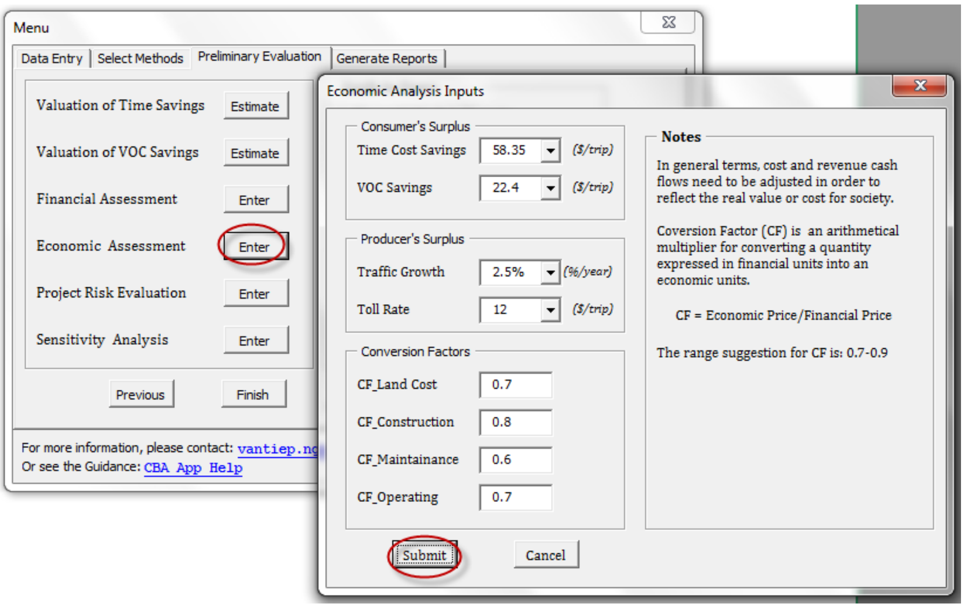


Figure 2.27. Economic Analysis Page

Step 5: Project Risk Analysis

Click the **Enter** button to carry out the process of risk analysis. Common risks of transport projects are initially identified by experts and the CBAFS designer, so you can select the appropriate ones for your project to assess the risk impact (Figure 2.28).

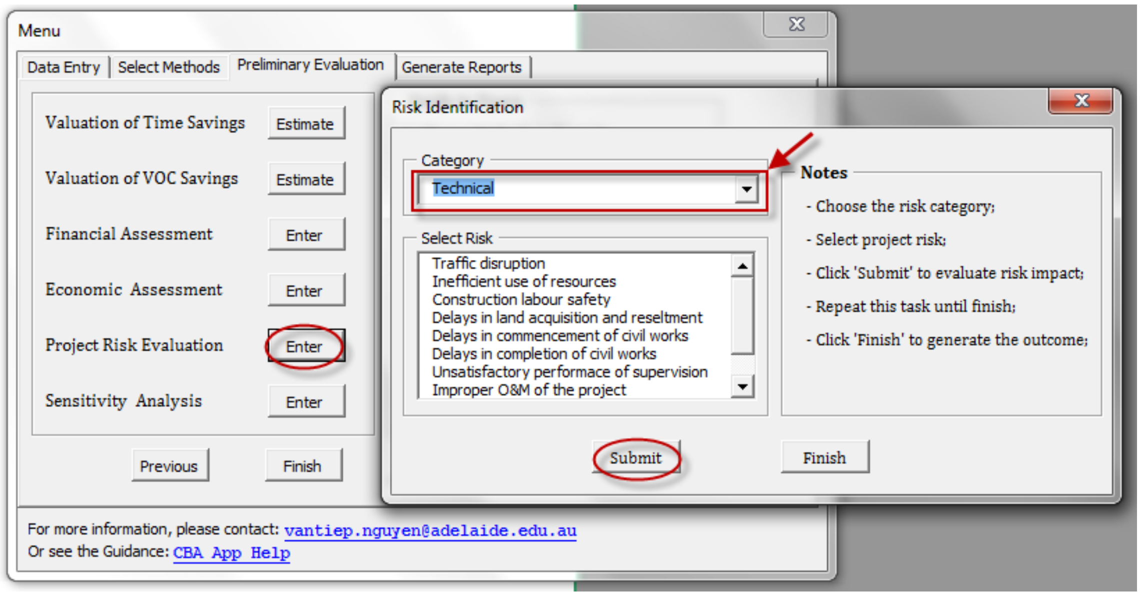


Figure 2.28. Risk Assessment Page

Depending on evaluation layers, you can identify risk likelihood and risk impact using both qualitative and quantitative assessment (Figure 2.29).

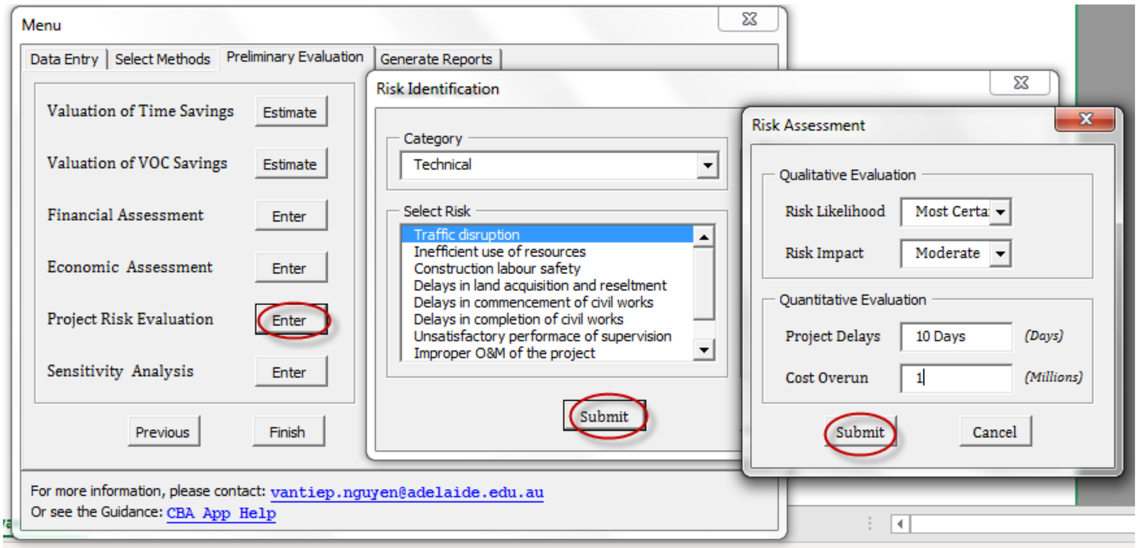
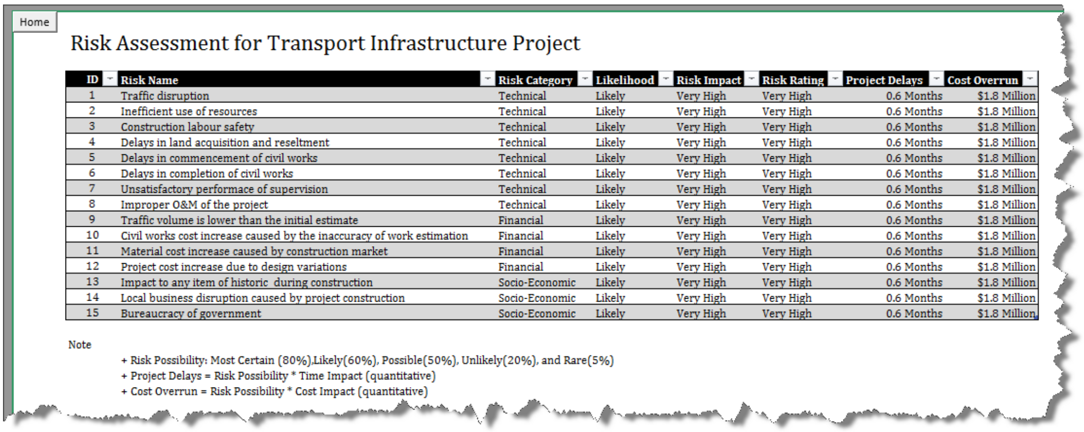


Figure 2.29. Qualitative and Quantitative Assessment

When you finish this process for all risks, click the **Finish** button to observe the outcome in "Risk Evaluation" worksheet (Figure 2.30).



Home

Risk Assessment for Transport Infrastructure Project

ID	Risk Name	Risk Category	Likelihood	Risk Impact	Risk Rating	Project Delays	Cost Overrun
1	Traffic disruption	Technical	Likely	Very High	Very High	0.6 Months	$1.8 Million
2	Inefficient use of resources	Technical	Likely	Very High	Very High	0.6 Months	$1.8 Million
3	Construction labour safety	Technical	Likely	Very High	Very High	0.6 Months	$1.8 Million
4	Delays in land acquisition and reseltment	Technical	Likely	Very High	Very High	0.6 Months	$1.8 Million
5	Delays in commencement of civil works	Technical	Likely	Very High	Very High	0.6 Months	$1.8 Million
6	Delays in completion of civil works	Technical	Likely	Very High	Very High	0.6 Months	$1.8 Million
7	Unsatisfactory performace of supervision	Technical	Likely	Very High	Very High	0.6 Months	$1.8 Million
8	Improper O&M of the project	Technical	Likely	Very High	Very High	0.6 Months	$1.8 Million
9	Traffic volume is lower than the initial estimate	Financial	Likely	Very High	Very High	0.6 Months	$1.8 Million
10	Civil works cost increase caused by the inaccuracy of work estimation	Financial	Likely	Very High	Very High	0.6 Months	$1.8 Million
11	Material cost increase caused by construction market	Financial	Likely	Very High	Very High	0.6 Months	$1.8 Million
12	Project cost increase due to design variations	Financial	Likely	Very High	Very High	0.6 Months	$1.8 Million
13	Impact to any item of historic during construction	Socio-Economic	Likely	Very High	Very High	0.6 Months	$1.8 Million
14	Local business disruption caused by project construction	Socio-Economic	Likely	Very High	Very High	0.6 Months	$1.8 Million
15	Bureaucracy of government	Socio-Economic	Likely	Very High	Very High	0.6 Months	$1.8 Million

Note

+ Risk Possibility: Most Certain (80%),Likely(60%), Possible(50%), Unlikely(20%), and Rare(5%)
+ Project Delays = Risk Possibility * Time Impact (quantitative)
+ Cost Overrun = Risk Possibility * Cost Impact (quantitative)

Figure 2.30. Risk Evaluation Worksheet

Step 6: Sensitivity Analysis

For sensitivity analysis, click the **Enter** button and this will show you the sensitivity worksheet for assessment. You need to assign values for the scenario case and then click **the Submit** button to observe the difference in results compared to the Base Case.

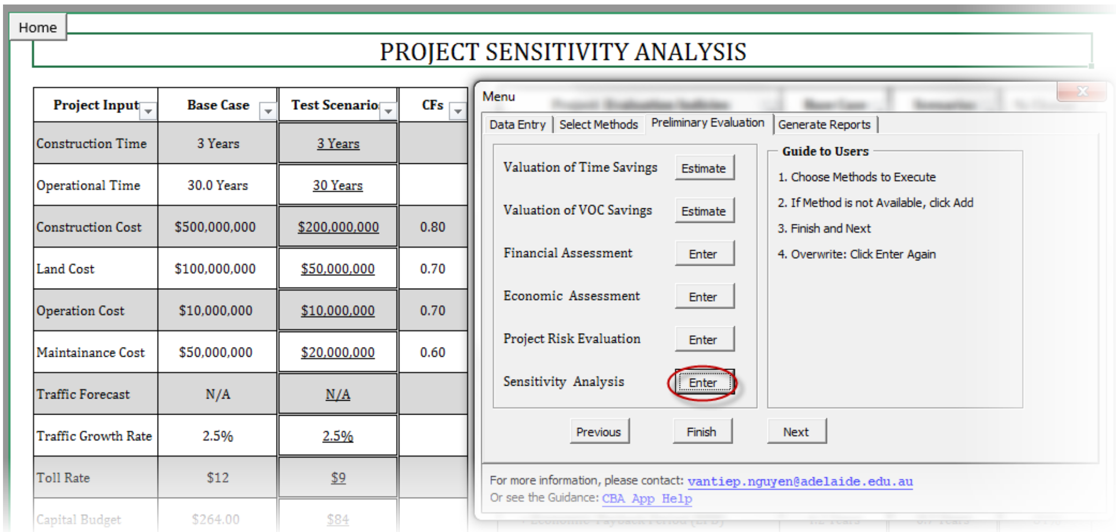


Figure 2.31. Sensitivity Analysis Worksheet

2.4 Generate Reports

Step 1: You need to link all calculation results to the Dashboard by clicking the Enter button

Step 2: Before generating reports, you need to export all tables and figures by clicking the **Export** button (Figure 2.31).

Step 3: Depending on your purpose, click the **Print** button for this task.

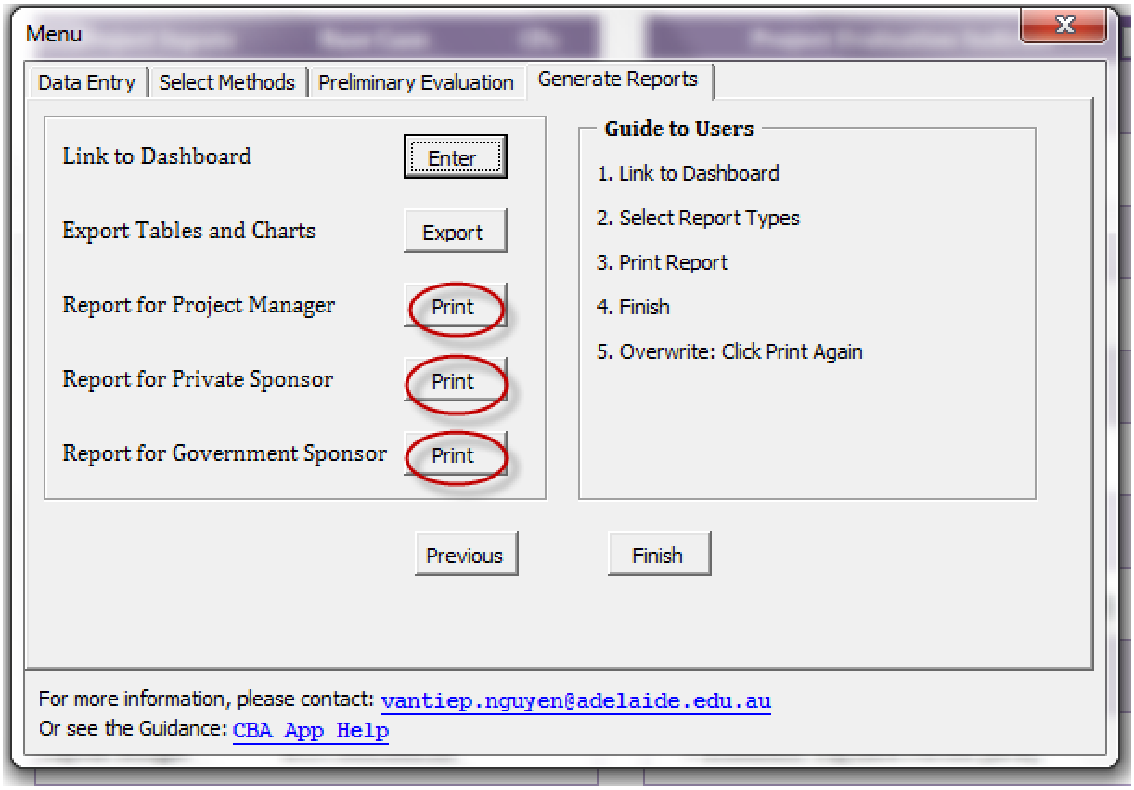


Figure 2.31. Report Generators

Finally, you can open the report and add some information before sending it to your manager, investor or government for assessment.

Appendix Q: Satisficing vs Optimisation[13]

System considerations	Optimization	Satisficing
Point of view	Discrete and particular	Holistic [16]
Causality	Clear cause and effect	No clear causality
System constraints	Dependent variables	Both dependent and independent variables
Management styles	Top-down management approach [34]	Governance approach
Time frame	System life cycle [27]	Continuous [27]
Tools and techniques	Reductionism-based [28]	• Systems thinking based tools; • System modelling such as System dynamics (SD) and Agent-based modelling (ABM); • Others.
Stakeholders	Identifiable	Emergent
Solution options	Options known [24]	Options unknown unknowns.
Risk assessment	Traditional risk management	Systemic risk management [35]
Interaction	Linear	Non-linear
Output	'Best' solution [24]	'Good enough' option [16]
Structure	Hierarchical structure [17]	Network structure [17]
Approach	Process [27]	Methodology [27]
Decision-making	Top Down	Bottom Up

[13] Adapted from Gorod, Nguyen and Hallo (2017)

Appendix R: Expert Interview Findings

List of Participants	Participants' Background	Practical Experience	Comments on the stakeholder-centric CBA framework		Proposed Solutions
			Advantages	Challenges	
1	Civil Engineering	Urban planner, mayor, and CEO of large-scale of public health organisation.	• Stakeholders get an opportunity not only to express themselves fully but also to realize whether their needs and requirements are feasible or not. • Enables project evaluation team to understand stakeholder needs and associated requirements.	• Having all stakeholders in the debate framework can be a bit challenging. • Addressing stakeholders' motivation would take time and resources.	See Chapter 4
2	Project Management	Project evaluation team member, and project manager.	• Provides supplementary parameters to improve the accuracy of inputs and to provide solid evidence for stakeholder debate • The decision made is feasible, so the project execution is more efficient and potential risks are reduced.	• The scale of the evaluation program is big and complicated. • It may be difficult to have team members who have both interpersonal communication skills and technical skills used for project evaluation.	See Chapter 6
3	Technology Management	Councillor, strategic advisor, project evaluator, and project program management lecturer.	• Steps presented in the SCF allow evaluation team members to have a better understanding about stakeholder needs and their requirements.	• Technology implemented in infrastructure projects is complicated and this may add uncertainty that would make it difficult for discussions and decisions.	See Chapter 4
4	Architecture and Built Environment	Green building advisor; researcher; stakeholder engagement advisor; and housing quality controller.	• The SCF looks at the various means of communicating and working with stakeholders, so it improves the communication proof of feedback.	• It may be difficult to communicate with the representatives of some key groups.	See Chapter 4 and Chapter 6

List of Participants	Participants' Background	Practical Experience	Comments on the stakeholder-centric CBA framework		Proposed Solutions
			Advantages	Challenges	
5	Mathematics and Statistics; and Ecology	Governance and board, and principal (project review, environmental management, and quality control), Australia-NZ Impartiality Committee member.	• The SCF gives a space for discussing and ruling out the options which may not be feasible or applicable to the project.	• It may be difficult to quantify non-market project impacts to provide information required for debate.	See Chapter 5
6	Accounting, and Project management	General manager for an international engineering and infrastructure company, strategy & business planner, strategic & major project commercial advisor, and bid strategy development advisor	• The satisficing benchmark proposed in the SCF helps the evaluation team to realize stakeholders' expectations which are crucial for stakeholder management. • The involvement of professional stakeholder groups increases the transparency of project evaluation and making the investment decision.	• Team members need to have multiple skills for analysis rather than focusing on a particular skill used for evaluation. • It would be difficult to reach agreements regarding cost estimation and traffic forecast.	See Chapter 6
7	Applied Science in Building Technology	Construction project manager, construction company director, and senior lecturer of project management.	• The SCF reduces the risk of project implementation and increases the opportunity of stakeholders involved in the analysis process. • It allows the evaluation team to recognise hidden factors that may affect project performance once it is approved and executed.	• The quality of framework implementation depends on the capacity of the evaluation team. • It may be challenging to bring professional stakeholders (e.g. designers, urban planners, contractors) on board to get their feedback as well as their collaboration.	See Chapter 6

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Nguyen, T., Cook, S., & Ireland, V. (2017). Application of system dynamics to evaluate the social and economic benefits of infrastructure projects. *Systems, 5*(2), 1-29.

Nguyen, T., Cook, S., Ireland, V., & Gunawan, I. (2017, July). *A hybrid approach to Cost-Benefit Analysis in transport infrastructure projects*. Paper presented at the International Conference of System Science and Engineering (ICSSE), Vietnam (pp. 569-574). IEEE.

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