

AN ANALYSIS FRAMEWORK FOR PUBLIC-PRIVATE PARTNERSHIPS

by

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ABSTRACT

A number of decisions confront both the public and private sectors when considering the use of a Public-Private Partnership (PPP) approach for a given project. They include: identifying the design alternatives which best satisfy public needs and the project's constraint set; what PPP approach is best suited for the alternatives selected; and, for a given PPP approach, how should risks be mitigated, residual risks assigned, and what compensation is justified. Additional decisions from a private-sector viewpoint deal with whether to pursue a proposal or not, and under what conditions should a consortium withdraw from the process. In seeking help with these decision problems, one finds that the knowledge base required is highly fragmented, little objective assessment of the pros and cons of various approaches is available, few real life experiences have been analysed and documented in the form of case studies, and, formal tools to assist with these decisions are few and invariably lack the depth commensurate with the magnitude of the commitments and risks involved.

This work presents an analysis framework designed to address several of these decisions. This framework was derived based on a thorough review and analysis of the literature, a case study of the Northumberland Strait Crossing project (The Fixed Link to Prince Edward Island), and significant interaction with the B.C. Ministry of Transportation and Highways (MoTH-B.C.). As part of this framework, an economic evaluation model which provides a mechanism for unifying the phases, and the cost and time consequences of the performance/risk dimensions which characterize a project is developed. This model can be used for both deterministic and probabilistic analyses, from which valuable insights dealing with the behavior of PPP projects can be drawn. They include: quantification of overall economic and financial performance as a function of different variable values; estimation of

overall risks, their composition and probabilities of failure; bounds on rates of return; tradeoffs between rates of return and risk assignment strategies; and, the relative effectiveness of different strategies for project speed-up (e.g. fast-tracking versus construction acceleration). A hypothetical case study is used to illustrate the power of the developed framework and the diversity of issues that must be addressed for PPP projects.

Key findings in this research include:

- Each project is a unique case and has to be assessed based on its merits and constraints. However, documentation of the experience gained in every project, especially in terms of risks is essential for enhancing the scant knowledge base that currently exists;
- In general, and given the government's capability to acquire financing at a lower price than can the private sector, BOT's could be more expensive from a user-charge perspective, unless savings can be achieved in other project inputs such as capital costs and operating and maintenance costs. However, they can be potentially viable in cases when no funds are available, or for projects that have near monopoly situations; and,
- Acceleration strategies such as fast-tracking design and construction and acceleration of construction exhibit only marginal benefits. The greatest benefits of adopting these strategies are expected when penalties are imposed for untimely completion of construction.

The thesis highlights some of the knowledge gaps that exist in the literature and concludes with several recommendations for further research to enhance the developed framework.

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CHAPTER 1 - INTRODUCTION

1.1 BACKGROUND

The need for new and revitalized transportation infrastructure in North America and abroad is substantial and growing. And yet, governments at all levels are so deeply mired in debt that they can no longer borrow funds and construct infrastructure in the traditional way. More and more infrastructure is being developed based on a user-pay approach. Having gone this far, the next step is to utilize Public-Private Partnerships (PPP), such as the Build-Operate-transfer (BOT) approach, for acquiring needed infrastructure. This approach, or one of its variations such as BTO (Build-Transfer-Operate), has the attraction that it can be "off-balance sheet" for the government, thus not hampering its already diminished borrowing capacity for other needs. Another attraction, at least in theory, is that the risks of development and operation can be transferred to the private sector. However, this sector wishes to be compensated for such risks through discount rates (equity returns) that are substantially higher than the social discount rate used by governments when evaluating such projects. The argument of the private sector is that they can be more efficient than the government in constructing infrastructure, both in terms of speed and cost of delivery, through the use of modern project management tools, design and process innovation, and adopting more flexible modes of project procurement. Thus, it can earn the higher discount rate with little or no extra cost to the user. The validity of this argument bears close scrutiny, and it provides some of the motivation for the research described in this thesis.

In a recent report made by the World Bank on PPP for infrastructure in general and BOT in particular, the following statement summarizes the current situation for alternative procurement modes "The slow implementation of BOTs partly reflects their newness but also indicates more fundamental obstacles. First, few countries have regulatory systems well-developed enough that definitions of rights and obligations of private investors and the state can be straightforward. Contract negotiations generally occur in a black box with an abundance of gaps and ambiguities. And, the BOT arrangement is still so rare that replicable models do not exist. Each country has a unique environment, partly because of the unique character of each deal, and partly because details are often secret. Changes of government can further complicate matters. So transaction costs in these projects are relatively large." In fact, in the same report BOT was recognized as one of the high priority areas for research in the World Bank agenda for the 1990's. The report emphasizes that the potential for BOT schemes suggests the need for more research on them, in light of their apparent popularity, and recommends that a new area for research should cover technical, institutional and political ways of extending competitive markets and also the possibilities of private sector participation (Israel, 1992).

The emphasis in this thesis is on transportation infrastructure projects. Nevertheless, some of the findings in this research are broadly applicable to other types of infrastructure. The thesis presents an analysis framework designed to address several of the decisions which confront both the public and the private sectors when assessing the suitability of such projects for a PPP approach. As part of this framework, an aggregated yet realistic economic model of the development process of public infrastructure is developed to be used for both deterministic

and probabilistic analyses, from which valuable insights dealing with the behavior of PPP projects can be drawn.

1.2 MOTIVATION

The success of Eurotunnel in raising \$1.72 billion in equity funds recently for the Channel Tunnel project has inspired world-wide interest in BOT schemes. In recent years, there has been an ever growing trend for governments at all levels to expand the private sector's role in undertaking major public investments, particularly in infrastructure projects, including financing these projects. This has meant that governments look to the private sector to finance projects using the project's income stream. But the task is not easy since the developer, on the one hand, has to pursue the project in an environment full of risks and uncertainties, which leaves him exposed to significant losses including opportunity costs throughout all phases of a project. Typically, there are great risks involved in such projects, there is no guarantee of profit, often there is no guarantee of revenues, and usually the capital investment is both large and relatively long term (Tiong, 1990a). The government, on the other hand, cannot withdraw or adopt a passive role. It has to ensure the right political and commercial environments in which to advance the project. A number of prerequisites are required such as strong government support, a stable currency, a stable economic system, and considerable cooperation between the government and private sector institutions (Tiong, 1990a).

Notwithstanding the complexity of identifying and assessing PPP projects, infrastructure projects, being usually large and capital intensive, are particularly difficult to analyze. Yaworsky and Russell (1991) suggest that despite the range of available risk assessment

methods and techniques, significant aspects of the lack of large projects success may be attributed to shortcomings in current identification, assessment and management processes. Jaafari and Schub (1990) also indicated that many project failures are related to inadequacies in risk planning and control processes. Large engineering projects present a particular challenge from a planning and organizational perspective, and are characterized by structural complexities and a high degree of environmental uncertainty (Yeo, 1982; Tatum & Fawcett, 1986). The lack of success of construction projects, particularly large ones, has induced organizations such as the World Bank (1988) to call for broader risk analysis and more deliberate efforts at risk management.

Therefore, there is a demonstrated need for the government as well as the private sector for an analytical tool with which to be able to identify the potential projects suitable for PPP, the risks involved, the best fit in the PPP spectrum and roles and responsibilities for each sector.

The knowledge base required for undertaking this task is highly fragmented. Little objective assessment of the pros and cons of various procurement approaches is available, few real life experiences have been analyzed and documented in the form of case studies, and formal tools to assist in the decision-making process are very few and invariably lack the depth commensurate with the magnitude of the commitments and risks involved.

In addition to the foregoing, an expressed interest by the Ministry of Transportation and Highways in British Columbia (MoTH- B.C.) in this research at its early stages has helped sharpen the focus and provided an excellent opportunity to observe and participate in the decision process for a major project.

While the emphasis in this research is on PPP in general, which includes Build-Operate-Transfer, discussion will be focused on BOT for much of this thesis. Other members of the PPP spectrum will be defined later in the following chapter.

1.3 OBJECTIVES

In PPP projects the private sector is expected to assume new and extended roles including ones which have been traditionally assumed by the public sector. Invariably, accompanying these additional roles are risks and skills with which the traditional design and construction sectors have limited experience. It thus comes as a surprise to many of the participants in a BOT venture the additional risk exposure that government wishes them to assume. In many cases, their first instinct is to try and pass the risks back to the government, while maintaining the rates of return warranted by assuming greater responsibilities and risks. This can complicate significantly the negotiation of a concession agreement and, in the extreme, make it infeasible.

Currently, implementing PPP approaches for procurement of public infrastructure projects is hardly treated in the literature in any objective way. Lacking is a robust analysis framework with which to examine the potential of PPP projects, identify the risks involved, and investigate the implications of various risk assignments among participants. Therefore, the objectives sought for this research are set to fill this knowledge gap. These objectives are:

- 1) To develop a quantitative/qualitative analysis framework that will assist both the private and the public sectors to develop insights into the anatomy of the project being analyzed. This is particularly essential to :

- 1.1) Assess the suitability of an infrastructure project for a PPP mode of procurement as opposed to the traditional one;
 - 1.2) If suitable, identify the PPP mode (s) which best match the project's profile, and identify roles and responsibilities for each sector;
 - 1.3) Identify the magnitude of risks involved; and
 - 1.4) Investigate some of the assertions made in the literature. For example, the benefits of adopting implementation strategies such as fast-tracking the design and construction phases and accelerating construction.
- 2) Develop a framework that can assist in crafting a request for proposal and negotiating a concession agreement of PPP projects.

A particularly unique characteristic of all PPP projects is their prolonged life cycle. Therefore, a carefully prepared concession agreement between all parties involved, which clearly stipulates their respective roles and responsibilities throughout the different project phases is extremely vital to the success of such projects. Any unforeseen events, default of one party or another, failure to account for shortfalls or windfalls in revenues, significant errors in the estimates, etc. can jeopardize the project's outcome if not considered in a pre-emptive fashion. Thus, an important objective for this work is to develop a tool which allows the analyst to examine an array of different scenarios and different project constraints at its early stages. This ability is extremely useful, especially while crafting/responding to a request for proposal and negotiating terms and conditions of the concession agreement.

1.4 METHODOLOGY

A comprehensive review of the literature was performed as it relates to issues of risk assessment and risk management in construction projects, BOT intricacies and peculiarities, adoption of alternative modes of procurement in construction projects including the benefits and disbenefits of each approach, and case studies. In undertaking this task, the prime goal was to identify knowledge gaps, develop an understanding of the PPP process from its early stages through to the implementation phase, and assess the means with which the sought objectives can be achieved.

Pursuit of these objectives was done largely through developing a robust economic evaluation/investment model which embraces all phases of the project life-cycle, and provides a mechanism for unifying the phases and the cost, time and scope consequences of the performance/risk dimensions which characterize a project. As a fundamental prerequisite to this work, the different risk categories likely to affect a project are analyzed. In so doing, a structured approach was developed which builds on extracting experts views on particular risk categories and their respective positive or negative impact on the different project parameters. In particular, *cost & time, technical, environmental, economic, financial, political and regulatory, organizational & contractual, and stakeholder* risks are addressed in this research. The moment analysis technique and the principles of engineering economics were employed to formulate a Net Present Value (NPV) model, with which robust analyses can be conducted and useful insights drawn.

As formulated, the economic model has at least two advantages. First, it is an explicit mathematical formulation which facilitates developing insights into the deterministic and

probabilistic behavior of a project as a direct function of key input variables, by producing approximate results given their uncertain estimates. Second, it allows the analyst to maintain a global perspective on a project.

In addition, an invaluable opportunity existed early in this research to participate in a study initiated by the Ministry of Transportation and Highways in British Columbia (MoTH-B.C.). As part of this study the developed framework was employed to analyze an on-going bridge replacement/rehabilitation project in British Columbia - Canada. The objective was to examine its suitability for a BOT process as well as other PPP approaches. The extensive interaction with MoTH personnel and the project team has contributed significantly to developing a better understanding for the decision-making process from its initial stages. In the course of this study, several templates for the project process were prepared to simulate and compare traditional versus PPP approaches. They were made for generic projects as well as for the specific bridge project. The benefits and disbenefits for adopting PPP as opposed to the traditional approach were also investigated from the perspective of both the public and the private sectors. Finally, the case for and the case against PPP for that particular project was examined. Much of this work has directly contributed to the objectives of this research and their pursuit.

1.5 STRUCTURE OF THE THESIS

The following chapter lays out the findings of the literature research on the subject area. It examines the various members of the PPP spectrum, summarizes the benefits and disbenefits of adopting PPP from the perspective of both the public and the private sectors, and overviews related previous works. Chapter 3 presents a case study on the Northumberland

Strait Crossing BOT project. This study is presented to serve two specific purposes. First, to identify the ingredients of a typical PPP project and highlight the associated risks and uncertainties. Second, to lay the groundwork for the proposed framework and demonstrate its ability to handle such risks and uncertainties. Both of these two chapters contribute to an understanding of the dimensions of the problem at hand and provide support for the objectives sought in this research. Based on the findings described in these chapters, an overview of the proposed framework is presented in Chapter 4. It embraces the entire PPP process and includes identifying the motives of both the public and the private sectors to engage in such a process, and concludes with signing the concession agreement and finally its implementation. Chapter 5 describes the objectives for an economic model and details of the model developed to respond to them. Chapter 6, presents a tool for assessing potential project risks. It consists of a structured approach for producing the input values which will be directly used in the economic model explained in Chapter 5. Chapter 7 then presents selected results for a hypothetical project to illustrate some of the diverse and significant issues that have to be addressed when assessing a project's suitability for a PPP approach. This hypothetical project is abstracted from the on-going bridge replacement/rehabilitation project mentioned earlier. Finally, the thesis concludes with a description of the contributions of this work, and suggested areas for further research.

CHAPTER 2 - LITERATURE RESEARCH

2.1 CHAPTER OBJECTIVES

The objectives sought in this chapter are to summarize the relevant findings in the literature about Public-Private Partnership (PPP) approaches, and benefits and disbenefits from the perspectives of the public and the private sectors. In so doing the need for a structured process to qualitatively and quantitatively analyze such projects is demonstrated. Current analysis frameworks and their major shortcomings are also reviewed.

While there is a host of both macro and micro issues concerning PPP, emphasis in this research is on the latter. That is, the views sought in the literature are those pertaining to the investment and risk analysis of a project from both public and private sector perspectives in so far as they are directly attributable to the project's cash flows, and can be expressed in the form of quantitative models. Thus, it is not intended in this research to provide an economist's or planner's perspective on the appropriate roles for government in the economy, nor does it dwell on benefit/cost analysis issues, etc. In particular, this research will concern itself with developing quantitative and qualitative tools to assist in assessing the applicability of a project for a PPP procurement approach and for determining the most equitable distribution of roles and risks among participants.

Throughout this research, an assumption is made that the project to be analyzed corresponds to a new facility either to replace an already existing one, or a new green field project. In either case it will be a user-pay facility.

An extensive literature search was conducted in order to identify:

- the spectrum of public-private partnership approaches, and their pros and cons from both public and private sector perspectives;
- literature pertaining to the essential ingredients for a project to be a good candidate for a public-private partnership approach, including critical success factors;
- the risks and their allocation associated with different public-private partnership arrangements;
- intricacies and peculiarities of a specific form of PPP mode of procurement, namely BOT;
- literature pertaining to existing and proposed qualitative and quantitative analysis frameworks for PPP projects, for use in selecting the PPP arrangement best suited to a particular project, and assisting in negotiating the terms of a concession agreement; and,
- case studies.

The starting point is a definition of PPP as set forth in the paper by Reijniers (1994): “Bringing about, maintaining, managing and operating provisions and activities by means of a project-wise approach by the public and private sectors, starting from a joint risk acceptance as regards estimated costs and expected returns, aimed at the joint realization of commercial and social objectives.”

The value of this definition lies in the recognition that both sectors assume risks, contrary to the view of some that PPP's are useful mechanisms for off-loading all risk to the private sector, and that a complex agenda of objectives exist. Each party in this onerous and long process has its own objectives that could be and often are very different from all the others.

Reijniers (1994) points out that the interests of the public sector deal with:

- legislation, regulation and authorities
- political opinion and political influence
- democratic decision-making processes
- the minimization of risks
- the realization of a social goal,

while the interests of the private sector are directed at

- achieving returns on the invested funds
- daring to take business risks
- having to anticipate market and competitive developments
- realizing a corporate goal.

The differences in these objectives, and in the working cultures of the public and private sectors - i.e. "there is a difference in management approach; there is a difference in the perception of risks and their consequences; there is a difference in decision-making processes; and there is a difference in the opinion about the time factor (Reijniers, 1994)" - can create significant tensions between the public and private participants in a project, and in some instances, can make the perceived benefits of a PPP arrangement unattainable. Recognition of the respective strengths of each sector, identification of potential risks and their relative magnitude, and an allocation of responsibilities that reflect these strengths to manage risks when negotiating the terms of a PPP arrangement may be viewed as factors critical to the success of a PPP project.

2.2 CHAPTER STRUCTURE

This chapter is composed of two consecutive and interrelated sections, each of which contributes to developing an appreciation of the uniqueness of the problem addressed in this research and an understanding of the knowledge gaps that currently exist in the literature.

The first section highlights the unique characteristics of PPP arrangements in contrast with the traditional approach, and despite the demonstrated need, the lack of analytical frameworks that assist in evaluating and negotiating such projects. A brief overview of the different PPP approaches is given including definition of the salient characteristics of each arrangement, and identification of roles of the private sector. This is followed by a summary of the relevant findings in the literature as they pertain to the general motives and perceived benefits/disbenefits in adopting a PPP approach versus a traditional one, from the viewpoints of both the public and private sectors. The paucity of the literature dealing with such arrangements is further illustrated by examining the current knowledge base about a specific form of PPP arrangements, namely BOT. A summary of the viewpoints of various authors as to the critical success factors for a successful PPP undertaking is then made, which illuminates the skills that the proponents of PPP projects must possess. This section then concludes with a commentary on knowledge gaps and research challenges.

The second section, recognizing the dimension of the problem and the objectives of this research, focuses on existing attempts to address them and indicates their relevant strengths and weaknesses, thus providing important background to this thesis. An overview of current and emerging state-of-the-art analysis frameworks and supporting tools designed to assist

decision-makers in assessing the advantages and disadvantages of adopting a PPP approach for a specific project, and in determining the most appropriate PPP mode is provided.

2.3 THE UNIQUENESS OF PPP ARRANGEMENTS

2.3.1 The PPP Spectrum

Various PPP forms exist, in which the roles and the risks shared by all parties involved vary considerably. Contingent upon the distribution of these roles and risks among the project participants, different and completely novel project perspectives may arise. Both sectors in this case will have to demonstrate great skills and creativity to be able to manage new situations with which they are unfamiliar, and most importantly, negotiate at the outset, terms and conditions that best suit their abilities and expectations.

In practice, there is a quasi-continuum of contracting or procurement forms which encompasses the full spectrum from a fully-public approach or traditional approach, to a fully-private approach. This continuum is depicted in Figure 2.1.

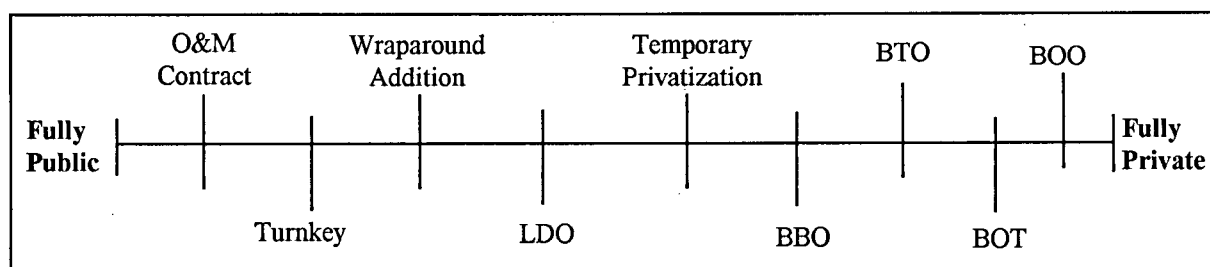


Figure 2.1 The Public-Private Continuum

In what follows, members of the PPP spectrum are briefly defined (Price Waterhouse, 1993), and involvement of the private sector in each are graphically depicted using a generic cash

flow diagram which covers the major phases of a project (see Figures 2.2 through 2.11). Noteworthy is that some of these members are concerned with developing or upgrading existing facilities. Although the focus herein is on new facilities, all members of the PPP spectrum are discussed in this section for completeness.

2.3.1.1 Fully-Public Approach

The fully-public approach corresponds to the traditional approach used by public bodies for acquiring infrastructure. The private sector is involved in this approach, but only through the provision of design, construction, and commissioning services, as well as other specialized consulting services in the predesign and possibly the tendering and design field services phase.

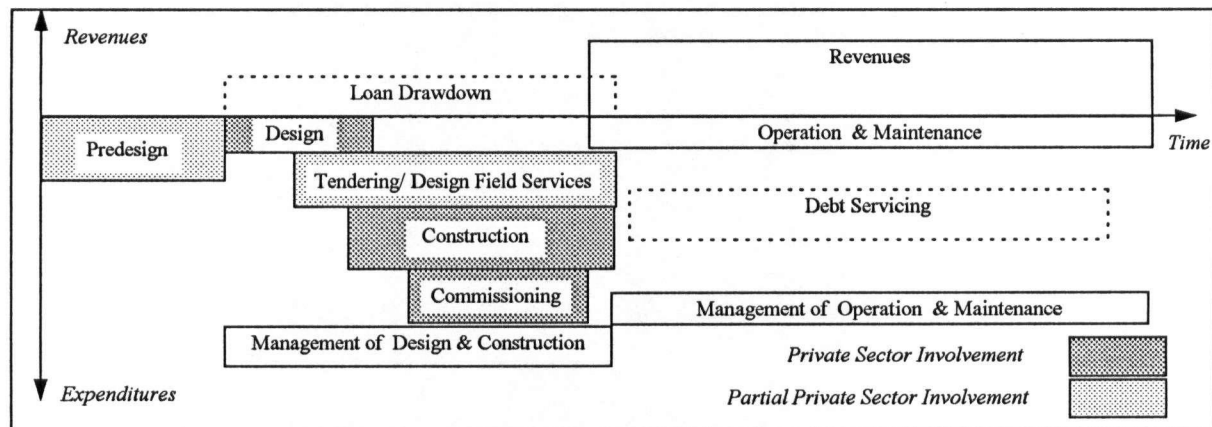


Figure 2.2 Private Sector Roles in Fully-Public Approach

In this form of procurement, the government funds the project, owns it, and pays all associated costs including the private sector's fees. It assumes overall responsibility over the project and therefore most of the risks. Assignments of roles and risks to the private sector are generally designed to satisfy specific project needs and requirements, and they are spelled-out in the project contract and its terms and conditions. In general, the roles and responsibilities

of all parties involved in this approach are well understood and considerable precedents and experience exist.

2.3.1.2 Operating & Maintenance Contract

For some publicly-owned facilities, and based on a traditional bidding process, the private sector may be granted a specific contract to operate and maintain the facility, and in some cases collect revenues, for a specified period of time and under the government's supervision, in addition to the roles allocated to them for the design and construction phases. Government also pays the private sector's fees and holds title to the facility. The private sector exposure to risk in this case depends on the specific contract terms and conditions, and the technical skills required to accomplish the assumed tasks.

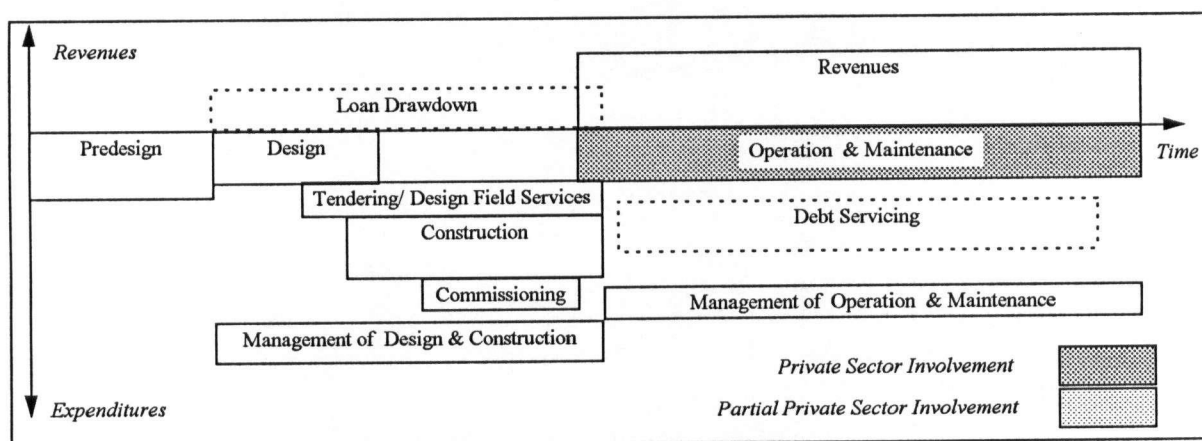


Figure 2.3 Private Sector Roles in Operating & Maintenance Contract

2.3.1.3 Turnkey Development (Design-build)

In this type of contract, the private sector designs and constructs a facility to meet performance objectives defined by the public sector. The private sector may acquire or provide the land and/or construction financing. Upon completion, the private sector is

reimbursed by the government for design and construction. Operation and maintenance of the facility could be also performed by the private sector under a separate contract. Review of a rather thin literature and discussions with industry personnel involved with design-build projects suggest that some potential for design and process innovation exist in such arrangements (e.g. fast-tracking design and construction etc.), and cost savings of up to 30 percent may be achievable, accompanied by some savings in time (Akintoye, 1994; Heery, Thomsen, and Wright, 1993). Some arguments exist, however, that the public sector mind-set and the requirement to pursue a sequential bidding process starting with design and then construction and operation, to guarantee best value for the money spent, often constitutes a stumbling block against adopting design-build. Nonetheless, several projects have been successfully pursued worldwide by the public sector through design-build approach, such as the Calaveras Hydroelectric Project in Northern California, which is owned by the Calaveras County Water District (Johannesson, 1990).

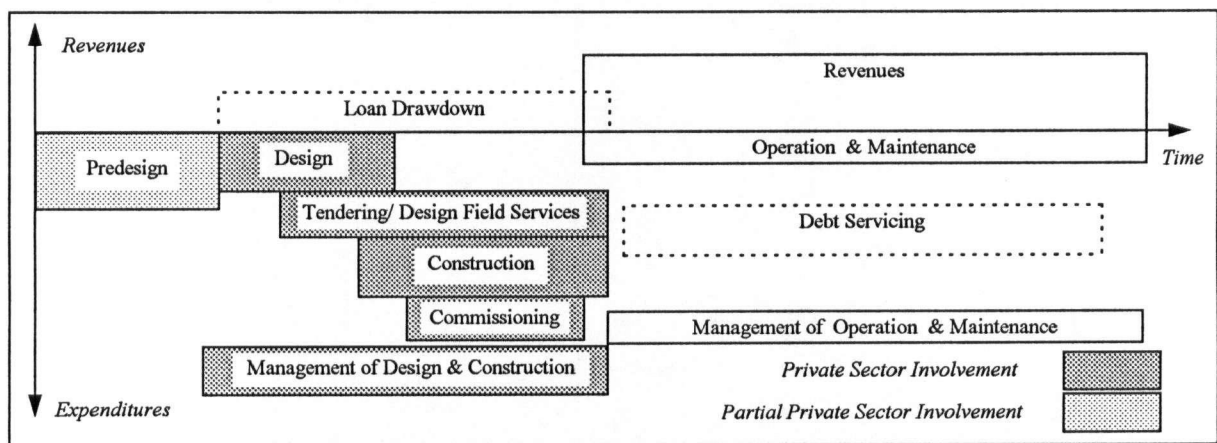


Figure 2.4 Private Sector Roles in Design-Build

2.3.1.4 Wraparound Addition

A wraparound addition arrangement applies when the private sector finances and constructs an addition to an existing public facility, then operates both the existing and the new facilities for either a specified period of time, or until it recovers its investment plus a reasonable return. The private sector in this approach may assume some or all of the risks associated with developing the new facility as well as operating and maintaining both the new and the existing facilities for the term of the contract. This will be determined based on an agreement between both sectors. In all cases the public sector will continue to hold title to the project.

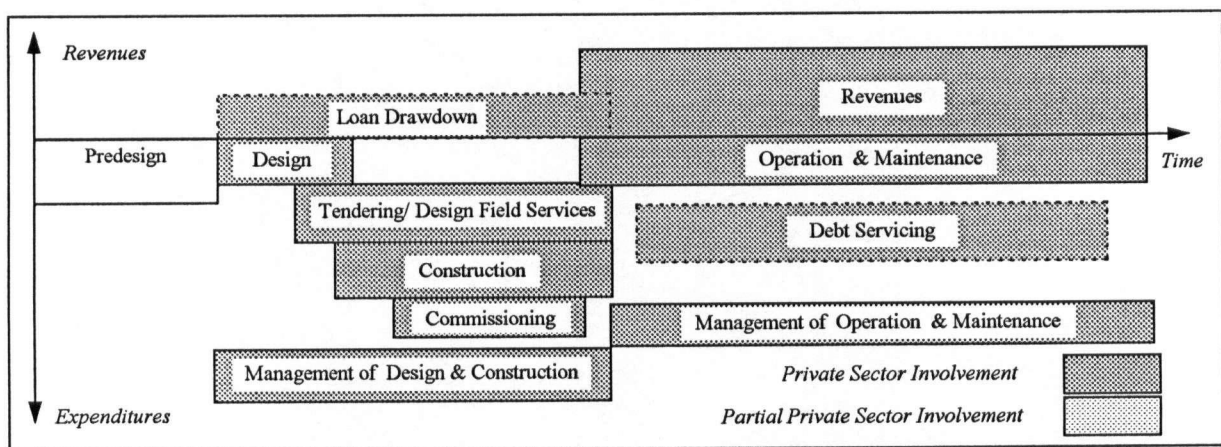


Figure 2.5 Private Sector Roles in Wraparound Addition

2.3.1.5 Lease-Develop-Operate (LDO)

A slightly different approach than the wraparound addition is Lease-Develop-Operate. It applies when the private sector is given a long-term lease to operate and if required expand an existing facility. The private sector agrees to invest in facility improvements, and can recover the investment plus a reasonable return over the term of the lease. The government holds title to the facility throughout the contract period. The role of the private sector is to operate and

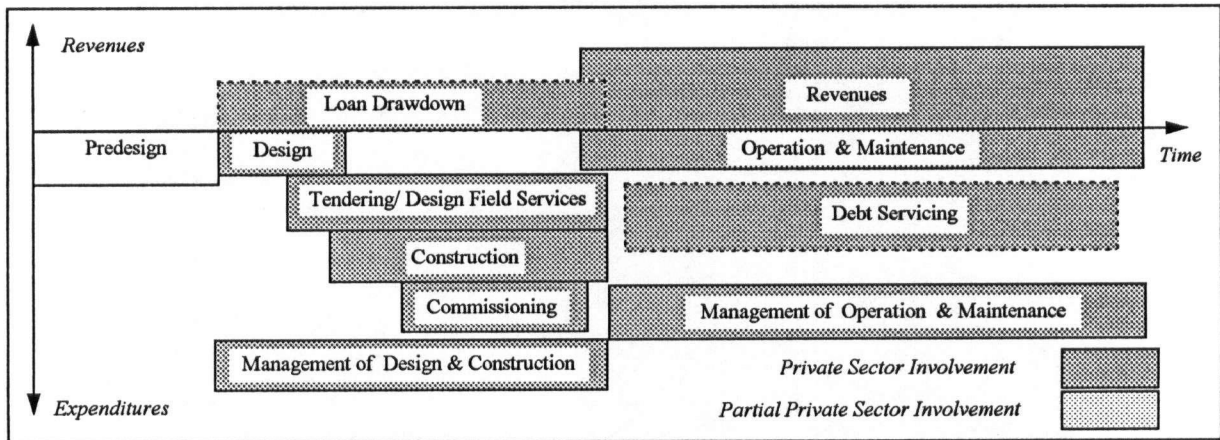


Figure 2.6 Private Sector Roles in Lease-Develop-Operate

maintain the facility and if needed upgrade it to meet certain performance requirements.

2.3.1.6 Temporary Privatization

Temporary privatization involves the transfer of an existing public facility to the private sector which will renovate or expand it. Unlike the two previous approaches, the private sector holds title to the facility. It owns and operates the facility for either a specified period of time, or until it recovers the investment plus a reasonable return. Liability issues and public acceptance are of particular concern in this approach.

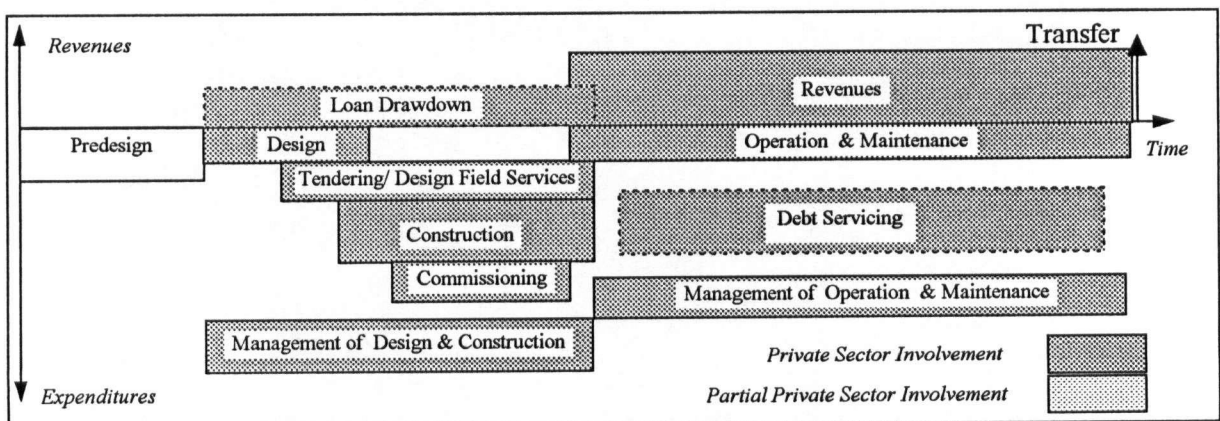


Figure 2.7 Private Roles in Temporary Privatization

2.3.1.7 Buy-Build-Operate (BBO)

A buy-build-operate arrangement applies when an existing facility is transferred to the private sector, which in turn will renovate or expand it. It then owns the facility in perpetuity and may upgrade it by building new additional facilities if required. The role of the government in this case will be confined to safe-guard the public welfare in terms of quality of the service, and safety and cost to the users. This is usually accomplished by imposing certain controlling rules and regulations, issuing permits, and supervision by the government.

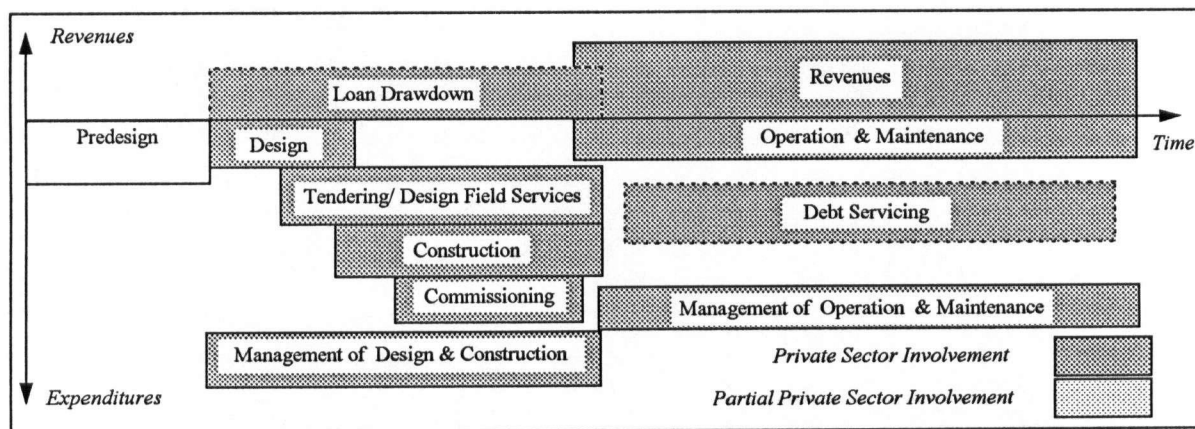


Figure 2.8 Private Sector Roles in Buy-Build-Operate

2.3.1.8 Build-Transfer-Operate (BTO)

A BTO arrangement involves two major phases. First, the private sector finances and builds the facility, and upon completion transfers ownership to the government. This is done mainly to offset liability issues and in some cases alleviate public concerns. The government then leases the facility back to the private sector under a long-term lease, during which the private sector operates the facility and has the chance to recover its investment and a reasonable return through user fees, land development, or any other agreed upon schemes.

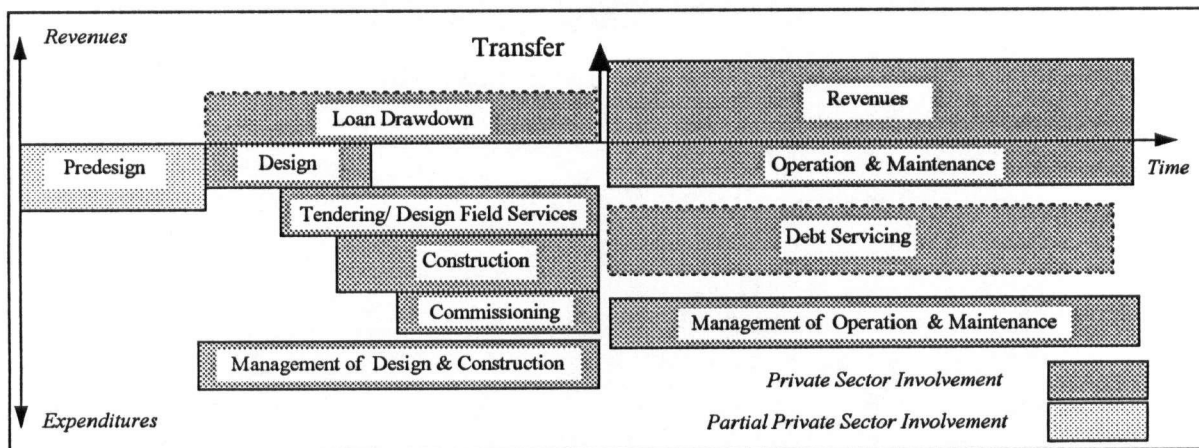


Figure 2.9 Private Sector Roles in Build-Transfer-Operate

2.3.1.9 Build-Operate-Transfer (BOT)

Under this arrangement, the private sector signs a concession agreement to finance, design, build, and operate a facility for a specified period of time. During this period the private sector recovers its investment and a reasonable return on its investment through the collection of user fees or any other agreed upon schemes. The ownership of the facility will be transferred back to the public sector after the concession period is terminated.

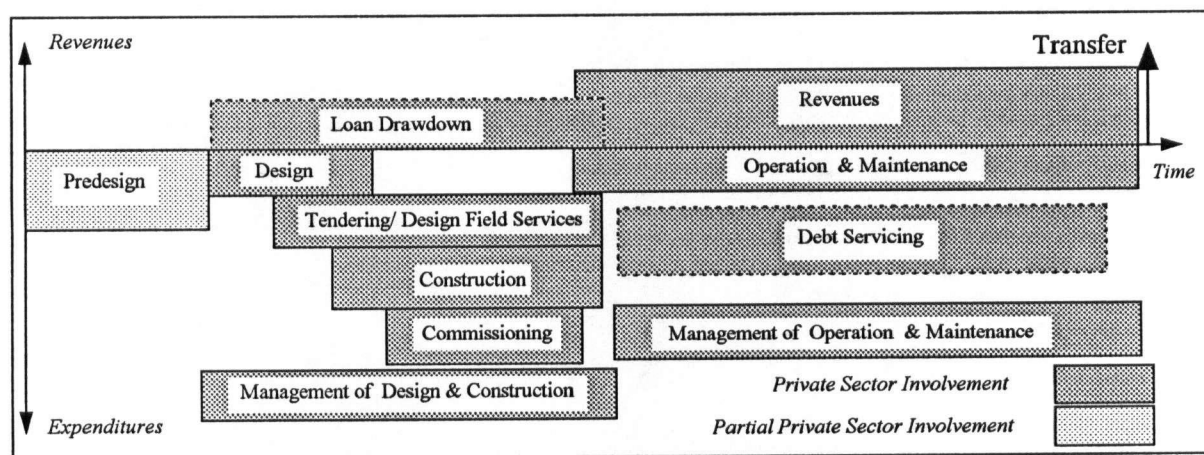


Figure 2.10 Private Sector Roles in Build-Operate-Transfer

In this approach, the private sector is required to assume new and expanded roles, responsibilities and risks with which it has little experience. These new risks come over and above those typically encountered in large engineering projects.

2.3.1.10 Build-Own-Operate (BOO)

Under this arrangement, the private sector signs a concession agreement to finance, build, and operate a facility in perpetuity. Similar to BBO, the role of the government in this approach is relatively limited. This approach however involves introducing new facilities to a current system. The government in this case will have to ensure that the realization of such a facility is in the public interest.

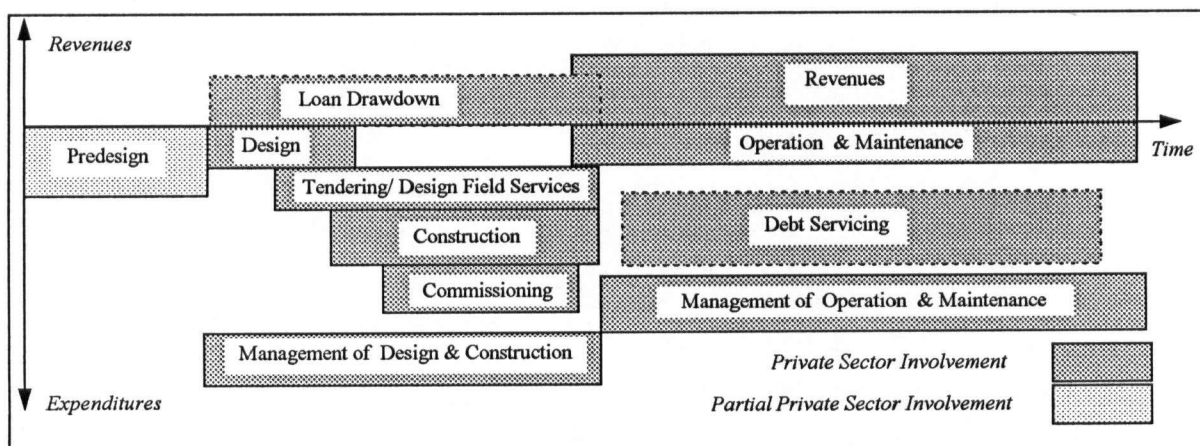


Figure 2.11 Private Sector Roles in Build-Own-Operate

2.3.1.11 Fully Private Approach

A fully private approach applies when the government is not involved in any aspect other than issuing the relevant permits and enforcing its rules and regulations for the project.

Choosing an appropriate contracting form from the above mentioned continuum is far from a science, and although the consequences of choosing a wrong approach can be proven costly, little advice is offered in the literature. There is no formula into which one plugs project, economic environment and owner variables to produce a contracting form. Often, there is no single best form, but several are appropriate. The selection process, therefore, takes a "process of elimination" approach in an ad-hoc fashion, paring away obviously inappropriate forms until suitable alternatives remain (Gorden, 1994).

As more roles and accordingly risks are assigned to the private sector, PPP approaches dictate new and completely different project perspectives compared with the traditional approach. Recognition of these roles and risks by both sectors in this case become central both at the negotiation and the implementation phases of a successful PPP. Little experience have been documented in the form of case studies. This is due to the relative newness of the approach in infrastructure projects and the unwillingness, on the part of project proponents, to share their experience in order to maintain their competitive edge in the area. In fact, the lack of a comprehensive analytical process is surprising, especially considering the amount of capital involved, the more than usual risk exposure, and the potential of great losses for both the public and private sectors.

Notwithstanding the aforementioned, PPP's are gaining popularity. As of October of 1994, \$56 billion in 147 projects worldwide were financed based on PPP, and 493 projects having a total of \$352 billion are being investigated (Hugget, 1995). These are all projects exclusive only to the transportation sector. Similar statistics are available for other sectors such as wastewater management, power generation, etc. Evidently, there are some perceived benefits

sought by both sectors that justify their involvement in such a lengthy, and risky endeavor. Development of an understanding of the benefits/disbenefits of adopting a PPP approach can not only provide insights on the overall infrastructure development process through PPP, but it is also useful for forging a framework for their analysis. In the following section, a summary of the cited viewpoints of both the public and private sectors in this regard is presented.

2.3.2 Benefits And Disbenefits Of Public-Private Partnerships

2.3.2.1 Public Sector Viewpoint of Benefits/Motivations for a PPP Approach

In certain situations, when the required investment in infrastructure projects is so large that public sources of financing are not sufficient, and relying on the private sector alone does not offer a permanent or plausible solution, the use of public-private partnerships emerges as a viable alternative (Chaux-Debry, 1990). The PPP arrangement is viewed as a way to minimize the demand major projects make on the public purse and get the project's debt off the government's balance sheet (Tiong, 1990; Haley, 1992; MoTH, 1993). However, this assertion might be compromised when there are revenue guarantees provided by the government to the private sector.

PPP approach also makes it possible to reallocate limited financial resources to other projects (Bott, 1992). It is believed, by advocates of the approach, that it permits investments in new, improved, or repaired facilities that government could not otherwise afford (Israel, 1992; Price Waterhouse, 1993; Beesley & Hensher, 1990; Spencer, 1990).

Other views stem from the idea that the private sector is more flexible and can fast-track the design and construction. It remains, however, to examine under what conditions fast-tracking can provide substantive benefits. It is argued that the government is seemingly incapable of changing its modus operandi but rather is best at building a solid project foundation in terms of support and provision of revenue guarantees, and legislative and regulatory approvals. The private sector is seen to provide more rapid or efficient development or operation of a facility (Israel, 1992; Price Waterhouse, 1993; Haley, 1992), and thought to bring modern managerial techniques and efficiencies to government projects, and reduce burdens on public sector management (Israel, 1992; MoTH, 1993; Spencer, 1990). Noteworthy, however, is that more and more governments are currently applying modern project management techniques and trying to find ways to avoid the straight-jacket of lump sum tendering and sequential design and construction.

Although it is suggested that the PPP approach speeds up the decision-making process as well as the construction and operation of a facility (Beesley *et al.*, 1990; Spencer, 1990), supporting evidence for this assertion is hard to come by. Therefore, it needs to be challenged, since in PPP, government will unlikely contract out its power as the public servant, and it will still be in control of the entire process especially during the evaluation and approval process which is the most crucial and time consuming phase.

The traditional process of the client preparing designs to rigid performance specifications, and tendering those designs for construction is seen as the principle factor in stifling innovation in project implementation. PPP introduces competition into the development and operation of facilities, leading to lower operating costs and creative implementation strategies (Israel,

1992; MoTH, 1993; Walton & Euritt, 1990). This assertion, however, downplays the issue of risks associated with introducing new techniques to the traditional process and who should assume these risks. Also, the traditional approach does not necessarily preclude the use of construction expertise during design.

It is also argued that the implementation schedule of the project is not tied to the fiscal allocation of funds which should result in better schedule economics and better control over the project's cash flow (MoTH, 1993; Dunchene, Geffrin & Meyere, 1990; Walton *et al.*, 1990).

Moreover, the sale of freeways to the private sector would free up capital currently frozen as a government asset and could provide the leverage to attract new private investment to finance needed rehabilitation of highways and freeways (Walton *et al.*, 1990). However, this position raises the question, when is a piece of infrastructure an asset?

PPP agreements provide much stronger incentives for proper pricing, planning, and maintenance, because there is a clear articulation of the financial commitment (Beesley *et al.*, 1990; Walton *et al.*, 1990; Spencer, 1990). Noteworthy in this regard are the incentives for the private sector to maintain a facility to high standards during the PPP concession period. The concession agreement should clearly specify the standards for operating and maintaining the facility, along with a statement of the monitoring process to be adopted by government.

Others argue that governments sometimes have the need to stimulate the economy by undertaking projects to create jobs and involving the private sector (MoTH, 1993).

At least in theory, the PPP approach has the effect of removing a capital constraint, since the project size is not determined by rigid budget constraints (Beesley *et al.*, 1990; Spencer, 1990). Although the project will have to demonstrate the capacity to repay its capital plus reasonable profit. The price of capital, however, is higher in the private sector because there is higher risk. The extent of the difference in capital cost relative to the public sector will depend on project characteristics and the degree of risk-sharing with the government.

PPP can transfer risks to the private sector that would otherwise be borne by the government (Israel, 1992; Price Waterhouse, 1993), such as construction completion risks, liability, inflation risks, etc. In return, however, the potential exists for high rates of return being used by the private sector to compensate for these new risks, which may result in a more expensive facility to the users.

Arguments also exist that it is all too easy to dispense "federal funds," or "grant money" with little regard to the true need or market orientation. The private sector is usually better prepared to evaluate the market potential of projects and they often blend in some consideration of public welfare as well (Smith, 1990).

Motivations of governments adopting this approach range from shortages of hard currency in developing countries; an increased desire to transfer infrastructure costs more directly to users; a reluctance or inability to fund large capital; to simply the predominance of political philosophies favoring privatization (Yaworsky, 1994).

2.3.2.2 Public Sector Viewpoint of Disbenefits for a PPP Approach

The private sector is placed in a relatively high-risk situation in comparison with its role in the traditional project delivery process, and might be unwilling to accept such risks. Typically, PPP's are reliant on the independent financial feasibility of the infrastructure and a demonstrated profit potential is necessary to attract private investment (Price Waterhouse, 1993). One way of dealing with this, at least in part, is to index revenues, with adjustments on an annual or bi-annual basis. For example, Eurotunnel, the proponent of the Chunnel project was given the freedom to set its tariffs. Another example deals with the toll rate on Bangkok Second expressway where the project sponsors proposed an initial rate of \$1.20 per car, with the rate subject to revision every five years (Tiong, 1990a).

The private sector cannot borrow as economically as government, and often strong governmental guarantees are required. This in turn may prejudice the off-balance sheet aspect mentioned earlier. Also, there is a risk of financial failure, or default by the private sector, and the government has to pick up the pieces (Price Waterhouse, 1993).

A PPP almost invariably requires an explicit agreement regarding rates of return and user fees before the project development begins. The sponsoring government has to decide what is a reasonable rate of return and user fee for each risk level for the project, which to some extent is market driven. It may also need to establish a regulatory mechanism to monitor and control the agreed upon rate of return (Price Waterhouse, 1993). In addition, the government will have to develop new mechanisms to supervise control, and audit these projects, which will mean new costs and expenses including training and retraining of existing staff. This in turn

might instigate opposition of the government representatives who are familiar only with the traditional process of procuring public projects, and are unwilling to change the modus operandi of the government.

Other potential disbenefits deal with quality and safety issues, which can arise from an attitude of cutting corners resulting in service decline, or lack of maintenance (Price Waterhouse, 1993; Dasonville, 1990).

Some argue that there are concerns about the private sector holding title of public-purpose infrastructure, transferring right-of-way, and the general public acceptance for such a scheme. PPP approach often instigates more stakeholder issues than the traditional approach (Yaworsky, 1994; Price Waterhouse, 1993).

A PPP approach often requires unique managerial and negotiation skills which are not required for the traditional approach (Price Waterhouse, 1993). Moreover, public authorities give up power to the private sector, while the private sector takes on financial and operating responsibilities for which they have limited experience (Haley, 1992).

It should be anticipated that sufficient allowances to cover all expenditures and risks of the project will be made by the contractor (Ayber *et al.*, 1990). The private sector will require compensation for the more than usual risks assumed, which may result in a more expensive facility to the public (Young *et al.*, 1988).

People who believe that private sector financing of transportation is not only counterproductive but dangerous, make three points:

- First, it creates the false illusion that public-private agreements can solve long-term transportation problems.
- Second, it allows developers to plan highways and interchanges, which may not be in the public interest.
- Third, private financing only results in more interchanges and more highways so that developers can generate more unplanned growth, which increases the dependence on the car, which increases the demand for more highways, and so on (Donald, 1987).

Other problems that might face the government dealing with PPP is the organizational consideration while the consortium is continuously evolving and new participants become involved and old ones depart. That is, who is in charge of the project throughout the different project phases and until the facility is transferred to the government? What are the liabilities in case of breach of contract? With whom is the government dealing in this case? This is an especially significant problem for long operating periods, where the risk of dissolution of the consortium is increased.

In addition, the government will have to address the issue of determining the most feasible length of the concession from the perspective of both the public and the private sectors, as well as transferring the facility back to the public sector and whether this phase should be a long or a short term. At the end of this phase, the public sector will inherit a revenue stream, a significant part of which was dedicated to debt servicing and another part was ear-marked

for operating and maintaining the facility. The government will, therefore, have to explore the possibilities of handling these revenues and address the need to utilize the general funding pool generated by other sources such as taxes to operate and maintain the facility as opposed to the same revenue stream which will then be regarded as general revenues.

Generally, the private sector looks for stable, predictable situations with a potential of growth, which limits the number of projects that are suitable candidates for PPP.

2.3.2.3 Private Sector Viewpoint of Benefits/Motivations for a PPP Approach

PPP projects seem to be viable and very profitable (Haley, 1992; Prendergast, 1993; Tiong *et al.* 1992; Ayber *et al.*, 1990). Moreover, the ability to arrange for a complete project planning and management process including financing, offers contractors an important competitive edge since, in recent years, major contractors are realizing the importance of a competitive strategy in winning new jobs, especially in new markets overseas. For example, Japanese contractors, suppliers and banks frequently take an active role in offering export-credit facilities and other project-financing initiatives as a powerful competitive advantage over other competitors (Tiong *et al.*, 1993). PPP's open up opportunities to penetrate expanding and new markets for the construction and operation of infrastructure projects with reduced government involvement and greater opportunity to earn profits (Tiong, 1990a; Tiong *et al.*, 1992; Crosslin, 1991).

The investment required for large infrastructure projects is enormous, and if raised and managed successfully, return and leverage opportunities can be very high (Tiong *et al.*, 1992).

A PPP project has the potential to offer the private sector an extended cash flow stream of high quality.

Transportation projects in general tend to be less monopolistic, because of the availability of alternative routes. However, they can have near monopoly status such as the Dartford crossing, the Chunnel project (Tiong *et al.*, 1992), and the Prince Edward Island bridge. Such near monopoly opportunities can in fact be extremely appealing to the private sector, in part because of the ability to capture additional revenues from growth in demand (Carlile, 1990).

PPP's offer the private sector the opportunity to assume the overall project responsibility whereby their expertise can be utilized to the fullest, without the hindrance of government bureaucracy or intervention (Ayber *et al.*, 1990). This, however, will depend on the adopted PPP approach, and the type of agreement between the public and the private sectors.

The increasing inability of local governments to pay for necessary highway improvements using traditional sources, and the further deterioration of existing facilities, has resulted in a growing acceptance among decision-makers and the public of the private sector involvement in public projects (Sabina & McNeil, 1994). This in turn has encouraged the private sector to offer more service and act more aggressively on these types of projects.

9

2.3.2.4 Private Sector Viewpoint of Disbenefits for a PPP Approach

Usually, the expected traffic and especially the fare likely to be charged do not permit an urban transportation infrastructure project to be directly profitable and/or recover its initial

expenditures without some sort of governmental subsidies or revenue guarantees (Chaux-Debry, 1990).

PPP's often require an explicit agreement regarding rates of return and user fees before the project development. As stated previously, the private sector is in a relatively high-risk situation. It might not be feasible to accept the risks associated with the protracted development process for this kind of projects and the rigorous public reviews, while inflation rates and the whole economic environment continuously change. Revised rates of return or user fees might be the only way possible to overcome such risks (Price Waterhouse, 1993).

The private sector will have to share new responsibilities traditionally assumed by the public sector. It will also have to play a number of new and complex roles throughout the project life cycle and assume more than usual risks. For example, during the early stages of the project the private sector will play the role of a promoter to gain acceptance for the project among stakeholders and the public, and to acquire financing, while in the implementation phase it will play the role of designer, and a general contractor followed by a lead role in operation and maintenance of the facility. Sometimes these new roles lead to conflict of interest and place the private consortia in a paradoxical position. For example, in the event of a downturn in the market for the completed project's product, the owner half of the contractor would favor a reduction in the project size but the contractor half might not as it would reduce its volume of work (Tiong, 1990a; Tiong *et al.*, 1993).

Many private sector firms have experience in only certain relatively smaller-scale projects or act as subcontractors and they lack the in-house capability and track record to take on the

large-scale multibillion-dollar ventures which are not uncommon in infrastructure projects (Tiong *et al.*, 1993). In addition, PPP projects are often large in size and require cooperation of more than one firm in some sort of consortium or joint venture. This will bring along new risks such as the high potential for hidden agendas, the definition of equitable risk distribution among participants, the lack of communication, the lack of commitment and conflict of interest (Tiong *et al.*, 1993).

The private sector will have to equip itself with project financing and negotiation skills which it might not be familiar with. Traditionally, contractors take a reactive business approach, and they often bid for jobs through an open tendering process. In PPP projects, the private sector must be a strong promoter in selling the project idea to bankers, potential equity investors, the host government, the public and other influential parties (Tiong *et al.*, 1993).

The concession and construction periods are significantly long, and if no revenues are available to the project during construction, capitalized interest costs will form a significant part of the overall cost to be financed (Tiong, 1990a). Moreover, commercial risks are very high due to the difficulty of predicting traffic or revenue streams for long periods of time in the future. Furthermore, although it can be dealt with in the concession agreement, investors don't control the commercial environment of their project and cannot even exclude the possibility that the public authorities will provide a directly competitive toll-free infrastructure (Dunchene *et al.*, 1990).

PPP's often require large front-end costs to perform studies, prepare tenders in the face of strong competition, and engage in long negotiations (Tiong *et al.*, 1992; Yaworsky, 1994;

Dunchene *et al.*, 1990; Haley, 1992). These costs are usually not reimbursable by the government, and private sector proponents will not recover them unless they are awarded the contract (Tiong *et al.*, 1993; Tiong *et al.*, 1992).

The entire process of project development using a PPP approach is complex, time-consuming, and expensive. The financial risk including inflation, exchange rates, liquidity, etc. are all substantial risks in any PPP infrastructure project.

Because of the substantial commitment involved, the political process required and the fact that the public is normally the end user, PPP projects tend to have a high public profile. The projects are usually not covered under an existing political and legal framework, hence the development process must inevitably break new ground, often against entrenched opposition (Tiong *et al.*, 1992).

The government cannot absolve itself of its environmental approval responsibilities without changing proponentcy of the project to the private partner. This is not necessarily desirable nor would it be readily acceptable to the private partner (MoTH, 1993).

2.3.3 BOT Form Of Procurement

Although BOT is not a completely new approach, it is relatively new in infrastructure application, and it was not until 1984 when the concept was first introduced for a major infrastructure project in Turkey, namely the Akkuyu nuclear power project (Ayber *et al.*, 1990; Suratgar & Morris 1988; Tiong *et al.*, 1990). Perhaps this explains the scarcity and the limited scope of literature that discuss the intricacies and peculiarities of a BOT approach.

A dichotomy of literature that discusses BOT exists. On the one hand, some literature examines the approach from a general perspective and tends to highlight some of its perceived risks and/or benefits. On the other hand, and relatively more numerous, is the literature dealing with problems, details or features of specific BOT projects.

For example, Young, Dicks, Limerick, & Twaford (1988) argue that high rate of return needed to compensate for the risks assumed by the private sector would offset some of the benefits and would, at the same time, carry the risk that governments would try to renegotiate such contracts in the future (see for example the difficulties surrounding the Pearson Airport agreement in Toronto, Ontario, Canada, negotiated by one government and then canceled by a new government). No guidelines, however, currently exist in the literature to resolve this issue.

In a more detailed work, Tiong (1990a) explains some of the risks and securities involved in any BOT project, and suggests various guarantees and incentives that could be provided by a government in order to enhance the opportunities of success. He argues that after commencement of construction, the amount of risk begins to increase sharply as funds are advanced to purchase materials, labour and equipment. Interest charges on loans to finance construction also begin to accumulate. The risks peak in the early operational years when the projects are under the greatest pressure due to peak debt servicing when the highest interest burden occurs. Once the project is running to specification, and assuming that the anticipated usage levels are met or exceeded and operating costs are in line, the revenues would be collected, debt would be repaid and the project sponsors would recover their investment hopefully with profit. However, in trying to identify these risks, Tiong (1990a) focused only

on the descriptive aspect of financing, political, and technical risks, and fell short of trying to quantify such risks.

In a comparative study made by Tiong (1990b), six BOT projects were studied - three in developing countries and three in developed countries. Those projects were: Shajio power plant- China, North South expressway- Malaysia, Bangkok second stage expressway- Thailand, Sydney harbour Tunnel- Australia, Dartford bridge- UK, and The Channel Tunnel- UK. This study was meant to compare and contrast the winning bids in terms of financing, responsibilities, and undertakings proposed by the project sponsors. It also provides insights into how the financing, technical, and political risks were allocated to the different parties involved. The paper further addresses the issues of guarantees and incentives either provided by or negotiated with the government. Tiong (1990b) argues that as the BOT projects were structured without any direct sovereign guarantee on the loans and without any recourse to the government, the indirect governmental supports proved to be vital in attracting the required financing. A summary of this comparison is presented in Tables 2.1, 2.2, and 2.3.

Feature	Australia	U.K.	U.K./France	China	Malaysia	Thailand
Project	Sydney Harbour Tunnel	Dartford Bridge	Channel Tunnel	Shajio Power Plant	North-South Ex-way	Bangkok Ex-way
Cost	\$550 mill	\$310 mill	\$9.2 bill	\$517 mill	\$1.8 bill	\$880 mill
Concession	30 years	20 years	55 years	10 years	30 years	30 years
Period	1992-2022	1988-2008	1987-2042	1987-1997	1988-2018	1988-2018
Equity (sponsors)	\$11 mill	\$1,800	\$80 mill	\$17 mill	\$9 mill	\$170 mill
Equity (Shareholders)	\$18 mill	-	\$1.72 bill	-	\$180 mill	-
Equity:Debt	5:95	0:100	20:80	3:97	10:90	20:80
Rate of return	6% Inflation indexed	N/A	10-20%	N/A	12-17%	10-20%

Table 2.1 Comparative Features of BOT Projects (Tiong, 1990b)

Government Guarantees	Australia	U.K.	U.K./France	China	Malaysia	Thailand
Support Loans	Yes	No	No	No	Yes	No
Minimum Operating income	Yes	No	No	Yes	Yes	No
Concession to operating existing facility	Yes	Yes	No	No	Yes	Yes
Commercial freedom	No	No	Yes	No	No	Yes
Foreign exchange guarantees	No	No	No	Yes	Yes	No
Interest Rate guarantees	No	No	No	No	Yes	No
"No Second facility" guarantees	No	No	Yes	No	No	No

Table 2.2 Comparison of Government Incentives (Tiong, 1990b)

Sponsors Undertakings	Australia	U.K.	U.K./France	China	Malaysia	Thailand
Concession Company	Foreign/local Contractor J.V.	Local J.V.	Local J.V.	Foreign investor	For./local Cont. J.V.	For./local Cont. J.V.
Construction Contract	Turnkey	Lump sum	Lump sum & Target cost	Turnkey	Turnkey	Turnkey
Tolls	Agreed to limited toll increase	Agreed to limited toll increase	Rates fixed by Eurotunnel	Rates fixed by Hopwell	Agreed to limited toll increase	Fixed by Bangkok Ex-way
Project Finance	Raised finance locally	Raised finance locally	Raised equity locally	Raised offshore finance	To raise finance locally & offshore	To raise finance locally & offshore

Table 2.3 Project Sponsors - Undertakings & Responsibilities (Tiong, 1990b)

In a more specific work, Ayber and Sahin (1990) discuss the advantages and disadvantages of pursuing the Akkuyu Nuclear power project in Turkey by BOT. They concluded that any nuclear plant construction company which is acquainted with the intricacies of world trade and possesses a well proven reactor technology would be well equipped to achieve fruitful cooperation under a BOT type of contract.

A host of other publications which discuss peculiarities and specifics about public-private partnership in general and BOT in particular for specific projects was also identified. Examples of these projects are the Channel tunnel (McDermott, 1991; Wood, 1991), the Northumberland Strait Crossing (Duncan, 1988; Feltham, 1990), the Third Dartford River Crossing (Carlile, 1990), the Sydney Harbour Tunnel (Baxter, Hilton & Nye, 1990; Cunneen, 1991; Gomes, 1990; Neilson, 1991), and others (Ayber *et al.*, 1990; Chaux, 1990; Croc, 1990; Dunchene, Geffrin & Meyere, 1990; Hargrove, 1990; Orefuil, 1990; Israel, 1992).

Common deficiencies in the foregoing literature are: they are not detailed enough to constitute useful case studies for the projects analyzed; most of them assume that the project has already been awarded to a consortium; they address specific aspects and do not provide an overall picture; and, most importantly, none is directed towards offering a framework to analyze or evaluate BOT/ PPP projects.

Yaworsky (1994) presented a detailed, and, from the perspective of this research, useful case study for the Channel tunnel. Throughout his analysis, which covered the project's evolution from 1802 till 1991, the objective was to illustrate the magnitude, complexity and the more than usual risks associated with large and BOT projects. In the same work, he listed specific risk categories and developed a comprehensive qualitative framework to identify most of these risks. This framework constitutes a useful building block for this research. Relevant aspects of Yaworsky's work are examined later.

2.3.4 Critical Success Factors For PPP Arrangements

Several authors describe their own views as to the critical success factors for PPP arrangements. For example, Tiong *et. al.* (1992) assume the perspective of BOT sponsors and suggest some critical success factors specifically for winning BOT contracts. They explain that the consortium bidding for a BOT concession must be willing to take calculated risks and at the same time be adaptable to changing demands and circumstances. In their view, the six critical success factors that are vital for BOT project sponsors are:

- *Entrepreneurship*: Which means the will to take calculated risks and the ability to cultivate goodwill and a working relationship with the government;

- *Picking the right project:* Two basic requirements must be satisfied. First, there should be a demonstrated and accepted need for the project. Second, there should be a near-monopoly situation in the provision of the service or product;
- *A strong team of participants:* This deals with the organizational aspect. The project team must possess a combination of diverse skills and talents. This requires a multidisciplinary team to be formed from the beginning which may be small but it must consist of highly qualified professionals with the requisite technical and financial engineering skills. As negotiations progress, the team must be further strengthened to include project and construction managers, financial and legal advisors, specialist subcontractors and suppliers. Also, local partners with political connections are very important;
- *An imaginative technical solution:* The concept or solution proposed must be characterized by simplicity, functionality, innovation and cost effectiveness;
- *A competitive financial proposal:* Competitive proposals generally involve low construction costs, a reasonable debt/equity ratio, acceptable tariff levels, short construction and concession periods, and accurate forecasts of future demands; and
- *The inclusion of special features:* Which must address specific needs and concerns of the government.

Reijniers (1994) makes the observation "For a PPP project to be successful, it is important to bear in mind that, if the public sector is a participant, it must act as a private company in terms of management (i.e. effectively and efficiently, focused on the realization of goals with the funds available, within the time set and with accepted revenues). He cites the following list of factors he deems as critical to the success of a PPP arrangement:

- 'Key' decision makers form part of the project team right from the start of the preparation of the project (the project 'kick off').
- Measurable results are available to enable active monitoring of the progress (clear goals and well organized phasing).
- There is a focus on results, and the project is goal-directed.
- There is active periodic progress monitoring during implementation.
- There is an independent project team and an independent project leader, who report to a steering committee consisting of top representatives from both the public and private sectors (project organization).
- The political and economic risks are distinctly spread at an early stage.
- There are adequate and clear working methods and agreements.
- The private sector is allowed to fulfill its entrepreneurial role.
- There is mutual confidence.

In addition a number of other conditions which apply equally to both sectors must exist. For example, a meeting of the minds and a relationship of trust between both sectors must exist in order to successfully implement any PPP project. Both sectors should assign empowered negotiation teams to take decisions. There should be no hidden agenda and there should be no "empty chair" negotiations. There must be a clear understanding that risk sharing between both sectors is the essence of PPP. The public sector cannot off-load all risks to the private sector, and the private sector should expect to assume a higher level of risk than a normal construction project. Finally, the concession agreement should define the relationship and expectations of both sectors over its duration, and hence should be crafted and examined with

great care (Pirie, 1994).

2.3.5 Research Challenges

As explained above, many conditions must be satisfied in order to maximize the chances of success for any BOT or PPP project. A key condition is "a meeting of the minds" between the public and private sectors. Naturally, each sector is willing to participate in such a lengthy process and share the risks only in so far as it can achieve its own objectives. Although not common, and currently debatable among experts in the field, some projects have the blessing of the government when the proposal costs are paid for by the government in the form of honorarium. For most PPP projects, however, the costs incurred by the project sponsors in the conceptual design and preparation of the proposal are not reimbursable. The sums involved can be enormous and can seriously deplete the sponsor's resources. This is especially so if the project is initiated by the sponsors themselves. Consultants and advisors frequently charge for their services unless they also have an equity interest in the project. What is also significant about these projects is that risks do not end by the completion of construction as is the case with the traditional approach. The developer is still exposed to all of the risks associated with collecting revenues and operating and maintaining the facility over an extended period of time, which in itself is uncertain due to various reasons. Change in governments or government regulations, strikes, severe damage to the facility, the development of competing facilities, flaws in forecasting inflation or demand, etc. are all examples of risks which make pursuing PPP projects a challenging task.

Findings from the literature search emphasize that departure from the traditional approach

utilized by the public sector to any form of PPP is invariably accompanied by potentially significant risks and disbenefits to both sectors.

Given the complexity of this approach, the more than usual risk exposure, the immense capital involved, and the commitments for an extended period of time with the potential for significant losses including opportunity costs for both sectors, there is a demonstrated need for an analysis framework to assist in identifying, evaluating and negotiating PPP projects.

2.4 EXISTING ANALYSIS FRAMEWORKS FOR PPP ARRANGEMENTS

Only a few analysis frameworks are cited in the literature, none of which fully satisfies the demonstrated need mentioned above. For example, Crosslin (1991) offers a decision support system methodology which is designed to minimize two primary decision errors: accepting unsound or inferior projects; and/or rejecting sound or superior projects. The suggested methodology is generic, however it could be further enhanced and expanded to be applied to the BOT approach. In summary, the methodology is a quantitative model in which baseline assumptions for project parameters are input into a pro forma income statement model. Some of these parameters are under management control of the government agency such as contract duration and discount rate, and others are exogenous such as revenues, interest rates, and inflation rates. The outputs of the pro forma income statement model are then input into "The First Life Cycle Cost Model" to estimate net present values of the proposed PPP project and the government-financed alternative. This process is repeated or simulated using various combinations of management controlled and exogenous parameter values to determine a feasible set of management controlled parameter values. The best set of project parameters is

selected from the feasible set and used to formulate the project request for proposals. Proposals received are then evaluated using "The Second Life Cycle Cost Model" to select the winning developer and justify the contract award to appropriate officials. The flow of data and information through the model is depicted in Table 2.4. Crosslin (1991) explains that, by definition, pro forma income statements are projections of what might happen, not what has happened. Certain assumptions, therefore, are necessary and should be based as much as possible on concrete historical evidence, and possibly on market research done by the government agency specifically for the PPP project. Crosslin (1991) further suggests that for maximum usefulness of the methodology, the quantitative model should be part of a decision support system that guides a manager toward the proper PPP decision. He calls for a structured methodology for planning, evaluating and implementing a PPP. Simulation techniques, such as Monte Carlo simulation, and sensitivity analysis are only one exercise among others towards identifying the feasible set of PPP project parameters. However, the need to treat uncertainties associated with input parameters, the values of which are to be estimated far into the future, is completely understated in Crosslin's work. This, in addition to the lack of formally treating the risks that are most likely impact the project evaluation and/or implementation, are two major deficiencies in this work. Thus, although a useful building block for this research, Crosslin's work is overly simplistic and does not provide a solid foundation for the objectives sought in this research. Other than two simple and hypothetical examples, Crosslin did not indicate that his model was implemented.

Pro Forma Income Statement Model	First Life Cycle Cost Model	Second Life Cycle Cost Model
<u>Inputs:</u> - Baseline assumptions - Capital outlays	<u>Inputs:</u> - Income and expenses from Pro Forma model - Discount rate - Facility salvage assumptions - Sensitivity assumptions	<u>Inputs:</u> - Developer's proposals * Capital outlays, amount and timing * Profit sharing formulas - Government estimates of demand/usage - Discount rate - Cumulative NPV of government alternatives
<u>Outputs:</u> - Income and expenses by year	<u>Outputs:</u> - Present values by year - Cumulative NPV * PPP * Government alternative - Simulation & sensitivity analysis of project parameters	<u>Outputs:</u> - Cumulative NPV of each developer proposal - Comparisons to government alternative - Selection of the best proposal

Table 2.4 Public-Private Partnership Decision Support System (Crosslin, 1991)

Russell and Ranasinghe (1992) presented an analytical model for economic risk quantification of large engineering projects. Objectives of their model were to explore economic feasibility and tradeoffs between cost and time performance versus risk as a function of various strategies for executing and sequencing major work packages. Hence, although both Crosslin's and Russell & Ranasinghe's models seek to analyze large projects, their contexts are very different. The focus of Russell and Ranasinghe's model is purely analytical with the main goal being to identify and quantify economic risks; while without dwelling on the analytics of risk and sensitivity analysis, Crosslin's model uses them as a prerequisite towards the main goal of the model, which is to evaluate alternative proposals from different developers and compare them to that sponsored by the government.

Yaworsky (1994) argues that the lack of a suitable risk planning framework for project participants is hampering the approval and implementation of large and BOT projects. Proponents seek guidance with respect to appropriate processes and procedures, a structure of organizing risk planning knowledge and experience, and guidance on effectively utilizing relevant portions of the diverse body of knowledge with respect to risk analysis. He thus presents a comprehensive literature review on the subject, and suggests a holistic framework for risk planning for such projects. This framework is depicted in simplified form in Figure 2.12 and in a more detailed form in Figure 2.13. These two figures clearly demonstrate the complexity of the problem.

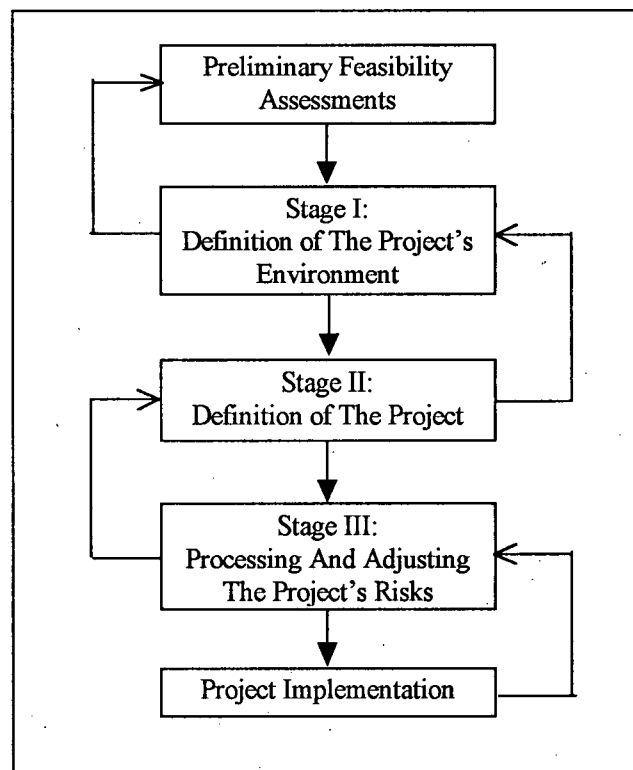


Figure 2.12 Simplified View of a Holistic Risk Planning Framework (Yaworsky, 1994)

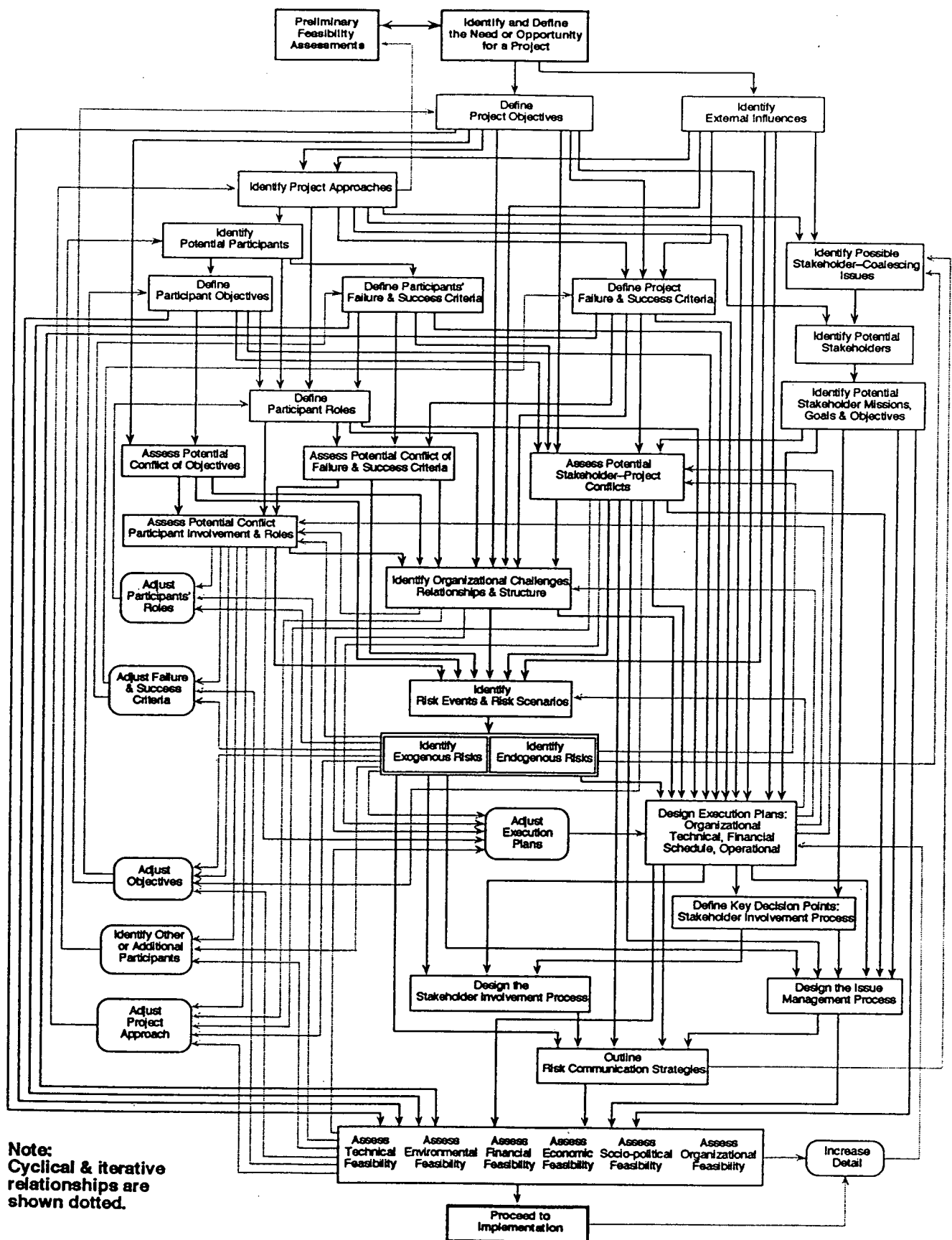


Figure 2.13 Holistic Risk Planning Framework (Yaworsky, 1994)

Yaworsky (1994) claims that those traditionally involved in engineering projects have focused more attention on the technical and other quantifiable aspects of project risks. In BOT projects, on the other hand, engineers and project planners find themselves increasingly bewildered by the breadth and complexity of such projects and the range of issues they must grapple with to move the project through the long approval processes and maneuver through the minefields of ill-understood stakeholder concerns and opposition. His holistic risk planning framework, presents one possible process to address many such issues, but provides only for the qualitative aspect of analyzing such complex projects.

As shown in Figure 2.13, Yaworsky (1994) identified seven risk categories that need to be quantitatively and qualitatively assessed for such projects namely, technical, environmental, financial, economic, socio-political, stakeholder and organizational (definition of these risks is presented in Chapter 6). He deduced these risk categories from the literature and from analyzing the Channel tunnel case.

In conclusion, a structured methodology to qualitatively and quantitatively assess these risks is needed. Although assessment of these risks in a quantitative terms is often not attainable - for example assessing the political will and commitment to implement a certain project - recognition of their existence by way of formal and systematic analysis is of utmost benefit to the decision-makers.

CHAPTER 3 - THE PEI BRIDGE CASE STUDY

3.1 INTRODUCTION

In order to further illustrate the complexity and risks associated with PPP arrangements in general and BOT in particular for large infrastructure projects, a case study of the Fixed Link project between Prince Edward Island and New Brunswick is presented in this chapter. This study will be used as a backdrop for some of the issues discussed later in Chapters 5 and 6.

3.2 CHAPTER OBJECTIVES & STRUCTURE

Two aspects of this case study are of particular interest. The first is the various risks that may plague such projects, especially in their initial stages. The focus in this research will be on *cost & time, technical, environmental, financial, economic, organizational & contractual, political & regulatory*, and *stakeholder* risks. Most of these risk categories were identified in Yaworsky's work mentioned earlier, and their definitions are discussed in Chapter 6. The second aspect is the impact risks from the various dimensions have on different project phases. The definition of the various project phases is discussed later in Chapter 5.

The objectives sought in this chapter are:

1. To illustrate the various risks that may plague PPP projects, especially in their initial stages, by examining the chronology of events to date of the PEI project. Such risks

become of particular concern in addition to those traditionally assumed by proponents of large engineering projects;

2. To demonstrate the usefulness of the risk categorization developed in Chapter 6;
3. To demonstrate the complexity of deciphering the events as they occur and present a view of relevant potential risks and the most likely affected phases of the project by such risks; and,
4. By exploring such a case study, the problems associated with trying to identify and assess opportunities of PPP from the perspective of both the public and the private sectors, and therefore the need for the analytical process proposed in this research, will be further demonstrated.

An extensive literature search involving newspaper clippings, historical and geographical books on Prince Edward Island and the project, papers by project participants from both the private and public sectors on the project, and a review of the contract documents was made to construct this case study. No interviews were conducted, and, although perhaps open to other interpretations, all views on risks and affected phases of the project were made by the author based on his reading and analysis of the events.

In the next section a background of the project locale and environment is presented. This is followed by some technical details of the project. The following section lays out the chronological events of the project progress as they occurred. The chapter concludes with an analysis of the case study.

3.3 BACKGROUND

The proposed bridge is to provide a fixed link between two Canadian Atlantic provinces, namely Prince Edward Island and New Brunswick, crossing the Northumberland Strait (see the map in Figure 3.1). This \$840 million fixed crossing would take less travel time and therefore reduce the cost of crossing for the transportation industry (Project Magazine, 1987).

The Northumberland Strait represents a physical barrier for people and goods traveling between Prince Edward Island (PEI) and the mainland. The Strait is a channel of water about 300 Km long and between 13 and 55 Km wide. It is covered with ice from January to April. It is one of the richest lobster-fishing areas in Atlantic Canada and also a great area for fishing scallop, herring, mackerel, clams, flounder and rock crab.

In 1873, under the Terms of Confederation, the Government of Canada guaranteed that it would provide a continuous transportation link between PEI and Canada's mainland. At that time, ice-breaking ferries were not reliable and thus could not be depended upon to handle the necessary transportation of goods and services in all seasons. During the period 1885 to 1890, Senator Howlan from PEI constantly lobbied for the construction of a fixed link, in this case a tunnel, to secure a transportation link with the mainland. This idea was abandoned because of the development of efficient ice-breaking ferries, and in 1917-18 the first year-round service was in fact started. However, the government of PEI has requested improvement to the ferry service on various occasions.

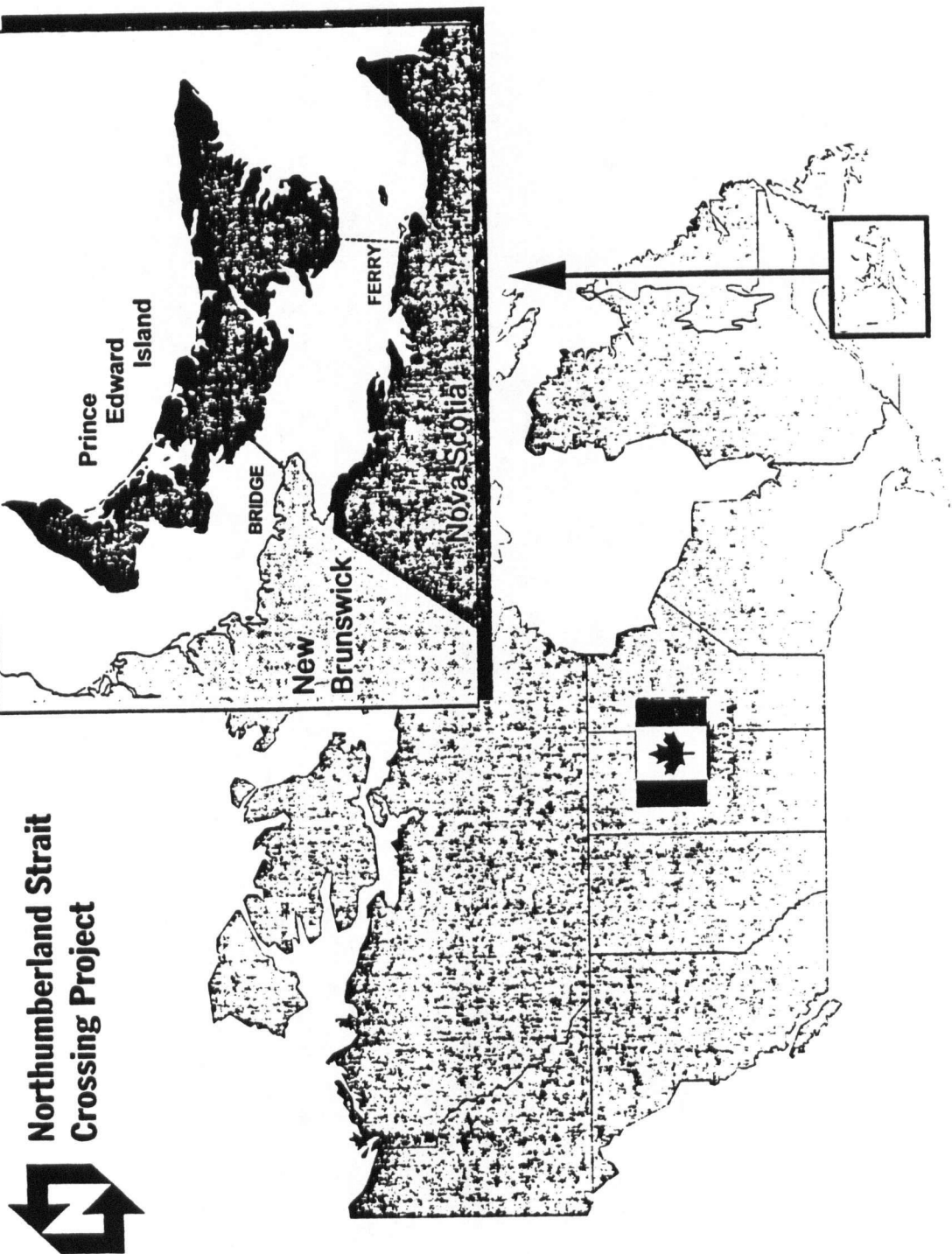


Figure 3.1 The PEI Fixed Link Project Locale

In mid-1960's a serious attempt to build a causeway-bridge link between the Island, at Port Borden, and the mainland, at Cape Jourimain, was undertaken, based on an engineering study conducted in 1958. Construction of roadways on each end to connect to the existing highway system was carried out. In 1969 this project was canceled due to what was perceived at that time to be hazards to shipping and due to financial reasons. The idea, though, of a fixed link continued to surface.

In 1985 and 1986 three unsolicited proposals from the private sector expressed interest in constructing a fixed link provided the government of Canada would make available the subsidies which are presently being paid to the ferry service, and allow the proponents to charge tolls. This private sector initiative together with increasing traffic, rising ferry costs and perceived problems with the level and quality of the existing ferry service, especially during the peak summer period, interested the government. In December 1986, studies to determine the feasibility of such a project were authorized. In May 1987, a call for expression of interest and prequalification issued by the Federal Government attracted 12 international groups. Seven were approved in August 1987, and a draft proposal call was made in November 1987.

The proposed fixed link would replace the ferry service and span the Strait at its narrowest point between Borden, PEI and Jourimain Island in New Brunswick, which is a distance of 13 Km. As part of the project agreement, the ferry service will cease operation upon opening of the bridge facility (Begley, 1993; Duncan, 1988; Feltham, 1990; Pirie, 1994; Tadros, 1994; Thompson, 1988).

The population of PEI is approximately 127,000. During the summer the population swells with the influx of tourists. The people are known for their strong sense of pride in being islanders and a vocal minority do not accept any change to the island way of life. For this group, a fixed link threatens the insular nature of their existence. For the majority, however, a fixed link is viewed as a progressive step to a better future (Feltham, 1990). In a formal survey done on 2154 visitors to the Island in 1987, it was found that 75% are in favor of some form of a fixed crossing while 12% are against and 13% are neutral. Of those in favor of the project, 3 to 1 prefer a bridge versus drive through tunnel (Project Magazine, 1987). In January 1988, a plebiscite showed that 59.46% of the population were in favor of the fixed link and 40.21% voted against it (Begley, 1993). Also, there was a fierce criticism among opposing groups for a PPP approach involving private financing as opposed to a traditional government approach.

3.4 PROJECT DESCRIPTION

The water at the proposed site is relatively shallow with a maximum depth of 36 meters. The soil conditions over most of the crossing location were the subject of intense investigations in the 1960's and indicate that a glacial till, that varies in depth from zero to 13 meters overlies sedimentary rock.

The bridge structure as proposed, is one of the longest highway bridges over a sea channel anywhere in the world. Adding to the difficulty are the rigors imposed on such a structure by the dynamic ice climate of the Northumberland Strait (Feltham, 1988).

The estimates as of 1988 were that construction of such a bridge would take about four years and would result in a crossing that could accommodate two lanes of highway traffic at approximately 2000 vehicles crossing per hour, which is a great improvement over the existing ferry service. It is estimated that such a structure could be built with a useful life of 100 years and financing period of about 35 years (Feltham, 1988).

The major components of this bridge project include the approach roads, abutments, approach spans in the near-shore areas, deep water marine spans and navigation span, as well as associated land-based infrastructure required for the operation and maintenance of the crossing. This approximately 13 kilometer bridge is comprised of:

- Forty five marine/navigation spans with spans ranging from 250 meters to 165 meters in length, with a total length of 11,080 meters.
- Seven approach spans on the PEI side of the crossing with a total length of 555 meters.
- Fourteen approach spans on New Brunswick side of the crossing with a total length of 1,275 meters (Tadros, 1994).

The substructure and superstructure and all associated structural elements had to be designed in accordance with the most current codes and standards. Environmental loading from wind, waves, ice, currents and earthquakes also had to be considered. In addition, a criterion that calls for the seasonal ice-out not be delayed any more than two days, once in 100 years has to be ensured. That is, the existence of the bridge should not delay the passage of the ice out of the Strait by more than two days (Tadros, 1994).

For this BOT project, the government is committed to paying 35 annual payments fully indexed to inflation of \$35 million Canadian (1988 dollars). This will commence on the estimated date of substantial completion which is the end of March 1997, and continue annually thereafter for 35 years. During this 35 years the developer is entitled to charge toll rates consistent with the toll rates charged for the ferry service the year before the bridge opened. The developer is entitled to automatic increases in toll rates equal to 75% of the annual increase in the Consumer Price Index, and in the event certain costs such as insurance premiums increase at a rate higher than the inflation rate, further adjustment could be requested (Pirie, 1994).

In addition, the project proponent developed a bond which was issued by a Provincial Crown Corporation of the Province of New Brunswick which was created to receive the annual indexed payments from the Federal Government and would in turn flow these funds through to a Trustee for the bond holders (Pirie, 1994). The bonds offer a 4.5% real return per annum compounded semi-annually, with no interest being paid during construction.

A very extensive security package comprised of parent company guarantees, a \$200 million performance bond and a \$20 million labour and material payment bond had to be supplied to secure the government against the completion risk. In addition, the government required a separate Letter of Credit for \$73 million to be set aside as extra protection against cost overruns (Pirie, 1994).

Thompson (1988) provided a contractor point of view and summarized the risks involved in the PEI project, at the time of the proposal call, as follows:

1. *Design risks:* The developer is liable for all design risks. Professional liability insurance is not large enough to cover an \$840 million project.
2. *Construction risks:* Risks associated with labour productivity, weather related delays, strikes, availability of equipment and material, and safety have to be considered. Most of these risks, however, may be seen as traditional ones which have to be assumed by the contractor regardless of the procurement approach. However, in a PPP project the contractor does not have any entity to turn to in case of claims or error in the estimations. The contractor inherits all of these risks and their consequences.
3. *Financing:* No firm guarantees regarding financing were available. The cost of financing for thirty five years is twice the construction costs, and a 1% swing in interest rates translates to \$90 million in cost.
4. *Operating and Maintenance:* The facility will have to be operated for 35 years and in the winter it will be operated in severe weather conditions, which may require some escort services and strict control and safety rules.
5. *Toll revenues:* There is no control over the volume of traffic, despite the fact that lower bounds are foreseeable.
6. *Insurance:* Insurance at unknown cost is required to deal with safety during the 35 years of operation of the facility and the possible damage to people, vessels, or the facility itself.

In addition there were other political and legislation problems. First, the laws of Canada prohibit the creation of a monopolistic utility by the private sector. Second, an amendment was required to the Terms of Union Agreement between the Federal Government and the Province of PEI as to the replacement of the ferry service with the bridge facility (Pirie, 1994). Therefore, extensive negotiation skills and understanding were required from both the public and private sectors, in order to successfully forge this unique PPP arrangement.

In its current form, the project took in excess of 5 years to finalize with a forecast construction period of only 4 years. The PEI bridge, nevertheless, is the first substantial BOT project undertaken by the Canadian government to provide major infrastructure (Pirie, 1994).

An organizational structure for the project is presented in Figure 3.2, to demonstrate the complexity of the project.

3.5 CHRONOLOGICAL EVENTS OF THE CASE STUDY

In what follows, a chronology of the events for this project is presented. As part of this presentation, relevant risk categories and the affected project phases are highlighted. By way of project context, Consumer Price Index (CPI) and Prime Interest Rate data are presented in Figure 3.3, and exchange rate data is presented in Figure 3.4. The objective is to demonstrate the unpredictability of the economic environment in which the project was supposed to proceed.

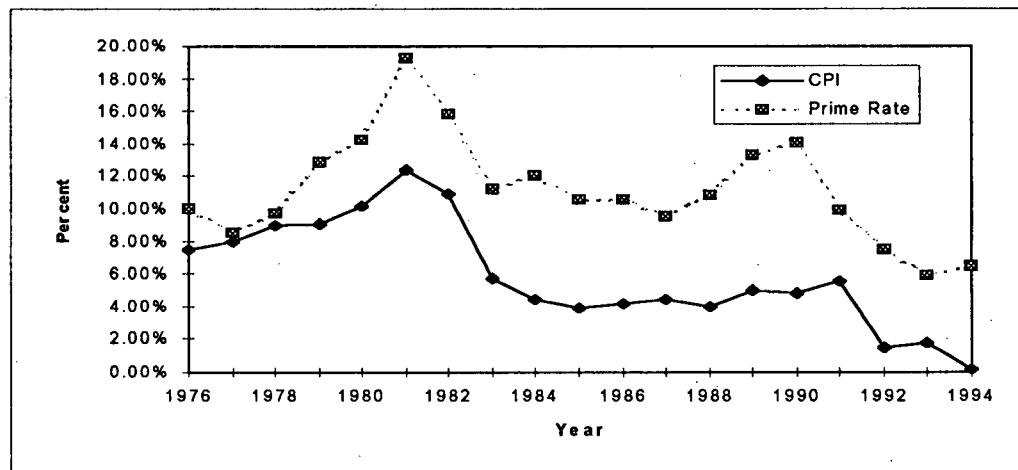


Figure 3.3 Canadian Consumer Price Index and Prime Rates (Bank of Canada, 1994)

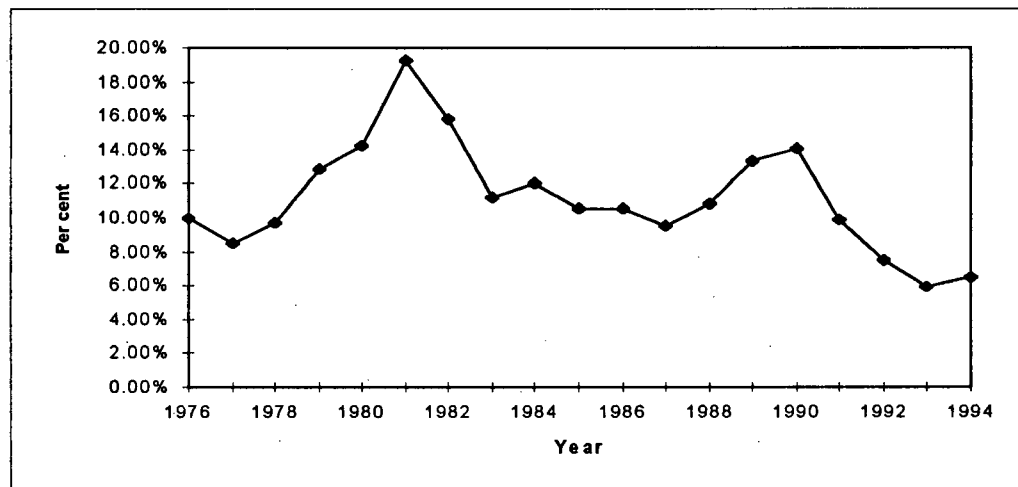


Figure 3.4 Canadian Dollar Exchange Rate Versus U.S. Dollar (Bank of Canada, 1994)

DATE	EVENT / REFERENCE	RISK CATEGORIES	PHASE
1832	Steamer service begins between Pictou and Charlottown. <u>" Begley, 1993 "</u>		
1873	Ottawa takes on an obligation to supply PEI with a continuous year-round link <u>" Feltham, 1990 "</u>		
1877	"Northern Light" steamer establishes a regular winter connection to the mainland except in heavy ice and storms. <u>" Begley, 1993 "</u>		
1885	Senator Howlan proposes constructing a tunnel under the Strait. <u>" Begley, 1993 "</u>		
1917	The first ice-breaking, year-round ferry for cars was used for crossing the strait. <u>" Feltham, 1990 "</u>		
1956	PEI government approaches the Federal Government with a proposal to investigate the feasibility of a permanent crossing. <u>" Begley, 1993 "</u>		•Original Predesign
1958	Consulting engineers and government agencies determine that a rock-filled causeway is feasible but that the effects of ice and tides would require attention. <u>" Begley, 1993 "</u>	•Technical	•Original Predesign
1965	The Federal Government decides to proceed with the design and construction of a causeway for road and rail. <u>" Begley, 1993 "</u>		•Original Design
1969	Plans for the proposed crossing are abandoned when the province opts instead for an economic development agreement and improved ferry service. <u>" Begley, 1993 "</u>		
1985	Three unsolicited proposals to design, finance, construct and operate a fixed crossing are received by the Federal Government. <u>" Begley, 1993 "</u>		•Start of "new" Predesign phase

DATE	EVENT / REFERENCE	RISK CATEGORIES	PHASE
June, 1987	Twelve consortia respond to an expression of interest request from the Federal Government made in May. <u>" Begley, 1993; Tadros, 1994 "</u>		•Predesign
Nov. 16, 1987	Federal Government prepares a call for tender proposals. <u>" Begley, 1993 "</u>		•Predesign
Dec. 3, 1987	The government has made it clear to potential builders that they must price their proposals at less than the inflation-adjusted cost of the ferry (operating plus capital). A dozen groups expressed interest. PEI Premier has given the idea his qualified support and addresses social, economic and environmental concerns. <u>" The Globe and Mail "</u>	•Economic	•Predesign
Jan. 18, 1988	The PEI plebiscite indicates that 60% of the Island population are in favor of a fixed link, and 40% are opposing. <u>" Begley, 1993 "</u>	•Political	•Predesign
Sept., 1988	Seven bidders submitted proposals, reduced down to 3.		•Predesign
1988	Key ministers lose seat in a federal election and political will to proceed with the project is diminishing.	•Political	•Predesign
Jan, 1989	The project is put on hold by the Federal Government until the panel could conduct reviews. These are to be conducted on a "generic" bridge, not the design proposals. <u>" The Globe and Mail "</u>	•Cost & Time	•Predesign
Aug. 16, 1990	New Brunswick panel examining the environmental risks involved in building a fixed crossing between New Brunswick and PEI finds the project unacceptable. Opponent groups are expressing their concerns, and the government states that the report is not binding. <u>" The Globe and Mail "</u>	•Cost & Time •Political •Stakeholder	•Predesign

DATE	EVENT / REFERENCE	RISKS CATEGORIES	PHASE
Aug. 17, 1990	PEI Premier says the idea of a fixed link with the mainland is not dead. The federal environmental panel said in its report that a bridge could be acceptable if someone comes up with a design to reduce ice buildup. A tunnel might also be acceptable. The PEI Premier wants Ottawa to improve ferry service to Prince Edward Island while the fate of the project is decided. <i>"The Globe & Mail"</i>	<ul style="list-style-type: none"> •Political •Technical •Environmental 	•Predesign
Aug. 20, 1990	Environmental impacts threaten the progress of the project. But the idea remains sound enough to warrant search for technical solutions to the ice problem. <i>"The Globe and Mail"</i>	<ul style="list-style-type: none"> •Cost & Time •Technical •Environmental 	•Predesign
Aug. 25, 1990	Many Atlantic Canadians now believe the idea of a fixed link with PEI is still only an illusion. The three remaining companies proposing to build the link, as well as the consultants and politicians who had been promoting it, were stunned by the panel decision. The panel's report pointed to dangers of the bridge spans blocking ice in the Northumberland Strait, causing problems for spawning fish and damaging the lobster fishery. As well, it backed the 600 workers on the Marine Atlantic ferry who would lose their jobs if the link were built. One of the three would-be builders urged the government to set aside the panel's findings as "largely irrelevant." <i>"The Globe and Mail"</i>	<ul style="list-style-type: none"> •Environmental •Stakeholder •Political 	•Predesign
Apr. 17, 1991	Experts now say that the ice buildup is no problem. The PEI bridge schemes are revived again after a new study conducted by a committee of experts appointed by the Federal Department of Public Works. The new findings enraged opponents of the fixed crossing, who said the government was ignoring the findings of its own environmental review. <i>"The Globe and Mail"</i>	<ul style="list-style-type: none"> •Technical •Environmental •Political •Stakeholder 	•Predesign

DATE	EVENT / REFERENCE	RISK CATEGORIES	PHASE
June 26, 1991	On May 9, Mr. MacKay, the Minister of Public Works, invited the three consortia bidding for the project to submit proposals. The bridge is supposed to cost roughly \$700-million and take about five years to build. <i>" The Globe and Mail "</i>	<ul style="list-style-type: none"> •Technical •Economic •Political 	•Predesign
Nov. 12, 1991	Plans from three potential builders for the fixed link between PEI and the mainland are now in the hands of ice experts, engineers and scientists, while opponents of the fixed link vow a renewed battle over the proposal. The Federal Department of Public Works says if all three proposals fail the environmental tests then the project is dead. <i>" The Globe and Mail "</i>	<ul style="list-style-type: none"> •Cost & Time •Technical •Environmental •Political •Stakeholder 	•Predesign
Jan. 31, 1992	Federal Public Works Minister announced that all three companies that want to build the 13-kilometer bridge have met the environmental requirements of the project. Construction could start in the fall of 1992 if a company can meet the financial requirements of the Federal Government and can address public concerns about the impact of its proposed bridge on the environment. Opponents of the link are considering taking a court action to block construction. <i>" The Globe and Mail "</i>	<ul style="list-style-type: none"> •Cost & Time •Technical •Environmental •Political •Stakeholder 	•Predesign
Jan. 31, 1992	The PEI government has 10 conditions that must be met before construction can start. Opponent groups say they are infuriated with the whole way Public Works is handling the project. <i>" The Vancouver Sun "</i>	<ul style="list-style-type: none"> •Cost & Time •Political •Stakeholder 	•Predesign

DATE	EVENT / REFERENCE	RISK CATEGORIES	PHASE
May 28, 1992	With a \$40.6-million bid, Strait Crossing Inc. takes the lead in the race for a federal contract to build the bridge. PEI Bridge Ltd. bid was \$46.2-million, and Borden Bridge Co. bid was \$64.2-million. Ottawa had warned it wanted a proposal requiring no more than \$41.6-million in annual subsidies for 35 years. Now Ottawa demands \$200-million up front, which it would keep if the company does not deliver the bridge. In addition, the company would have to establish a contingency fund of 10% of the project value to cover any cost overruns. <i>" The Globe and Mail "</i>	<ul style="list-style-type: none"> •Technical •Economic •Financial 	<ul style="list-style-type: none"> •Predesign •Financing
June 8, 1992	The main SCI bridge section includes 44 spans, each 820 ft. long, with a 160 ft. clearance over a shipping channel. Its two approaches will incorporate 23 spans. <i>" ENR "</i>	<ul style="list-style-type: none"> •Technical 	<ul style="list-style-type: none"> •Predesign •Design •Construction
June 27, 1992	Strait Crossing's proposal is viewed to be in non-compliance, and PEI Bridge Ltd's bid is now being considered. The project still faces an environmental review that includes public hearings and examination by a committee of officials from the three maritime provinces and the Federal Government. <i>" The Globe and Mail "</i>	<ul style="list-style-type: none"> •Cost & Time 	<ul style="list-style-type: none"> •Predesign
July 7, 1992	The second consortium has failed to meet federal criteria for the contract. The last and most costly bid is now being considered. <i>" The Globe and Mail "</i>	<ul style="list-style-type: none"> •Cost & Time 	<ul style="list-style-type: none"> •Predesign
July 1992	Third bidder disqualified.	<ul style="list-style-type: none"> •Cost & Time 	<ul style="list-style-type: none"> •Predesign

DATE	EVENT / REFERENCE	RISK CATEGORIES	PHASE
July 18, 1992	Once again the government will begin negotiations with Strait Crossing Inc. Proposals from Strait Crossing Inc. and two other contenders to build the bridge were recently rejected by the Public Works Department because of technical problems. But the government plans to proceed if the project is financially possible. For and against groups are still debating the issue. A link would also require approval from the governments of PEI and New Brunswick. <i>" The Vancouver Sun "</i>	<ul style="list-style-type: none"> •Cost & Time •Technical •Financial •Political 	•Predesign
July 18, 1992	Link project is still alive, and the government will begin negotiations with Strait Crossing Inc. <i>" The Globe and Mail "</i>	<ul style="list-style-type: none"> •Political 	•Predesign
July 28, 1992	Strait Crossing Inc. will begin on-site exploration next week, although it has not yet been awarded the contract. The government says they are taking risks with this, since if they don't get the contract, it's their loss. A decision will be made within the next two months. <i>" The Globe and Mail "</i>	<ul style="list-style-type: none"> •Technical •Political 	•Predesign
Oct. 22, 1992	Strait Crossing Inc., the Calgary-based consortium, has completed its bid, and is waiting for the government to give the project the green light. <i>" The Globe and Mail "</i>	<ul style="list-style-type: none"> •Cost & Time •Political 	•Predesign
Nov. 9, 1992	Hundreds of protesters demand another plebiscite on the proposed bridge. <i>" The Globe and Mail "</i>	<ul style="list-style-type: none"> •Political •Stakeholder 	•Predesign

DATE	EVENT / REFERENCE	RISK CATEGORIES	PHASE
Dec. 1992 4,	The Federal Government has chosen Strait Crossing Inc. to build the bridge, but the Public Works minister says it is too early to call the bridge a done deal. Ottawa will put up about \$5-million to compensate Strait Crossing should the Federal or Provincial Governments pull out of the project before a contract is signed. An anti-bridge lobby said it will step up plans to block the project in court. <i>" The Globe and Mail "</i>	<ul style="list-style-type: none"> •Political •Economic •Stakeholder 	•Predesign
Dec. 1992 8,	Ottawa, New Brunswick and PEI have ironed out the final wrinkles of an agreement to proceed with the bridge construction. The deal will probably be signed next week. <i>" The Globe and Mail "</i>	<ul style="list-style-type: none"> •Political 	•Predesign
Dec. 1992 15,	Governments set to sign agreement on the PEI bridge. Part of the agreement provides \$10-million in compensation from Strait Crossing and unspecified amount from the Federal Government for damages suffered by fishermen because of the project. Opponents plan a court action over lack of consultation. <i>" The Globe and Mail "</i>	<ul style="list-style-type: none"> •Political •Economic •Stakeholder •Financial 	•Predesign
Dec. 1992 17,	Shortly after the politicians signed the agreement an anti-bridge group announced it will launch a court challenge to the project. The group said that it will ask the Federal Court of Canada to prohibit Ottawa from signing a contract with Strait Crossing Inc. <i>" The Globe and Mail "</i>	<ul style="list-style-type: none"> •Cost & Time •Stakeholder 	•Predesign
Dec. 1992 17,	The consortium picked by Ottawa to build the bridge has to hold public hearings on an environmental management plan, and has also to arrange financing for the 13-kilometer bridge. <i>" The Vancouver Sun "</i>	<ul style="list-style-type: none"> •Cost & Time •Financial •Political •Stakeholder 	•Predesign

DATE	EVENT / REFERENCE	RISK CATEGORIES	PHASE
Dec. 18, 1992	Almost three-quarters of the \$800-million cost of the bridge will be spent in Atlantic Canada. If all goes well construction should begin on March 15. <i>" The Globe and Mail "</i>	•Technical	•Design •Const.
Jan. , 1993	The project's first phase will involve construction of a \$60 million staging area in Borden PEI, to produce footings weighing up to 5000 tonnes each, and girders weighing up to 7000 tonnes each. One more hurdle faces SCI; it must present the Federal Government with an acceptable financial package which will include an environmental management plan and a regional economic benefit implementation plan. Other partners in the consortium are Northern Construction Co. Ltd., a subsidiary of Morrison Knudsen Corp., Boise, Idaho, and GTMI (Canada) Inc., a subsidiary of GTM Entrepouse, Paris, France. SCI selected a repetitive concrete design so marine work could proceed quickly. <i>" Heavy Construction News "</i>	•Cost & Time •Technical •Environmental •Economic •Financial •Organizational	•Predesign •Design •Const. •Managem-ent during Design & Construction
Jan. 25, 1993	Strait Crossing Inc. is offering about \$600-million of inflation-indexed bonds to help finance construction. The bond financing is expected to meet about 70% of the bridge costs. <i>" The Globe and Mail "</i>	•Financial	•Financing
Jan. 25, 1993	Strait Crossing' president Paul Giannelia has two sales jobs left to do before he can put the contract in his pocket and start building. He has to finish arranging private-industry financing, scheduled for mid-March but possibly to be delayed until early April. He also must, by federal order, consult Islanders and New Brunswickers about the bridge's environmental impact. <i>" The Vancouver Sun "</i>	•Cost & Time •Financial •Economic •Stakeholder	•Predesign •Financing

DATE	EVENT / REFERENCE	RISK CATEGORIES	PHASE
Feb. 1993	3, A legal challenge to the proposed bridge linking PEI to New Brunswick will be heard in Toronto early in March. <i>"Daily Construction News"</i>	•Cost & Time	•Predesign
Mar. 1993	1, A three-day hearings today in the Federal Court of Canada in Toronto. PEI-based coalition Friends of the Island is suing to halt the project, while the Federal Government, Strait Crossing Inc., New Brunswick and PEI are contesting the suit. <i>"The Globe and Mail"</i>	•Cost & Time	•Predesign
Mar. 1993	2, The federal government is ignoring its own environmental guidelines and key constitutional provisions by proceeding with the project. The PEI based coalition, Friends of the Island, has filed suit in a bid to prevent the link, arguing the massive span could prove an environmental disaster. Ottawa hopes to sign a contract this month. <i>"Vancouver Sun"</i>	•Cost & Time	•Predesign
Mar. 1993	3, It does not matter that the federal environmental assessment panel looking at the generic design rejected the proposal. Public Works Canada, Mr. Morphy told the Toronto hearing, that is simply a recommendation, the department has to decide whether to accept the recommendation or take steps to deal with problems raised by the panel report. The department took the latter course by striking a committee of experts that suggested ways of dealing with the possibility that the bridge would interfere with the movement of ice through Northumberland Strait. <i>"The Globe and Mail"</i>	•Cost & Time •Political •Stakeholder	•Predesign

DATE	EVENT / REFERENCE	RISK CATEGORIES	PHASE
Mar. 9, 1993	After five days of hearings that ended yesterday in Toronto, Madam Justice Barbara Reed reserved judgment on a motion to delay the construction of a bridge to PEI. <i>" The Globe and Mail "</i>	•Cost & Time	•Predesign
Mar. 15, 1993	The 600 employees of Marine Atlantic whose jobs will end once the bridge is up are unhappy that their chairman is backing the bridge saying that he is not at the ferry company to look after the union, but to do what the Federal Government wants. Friends of the Island hired Toronto lawyer Mark Freiman, to help in its attempt to stop the project. Right now, in Alberta, a group called the Friends of the Oldman River plans to take SCI to court later this month, charging it contributed to environmental damage in a 34 kilometer fishing area when it worked on the controversial \$450 million Oldman Dam. In both the Oldman and the PEI cases, the Oldman Friends say, the Federal Government ignored the recommendations of its own Federal Environmental Assessment review Office to turn down the project. <i>" The Globe and Mail "</i>	•Cost & Time •Political •Stakeholder	•Predesign
Mar. 16, 1993	Mr. Patrick Boyer, who is the only declared candidate for the Tory leadership, says debt crises has to be addressed before the IMF steps in and imposes its own tough rules. The fixed link to PEI and the Hibernia oil project would get the axe, if Patrick Boyer becomes the next prime minister. <i>" The Globe and Mail "</i>	•Political	•Predesign

DATE	EVENT / REFERENCE	RISK CATEGORIES	PHASE
Mar. 20, 1993	Court halts bridge until environmental impact study made. The court said the Federal Public Works Department violated Ottawa's environmental guidelines by refusing to permit a review of specific proposals for the bridge. Madam Justice Barbara Reed also said that the project was unconstitutional because it would end the ferry service between the island and the mainland. It was entrenched in the constitution to provide an efficient steam service to and from the tiny province. A consortium lawyer had told Judge Reed that a delay could place the project's future in doubt. <i>" The Globe and Mail "</i>	•Cost & Time	•Predesign
Mar. 22, 1993	Judge Reed states that public hearings on a generic proposal are not a substitute for a specific evaluation of the actual project. She also based her decision on the government's constitutional obligation to provide a ferry service to PEI. This is a terrible news for the lobbyists, developers, lawyers and politicians who support the bridge, a group that never believed a tiny band of fishermen, ferry workers and academics could derail the project. SCI's proposal is criticized by project opponents for defective environmental and economic feasibility. <i>" The Globe and Mail "</i>	•Cost & Time	•Predesign
Mar. 22, 1993	The Federal Court of Canada stirred the PEI election pot Friday with a ruling that the proposed bridge must undergo a second environmental review. <i>" The Vancouver Sun "</i>	•Cost & Time •Environmental •Political	•Predesign

DATE	EVENT / REFERENCE	RISK CATEGORIES	PHASE
Mar. 23, 1993	<p>Marine Atlantic's monopoly is in jeopardy on one of its key routes. A proposal to build a bridge to join PEI with the mainland received preliminary approval from the Federal Government, threatening to eliminate the jobs of as many as 700 workers on the New Brunswick - PEI line within five years. However, the bridge plan was handed a major setback last week when the Federal Court of Canada ruled that the project must be halted until a detailed environmental assessment of its impact on the area is completed.</p> <p><i>" The Globe and Mail "</i></p>	<ul style="list-style-type: none"> •Political •Stakeholder 	•Predesign
Mar. 31, 1993	<p>Further delays will now plague this mega project, and the costs may rise. Fixed-link promoters must now regroup, including the government elected in PEI on Monday. They know that a full-blown environmental assessment will be required and that the Friends of the Island will be waiting. There's nothing the governments and promoters could possibly say to convince fixed-link opponents of either the bridge's merits or its compatibility with the environment. The opponents don't want any kind of fixed link, period. Judge Reed, in an exceptionally literal reading of the terms of union under which PEI entered Confederation, said Ottawa still has an obligation to provide "efficient steam service." Only by amending the Constitution can it replace a ferry with a bridge.</p> <p><i>" The Globe and Mail "</i></p>	<ul style="list-style-type: none"> •Cost & Time •Economic •Organizational •Stakeholder 	•Predesign

DATE	EVENT / REFERENCE	RISK CATEGORIES	PHASE
Apr. 1, 1993	Critics of the proposed bridge between PEI and New Brunswick are concerned that the environmental review they won in a recent Federal Court of Canada judgment will be lost in the halls of power. The suspicions of the opponents were triggered by an SCI news release that said the company is confident that it will be able to sign a financial agreement with Ottawa by April 30. In the release the company said the Federal Public Works Department has indicated that the screening process can be undertaken on an expedited basis and in time for the April 30, financial closing date. <i>" The Globe and Mail "</i>	<ul style="list-style-type: none"> •Stakeholder •Political 	•Predesign
Apr. 2, 1993	The Federal Government is appealing a court judgment ordering an environmental assessment of the chosen design for the PEI bridge. Public Works Minister Elmer MacKay said yesterday that the government will reluctantly comply with the ruling in the meantime by conducting an environmental assessment on the bridge design proposed by Strait Crossing Inc. <i>" The Globe and Mail "</i>	<ul style="list-style-type: none"> •Cost & Time •Political 	•Predesign
Apr. 12, 1993	Further environmental study of plans for the bridge will likely delay the signing of contract for the mega project well into spring. <i>" The Globe and Mail "</i>	•Cost & Time	•Predesign
Apr. 17, 1993	The premiers of New Brunswick and PEI say they are confident that construction of the toll bridge will begin within two weeks. <i>" The Globe and Mail "</i>	•Political	•Predesign

DATE	EVENT / REFERENCE	RISK CATEGORIES	PHASE
May, 1993	Despite the Federal Court of Canada's decision in March that a full-scale environmental impact study should be carried out before construction starts on the proposed fixed link, project officials are confident a contract will be awarded in May or June. <i>" Heavy Construction News "</i>	•Cost & Time	•Predesign
May 3, 1993	A member of a federal panel that rejected a plan to build the bridge says Ottawa should order a full environmental assessment of the \$840 million project. Ice buildup could damage the marine ecosystem of the Northumberland Strait, he said. The chairman of a different panel that reviewed the bridge's effect on ice buildup said the data on currents, wind, temperature and ice breakup for the past 30 years was more than adequate. <i>" The Globe and Mail "</i>	•Cost & Time •Political •Stakeholder	•Predesign
May 6, 1993	The bridge project would provide about 1000 jobs in Atlantic Canada during construction but would eliminate more than 600 ferry jobs when it opens in 1997. The PEI business people believe the proposal has been studied sufficiently at the 64 meetings in the past 6 years. <i>" The Globe and Mail "</i>	•Political •Stakeholder	•Predesign
May 11, 1993	The controversial bridge, although billed as a private project, will be entirely paid for by Canadian taxpayers. SCI will receive enough government subsidies every year to pay the entire costs of the interest and principal on its loan for the \$800 million project. <i>" The Globe and Mail "</i>	•Political •Stakeholder	•Predesign

DATE	EVENT / REFERENCE	RISK CATEGORIES	PHASE
May 11, 1993	<p>SCI is allowed to raise tolls annually up to 75 per cent of the increase in the consumer price index. If SCI were late they will pay for the ferry, if there are cost overruns they will pay. \$600 million will be raised by bond issues and the money to build the bridge will come from this pool. No interest will be paid to bond holders until the bridge is finished in 1997, but after that the accrued interest and principal will be about \$800 million. The real interest rate paid to bond holders will be 4.75 per cent annually. In an interview with the government's project manager for the bridge, he said the \$42 million subsidy was the amount the government figured it would cost each year to subsidize the ferry service and renew vessels over the next 35 years. There were earlier concerns about how the \$42 million figure was derived.</p> <p><i>" The Globe and Mail "</i></p>	<ul style="list-style-type: none"> •Technical •Economic •Financial 	<ul style="list-style-type: none"> •Const. •Financing
May 12, 1993	<p>Canadian taxpayers are on the hook for almost \$1.5 billion to build a bridge to PEI. SCI says government subsidies will cover only 80% of funds needed to complete the bridge.</p> <p><i>" Vancouver Sun "</i></p>	<ul style="list-style-type: none"> •Political •Stakeholder 	<ul style="list-style-type: none"> •Predesign
May 12, 1993	<p>The government was forced to defend the \$800 million project in the House of Commons yesterday after a story in The Globe and Mail reported that it will be entirely paid for by Canadian taxpayers. SCI denies that the government will assume the full risk for the project if it is not completed.</p> <p><i>" The Globe and Mail "</i></p>	<ul style="list-style-type: none"> •Political •Stakeholder 	<ul style="list-style-type: none"> •Predesign

DATE	EVENT / REFERENCE	RISK CATEGORIES	PHASE
May 14, 1993	Public Works Minister says, any environmental impact of the proposed bridge would be either insignificant or could be overcome by known technologies. The government will decide within 30 days whether to hold public hearings on the effect of the project. <i>" The Globe and Mail "</i>	<ul style="list-style-type: none"> •Cost & Time •Political •Stakeholder 	•Predesign
June 16, 1993	Legislation allowing the Federal Government to enter into a contract with SCI received third reading yesterday in the Commons. The bill approved in a 146-17 vote, now goes to the Senate for examination. <i>" The Globe and Mail "</i>	•Political	•Predesign
June 24, 1993	A bill to allow construction was approved yesterday by the Senate. <i>" The Globe and Mail "</i>	•Political	•Predesign
June 25, 1993	In mid-May, Mr. MacKay, The Public Works Minister, said his department had completed a court-ordered assessment of the proposed bridge. There is not enough public concern to warrant a public environmental assessment. <i>" The Globe and Mail "</i>	•Political	•Predesign
July 17, 1993	Federal Court Justice Bud Cullen reserved judgment yesterday in a legal challenge of the government's environmental assessment of the planned bridge. <i>" The Globe and Mail "</i>	<ul style="list-style-type: none"> •Cost & Time •Political •Stakeholder 	•Predesign
July 20, 1993	The proposed bridge is a classic example of a Maritime mega project; it uses taxpayers' money to build something that has no economic justification. <i>" The Globe and Mail "</i>	•Stakeholder	•Predesign

DATE	EVENT / REFERENCE	RISK CATEGORIES	PHASE
Aug. 13, 1993	The Federal Court scuttled yesterday what may have been the last chance to challenge the proposed bridge. A request by the Friends of the Island was dismissed. Ottawa is expected to amend the Constitution by the end of this year. <i>" The Globe and Mail "</i>	<ul style="list-style-type: none"> •Political •Stakeholder 	•Predesign
Aug. 16, 1993	Even if all the environmental hurdles have been overcome, there are still financial questions that have to be satisfactorily answered. One critic of the bridge, Acadia University economic professor Peter Townley, writing in Policy Options magazine, took apart the 1987 economic feasibility study Ottawa uses to justify the project. A bridge may be slightly more expensive than the status quo. <i>" The Globe and Mail "</i>	<ul style="list-style-type: none"> •Stakeholder 	•Predesign
Aug. 18, 1993	The saga of the span continues. Anti-bridge coalition said it will continue a legal challenge of the bridge. <i>" Vancouver Sun "</i>	<ul style="list-style-type: none"> •Stakeholder 	•Predesign
Aug. 25, 1993	Court challenges to the bridge have increased the price of the project, SCI says. SCI spent \$1 million fighting two court challenges, as well, the company has had to maintain staff of about 500 in Canada and the United States through a construction-less spring and summer. <i>" The Globe and Mail "</i>	<ul style="list-style-type: none"> •Cost & Time •Economic 	•Predesign
Aug. 25, 1993	Prices rose in the Canadian bond market 5 to 20 cents across the curve. The Federal Finance Department announced postponement of a planned issue of 4.25 per-cent real rate bonds maturing Dec. 1, 2021. The delay was aimed at avoiding conflict with the expected issue of inflation-indexed bonds by SCI. <i>" The Globe and Mail "</i>	<ul style="list-style-type: none"> •Financial •Economic •Political 	<ul style="list-style-type: none"> •Predesign •Financing

DATE	EVENT / REFERENCE	RISK CATEGORIES	PHASE
Sept. 27, 1993	Federal politicians are poised to sign the final agreement this week, but environmentalists and fishermen are vowing to turn the deal into political poison. <i>" The Globe and Mail "</i>	<ul style="list-style-type: none"> •Political •Stakeholder 	•Predesign
Sept. 30, 1993	After more than a century of schemes, dreams and politically motivated false starts, a 13 Kilometer bridge linking PEI with the mainland is about to become a reality. In recent weeks, SCI had begun issuing tenders and has reached agreements with labour organizations on PEI for the initial phase of construction of the huge structure. <i>" The Globe and Mail "</i>	•Technical	<ul style="list-style-type: none"> •Tendering & D. F. S. •Const.
Oct. , 1993	Work on the Canada's longest bridge was expected to start immediately after the scheduled Oct. 7 signing of documents for financing, designing, building and operating the Crossing. <i>" Heavy Construction News "</i>		
Oct. 9, 1993	Building of PEI bridge to begin in 10 days. The first of 35 annual payments of \$41.9 million from the Federal Government is to be received when the bridge is completed on May 31, 1997. A compensation package for the ferry workers is to be worked out by Marine Atlantic over the next 60 days. <i>" The Globe and Mail "</i>	<ul style="list-style-type: none"> •Technical •Financial •Economic 	•Const.
Oct. 20, 1993	Three ferry workers and a truck driver were charged yesterday in a connection with protests opposing the bridge. <i>" The Globe and Mail "</i>	•Stakeholder	•Managem-ent during D.& C.
Nov. , 1993	McNamara Construction Co. has been awarded a \$4.5 million site grading contract for a precast concrete storage yard at Borden, PEI. <i>" Heavy Construction News "</i>	<ul style="list-style-type: none"> •Technical •Organizational 	<ul style="list-style-type: none"> •Tendering & D. F. S. •Const. •Managem-ent during D.& C.

DATE	EVENT / REFERENCE	RISK CATEGORIES	PHASE
Nov. 5, 1993	While residents of New Brunswick look forward to the money the massive project will bring to the local economy, many are wary of the potential side-effects of a sudden increase in population. <i>" Vancouver Sun "</i>	<ul style="list-style-type: none"> •Political •Stakeholder 	•Management during D.& C.
Dec. 7, 1993	The consortium building the bridge has taken on a decidedly foreign flavor since winning the project less than a year ago, raising fears that lucrative economic spin-offs may also flee the country. <i>" The Globe and Mail "</i>	<ul style="list-style-type: none"> •Organizational •Political •Stakeholder 	•Management during D.& C.
Dec. 11, 1993	The Canadian Environmental Defense Fund has called on the Federal Government to review its contract with the U.S.-French consortium building the bridge. <i>" The Globe and Mail "</i>	<ul style="list-style-type: none"> •Political 	•Management during D.& C.
Dec. 15, 1993	The construction of the fixed link is a major reason for the expected strong economic growth in the next two years in PEI and New Brunswick. The Royal Bank predicts that PEI will enjoy an average of 4.6 growth in the coming two years <i>" The Globe and Mail "</i>		
Jan. / Feb. , 1994	The bridge will be made of precast units and will be composed of 44 main spans of 250 meters and two access viaducts on each extremity with spans of 100 meters. The complete structure will be precast in a casting yard in PEI and apart from the main frame, prefabricated parts include the marine bases and piers and precast units. These reach a record rate of 6000 tons and are placed with a floating crane specially devised for this type of a project. <i>" World Highways "</i>	<ul style="list-style-type: none"> •Technical 	<ul style="list-style-type: none"> •Design •Const.

DATE	EVENT / REFERENCE	RISK CATEGORIES	PHASE
Feb. 12, 1994	The House of Commons is getting ready to debate an amendment to the Constitution to allow construction of the bridge. The government of PEI signed an agreement last fall with SCI to start preliminary work for the bridge. <i>" The Globe and Mail "</i>	•Political	•Managem-ent during D.& C.
Apr. 2, 1994	Nova Scotia and New Brunswick government employees have collectively invested more than \$150 million from public servants' pension funds into the project by buying a portion of a special bond issue last year. <i>" The Globe and Mail "</i>	•Financial	•Managem-ent during D.& C.
Apr. 5, 1994	Just as work on the bridge was getting started, company founder and majority owner Paul Giannelia abruptly sold his construction empire to two German companies in a series of complex transactions. <i>" The Globe and Mail "</i>	•Organizational	•Managem-ent during D.& C.
Aug. , 1994	As of mid-June, 5 companies had been awarded major equipment and material supply contracts for the bridge. <i>" Heavy Construction News "</i>	•Technical •Organizational	•Tendering & D. F. S. •Managem-ent during D.& C.
Dec. 7, 1994	The Federal Government is trying to intimidate a group that unsuccessfully challenged Ottawa's decision to build the bridge, by going to court to get costs from Friends of the Island. <i>" The Globe and Mail "</i>		
Jan. 7, 1995	The Federal Government cannot recover legal fees from the group, a Federal Court Canada judge has ruled. <i>" The Globe and Mail "</i>		
Jan., 1995	Despite strict site safety guidelines a 49 year old worker fell to his death at the Borden casting yard. <i>" Heavy Construction News "</i>	•Technical	•Const. •Managem-ent during D.& C.

DATE	EVENT / REFERENCE	RISK CATEGORIES	PHASE
Feb. 27, 1995	Morrison Knudsen Corp. (MK) a major partner in the project announced an estimated loss of \$141 million U.S. for the fourth quarter and a net loss of \$175 million U.S. MK's board works to prevent insolvency. Acting chief operating officer, Robert Tinstman, says the company will not pursue mega projects that required unusual and complex financing. The focus on such projects "diverted us from our basic business where we were successful in the past," he says. <u>"ENR"</u>	<ul style="list-style-type: none"> •Technical •Organizational 	<ul style="list-style-type: none"> •Cons. •Management during D. & C.
June 20, 1995	Two-day hearing is taking place as workers construct the initial phases of the bridge. The Friends of the Island group claim that former public works minister Elmer MacKay had no right to determine on his own that environmental effects of the bridge were insignificant. The court can dismiss the appeal, order another assessment or demand a full-blown public review. <u>"Vancouver Sun"</u>	<ul style="list-style-type: none"> •Stakeholder 	<ul style="list-style-type: none"> •Management during D.& C.

DATE	EVENT / REFERENCE	RISK CATEGORIES	PHASE
June 20, 1995	<p>The Friends of the Island are challenging the fixed link in court. For the first time, the Federal Court of Appeal has authorized a live broadcast of its proceedings. The case <i>Friends of the Island v. Canada (Minister of Public Works)</i> is now being televised. The appeal hinges on whether the assessment of the bridge's environmental impact should be made only by the private developer, or whether an independent jury should be involved. Strait Crossing says Public Works has correctly concluded on three occasions that no significant environmental impacts would result from the bridge. It admits however, that the first assessment was rejected unanimously by the independent panel, and the second evaluation did not satisfy the law and that the court therefore ordered it to try again. Strait Crossing's final argument is, in effect, a plea to the court to ignore the law so as not to threaten the project's financial stability, the temporary employment of 1,200 people and more than \$700 million that has been spent or committed so far. It is generally agreed that 5% of the project has been completed.</p> <p><u>"The Globe and Mail"</u></p>	•Stakeholder	•Management during D.& C.
June 24, 1995	<p>The latest court challenge of a bridge to link PEI with mainland fizzled out when a Federal Judge, Mark MacGuigan, ruled that Canadian government acted properly when it decided independently that the bridge would not harm the environment. Calgary-based Strait Crossing had suggested financing would be threatened if the appeal was successful. The Friends of the Island group will consider a new court challenge, but admits it is running out of money. <u>"The Guardian"</u> & <u>"The Chronicle Herald"</u></p>	•Stakeholder	•Management during D.& C.

DATE	EVENT / REFERENCE	RISK CATEGORIES	PHASE
July 4, 1995	Ottawa and PEI are locked in a jurisdictional tug of war over whose laws govern the workers building the bridge. Strait Crossing consortium has signed union contracts that stipulate a 50-hour work week with a scheduled 10 hours of overtime, for a total of 60 hours. The contract conforms with PEI labour laws, but the Federal Human Resources Department insists that the interprovincial project falls under the Canada Labour Code, which sets out a maximum basic work week of 40 hours. That would force Strait Crossing to pay overtime - a time and a half- for all hours worked beyond 40, effectively doubling its overtime bill. <i>" Vancouver Sun "</i>	<ul style="list-style-type: none"> •Political •Technical 	•Const.
July 6, 1995	Gaston Martin, of the human resources department in Moncton, N.B. says "it is not a dispute- it's different opinions being debated. It's not sort of cut and dried, like the usual type of jurisdictional split, because there are different, very complex issues." He said that Ottawa has ceded ground to the province, accepting that the federal code will not apply to most unionized workers. <i>" Vancouver Sun "</i>	<ul style="list-style-type: none"> •Political •Technical 	•Const.

Obviously, the developer of the proposed 13 Km bridge has been pursuing the project through numerous ever lengthening phases, none of which is without tremendous risks. During this time, politicians have changed, the economic backdrop in terms of inflation (see Figure 3.3), interest rates (see Figure 3.3), unemployment, and so forth has changed dramatically, and ever increasing numbers of stakeholders in the project are coming forth.

3.6 CASE STUDY LESSONS

It is suggested that special features of the PEI Fixed link project may have made it a relatively easy candidate for a PPP approach in terms of its evaluation. These features include the following:

1. It is a new bridge that is supposed to replace an already existing user-pay facility, represented by the ferry service. Not only did this ease public acceptance for a toll on the bridge, since no "free good" is to be replaced by a tolled one, but also acceptable toll levels for the new bridge could be measured against existing ferry rates;
2. The almost monopolistic situation enjoyed by the bridge reduces the revenue risks significantly, since a lower bound on traffic is foreseeable equal to current ferry usage; and,
3. A significant part of the revenues is guaranteed through an indexed annual governmental subsidy.

A tableau was developed to analyze this case study (see Table 3.1). The goal was to highlight issues and risks applicable to each phase of this BOT project. However, the analysis made reflects only on the events identified in the previous section which while extensive, do not constitute a complete picture of the project to date.

It has to be noted that this analysis tableau was prepared in hindsight for the PEI bridge project case study. Its value lies in enhancing the knowledge base about the nature of risks in PPP projects. Such a knowledge base becomes vital for analyzing prospective PPP

projects when risks are viewed as future events which may or may not occur. Thus, essential tasks that face the project proponents of new projects include identification of all significant risks, estimation of their probability of occurrence and consequences in terms of changes to cost, time and scope.

MAJOR PHASE	PERFORMANCE DIMENSION	ISSUES/RISKS
PREDESIGN	<i>Cost/Time performance/risks</i>	<ul style="list-style-type: none"> - Several rounds of proposal evaluation took place before it was accepted. - The project was repeatedly put on hold for lengthy environmental reviews. - An extensive effort including time and cost for lobbying, conducting public hearings, marketing, court settlements, and public relations was undertaken by the project's proponents. - No compensation was given to the unsuccessful bidders.
	<i>Technical performance/risks</i>	<ul style="list-style-type: none"> - The proposal had to advance through a competitive bidding process. - The proposal had to consider the impact of the severe weather condition on construction and operation of the facility especially in Winter. Creativity and feasibility of the technical solution were of utmost relevance. - The proponents conducted on-site geotechnical studies before award of contract. - Insurance was required for the 35 years of operation against damage to people, vessels, or the facility itself.
	<i>Economic performance/risks</i>	<ul style="list-style-type: none"> - The extended life cycle of the project required estimates of factors like inflation far into the future. - No control over the amount of traffic, and estimating demand and revenues for an extended period of time into the future was extremely uncertain. - The lengthening duration of this phase has continuously undermined the economic feasibility of the project, given the uncertainty of the project's future and the diminishing resources of the project proponents. - The economic environment in which the project had to advance was unpredictable (see Figures 3.3 and 3.4). - Issues raised through this phase such as completion bonds, compliance bonds, labour and material bonds, protection against cost overruns and compensation for the affected groups were continuously changing the economic prospect of the project.

Table 3.1 Case Study Analysis Tableau

MAJOR PHASE	PERFORMANCE DIMENSION	ISSUES/RISKS
PREDESIGN (Cont'd)	<i>Economic performance/risks (Cont'd)</i>	<ul style="list-style-type: none"> - The government required a proposal which does not exceed the guaranteed annual subsidy of \$41.6 million for 35 years, and a subsidy indexed to inflation was crucial.
	<i>Financial performance/risks</i>	<ul style="list-style-type: none"> - The project proponents had to make evident their ability to finance the project. - An innovative financing plan was crucial to the success of the proposal. - The ability to issue bonds and raise funds in a timely fashion was vital. - Cost of funds was influenced by the government guarantees to provide an indexed subsidy and partially indexing tolls to inflation. - Costs associated with securing significant completion bonds, compliance bonds, labour and material bonds, protection against cost overruns and compensation for affected groups which came up during this phase had to be a part of the financing plan.
	<i>Environmental performance/risks</i>	<ul style="list-style-type: none"> - Environmental feasibility of the proposed project was continuously challenged by the government and the public. The project proponents inherited all environmental risks, and they had to ensure an environmentally friendly solution.
	<i>Political & regulatory issues/risks</i>	<ul style="list-style-type: none"> - Political will and commitment to support the project fluctuated throughout the time. Federal and provincial elections have affected the project's progress. - A constitutional amendment had to be passed to replace the existing ferry system. - The project imposed significant impact on the job situation in the two provinces and the surrounding ones. - The laws of Canada prohibit the creation of a monopolistic utility by the private sector. Needed was the approval of The House of Commons and the Senate. - Multiple political entities were involved in the process, since the project connects two provinces and the "client" is the Federal Government. - 40% of the PEI population were against the concept of a fixed link. There was some opposition to a fully private approach to build the bridge.

Table 3.1 (Cont'd) Case Study Analysis Tableau

MAJOR PHASE	PERFORMANCE DIMENSION	ISSUES/RISKS
PREDESIGN (Cont'd)	<i>Organizational and contractual issues/risks</i>	<ul style="list-style-type: none"> - Commitment of all participants and identification of their respective roles and responsibilities and risk share was vital. - With the changes in governments as well as the consortium organization structure, there had to be a designated spokesman with the authority to take decisions from both sectors to proceed with the process expeditiously.
	<i>Stakeholder issues/risks</i>	<ul style="list-style-type: none"> - Vocal resistance to the idea of a Fixed link between the two provinces existed. The groups opposing the project have continuously challenged it in court. - Public acceptance to a privately owned and operated facility, especially a tolled one, has repeatedly threatened to derail the entire process. - The project imposed significant impacts on existing trades and job situation, e.g. the ferry service, the fishery and so forth.
DESIGN	<i>Cost/Time performance/risks</i>	<ul style="list-style-type: none"> - The bridge design had to pass through several public reviews and court challenges.
	<i>Technical performance/risks</i>	<ul style="list-style-type: none"> - Professional liability insurance is not large enough to cover an \$840 million project. Issues of design liabilities were a problem. - The project proponents were responsible for conducting all field analysis on soil, water, tides, climate, and earthquakes in addition to all traffic studies. - 100 year useful life for the bridge was required. - The 13 km length of the bridge makes it one of the longest in the world to cross a water channel. - The bridge spans had to maintain the navigation capabilities unaffected. - Environmental loading from wind, waves, ice and earthquakes constituted significant factors for the bridge design. - The project design had to ensure all safety and quality requirements throughout its operational life time. - The existence of the bridge should not delay the passage of the ice out of the Strait by more than two days.

Table 3.1 (Cont'd) Case Study Analysis Tableau

MAJOR PHASE	PERFORMANCE DIMENSION	ISSUES/RISKS
DESIGN (Cont'd)	<i>Technical performance/risks (Cont'd)</i>	<ul style="list-style-type: none"> - The project proponents are liable in case of any problem. No entity to turn to in case of any claim or default. - Local skills and expertise had to be used for this project.
	<i>Financial performance/risks</i>	<ul style="list-style-type: none"> - Timely financing had to be ensured to cover all design expenses.
	<i>Environmental performance/risks</i>	<ul style="list-style-type: none"> - The project design had to pass several environmental tests. - The project proponents were responsible for producing an Environmental Impact Statement (EIS) for the project.
	<i>Organizational and contractual issues/risks</i>	<ul style="list-style-type: none"> - Full integration between design and construction teams had to be ensured and communication was essential.
TENDERING & DESIGN FIELD SERVICES	<i>Technical performance/risks</i>	<ul style="list-style-type: none"> - Recruiting all contractors and subcontractors in a timely fashion was the responsibility of the project proponents.
	<i>Financial performance/risks</i>	<ul style="list-style-type: none"> - Timely financing had to be ensured to cover all expenses during this phase.
	<i>Organizational and contractual issues/risks</i>	<ul style="list-style-type: none"> - Identification of roles and responsibilities for all project participants was the responsibility of the project proponents.
CONSTRUCTION	<i>Cost/Time performance/risks</i>	<ul style="list-style-type: none"> - Governmental Jurisdiction disputes surfaced during this phase. This may double the overtime bill for the project.
	<i>Technical performance/risks</i>	<ul style="list-style-type: none"> - Labour agreements stipulated that local labour force is to be used and also stipulated basic and overtime working hours. The project proponents had to assess the cost and availability of local material, equipment, and labour. In addition, training of local forces was necessary. - Construction season was extremely short. The bridge construction was susceptible to weather, currents, and ice conditions. In addition it was susceptible to constructability issues such as safety during construction, labour productivity, and so forth. - No one to turn to in case of claims accidents or problems.

Table 3.1 (Cont'd) Case Study Analysis Tableau

MAJOR PHASE	PERFORMANCE DIMENSION	ISSUES/RISKS
CONSTRUCTION (Cont'd)	<i>Technical performance/risks (Cont'd)</i>	<ul style="list-style-type: none"> - There were penalties for late delivery of the project. If completion dates were not met the project proponents will have to operate the ferry service at their own expense. Additionally, security bonds against cost overruns had to be ensured by the project proponents.
	<i>Financial performance/risks</i>	<ul style="list-style-type: none"> - Timely financing had to be ensured to cover all construction expenses.
	<i>Organizational and contractual issues/risks</i>	<ul style="list-style-type: none"> - The financial position of a major partner, Morrison Knudsen, imposed additional pressure on the entire project organization.
FINANCING	<i>Technical performance/risks</i>	<ul style="list-style-type: none"> - Timely collection of adequate financing was crucial to the success of the project.
	<i>Financial performance/risks</i>	<ul style="list-style-type: none"> - Government guarantees have helped lowering the cost of financing.
	<i>Political & regulatory issues/risks</i>	<ul style="list-style-type: none"> - Government approval and permission were needed to issue project bonds.
MANAGEMENT/QUALITY ASSURANCE OF DESIGN & CONSTRUCTION	<i>Technical performance/risks</i>	<ul style="list-style-type: none"> - All tasks of this phase were the responsibility of the project proponents. - Involvement of new partners dictated redistribution of roles and responsibilities.
	<i>Political & regulatory issues/risks</i>	<ul style="list-style-type: none"> - Jurisdictional disputes threatened to increase the overtime bill significantly. - A debate took place during this phase in the House of Commons over the constitutional amendment to build this bridge. - Involvement of foreign partners instigated concerns of loss of the economic benefits from the project to foreign companies.
	<i>Financial performance/risks</i>	<ul style="list-style-type: none"> - Timely financing had to be ensured to cover all expenses involved in this phase.
	<i>Organizational and contractual issues/risks</i>	<ul style="list-style-type: none"> - Internal transactions and redistribution of roles and responsibilities among participants were taking place during this phase.
	<i>Stakeholder issues/risks</i>	<ul style="list-style-type: none"> - The Friends of the Island group is still challenging the project in court.

Table 3.1 (Cont'd) Case Study Analysis Tableau

CHAPTER 4 - A 'PPP' ANALYSIS FRAMEWORK

4.1 INTRODUCTION

This chapter presents an overview of an analysis framework designed to assist both the public and the private sectors in evaluating PPP projects. It builds upon the experience gained during the course of working with MoTH-B.C., interacting with ministry personnel, compiling the PEI bridge case history, and relevant knowledge as presented in the literature.

The goal of this framework is to offer the analyst an organized approach to evaluate projects that are candidates for a PPP approach at the micro level (which covers specific project phases and potential risks). However, since a project might be economically viable to construct but not beneficial from a benefit-cost or planning viewpoint, and conversely, a project could be acceptable from a benefit-cost viewpoint but not economically viable, reference is also made to the macro level of the analysis as a prerequisite (e.g. identification of the need, definition of the project, its objectives, environment, and constraints).

4.2 THE FRAMEWORK OBJECTIVES

The objectives sought for the suggested framework are to aid both sectors in pursuing the following essential tasks:

1. *Develop the insights needed to analyze PPP projects.* As explained in the previous chapters, invoking PPP in the process of analyzing already complex projects, tends to magnify their complexity and invariably imposes new risks. A robust tool which allows

the analyst to explore various project scenarios in a systematic way is, therefore, crucial. In addition to examining various assertions made in the literature and by project participants (e.g. the potential for fast-tracking design and construction, and accelerating construction), the insights needed include identifying the potential risks, their consequences and their relative magnitude.

2. *Establishing the case for and the case against PPP for a given project.* This is an important task needed to substantiate the candidacy for any given infrastructure project for PPP. That is, since departure from the traditional approach of acquiring infrastructure is not without disadvantages, the pros and cons for adopting PPP as opposed to the traditional approach have to be thoroughly and objectively examined.
3. *Identifying the best fit in the PPP spectrum.* Obviously, not all forms of PPP are suitable for every project, and implementing the wrong form of PPP may prove costly (Crosslin, 1991). Therefore, adopting an objective approach to undertake such a task is paramount to the implementation of a successful PPP.
4. *Developing a meeting of the minds and negotiating a concession agreement.* One potential way of achieving these objectives is by examining fundamental issues such as a shared image of the magnitude of various risks, rates of return commensurate with the risks involved, equitable risk assignment among participants, required governmental guarantees, etc. Such issues are crucial to the establishment of lower and upper bounds for what may constitute acceptable terms and conditions for the project implementation from the perspective of both sectors, thus providing for a meeting of the minds, and a

constructive negotiation of the concession agreement.

4.3 DESCRIPTION OF THE FRAMEWORK

The starting point is what Yaworsky (1994) described as Propose-Evaluate-Negotiate (PEN) phases which precede and lead to the implementation of any BOT project. Recognizing the considerable front-end efforts and expenditures necessary before the project can ever be 'built', he suggested the "PEN-BOT" acronym as more appropriate than simply "BOT", and emphasized the "PEN" phases as being critical in terms of risks and uncertainties. In terms of this research, a more general acronym would be "PEN-PPP." Yaworsky (1994) proposed three iterative and cyclical stages (see Figures 2.12 & 2.13), which he suggested would be most applicable to the "PEN" phases of the "PEN-BOT" model. These three stages are:

Stage I - Definition of the project's Environment.

Stage II - Definition of the Project.

Stage III - Processing and adjusting the Project's Risks.

In addition, and without pursuing their details in depth, he alluded to another two stages namely "*Preliminary Feasibility Assessments*" which may take place early in the process, and "*Project Implementation*" which lies at the end of his framework.

Yaworsky's framework is used as a building block and is further enhanced in this research by operationalizing parts of it, to provide for the quantitative assessment aspect of the process, and to incorporate the experience gained while working with MoTH-B.C.

As depicted in Figure 4.1, the suggested framework is composed of seven cyclical stages, which basically take place during the "PEN" phases.

Stage I:

This stage is covered to a great extent in Yaworsky's work (1994), and is represented by 'Stage I' in Figure 2.12. It consists of a series of activities (see Figure 2.13) so as to define the project's environment, and includes identification of the need for the project (in the case of the public sector this activity may include performing a benefit-cost type of analysis), definition of its objectives, and identification of any external influences that may affect its progress (e.g. global forces, political agenda, etc.). The *environment* of the project is considered broadly as the circumstances and surroundings in which the project must exist, be influenced by, as well as influences (Yaworsky, 1994).

This stage also includes a preliminary feasibility assessment which is considered to be an evaluation, assessment or prediction of the project's behavior or characteristics as related to minimum thresholds of acceptability. This may be performed at a far more superficial level during this stage since enough information about the project is not yet available. As more information become available during subsequent stages, more formal assessment's will be required.

In a focused study made by Weaver (1991) in which he summarizes his findings on important topics such as preliminary engineering approval, documentation, forecasting as well as feasibility studies persistently ignored in recent editions of some 38 project-economics text, business school texts, chemical engineering texts and others, 79% of the books he reviewed

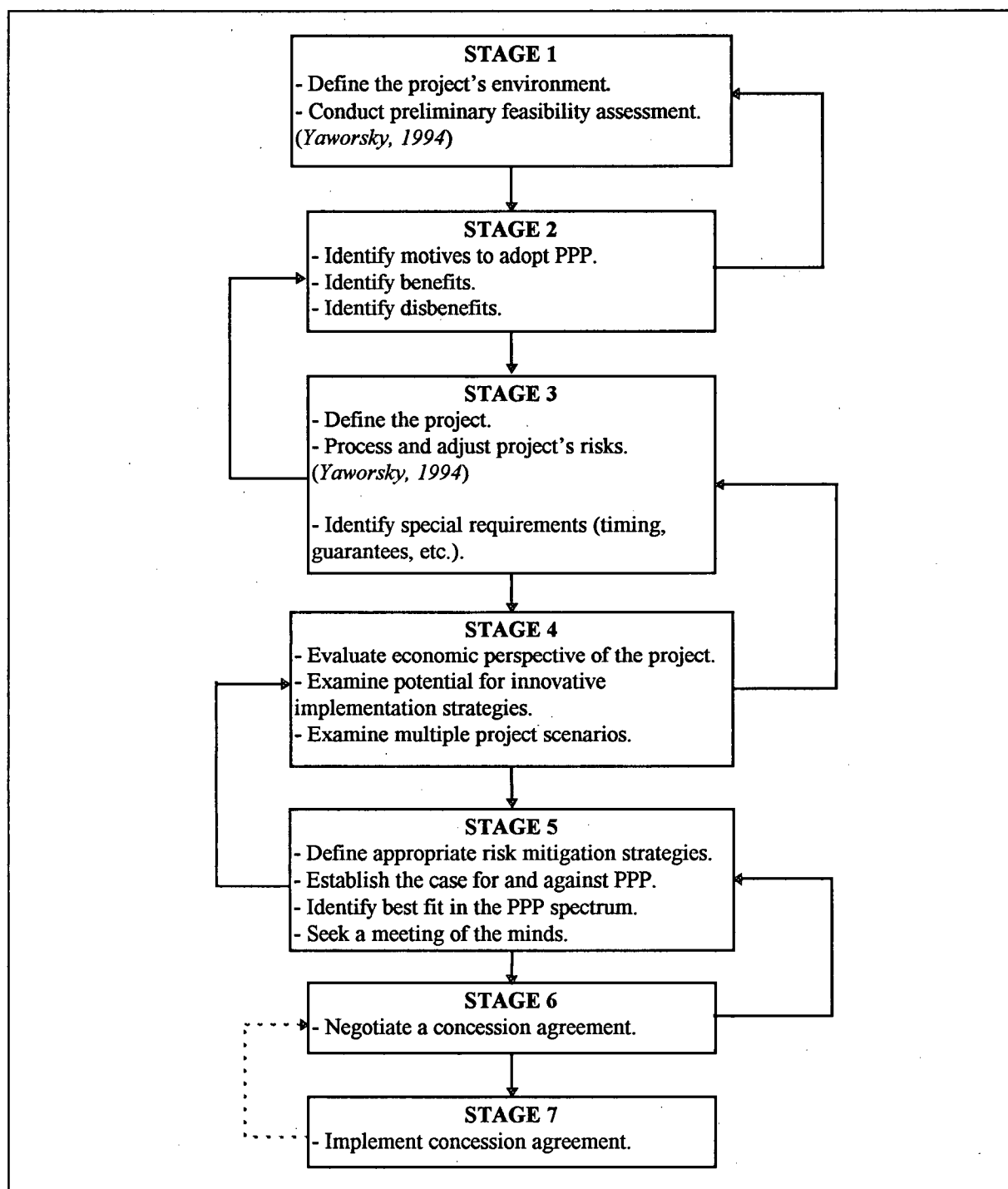


Figure 4.1 PPP Analysis Framework

ignored the subject of feasibility studies. He also raised some unanswered questions such as, how should early studies be handled? What data should be available before the first

profitability calculation? How often should it be repeated? However, in this research, it is assumed that the experience of the project team and project proponents will play a major role in finding meaningful answers to these questions.

In practice, the idea for a project may be born or resurrected in the private sector which may then wish to advance it as an unsolicited proposal. Or, alternatively, it may be born in the public sector. In either case, objectives and expectations of each sector may differ widely. Each sector, therefore, may approach this stage from a significantly different point of view. As a result, and especially in the case of unsolicited proposals, on the one hand, significant effort, time and money are often wasted by both sectors over investigating projects which are unworthy or of marginal benefits to the public. On the other hand, and realizing the considerable amounts expended during this phase by the private sector, a concept of *honorarium* paid by the government to the losing bidders is currently emerging to encourage more private sector involvement early in the process (Cowper-Smith, 1995). A debatable issue arises in this case as to who owns the proposal after it's been paid for? The government must, therefore, clearly communicate its objectives and expectations to the private sector as early in this stage as possible, to safe guard the public interest without unnecessarily depleting vital resources.

Stage 2:

Chapter 2 elaborated on several benefits and disbenefits for adopting a PPP approach as opposed to the traditional one. This stage is introduced in the framework to emphasize the need for a formal articulation of this issue. Each sector must clearly understand its motives

for involvement in such an onerous and prolonged process and assess benefits and disbenefits accordingly. In general, motives for the public sector may range from political will and budget constraints to innovation requirements. Motives for the private sector may be to pursue new ventures in a shrinking traditional market, seizing the opportunity of a forecast demand, or just a response to a request for proposal (RFP) made by the government. The commitment and effort needed for this approach may render the latter motive inadequate. Evidently, the level of commitment of both sectors to the partnership reflects directly on the chances of a successful implementation of a PPP.

However, throughout the protracted "PEN" stage of a project, its environment and constituent as well as the government change continuously. In addition, the consortium pursuing the project continues to evolve. Both sectors, therefore, must systematically assess the benefits and disbenefits and, if needed, redefine their objectives.

Stage 3:

This stage is covered in great detail in Yaworsky's work (1994), and is represented by 'Stages II & III' in Figure 2.12. It includes activities such as identify project approaches or technical solutions, identify potential project participants and stakeholders and their respective objectives, define failure and success criteria, assess the potential for conflict of objectives and of failure and success criteria, etc. (see Figure 2.13). In practice, some of these activities may be downplayed, or completely ignored due to unfamiliarity with what needs to be done. Or, especially in the public sector case, because of the difficulty faced by the project team to maintain full control over the process due to time constraints, the existence of hidden agendas,

or pressure from politicians or the public advocating one approach or the other, they may be forced to compromise some of these activities. Obviously, this may increase the risk potential.

An implicit assumption is made in Yaworsky's work, however, that the framework is applicable to a potential BOT project. But, since the outlook of a project in terms of its constraints, participants, stakeholders, failure and success criteria etc. is dependent to a great extent on the adopted approach, and given that the motives to adopt PPP are demonstrated by both sectors but it is not known this early in the process which approach is more appropriate (i.e. traditional versus any member of the PPP spectrum), this stage must be pursued based on the premise that PPP is as potentially viable as an approach as is the traditional one. A comparison of the project's outlook at its macro level, therefore, could be made between the traditional approach as a bench mark, and the PPP approach.

To illustrate, and drawing from the work performed for MoTH-B.C. in the course of this research, proprietary templates were designed to simulate the entire process for undertaking a bridge project by both traditional and PPP approaches, and a comparison was made. These templates included all activities, sub-activities, milestone events and estimated durations as approved by the project team and key MoTH personnel. By way of comparison, the significantly prolonged front-end of the PPP process in relation to the traditional one was demonstrable. This is a particularly important finding for projects where time is of the essence.

In addition to the aforementioned, special requirements which may potentially enhance the chances of success for the project such as suitable timing in which to advance the project in

terms of the political and economic environment, required governmental guarantees or subsidies, right for first refusal for future and competing facilities, etc. have to be carefully addressed at this stage.

Throughout this stage, all significant risks must be identified and analyzed based on the understanding developed about the project and its environment, and based on the experience gained and catalogued from previous projects (e.g. The PEI case study). A major fear is failure to identify a risk source, because it is novel, outside the experience set of the project team, or just simply overlooked. Moreover, since risks at this stage represent future events, the analyst must also estimate their probability of occurrence, and, if possible, their exposure or likely impact on basic project parameters in terms of cost, time or scope. A systematic process is developed in this research to assist the analyst in conducting such a task. This process (illustrated in Figure 4.2) is explained in detail in Chapter 6. Furthermore, it is suggested that a tableau similar to the one shown in Table 4.1 be completed in order to catalogue the risks thought to apply to each project phase and performance dimension. This tableau can then be used in the next stage to check which risks have been formally treated in the quantitative analysis, and which ones are not amenable to formal modeling (e.g. some aspects of political risk). Additionally, it can be used to assist in compiling a list of relevant risk mitigation strategies as suggested in stage 5. The information in this tableau will, therefore, have to be continuously modified and adjusted throughout stages 3, 4 and 5.

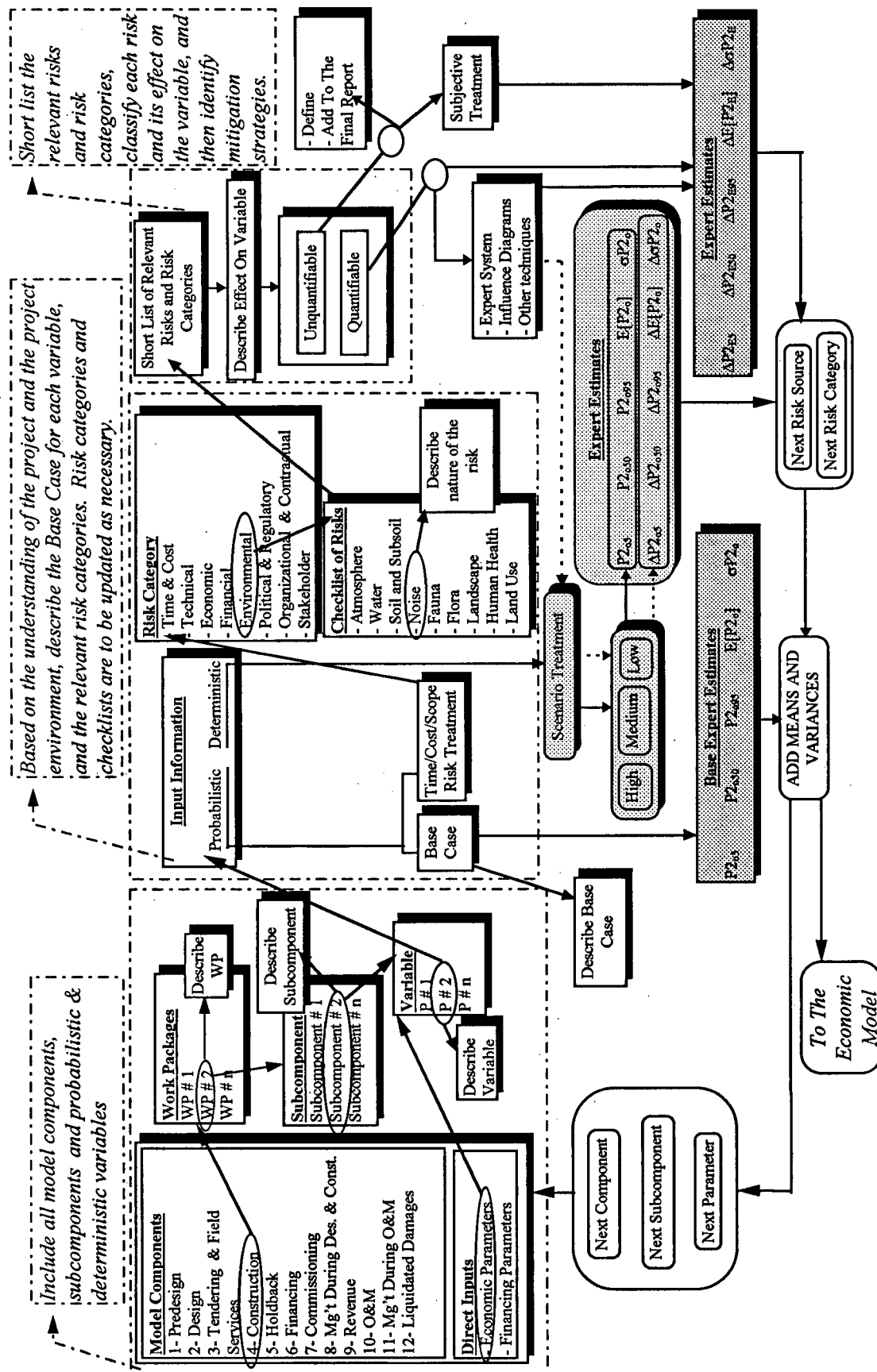


Figure 4.2 Risk Analysis Process For Public-Private Partnership Projects

1	2	3	4	5	6	7	8
Major phase	Performance dimension	Description of conditions/risks	Probability of occurrence	Impact on cost	Impact on time	Impact on scope	Mitigation strategies
Pre-design	Cost & Time performance/risks Technical performance/risks Economic performance/risks Financial performance/risks Environmental performance/risks Political & Regulatory performance/risks Organizational & Contractual performance/risks Stakeholder performance/risks						
Design.....	Cost & Time performance/risks Technical performance/risks Economic performance/risks Financial performance/risks Environmental performance/risks Political & Regulatory performance/risks Organizational & Contractual performance/risks Stakeholder performance/risks						

Table 4.1 Analysis Tableau For Project Risks Versus Phases & Performance Dimensions

Stage 4:

The compiled information on potential risks and their estimated impact as presented in columns 1 through 7 of Table 4.1 are required to perform the quantitative analysis at the micro level of a project in this stage. Chapter 5 presents an economic model developed for this purpose. Usage of realistic estimates for basic project parameters and the relative impact of risks on such parameters is essential to generate meaningful results while employing this economic model. The form of these estimates and their adjustment to include the impact of potential risks (columns 4, 5, 6, and 7 of Table 4.1) are explained in Chapter 6.

This economic model allows the analyst to examine multiple project scenarios. Such scenarios may include different modes of procurement (e.g. traditional versus PPP), different design alternatives each with different estimates and project parameters (e.g. tunnel versus bridge), or different variable values to include high, medium, and low estimates for key input variables such as inflation for example. Several issues could then be addressed in quantitative terms. For example, rates of return, probability of failure, effectiveness of different implementation strategies such as fast-tracking design and construction and accelerating construction, investigation of various financing scenarios, the relative magnitude of all significant risks etc., are issues which are vital to a successful undertaking of the project from the perspective of both the private and the public sectors.

In brief, each sector will approach the negotiation table with its own views and expectations. The economic model suggested in this research constitutes a robust tool for their use to quantitatively assess the viability of the project scenario in terms of risks and profitability,

examine the validity of the assertions or claims made by the other party, and ultimately provide for a meeting of the minds.

Stages 3 and 4 of this framework are the focus of this research and will be further explained in subsequent chapters.

Stage 5:

Results from previous stages are examined in this stage and requirement for further analysis are identified. Moreover, having measured the relative magnitude of all significant risks in the project, determination of appropriate risk mitigation strategies becomes essential. Such strategies are to be highlighted in column 8 of Table 4 in order to maintain a complete record of risk for monitoring purposes. This also provides for enhancing the knowledge base for use in future projects. Depending on the nature of risk, mitigation strategies may include, use of contingency plans, adoption of special insurance plans and so forth. Risk mitigation, however, is not treated in this research.

Other important tasks involved in this stage include:

- Establishment of the case for and the case against PPP. This can be achieved by qualitatively and quantitatively evaluating the pros and cons of adopting PPP versus the traditional approach. The analysis described earlier in stage 3 along with the results generated in stage 4 of this framework constitute the basis for such evaluation. Ideally, the analysis should include the PPP mode of procurement, and if applicable each design alternative, as well as the traditional one. A tableau similar to the one shown in Table 4.1 should be prepared for each approach. The traditional approach can then be used as a

bench mark to hold objective comparison among all options, and viable ones can be highlighted.

- Once the viability of PPP is proven, comparative analysis for the project outlook while adopting different PPP forms of procurement will assist in identifying the best fit in the PPP spectrum. A similar analysis to the one described above can be made for the different PPP modes of procurement to identify the most promising ones. Specific criteria must be made beforehand to make the decision. Such criteria may include cost to users, time for completion, magnitude of risks involved, public acceptability, etc.
- A meeting of the minds is the back bone of a successful implementation of PPP. The qualitative and quantitative risk assessment framework suggested in this chapter constitutes a particularly useful tool in that regard. Each sector can use this framework to evaluate the project outlook and assess the risks involved prior to formally engaging in such a lengthy process, and in light of the previously defined objectives by each sector assess the project potentials.

Stage 6:

Tremendous negotiation skills and understanding of the project and its environment, as well as the risks involved and their consequences are necessary while drafting a concession agreement. While advancing through the previous stages of this framework, and depending on the accuracy of the information and estimates used, each sector would have developed considerable insights into the anatomy of the project which in turn will assist in undertaking this stage.

Noteworthy is that the suggested framework is designed to raise the issues and highlight the risks involved. A potential area for conflict exists when the parties involved in the process tend to overestimate their risks. This may create significant difficulties in translating the commitment of each party into a concession agreement. This also represents a potential difficulty in promoting any such frameworks among project participants. The advantages offered by this framework, as envisioned by the author, will be achieved when both sectors can openly use it as a reference to compare and test their views. In practice, this may not be easily achievable. The usefulness of the framework is, nonetheless, substantial for each sector if they opt to use it individually.

Stage 7:

This final stage involves implementing the concession agreement and indicates the completion of the "PEN" phases by signing the agreement and commencing the final design and construction of the facility. In contrast to all the above cyclical stages where advancing to a preceding stage or revisiting a previous one is frequent, once this stage is initiated, revision of the concession agreement any time in the course of the implementation process will depend on the terms and conditions of the original concession agreement. This is indicated in Figure 4.1 by the upward solid and dotted arrows respectively.

Finally it has to be noted that the stages identified inherit the characteristics of the tasks they encompass. They often have no definite beginning or end, they generally overlap one another, and their durations can be very long. Thus, from a planning point of view, it is very hard to estimate durations, and consequently costs, for such stages with any degree of certainty.

Defining a time frame in which this framework can take place is in most cases difficult. Yaworsky (1994) presented a schematic diagram which highlights the typical overlapping and cyclical nature of these stages. Some periods where the project becomes dormant may also exist. This schematic is depicted in Figure 4.3.

The significance of this assertion becomes apparent when trying to establish a datum or a reference point in time with which to economically evaluate a project. It also indicates the potential for significant losses of time, money and effort by all parties involved in the process. This is particularly clear in the case of the PEI bridge project, which has been discussed and debated since the 1880's (Duncan, 1988), with construction finally starting in 1993.

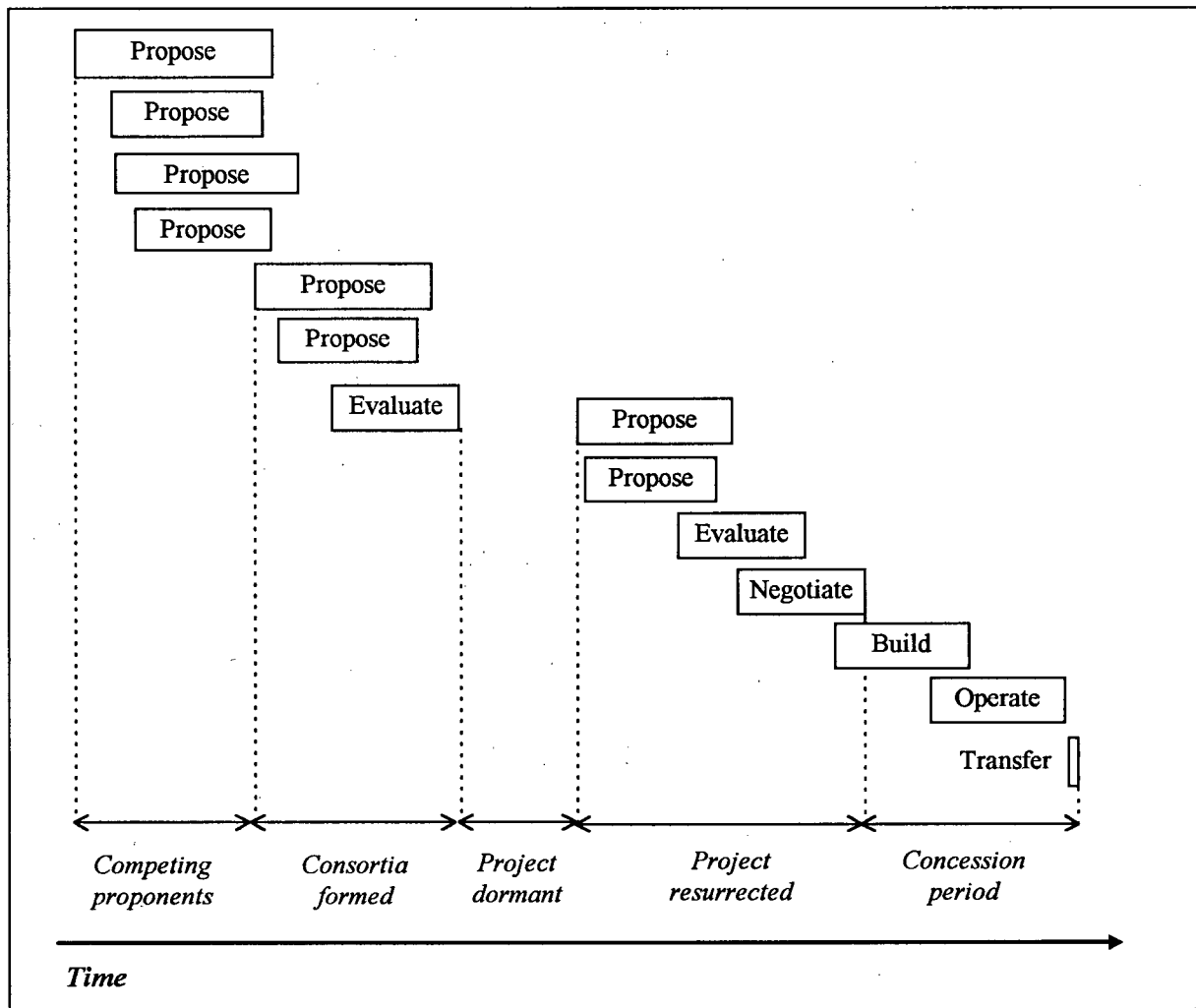


Figure 4.3 Typical Overlapping, Cyclical Phases of the 'PEN-BOT' approach (Yaworsky, 1994)

CHAPTER 5 - THE ECONOMIC MODEL

5.1 BACKGROUND

Dividing up the engineering development process, starting from a project idea all the way to a full scale in-production facility, into a number of phases is by no means unique or universal. There can be, and often are, any number of such phases, since the business of dividing up a generally continuous process into number of phases is arbitrary (Vernon, 1988). Nevertheless, staging the development process, especially for large projects, is useful in order to provide sufficient milestones against which the project's progress can be measured. More importantly, it facilitates identifying the various risks and risk areas in the project. In general, phases are distinguished by the type of characteristic tasks and linked by decision points (Adams & Brandt, 1987). For example, a generic perspective, for the various project phases, adopted by Adams & Brandt (1987) calls for four phases:

- 1- *Conceptual phase*: Identify need, establish feasibility, identify alternatives, budget, schedule, organize project team.
- 2- *Planning phase*: Implement schedule, conduct studies, design.
- 3- *Execution phase*: Procure, construct.
- 4- *Termination phase*: Train, transfer project, reassign team.

These phases are oriented towards a traditional model of project delivery, from the perspective of the owner (phase 1), the consultant (phases 2,3,4) and the contractor (phase 3). A slightly different view suggested by Vernon (1988) divides projects into six phases.

- 1- *Conceptual design*: Identify the aim and alternatives.
- 2- *Feasibility study*: Analyze and assess alternatives
- 3- *Performance specification*: Identify standards, specifications, level of detail required in design, etc.
- 4- *Outline design specification*: Preliminary design, and value engineering.
- 5- *Detailed design*: Complete detailed design and construction specification.
- 6- *Construction supervision*: Supervise construction works until completion.

Other views might include only Design, Construction planning, Construction, and Operation for project phases (Ashley, 1987).

The world bank has a different breakdown for the project phases (Baum and Talbot, 1985) which includes:

- 1- *Identification*: Identify ideas which may meet objectives and priorities.
- 2- *Preparation*: Assess the technical, economic, financial, social, political, institutional and environmental feasibility of the project.
- 3- *Appraisal*: Formal assessment process and commitment to finance and proceed.
- 4- *Implementation*: Construct project.
- 5- *Evaluation*: Evaluate the completed project against its objectives.

These five phases, since they present the viewpoint of a financing and/or developer institute, don't consider, for example, the operation phase.

Tiong (1990a) describes a typical BOT project as having five phases:

- 1- *Pre-Investment*: Feasibility study.

2- *Implementation*: Engineering and design, concession agreements, project financing.

3- *Construction*: Building the facility.

4- *Operation*: Operation and maintenance, sale of products or toll collection, loan repayment.

5- *Transfer*: Transfer of ownership to government.

Also, and as described earlier in Chapter 4, Yaworsky (1994) adopts a more detailed project cycle to analyze such projects namely, the "PEN-BOT" phases, which stands for: Propose, Evaluate, Negotiate, Build, Operate and, Transfer. Of note, the transition between these phases are characterized by owner approvals and decisions to proceed to the following phase. These decisions, however, might not be as clear in the generally cyclic and protracted PEN phases as they are in the BOT phases.

In order to analyze large infrastructure projects, as this research attempts to do, a detailed yet manageable real world representation for such projects is crucial. Building on the work just described, a decomposition of a project is proposed in this chapter which treats the complete life-cycle of a PPP project. A single level of representation for major work items and cash flows is maintained throughout the project life-cycle to keep the model formulation process simple and manageable. An alternative approach would be using a multi-tiered breakdown structure that includes for example phases and sub-phases. The proposed project decomposition includes the following:

1- *Predesign*

2- *Detailed Design*

3- *Construction*

- 4- Tendering and Design Field Services*
- 5- Commissioning*
- 6- Management during Design and Construction*
- 7- Financing*
- 8- Revenues*
- 9- Operation and Maintenance*
- 10- Debt Servicing*
- 11- Management during Operation and Maintenance.*
- 12- Transfer*

5.2 ECONOMIC MODEL OBJECTIVES

The objectives that guided development of the economic model are:

- 5.2.1- While unifying the phases and the cost, time and scope consequences of the performance/risk dimensions which characterize a project, the model is to provide basic insights into the economics of projects that are potential candidates for PPP;
- 5.2.2- It allows exploration of multiple project scenarios in terms of procurement approach (e.g. traditional versus PPP), different design alternatives as represented by project parameters (e.g. tunnel versus bridge), implementation strategies (e.g. fast-tracking design and construction, construction acceleration, etc.), and input variable estimates (for example: high, medium, and low estimates for general rate of inflation), and facilitates investigation of the behavior of economic performance measures as a function of the adopted scenario; and
- 5.2.3- It helps identify assignment of risks, returns commensurate with risk assignments, etc.

5.3 MODEL COMPONENTS

As shown in Figure 5.1, a highly aggregated cash flow representation of a project for purposes of generating a Net Present Value (NPV) economic model has been adopted. All NPV's are evaluated at time zero which coincides in the model with the start of the predesign phase and is the baseline for constant dollar costs. A major virtue of the net present value formulation is that it embodies many of the performance measures such as internal rate of return (IRR) on equity, internal rate of return on total capital, etc. Other performance measures can also be evaluated (e.g. probability of failure).

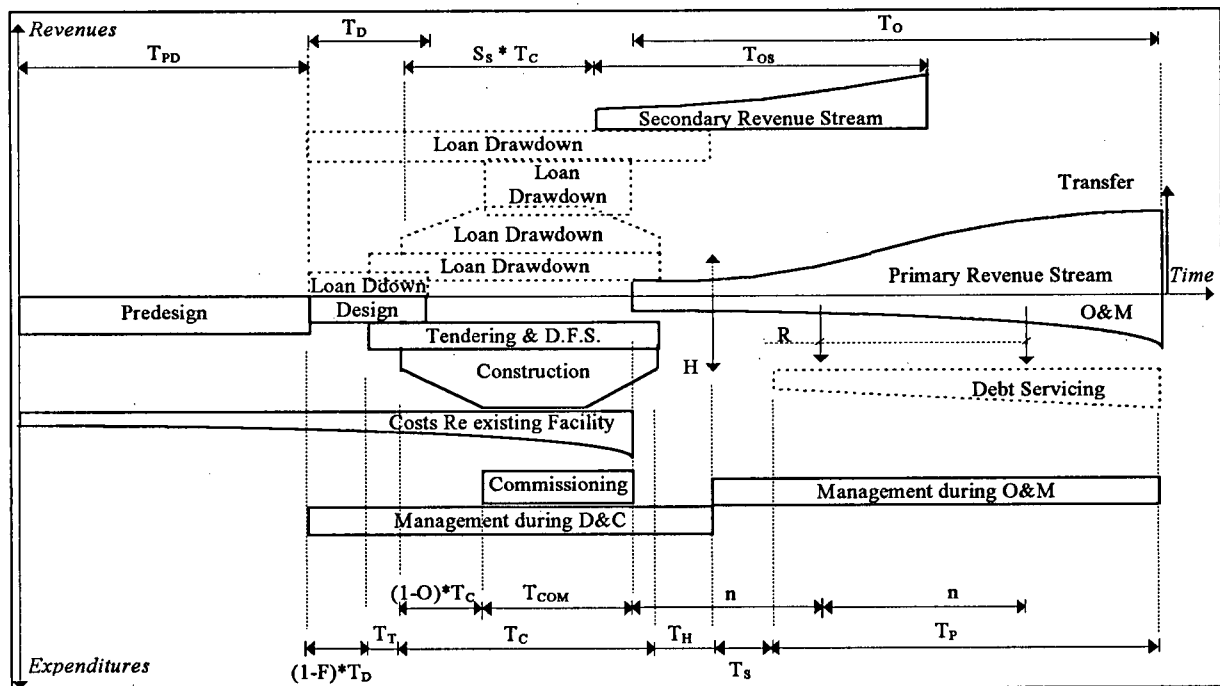


Figure 5.1 General Project Cash Flow

The model is designed to simulate a user-pay transportation infrastructure project, and to serve the needs of a public-sector development of the project, using an investment analysis

perspective, as well as a PPP approach. It is composed of a number of probabilistic and deterministic parameters and variables which are defined in Table 5.1.

CASH FLOW	SYMBOL	DESCRIPTION
Predesign		
	T_{PD}	Duration in years, of predesign phase
	C_{PD}	Constant dollar rate per unit time predesign expenditures
Detailed Design		
	F	Degree of overlap between design and construction ($0 \leq F \leq 1$)
	T_{Db}	Duration, in years, of design phase for traditional, public sector approach
	T_{DF}	Time penalty, in years, for design phase for fast-tracking degree when $F = 1$
	T_D	Design duration $T_D = T_{Db} + T_{DF} \cdot F$
	d_D	Cost of detailed design as a fraction of current dollar construction cost
	E_D	Fraction of detailed design cost paid from equity funds
Tendering and Design Field Services		
	T_T	Time, in years, required for tendering and award of first construction work package
	d_T	Cost of tendering and design field services as a fraction of current dollar construction cost
	E_T	Fraction of tendering and design field services paid from equity funds
Construction		
	T_{Cb}	Construction duration in years for traditional approach
	T_F	Construction duration time penalty, in years, for fast-track value of $F = 1$.
	T_O	Construction duration time penalty, in years, for construction and commissioning/revenue overlap value of $O = 1$.
	A	Degree of acceleration of construction phase ($0 \leq A \leq 1$)
	O	Degree of overlapping of construction and commissioning/revenue phases ($0 \leq O \leq 1$)
	T_C	Duration of construction phase $T_C = (T_{Cb} + T_F \cdot F + T_O \cdot O) (1 - A)$
	C_{ob}	Constant dollar construction cost for traditional approach derived from constituent work packages
	z	Shape factor for constant dollar expenditure
	w_1	Shape factor for constant dollar expenditure
	w_2	Shape factor for constant dollar expenditure
	C_{oA}	Constant dollar construction cost penalty for $A = 1$.
	C_{oF}	Constant dollar construction cost penalty for $F = 1$.
	C_{oO}	Constant dollar construction cost penalty for $O = 1$.
	C_o	Constant dollar construction cost $C_o = C_{ob} + C_{oA} \cdot A + C_{oF} \cdot F + C_{oO} \cdot O$
	E_C	Fraction of construction costs paid from equity funds
	$\Delta\theta_C$	Differential inflation rate for construction

CASH FLOW	SYMBOL	DESCRIPTION
Commissioning		
	T_{COM}	Time in years required for essential commissioning
	C_{oCOM}	Constant dollar cost of commissioning
	E_{COM}	Fraction of commissioning costs paid from equity funds
	$\Delta\theta_{COM}$	Differential inflation rate for commissioning
Management During Design & Construction		
	C_{oMTGC}	Constant dollar rate per unit of time for management expenditures during design construction phases
	E_{MTGC}	Fraction of management costs paid from equity funds
	$\Delta\theta_{G1}$	Differential inflation rate for Management during D&C.
Holdback Release		
	T_H	Time, in years, when holdback is released after both essential commissioning and construction are completed
	h	Holdback fraction
	E_H	Fraction of holdback release paid from equity funds
Primary Revenue Stream		
	T_o	Length of operating phase in years
	Γ	Fare or user charge per trip at time zero
	Γ_o	Inertia toll value in dollars/trip below which demand equals V_o
	V_o	Annual volume of trips at start of operation, assuming no tolls.
	v_f	Fraction of fixed or captive users
	λ	Decrease in usage as a function of toll level
	θ_v	Growth rate of trips per year
	g	Fraction of general inflation rate to which tolls are indexed
Secondary Revenue Stream		
	T_{os}	Duration of secondary revenue Stream
	S_s	Lag, in years, between start of construction and start of secondary revenue stream
	S	Constant dollar rate of secondary revenue stream
	$\Delta\theta_s$	Differential inflation rate for secondary revenue stream
Operating & Maintenance Costs		
	M	Constant dollar annual cost of O&M at time zero
	m	Slope of linear increase in constant dollar operating and maintenance costs
	R	Constant dollar cost at time zero of major expenditures for repainting/resurfacing
	n	Interval, in years, between major expenditures for repainting/resurfacing
	$\Delta\theta_{O\&M}$	Differential inflation rate for O&M
Management During Operating Phase		
	C_{oMGTO}	Constant dollar annual cost for management during operating phase
	$\Delta\theta_{G2}$	Differential inflation rate for management during O&M

CASH FLOW	SYMBOL	DESCRIPTION
Operating & Maintenance Costs of Existing Facility		
	M_{ex}	Constant dollar annual cost of operation and maintenance of existing facility at time zero.
	EX	Rate of increase in operating and maintenance cost for existing facility
	k1	Time in years for uniform expenditures
	k2	Time in years when costs start to increase
	$\Delta\theta_{EX}$	Differential inflation rate for O&M of existing facility
Financing and General Economic Variables		
	T_p	Length of time, in years, for amortization of debt
	T_s	Lag in years between holdback release and start of debt servicing
	θ	General, long term inflation rate
	i_c	Loan interest rate during design and construction
	i_p	Interest rate during debt servicing period
	y	Pretax minimum attractive return (discount rate)

Table 5.1 Definition of Model Parameters and Variables

The net present value for the total project is thus computed as:

$$\begin{aligned}
 NPV = & NPV_{PREV} + NPV_{SREV} - NPV_{PD} - NPV_D - NPV_T - NPV_C - NPV_{COM} - NPV_{MGTC} \\
 & - NPV_H - NPV_{O\&M} - NPV_{MGTO} - NPV_{DS} - NPV_{LD}
 \end{aligned} \tag{5.1}$$

in which:

NPV_{PREV} is the present worth of the primary revenue stream,

NPV_{SREV} is the net present value of secondary revenues,

NPV_{PD} is the net present value of the expenditures prior to detailed design,

NPV_D is the present worth of the equity input to detailed design,

NPV_T is the present worth of the equity input to tendering and design field services,

NPV_C is the present worth of the equity input to the construction phase,

NPV_{COM} is the present worth of the equity input to essential commissioning,

- NPV_{MGTG} is the present worth of equity input to management of the overall project during the design and construction phases,
- NPV_H is the present worth of the equity input to holdback release,
- $NPV_{O\&M}$ is the present worth of all operating and maintenance costs,
- NPV_{MGTO} is the present worth of the management costs during the operating phase,
- NPV_{DS} is the present worth of debt servicing, and
- NPV_{LD} is the present worth of liquidated damages (operation and maintenance of existing facility).

All components of these net present value expressions can be written as explicit functions of the variables defined in Table 5.1. For example, for the commissioning phase,

$$NPV_{COM} = \frac{T_{PD} + (1-F) \cdot T_D + T_T + (1-O) \cdot T_C + T_{COM}}{T_{PD} + (1-F) \cdot T_D + T_T + (1-O) \cdot T_C} \cdot \frac{C_{oCOM}}{T_{COM}} \cdot e^{[((\Theta + \Delta\Theta_{COM}) - y) \cdot t]} dt \cdot E_{COM} \quad (5.2)$$

See Appendix A for net present value expressions for each of the components in equation 5.1.

A long term goal in support of the NPV model should be to develop a computer based tool which provides for the analysis of different schemes and scenarios of construction, financing, operation and maintenance, debt servicing, etc. Such a tool should facilitate the treatment of a hierarchical representation of all variables that might be involved, including primary as well as derived variables (e.g. scope, productivity, and level of resources, as well as time).

The goals sought in this thesis in terms of model building are precursors to the long term goal mentioned above, and include development of an understanding of the dynamics of PPP in general, and identification of knowledge gaps and areas that need further research. A comprehensive, yet highly aggregated representation that captures the key variables and parameters of a major infrastructure transportation project was sought in the model formulation process. Simplifications have been sought in terms of the amount of data which must be specified, both to keep the task of describing the project to a manageable level, and more basically, to reflect the level of data available in the preliminary feasibility phase. For example, all time and cost inputs are specified directly in the appropriate components of the net present value equation, as opposed to working with more elaborate estimating functions expressed as a function of fundamental variables such as scope, resource level and productivity variables.

Moreover, decomposition of each individual cash flow item, in terms of number and scope of variables used, is dependent on the nature, as well as the familiarity with that cash flow as reflected in the literature. Therefore, consistency in representation for the different phases may vary accordingly. For example, only two variables (T_{PD} , C_{PD}) were used to represent the predesign cash flow, while several variables were used to describe construction expenditures and their associated cash flow.

In the following subsections a description of the various model components and cash flows along with the assumptions used is presented.

5.3.1 Predesign

Large infrastructure projects which are candidates for PPP arrangements, tend to be characterized by large front-end costs. Lengthy and extensive negotiations for such projects are the norm rather than the exception. Moreover, public involvement and stakeholder issues as well as political and social impacts can profoundly affect this phase both in terms of cost and time. As such, this phase can be full of uncertainties for high profile controversial projects especially those which have the potential for real or perceived environmental impacts (Yaworsky, 1994).

The cyclic nature and protracted length of this phase may not only frustrate the project sponsors efforts and deplete their resources, but it also tends to defer the realization of any benefits or revenues further into the future, assuming they win the concession. This may jeopardize the economic viability of the entire project and ultimately render it infeasible. Also, lack of familiarity by both the public and private sectors with negotiating a concession agreement makes the process even more complex and time consuming. Recognized needs, technological skill, managerial skill, financial resources, and political will, therefore, are fundamental factors needed for smooth and expeditious progress for this phase and indeed the entire project.

During this phase, project proponents in a public-private partnership will have to bear all expenditures associated with:

- Conducting preliminary studies;
- Forming and organizing the consortium;

- Preparing and submitting proposals to the government; and
- Lobbying to gain political and public support.

Some projects have tremendous government support, which provides full or partial reimbursement for the costs incurred by the private sector during this phase (for example, the Highway 407 project in Canada (Cowper-Smith, 1995)). In most cases, however, these costs are not reimbursable, and the sums involved can be enormous. For example, \$2,200,000 was spent by the project sponsors on the feasibility study and proposal submissions for the Sydney Harbor Tunnel project (Bruke, 1989). More dramatically, between \$15,000,000 and \$20,000,000 has reportedly been spent by the winning consortium for the PEI crossing.

From a public sector perspective, this phase includes all tasks and expenditures associated with conducting studies, retaining consultants (e.g. traffic, geotechnical and environmental studies, consortia evaluations, etc.), evaluating private proposals, organizing public forums, and overhead costs directly attributable to the project.

Given its cyclic nature, a fundamental question arises, for modeling purposes, as to what constitutes the beginning and the end for this phase? To illustrate, the idea of the Channel Tunnel project was under investigation since the early 1800's (Wood, 1991), but it wasn't until 1985 that the British and French governments jointly issued an invitation to promoters to construct the Chunnel (McDermott, 1991). In Canada, the idea of a fixed link between the province of Prince Edward Island and the mainland across the Northumberland Strait has been discussed and debated since the 1880's (Duncan, 1988). Design of the bridge in its current form started only in 1987, and construction started in 1993. To address this question, it is

assumed in this research that the beginning of the predesign phase is marked by the government initiating the process by issuing a Request For Proposal (RFP) or Request for Expression of Interest (REI) to the private sector, and ends either with a signed concession agreement, which facilitates pursuit of funding, or terminates permanently because of an unsuccessful negotiation process. All expenditures prior to this starting point (e.g. for preparing unsolicited proposals, lobbying, etc.) are assumed to be a sunk cost.

As indicated in Figure 5.1, this phase is represented by a uniform cash flow intended to correspond to all activities and expenditures prior to the start of detailed design. Although the actual expenditure profile could take any shape or form (e.g. trapezoidal), a uniform shape function was used in this model to represent the rate of expenditure (C_{PD}) throughout this phase duration (T_{PD}). The area under the expenditure profile is not fixed since the longer this phase is the more it costs. Considering the amount of uncertainty and the little that is usually known beforehand about this phase, use of other expenditure profiles would only add to the complexity of the model, with no warranted improvement to the outcome. Both variables, C_{PD} and T_{PD} , however, are assumed to be probabilistic variables to account for the time and cost uncertainties that characterize this phase.

Since this phase takes place very early in the process, and because it can be very protracted and highly uncertain, it is practically impossible to acquire financing from external sources to cover the expenses incurred in this phase. Hence, in this model, all predesign expenditures are assumed to be sourced from equity funds, which is reflective of general practice.

5.3.2 Detailed Design

Signing a concession agreement denotes the end of the predesign phase and the formal commencement of a detailed design phase. This phase includes all analyses, field studies and other specialized studies required to produce the drawings and specifications essential to tendering.

It has to be noted that, in practice, some preliminary design activities may take place prior to signing a final agreement. It is not uncommon that while final terms of a concession agreement are being worked out, detailed design starts. This was the case, for example, in the PEI bridge project, where the project proponents decided to conduct field studies at their own risk before a final agreement has been signed. However, as seen in Figure 5.1, no formal allowance has been made to overlap the predesign and design phases. Future development of the model should allow for overlap.

Typically, designs are contracted as a lump sum and could be estimated at the outset as a fraction of the construction costs. This is treated in the model by two assumptions. First, the current cost of detailed design is calculated as a deterministic fixed fraction of the current dollar construction costs (d_D). The fixed fraction concept allows for automatic and direct adjustment of design costs as construction costs vary. Also, it is comparable to general practice especially in the early stages of the feasibility studies. A deterministic fraction (d_D) is used in this model for simplicity, a probabilistic one should be considered in future development of the model. Second, a uniform expenditure over a probabilistic design period (T_D) is assumed. The uniform shape function is viewed to be a fair representation of the real

world situation, where expenditures are usually directly tied to work progress.

Funding for this phase is likely to come from a combination of equity and borrowed funds. This is allowed in the model by assuming a value for E_D which is the fraction of design costs obtained from equity funds. The value of E_D varies between 0, for 100% financing, and 1, for 100% equity. This value is often stipulated in the financing agreement, hence it is treated as deterministic.

One issue that has to be treated in this model is fast-tracking. The duration and cost of detailed design are negatively influenced by fast-tracking due to the extra drawings that have to be produced and the changes that have to be reflected in the drawings (Fazio, Moselhi, Théberge & Revay, 1988b). However, the literature falls short of providing any suggestions as of how to treat this relationship analytically. A simple function that is designed to simulate such a relationship is suggested in this research as follows:

$$T_D = T_{Db} + T_{DF} \cdot F \quad (5.3)$$

in which:

T_D is the design duration,

T_{Db} is the duration, in years, of the design phase for a traditional public sector approach,

T_{DF} is the time penalty, in years, for the design phase for fast-tracking degree of $F = 1$, and

F is the degree of overlap between design and construction ($0 \leq F \leq 1$).

Equation 5.3 considers variables in an aggregated form which is consistent with the general goal sought for the model as discussed earlier. Another approach, would be to consider the

impact of fast-tracking on lower level variables such as productivity (e.g. man-hours/drawing), scope (e.g. number of drawings) and resource level (e.g. size of design team). More research is required in order to establish a realistic relationship that considers such lower level variables.

All primary variables in equation 5.3 (i.e. T_{DB} , T_{DF} , and F) are probabilistic. This assumption is made to count for the uncertainty embedded in the estimates of the time required to complete design and the time penalties as a result of employing the fast-tracking strategy. The degree of overlap between design and construction (F) is also assumed to be probabilistic, simply to count for the variation between the actual implementation of such a strategy and what is planned.

5.3.3 Tendering and Design Field Services

This phase treats all activities related to tendering, the receipt and evaluation of work package bids, the negotiation of contracts, and all field services including preparation of shop drawings, field inspection, attendance at meetings, change order management, production of as-built drawings, etc. The length of this phase is equal to the duration of the construction phase plus a lead time of T_T required for tendering and award of the first work package. Since this lead time can be influenced by issues such as errors in the drawings, obscure bidding requirements, unforeseen delays in the bidding process etc., it is assumed to be probabilistic.

Similar to the treatment of the detailed design phase, tendering and field services costs are calculated as a deterministic fixed percentage of current dollar construction costs (d_T). However, treatment of a probabilistic percentage should be considered in future development

of the model. In addition, and since expenditures in this phase are generally in direct relation with the work progress it is assumed to be expended uniformly.

E_T is the fraction of tendering and field services costs to be paid from equity funds, and it ranges between 0, for 100% financing, and 1, for 100% equity. The value of E_T is often specified in the financing agreement, therefore it is assumed to be deterministic.

5.3.4 Construction

In order to analyze any major capital project it is necessary to estimate expenditure profiles for the different work packages. This is because shape of the capital expenditure function which is a function of project characteristics, influences the risk implications of a project (De la Mare, 1979). Moreover, since construction is the highest expenditure phase, and possibly the longest one in the development process, there is a need for a reasonably accurate modeling for the construction expenditure profile. A trapezoidal expenditure function for constant dollar construction costs, as shown in Figure 5.2, has been assumed because of the flexibility it offers (e.g. front-end loading vs. back-end loading, early start versus late start time schedules, etc.) while providing relative ease in modeling.

Given a specification of the constant dollar construction budget in terms of the base expenditure rate z , and the placement of the peak expenditure in terms of a fraction of construction duration (w_1 , w_2), as shown in Figure 5.2, the remaining characteristics of the expenditure function (e.g. peak expenditure) can be readily derived. z , w_1 , and w_2 are all assumed to be deterministic in this model, because of the relatively low sensitivity of NPV to sizable changes in these variables.

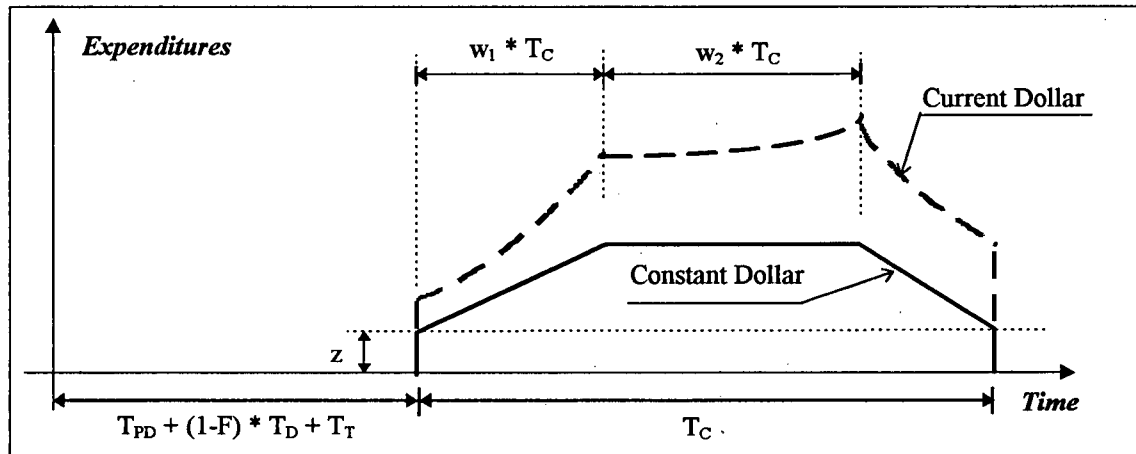


Figure 5.2 Constant and Current Dollar Construction Expenditure Profile

An assumption is made that the area under the curve (C_0), while uncertain, is independent of the duration (T_c) which is also uncertain. A slightly more sophisticated model would treat direct and indirect costs separately, with the latter corresponding to a rate of expenditure, with the total expenditure on indirects being time related.

Ideally, all construction work packages should be included in the model in terms of their respective costs, expenditure profile, place in time, and relative overlap. This should enhance the ability to simulate actual project situations and provide an extra dimension for examining the implications of adopting implementation strategies such as fast-tracking and construction acceleration. For example, acceleration and fast-tracking could be implemented for individual work packages as opposed to an entire phase. However, this approach complicates the model significantly and assumes the existence of more information than what is available early on. Therefore, a decision was made to represent the construction phase by a single work package, especially since the flexibility offered by the trapezoidal expenditure profile facilitates this simplification in terms of cost. However, to avoid underestimation of the uncertainty

associated with costs of the various project components, the area under the expenditure function may be estimated as the sum of major component costs. Thus, additional equations are provided for the probabilistic estimation of cost as a function of the major work components describing the project. For example, for a project composed of n major components, the constant dollar cost, C_{ob} , would be equal to

$$C_{ob} = \sum_i C_{obi} , \quad i = 1, \dots, n \quad (5.4)$$

in which C_{obi} is the probabilistic constant dollar cost for the i th component.

Construction costs are first estimated in constant dollars as of time zero (the origin in Figure 5.1), and then transformed to current dollars using a forecast of the general inflation rate and possibly a differential inflation rate (see equation 5.5). The notion of a differential inflation rate is provided to enhance flexibility by allowing the use of different inflation rates for the different phases (e.g. construction, management, operation and maintenance, etc.). This is important if, for example, the project has the potential to be self-disturbing. That is, its size is big enough to stimulate prices to the extent that the local inflation rate will be changed (e.g. the PEI bridge project). Thus, the inflation rate, θ_j , for the j th phase can be written as:

$$\theta_j = \theta + \Delta\theta_j \quad (5.5)$$

in which:

θ is the general inflation rate, and

$\Delta\theta_j$ is the increment (decrement) in inflation rate for the j th phase.

Differential inflation rates are accommodated for all phases in this model except for the "Primary Revenue Stream" which is treated as a special case and will be elaborated on later in this chapter, "Detailed Design" and "Tendering and Design Field Services" which are estimated as a fraction of construction costs, and "Predesign" since this phase takes place before construction is decided upon and is indexed to the general inflation rate.

Once the constant dollar expenditure function is transformed to the current dollar one, it is further multiplied by $(1 - h)$, where h is the deterministic holdback fraction, in order to obtain the anticipated payout during construction. The value of holdback fraction is determined based on current laws and regulations. No allowance has been made for variable holdback rates (a holdback rate which changes as a function of percent complete) - something that may occur in a public-private partnership arrangement versus a public sector one. It is viewed that this assumption is a reasonable representation of the real world scenario, without unnecessarily adding to the complexity of the model.

In formulating the construction cost model, consideration was given to the time and cost penalties that could result from speeding up a project (Fazio *et al.*, 1988b), as measured by F (degree of fast-tracking), A (degree of acceleration of construction), and O (degree of overlapping between construction and commissioning/revenue). F , A , and O are strategic planning variables, and their target values are assigned by the project team, based on their expertise and knowledge of the project at hand. For modeling purposes, they are treated as random variables, as the values actually achieved can differ markedly from target values. Much anecdotal evidence exists in the literature about both the positive (Looi & Petrossian, 1989 ; Fletcher, 1987) and negative (Fazio *et al.*, 1988b; Rosenfeld & David, 1991; Fazio,

Moselhi & Théberge, 1988a; Whalen, 1985) experiences associated with fast-tracking projects and accelerating the construction phase, with more emphasis on the negative. However, virtually no quantitative evidence is offered in the literature from which empirical relationships could be derived to measure the impact on fundamental variables, such as design and construction team productivity, of differing resource usage levels and degree of project speed up, as measured by F, A and O. This is an important knowledge gap that needs to be addressed. It is beyond the scope of this research to formally address this issue. Instead, simple linear relationships have been used to link cost and time with degree of fast-tracking, acceleration, and construction and commissioning/revenue phase overlap. Specifically, constant dollar construction cost is estimated as the sum of the cost of the traditional sequential approach plus penalty terms for all three revenue acceleration strategies - i.e.

$$C_o = C_{ob} + C_{oF} \cdot F + C_{oA} \cdot A + C_{oO} \cdot O \quad (5.6)$$

in which:

- C_o is the constant dollar construction cost,
- C_{ob} is the constant dollar construction cost for the traditional approach (see equation 5.4),
- C_{oF} is the increment in constant dollar construction cost for $F = 1$,
- C_{oA} is the increment in constant dollar construction cost for $A = 1$,
- C_{oO} is the increment in constant dollar construction cost for $O = 1$,
- F is the degree of overlap between design and construction ($0 \leq F \leq 1$),
- A is the degree of acceleration of construction phase ($0 \leq A \leq 1$), and
- O is the degree of overlapping of construction and commissioning phases ($0 \leq O \leq 1$).

Values estimated for C_{oF} , C_{oA} , and C_{oO} , respectively, correspond to acceleration strategies of $F = A = O = 1$ (a virtually impossible condition, but a useful mental construct). These terms are designed to compensate for productivity losses, shiftwork and overtime differentials, rework, etc., and are used to represent upper bounds on the penalties that could be incurred. Simply stated, equation 5.6 says that the penalties of project speed-up increase with increased efforts to accelerate. In practice, the penalties would most likely increase exponentially with increasing F , A and O , and it is likely that interactions between strategies would exist (i.e. the simultaneous use of fast-tracking and construction acceleration would cost more than the sum of the penalties if these strategies were used separately). Such interactions could be modeled by the inclusion of cross product terms in equation 5.6, provided data was available for their estimation (e.g. $C_{oAF} \cdot A \cdot F$).

Similar to the equation for constant dollar construction cost, the duration of the construction phase is estimated using the following equation

$$T_C = (T_{Cb} + T_F \cdot F + T_O \cdot O) \cdot (1 - A) \quad (5.7)$$

in which:

T_C is the duration of the construction phase,

T_{Cb} is the construction duration in years, for the traditional approach,

T_F is the construction time penalty in years, for a fast-track value of $F = 1$, and

T_O is the construction duration time penalty in years, for a construction and commissioning/revenue overlap value of $O = 1$.

All primary variables in equation 5.6 and 5.7 namely, C_{ob} , C_{oF} , C_{oA} , C_{oO} , T_{Cb} , T_F , T_O , F , A and, O are assumed to be probabilistic.

E_C is the fraction of construction expenditures sourced from equity funds, and it ranges between 0, for 100% financing, and 1, for 100% equity. Since the value of E_C is usually specified in the financing agreement, it is assumed to be deterministic.

No explicit treatment of time-related indirect construction costs was included in this model. The significance of such a component would become apparent if, for example, the project was viewed as being so controversial that extended interruptions are anticipated because of the actions of various stakeholder groups, or, the project became a focal point for work stoppages because of labour bargaining tactics. Given such an outcome, the project proponent will bear all additional costs associated with idle equipment and labours, extra mobilization and demobilization if necessary, etc. Additionally, the rate of expenditure on indirect costs increases with increasing speed of delivery. It is left to future work to include an indirect cost component, including its expression in terms of F , A and O .

5.3.5 Commissioning

Essential commissioning must be completed prior to use of the facility. In this phase all equipment (e.g. mechanical, electrical, etc.) will be made operational, deficiencies removed, finishing problems identified and resolved, etc. At the end of this phase the facility will be officially ready for full and safe usage. Since construction of some components of the facility need not be completed while essential commissioning is taking place, this phase can actually start prior to the final completion of construction.

A probabilistic lump sum C_{oCOM} , that represents the constant dollar commissioning costs is assumed to be expended uniformly over a probabilistic duration T_{COM} . It should be noted that virtually no information is available in the literature on expenditure profiles for commissioning work.

E_{COM} is the fraction of commissioning expenditures sourced from equity funds, and it ranges between 0, for 100% financing, and 1, for 100% equity.

5.3.6 Management During Design & Construction

This cost category applies to both procurement approaches. For the public sector approach, all government or government agency costs associated with overseeing the project would be included (although they may not be charged against the project and hence recaptured through tolling). For the public-private partnership approach, all costs associated with the management activities during design and construction of the consortium awarded the concession would be included. Additionally, fees not directly related to construction or design expenditures may be charged (e.g. for public relations consultants, construction management consultants, etc.) as well as lump sum performance bonuses at the end of construction, provided time and cost targets are met or bettered. For example, proponents of the PEI project have formed a Calgary based consortium called Strait Crossing Inc. to handle this task (Pirie, 1994). In the Channel Tunnel project, a rather unusual practice was the use of "Maître d'Oeuvre" (MdO) where the concession specified that an independent project manager be appointed by the concessionaires (McDermott, 1991).

In this model, the probabilistic costs incurred during this phase (C_{oMTGC}) are first estimated in

terms of a uniform constant dollar rate per unit of time, and then transformed to current dollars using the general inflation rate, and if applicable, adjusted by the corresponding differential inflation rate. These costs are assumed to continue until the holdback is released, at which time their composition changes to reflect the transition from a construction to operating mode.

E_{MGTC} is the fraction of the expenditures sourced from equity funds, and it ranges between 0, for 100% financing, and 1, for 100% equity.

5.3.7 Holdback Release

Holdback release usually occurs after a certain period of time has elapsed from substantial completion. Legal requirements determine this period of time as well as the percentage of holdback. Usually, some special trust fund could be set up for handling retainage. For modeling purposes, however, flows are simply reduced by the holdback percentage, including loan drawdown. At the time of release, which occurs T_H time units after the maximum of essential commissioning or construction is completed, holdback funds are assumed to be sourced from a combination of borrowed and equity funds. E_H is included in the model to represent the equity fraction as may be decided upon. It ranges between 0, for 100% financing, and 1, for 100% equity.

5.3.8 Loan Drawdown

Capital required for building public infrastructures is often very large and beyond the capacity of any individual or even group of companies. Therefore, it is usually consortia of companies,

and financial institutions that are involved in a PPP project. For example, for the Chunnel Tunnel project, five British companies, five French companies and five banks were part of the group winning the concession agreement (McDermott, 1991). Often the work magnitude of such projects is also very large and is usually divided into several work packages that are contracted as lump sum, fixed price, turnkey, target price, or a combination. Preparing a schedule that will consider harmony, priorities and requirements of all work packages is by no means an easy task. More critical is the preparation and timely implementation of a financing plan to secure the needed funds for undertaking such a schedule. Often, commercial and financial considerations rather than technical ones are likely to be the most important determinants in winning a concession for an infrastructure project (Tiong *et al.*, 1992).

Raising debt for PPP projects is one of the most difficult issues, and usually some government guarantees are required to attract financing (Tiong, 1990a). For example, when a BOT approach was first proposed by the Turkish government for the \$652 million Akkuyu reactor plant project, it failed to raise the necessary financing due to insufficient government guarantees (Aybers *et al.*, 1990). Obtaining financial commitments for the PEI project in the early phases was also extremely difficult as noted by Thompson (1988): " The fact that we could get no firm guarantees regarding financing is disconcerting. All we could get was letters of good intent and best efforts but no one to stand up and say we will finance your bridge at x% for thirty- five years. When one considers that the cost of financing for thirty-five years is twice the construction costs, and that a 1% swing in interest rates translates to \$90 million in cost, this becomes a large risk." Conversely, some governments are extremely supportive. For example the Malaysian government allocated \$235 million in start-up funds

toward the construction cost of the Malaysian Expressway BOT project. This corresponded to about 13% of the total project cost (Tiong, 1990b). The Australian government even provided an interest-free loan of \$125 million (about 23% of total project cost), with the loan repayable over 30 years, to cover the preliminary construction costs of the BOT Sydney Tunnel project (Tiong, 1990b). Innovative and creative financing schemes are extremely crucial not only as a competitive strategy for winning a PPP concession, but also to provide for successful implementation as well as minimizing the overall risks.

For modeling purposes, the continuous loan drawdown profile is assumed to mirror the total expenditure function which is the sum of all active cost components (design, field services, construction, management, etc.), adjusted where appropriate by equity fractions and holdback requirements. This is a useful approximation of reality. It corresponds to the arrangement of a line of credit, and then drawing against it in a continuous fashion, with or without interest being paid during the development phase (for the model developed herein, interest is assumed to be capitalized during construction). In practice, draws are made in discrete monthly payments, usually above some minimum value. Lending fees (e.g. standby fees) have to be considered in this type of arrangement, and for modeling purposes, such fees are assumed to be included in the interest rate. For this case of no interest being paid during construction, and depending on the financing agreement, the interest rate during the construction phase, i_c , could be different (and usually higher) from the rate that applies during operation, i_p , because of the different risk exposure. Estimates of these variables must consider the relative capability of each sector to acquire financing, since in general, the public sector can achieve lower rates. Moreover, loan interest rates could in practice be floating. This is partially

treated in the model by assuming an average financing rate which is probabilistic but time invariant. The assumption of probabilistic interest rates is particularly useful at the early stages of the analysis when rates are not yet tied down. In addition, the model assumes loans to continue up to the release of holdback, when the facility is fully operational and pay back from the revenue streams is facilitated. Working capital needs during the early stages of operation have not been treated in the model. It is left to future work to treat a broader range of financing schemes such as one or a combination of the following scenarios:

- *Bonds*

Another common borrowing scenario, especially for the public sector, is one which involves a single bond issue at the start of the design or construction phase. Of interest for this scenario is the need to manage the funds to maximize their earning power while meeting the cash flow requirements of the project. For the public-private partnership approach, consideration may have to be given to taxation issues in order to determine the effective earning power of the money. This scenario may also involve a requirement to pay interest during the development phase, or alternatively, interest could be capitalized.

- *Other arrangements*

Other scenarios might include special taxes levied to finance the construction and operation of the facility (such as fuel tax), raising vehicle registration fees, and raising parking fees (Murase, 1994).

5.3.9 Revenue Stream

Revenues from transportation infrastructure projects may be collected through various schemes, not all of which are applicable to every project. Traditionally, the public sector collects revenues from highways in the form of motor fuel taxes, registration fees, driver license fees, weight-distance taxes, other fees closely connected to the ownership and operation of motor vehicles, and other non-highway-based revenue such as income taxes which are related to the provision of services and general taxes on property and sales (Lockwood, Caldwell, and Williams, 1992). In addition, imposing tolls on public infrastructure and highways, has always been an option at the disposal of governments, who want to raise revenues over and above the yield of general road user charge (e.g. fuel tax), or allocating road users between tolled and untolled roads so as to ration available road space to users for whom it has the highest value (Johansen, 1991). All such revenues are usually funneled into a common pot from where, based on set priorities, budgets are made and funds are availed for new or expanded transportation projects as well as operating and maintaining existing ones (in fact, a major problem facing government is that the common pot is called general revenues, and these funds are diverted to other uses such as funding social programs, leaving inadequate funds to maintain and extend the source from which they are derived).

In providing for a successful partnership between the public and private sectors, however, a main revenue stream must exist for the project. This is because proponents of PPP projects depend totally on such a revenue stream to regain capital, collect their profits, maintain and operate the facility, and service the debt incurred during the earlier phases of the project. In addition, proponents of such projects would usually like to have a near monopoly situation.

which would make the project less risky, and potentially more profitable, although these situations are rare in transportation projects. Moreover, they usually look for projects with a potential for growth in order to enhance their chances of maintaining the desirable levels of revenues.

Nevertheless, infrastructure projects and especially transportation ones are often unable to provide the level of security of cash flow offered by industrial projects. Borrowing commercial practices from the latter type of projects and applying them to transportation projects, governments could guarantee the obligations under take-or-pay or take-and-pay contracts to purchase the service according to a set of predefined terms and conditions (Tiong, 1990a, Haley, 1992). These arrangements will at least guarantee some sort of revenues to the project proponents even before completing the project. Without them, estimating projected usage and revenue levels for such projects, and thereby assessing the potential for success, is far from straightforward, especially if the planning period extends far into the future.

A central issue in any PPP project is forecasting the level of usage or demand over the full operating period of the project. It is one of the most challenging tasks that faces project proponents, where almost always an inevitable and significant uncertainty about the accuracy of such forecasts exists. Since demand is in itself derived, that is many variables interact to generate demand, one source of uncertainty arises from estimating these primary variables. Trying to profile the likely users, their income, population levels, etc. as well as predicting factors such as fuel prices etc., are all examples of such variables (Button and Pearman, 1985). The second form of uncertainty surrounding traffic forecasts relates to the choice of

forecasting procedure itself, which varies from simple and crude methods to more involved and time consuming ones. The choice of forecasting technique depends on the type of the project, and its environment, the time frame for the analysis, etc. In general, the process of analyzing transportation demand for any project consists of six basic tasks: problem definition; choice of analysis technique; data collection; model calibration; model validation, and finally forecasting (Meyer and Miller, 1984). Some PPP arrangements recognize demand risk, and try to bound it by splitting the risk between the public and private sectors. For example, a unique provision in the concession agreement of the San Jose Lagoon bridge provides the proponents of the project, namely Autopistas de Puerto Rico (APR), the right to terminate the contract if traffic levels do not meet certain criteria. If any of the following occurs on a cumulative basis for six month periods, the agreement stipulates that ARP may be released from its obligation to operate the toll road and transfer ownership of the bridge to the Puerto Rico Highway Transportation Authority (PRHTA), with PRHTA paying ARP a rate of return of 12.5% on any capital contributed up to that point for the development, design, construction and operation of the bridge:

- During the first 3 years of operation, traffic levels are less than 80% of forecast;
- During the fourth through sixth years, traffic levels are less than 85% of forecast;
- During the seventh and eight years, traffic levels are less than 90% of forecasts; or
- During the ninth year until termination, traffic levels are less than 100% of forecast.

The "BTO" concession was signed in 1992, and is planned for 35 years, i.e. until the year 2026 (Murase, 1994).

For a user-pay transportation facility, and among a host of other factors (e.g. safety, convenience, etc.), demand is a function of the prices or tolls imposed. Although, historically, tolls played a significant role in financing the development of infrastructure in developing as well as developed countries, when tolling is the primary revenue source, usually its total value over the operating life of the facility is the greatest single source of uncertainty (Beesley, and Hensher, 1990; Thompson, 1988). From the perspective of a public-private partnership, this uncertainty is compounded if government policies at the provincial, regional and municipal levels are going to influence growth potential and the ability to set fare levels in a relatively straightforward manner. Thus, unless specifically treated in the concession agreement in a public-private partnership, it is expected that high uncertainty will surround the revenue function given the complexity surrounding the forecasting of long-term revenue, usually 10 to 30 years in the future, and in the case of the Chunnel project 55 years (Tiong, 1990b).

In simplest terms, toll revenue is the summation over time of the user-rate multiplied by the number of users (Meyer *et al.*, 1984). Several questions arise:

- What is the definition of users (e.g. direct versus indirect users), their classification (e.g. single occupancy, high occupancy, trucks, cyclists, pedestrians etc.) and profile (e.g. commuters versus occasional travelers)?
- How would demand levels, usage profiles, and classification differ as the imposed fare levels change ?
- What are the fare levels for all user categories that will optimize the total revenue function?

- What are the minimum fare levels that will yield no drop-off in usage?
- How would the method of tolling (e.g. direct versus indirect) affect usage?

Such issues are extremely crucial while assessing the potential for any PPP transportation project. However, although trying to find specific answers for these questions is beyond the scope of this research, a brief consultation with the literature indicated that they have not been fully treated especially when the study periods extend for long time into the future.

From the private sector perspective, trying to forge a detailed tolling strategy that will consider all user categories, mode distributions, the different peak and non-peak patterns, and impact of fare level on such issues adds to the complexity of the problem and indeed the associated uncertainty. Therefore, at least from the private sector point of view, the simpler the classification the better.

In what follows, the rationale for trying to deduce a reasonable function for the revenue stream in this model by means of direct tolling is laid out. In so doing, a single user category (i.e. all vehicles are identical) is used for simplicity. However, as depicted in Figure 5.3, two classes of users are assumed to traverse the facility: a fixed or captive group which will not seek alternative routes or transportation modes for any reasonable range of prices, and a variable group which is sensitive to price level.

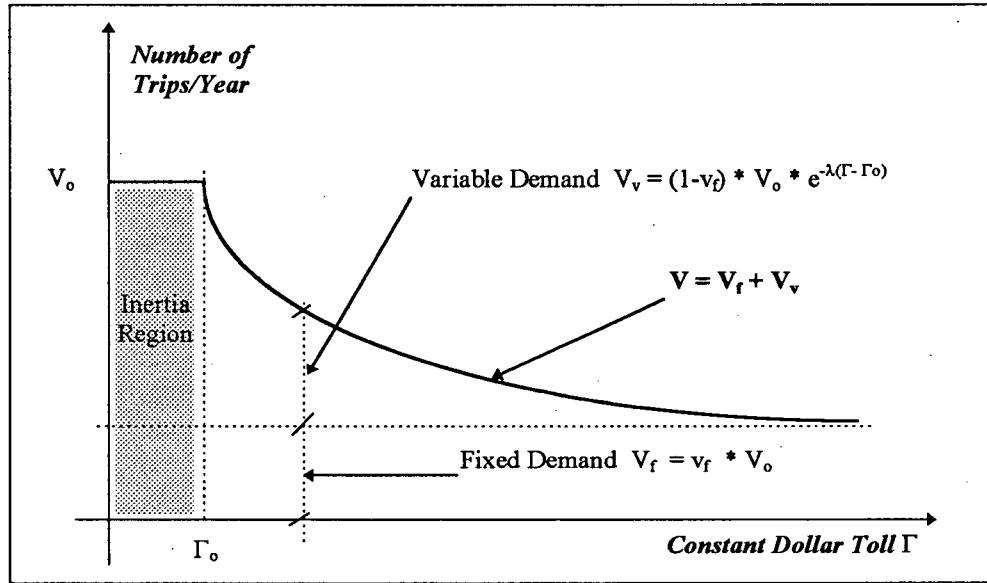


Figure 5.3 Demand Function

Thus, the total volume of use, V can be written as:

$$V = V_f + V_v \quad (5.8)$$

in which V_f is the fixed volume and V_v is the variable volume.

Let V_0 be the maximum volume of use for a toll less than or equal to Γ_0 at the start of operation. Γ_0 is the initial inertia toll value in dollars/trip, which indicates the maximum fare level which yields no drop-off in usage. And, assuming that the variable usage decays exponentially (Murase, 1994; and Johnston, 1990) with increasing fare Γ , V can be written as

$$V = v_f \cdot V_0 + (1 - v_f) \cdot V_0 \cdot \exp(-\lambda \cdot (\Gamma - \Gamma_0)) \quad (5.9)$$

where $\Gamma \geq \Gamma_0$

and in which:

v_f is the fraction of zero toll volume that is fixed, and

λ describes the decrease in usage with increasing fare (Murase, 1994; Johnston, 1990, Goodwin & Williams, 1985).

In this model, v_f remains invariant with time. This assumption needs to be challenged, especially if fares are indexed to a fraction (denoted as g in Table 5.1) of the general inflation rate like the case with the PEI bridge project where fares are indexed to 0.75 times the general inflation rate (Pirie, 1994) - i.e. they decrease in real terms with time, which may entail some increase in v_f with time. Moreover, V_o is allowed to grow in an exponential manner with time. However, it must be noted that in real life, volume growth may follow any pattern or shape.

Determining the value of Γ_o is yet another challenging task, and it represents another knowledge gap in the literature. This problem becomes more difficult when trying to introduce tolls on a new facility as opposed to replacing a facility which has an existing toll strategy (Murase, 1994).

In estimating a value for λ , use can be made of the concept of elasticity which is simply a sensitivity coefficient that links fractional change in the dependent variable with fractional change in the independent variable (Meyer *et al.*, 1984; Murase, 1994; and Johnston, 1990) - i.e.

$$\epsilon_v = (dV_v/V_v) / (d\Gamma/\Gamma) = -\lambda \cdot (\Gamma - \Gamma_o) \quad (5.10)$$

Some indications of ϵ_v can be found in the literature (Wohl, 1984; Meyer *et al.*, 1984), from which values for λ can be derived.

In summary, for the set of simplifying assumptions made, estimates of V_o , v_f , Γ_o and λ , as well as θ_v , which is the growth in usage versus time, are needed. Accordingly, current dollar revenue function at time τ can be calculated as:

$$\begin{aligned} \text{Revenues} = & \Gamma \cdot \exp[(g \cdot \theta) \cdot (T_{PD} + (1-F) \cdot T_D + T_T + (1-O) \cdot T_C)] \cdot [v_f \cdot V_o + (1 - v_f) \cdot V_o^* \\ & \exp(-\lambda \cdot (\Gamma - \Gamma_o))] \cdot \exp[(g \cdot \theta + \theta_v) \cdot \tau] \end{aligned} \quad (5.11)$$

where $\Gamma \geq \Gamma_o$.

Total revenues can then be calculated by integrating equation 5.11 over the entire operation period (T_o).

It has to be noted that all variables included in equation 5.11, except for Γ , and g , are assumed to be probabilistic in order to count for the uncertainty embedded in such a function. Γ and g are viewed as strategic variables that will be decided upon based on the given project parameters in order to meet rate of return requirements as well as user affordability criteria. Therefore, they are treated as deterministic variables in this model. Moreover, Γ is assumed to be a flat rate that does not change during the day or peak versus non-peak hours. It is also applied equally to all user classes.

Notwithstanding the tolling scheme described above, other methods of collecting revenues also exist, and need to be treated in future expansions of the model. In brief, these methods may include the following:

- *Congestion pricing*

Congestion pricing is another way of direct tolling. It is a transportation system management

technique which attempts to spread peak traffic demands to less congested segments of the network and to less congested periods of the day (Edlesten and Srkal, 1991). This technique treats roads like other commodities and puts a price on their use. Economists have long proposed congestion pricing, based on the belief that traffic congestion often results in inefficiencies in the transportation system and frequently imposes environmental costs on non-traveling residents. This is in addition to the waste of time and uneconomic use of motor engines and fuel (Button and Pearman, 1985). As a byproduct, congestion pricing will also generate substantial cash flows. The technique calls for electronically monitoring usage and charge users according to a preannounced pricing scheme. There are arguments both in support of and against such a system (Godwin, 1993; Edelstein *et al.*, 1991). However, the fact that advanced technologies are making it cost effective to implement, and the increasing frustration by motorists with traffic congestion, makes the public and politicians more accepting of the concept (Godwin, 1993).

In this scheme, automatic billing could be in the form of prepayment, direct billing, or credit cards. This scheme, however, is meant to be implemented within a region, where motorists are automatically charged relatively higher user fees for using congested links versus links that have excess capacity. Varying rates could be charged as a function of travel speed and convenience for each link of the multimodal transportation system. The toll rate would also vary by time of day and could be a function of various vehicle classifications.

The problem of estimating demands and acceptable fare level for each mode of transportation also exists in this tolling scheme. Moreover, the users must be regularly informed of charges for each link in advance, and any changes must be announced ahead of time. In addition

centralized control of transportation systems within a regional context must be provided to address data collection, traffic control, travel advisory information, and information sharing as well as fare collection (Edelstein *et al.*, 1991).

- *Shadow Tolling*

Shadow tolling is an indirect form of user fees, whereby payment is made by some third party, usually the government. Shadow tolls in this case are taken from existing government revenue streams, such as taxes. Therefore from the private sector perspective, a significant degree of risk transfer to the public sector regarding usage of the facility can be achieved (Huggett, 1994). Revenues in this case could be in the form of annual payments that is based on predefined criteria for toll per vehicle.

- *Other Revenue Streams*

Other revenue streams might exist for infrastructure projects, in the form of specialized taxes (e.g. fuel taxes), incremental income derived through commercial development of the right-of-way, sale of air rights, or a direct subsidy during construction and/or operation from government grants or guarantees. For example, the Canadian government provides an indexed \$35.0 million as of 1988 dollars in annual subsidy to Strait Crossing Inc., the developer of the PEI project, for the entire concession period of 35 years (Pirie, 1994). Also a minimum operating income was guaranteed by the Malaysian government to the developers of the Malaysian Express Highway project in the event of cash-flow problems due to a drop in traffic volume.

Alternative revenue streams are included in the model developed and are shown as a

secondary revenue stream in Figure 5.1. The start of income from such a stream is allowed to occur at any point of time depending on the project and type of stream, and are linked to the start of construction with a probabilistic lag factor S_s , as shown in Figure 5.1. It is specified in terms of a probabilistic constant dollar rate of expenditure S which is indexed to the general inflation rate plus a differential one.

One fundamental issue in any PPP arrangement that has to be addressed, is determining the length of the concession period. The private partner would very much like to collect its capital and its projected profits as soon as possible. During the operating period, the PPP consortium on the one hand, will collect revenues, some of which will be used to service the debts and some of which will be used to operate and maintain the facility. The public partner, on the other hand, would like to receive at the end of the concession a productive facility in good condition that is not technically obsolete and does not require excessive expenditures for operation and maintenance. A decision will have to be made with regard to the length of operation period by the private sector after which time, the facility will be transferred back to the public sector. Therefore, this period, denoted by (T_o) in Table 5.1, is treated in this model as deterministic and is assumed to commence after the essential commissioning is completed.

Liability issues may also dictate transferring the facility to the public sector prior to operating it such as in Build-Transfer-Operate "BTO" arrangements. Otherwise, and as in "BOT", the transfer phase is deferred until a certain period of time has elapsed during which the private sector will hold title and assume liability while operating and maintaining the facility.

5.3.10 Operating and Maintenance Costs

This phase includes all activities and tasks associated with operating the facility, monitoring, regular and routine maintenance and repairs. The operation and maintenance of public infrastructure facilities can be performed either by public or private sector employees. In BOT, BTO, or BOO projects, the private sector will generally be the party responsible for these functions. From an operation and maintenance perspective in a PPP project, as mentioned earlier, the government would not want to have at the end of the concession period a deteriorating facility that will require expensive operating and maintenance or perhaps total replacement. The private sector, would like to recover the capital plus profit as soon as possible, which might be, in some cases, at the expense of proper maintenance. However, from a life-cycle cost perspective, there might be some advantage to the public sector from lengthening the duration of a concession for a public-private partnership. The notion being, if the partnership has to operate and maintain the facility for a very extended time period, additional care and expenditures will be made during design and construction to incorporate quality, and during the operation phase, the facility will be properly maintained. In fact, it can be argued that one of the benefits of PPP arrangements such as BOT is that proper maintenance can be achieved through contractual obligations.

Regardless of who is responsible for undertaking this phase, underfunding is viewed as a widespread and persistent problem that undermines maintenance and repair of most public facilities (Barco, 1994; BRB, 1990). Therefore, the business of accurately predicting and budgeting for public infrastructure operating, repair and maintenance is a critical task that project proponents must accomplish.

There is a huge gap in the literature dealing with the operation and maintenance of public infrastructure as a function of project parameters. Models used to estimate expenditures in this phase are hard to generalize. For example, based-budget models, and zero-based budget models are cited in the literature. The first type of model, which is also called the ramping approach, uses a certain base of expenditures - usually last year's - with a steady increase in funds over a period of years to account for aging and inflation. After several years of operation, however, this type of model tends not to correlate well with actual operating and maintenance requirements. Nevertheless, its simplicity has made it very popular over the years. The second type of model requires that the base expenditures be rejustified each year. The budget itself can be based upon the size of the facility, replacement value, or by individual projects (Barco, 1994). No literature was found, however, on the break-down structure of activities included in operating and maintaining transportation infrastructure.

As depicted in Figure 5.4, the model suggested in this work considers two components for the operation and maintenance. The first component is similar to the first type of model described above, and has been formulated to have a base constant dollar component of expenditures (M) with a rate of annual increase (m). Both variables are assumed to be probabilistic to count for the uncertainty embedded in their estimates. The second component represents constant dollar intermittent expenses (R) which takes place periodically with an interval of (n) number of years. In a bridge project, for example, this may include regular repainting of the bridge structure, resurfacing the roadway and bridge deck, and upgrading toll collection/monitoring/signaling technology. Both components are adjusted to current dollars by a general inflation rate plus a differential one. Similarly, R is assumed to be probabilistic,

however, n is deterministic and will be based on a stipulated contractual agreement. Similar to the revenue phase, expenditures for operating and maintaining the facility are assumed to commence after completion of essential commissioning.

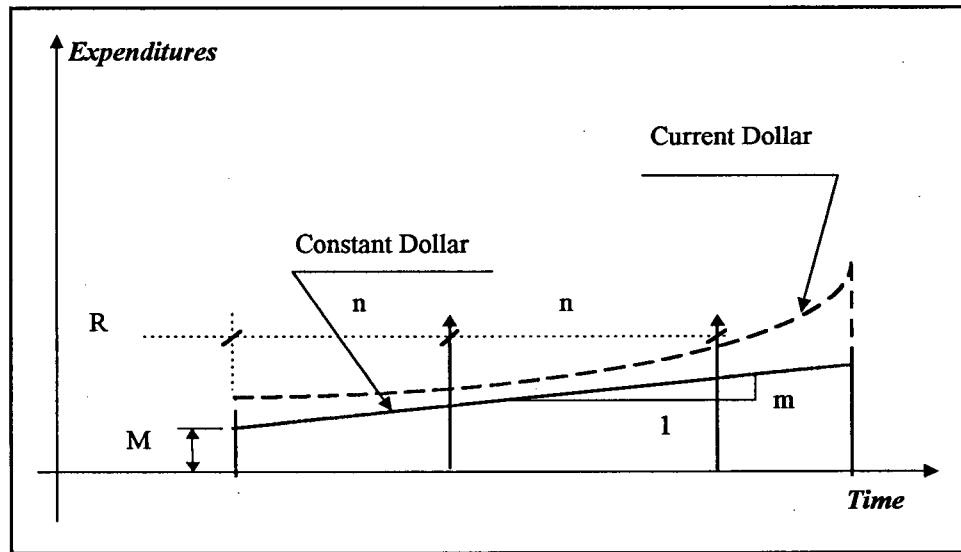


Figure 5.4 Operating and Maintenance Costs

5.3.11 Management During the Operating Phase

This cost category applies to both procurement approaches, and deals with the costs involved in overseeing operation of the facility, including management costs, legal and accounting costs, and costs associated with public hearings and/or other regulatory hearings for review of fare structures. In the Chunnel project for example, such costs are assumed by Eurotunnel (McDermott, 1991).

For modeling purposes, this probabilistic cost item is assumed to commence after the holdback is released and runs for the remainder of the operating life. For simplicity, funds are assumed to be expended at a uniform constant dollar rate, and are indexed to the general

inflation rate plus a differential one to obtain their current dollar equivalent.

5.3.12 Debt Servicing

In general, debt servicing costs deal with the repayment of principal, interest capitalized during construction and possibly initial working capital needs, including accrued interest, from revenues generated during the operating phase. Generally, the repayment profile mirrors the shape of the revenue stream, although terms vary considerably from project to project.

For modeling purposes, the repayment scenario treated in this work assumes that debt servicing will start only after release of holdback, and a further predetermined delay equal to T_s time units has elapsed. During this time interest continues to be capitalized based on the terms specified in the financing agreement. Thus, the expected duration required to repay debts in full can be derived from the following relationship:

$$T_p = T_o + T_{COM} + \{1 - O\} \cdot T_C - \text{MAX}\{T_C, ((1 - O) \cdot T_C)\} - T_H - T_s \quad (5.12)$$

in which:

T_p is the length of time for amortization of debt in years,

T_o is length of operating phase in years,

T_{COM} is time required for essential commissioning in years,

T_C is the duration of construction phase in years,

O is the degree of overlap of construction and commissioning ($0 \leq O \leq 1$),

T_H is the time, in years, when hold back is released after both essential commissioning and construction are completed, and

T_s is the lag, in years, between hold back release and start of debt servicing.

In addition, debt servicing is assumed to be indexed to the growth in usage (θ_v) and growth in fare ($\theta \cdot g$) in order to match the shape of the revenue stream.

5.3.13 Liquidated Damages/ Penalties

Including a term for liquidated damages in the model is important for complete modeling of a project. However, such a term can only be meaningfully included in a probabilistic formulation. Liquidated damages are applicable to all procurement approaches. They can be calculated based on one or both of two concepts. The first is the recapture of revenue foregone because of late project delivery. The second, is the increased maintenance and operation costs for an existing facility, which the new project is supposed to complement or replace. Thus, liquidated damages per unit of time may very well increase with time, as extended delays may necessitate considerably higher expenditures on the existing facility. For example, the consortium building the PEI bridge are responsible for the operation and maintenance of the ferry fleet should delivery of the bridge be delayed.

The second concept is treated in this model as depicted in Figure 5.1. Treatment of these costs however, might be different for each sector. Since it is usually the public sector's duty to maintain existing facilities, penalties for the private sector might only be considered if operation of the facility is delayed beyond a certain date. Some estimates of the rate at which damages are incurred could be made from examining different maintenance scenarios. In this work, the probabilistic costs incurred for maintaining an existing facility (M_{ex}) are assumed to be uniformly distributed until a specified time k_1 (see Figure 5.5). It then increases with time

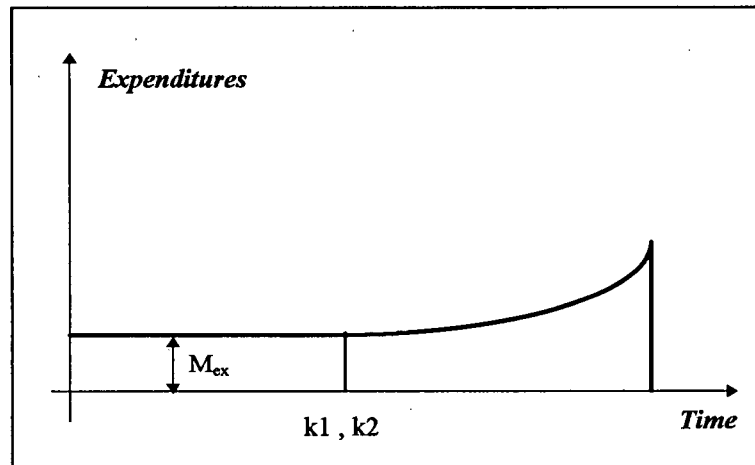


Figure 5.5 Operation and Maintenance Costs Of Existing Facility

in an exponential probabilistic fashion, and extends from a specified time k_2 ($k_2 \geq k_1$) until construction of the new facility is completed and the facility is operational. This is viewed to be a useful representation of a real life situation when the existing facility to be replaced is near the end of its service life, and major expenditures may be required to extend it.

5.3.14 Reversion/Salvage Value

Assuming that the project being analyzed is to replace an existing one, no term has been included for reversion/salvage value, or demolition of the existing facility. For the public-sector approach, reversion value is not applicable, as ownership resides with the public sector. For a public-private partnership, it is assumed that a nominal amount would be paid upon termination of the partnership agreement.

5.4 DISCOUNT AND INFLATION RATES

A fundamental variable for the project analysis is the discount rate. Tiong (1990b) reports in his comparative study for six BOT projects, that the pretax rate of return for those projects ranged from 6% to 20%. Depending on the risk level assumed by the private sector, they usually require a higher discount rate than the social rates of return adopted by the public sector. This means a higher costs to the users which translates into a lower usage rate, which in turn may mean less satisfaction of transportation objectives. However, an often cited argument in the literature (Haley, 1992; Israel, 1992; MoTH, 1993; Price Waterhouse, 1993; Spencer, 1990), is that the private sector is more flexible in implementation (i.e. can fast-track, and accelerate phases), and possesses more managerial skill than the public sector. This, the private sector and advocates of the PPP approach claim, should result in the same or slightly higher toll rate for the users, despite the higher discount rate required.

Testing the accuracy of such arguments, and determining a reasonable rate of return for the level of risks assigned to the public and private sectors are two important issues in any PPP agreement. The proposed model is designed to aid project analysts in this regard, by assuming different discount rates, and applying different implementation scenarios (i.e. different rates of fast-tracking, and acceleration), and comparing results. Impacts on the user charge in the different scenarios can thus be easily investigated.

An estimate for the general inflation rate is another crucial parameter in this model. In addition, differential inflation rates are also used in some phases, namely construction, commissioning, management during design and construction, operation and maintenance of

both new and existing facilities, and management during operation and maintenance of the new facility. Thus, for example, if a project is of a significant size relative to the local economy, the differential inflation rate for the construction phase would be positive. The challenge to the analyst is to estimate an average value for each over the life of the project. Moreover, while a net present value model can be formulated and solved for time varying rates for both general and differential inflation, estimation of their time varying behavior is a formidable task, and was ignored in this model. Instead, they are treated as random variables. This is equivalent to current practice which is restricted to time-invariant rates.

5.5 GENERAL MODEL ASSUMPTIONS

The strength of the model developed in this thesis lies in its explicit mathematical structure, which facilitates insights into the deterministic and probabilistic behavior of a project as a direct function of key input variables and parameters. This structure permits the speedy description and computation of a wide range of project scenarios. This capability is very important if one is to assess the merits of various claims made by proponents of one scheme versus another such as relative efficiencies of private sector, as well as to explore a diverse range of commercial terms that could form part of a concession agreement such as fast-tracking, acceleration, and overlap of phases.

Notwithstanding the foregoing, the following general assumptions of the model must be emphasized:

5.5.1- A current dollar as opposed to constant dollar formulation has been used for basically three reasons. First, project participants are mainly concerned with actual flows, and this is

particularly important when borrowed money is being used, since one borrows current not constant dollars, and expenditures for inflation and possibly interest have to be financed as well. Second, differential inflation rates occur for the various inputs, which limits the usefulness of a constant dollar analysis. And third, unless the government is prepared to negotiate a concession agreement that guarantees some minimum real rate of return, the analysis has to be conducted with a fixed discount rate that embodies expectations regarding real return, risk and future inflation. Thus, part of the risk that a partnership assumes is that it will not achieve its real return requirements.

5.5.2- Right-of-way costs are not considered. Some political and regulatory risks may exist depending on who acquires the land for the project, and who holds title to it, the public or the private sector. It is assumed that the government is more capable of handling such a task and therefore it is ignored in this model. However, it is a cost that will have to be accounted for regardless of the approach adopted.

5.5.3- The analysis is pretax, and hence the discount rate or minimum attractive rate of return is a pretax one. This assumption is viewed as reasonable as it is these that can be compared directly with other opportunities in the market place, for example bond yields. Nevertheless, the structuring of partnerships and projects to take advantage of the provisions of some tax act and to avoid others eventually must be considered.

5.5.4- The model uses nominal inflation, interest and discount rates. Thus, for example, a nominal rate of $x\%$ corresponds to an effective rate of: $\exp(x/100) - 1$.

5.5.5- The capacity of the facility is not reached during the study period. That is, since an exponential rate of growth is assumed, some simple calculations must be made to calculate the projected usage at the end of the operation period (T_o). This must be less than or equal to the capacity of the facility.

5.5.6- For the probabilistic analysis, all of the random variables are assumed to be uncorrelated. Although correlation of some variables may be more obvious than others, no data exists from which robust empirical relationships could be derived. Moreover, treatment of correlation in the exploratory model is not viewed as being critical to a meaningful understanding of the behavior of PPP projects. In general, this assumption means that overall project risk will be underestimated.

5.5.7- The model is cost and risk driven, not market driven. Since the revenue function assumes a drop-off in usage as fare level increases, this approach seeks to minimize the drop-off in usage and thus reduces political risk which may arise as a result of imposing overly increased tolls. Conversely, a market-driven approach seeks to maximize the rate of return, maximizing diversion of traffic and political risk.

CHAPTER 6 - RISK TREATMENT

6.1 BACKGROUND

Risk treatment in terms of identification, assessment and management for projects that are candidates for PPP is crucial for their success. Typically, winning consortium of such projects assume responsibility for a wide range of risks throughout the entire project life-cycle. Some of these risks represent new challenges, simply because they have been traditionally assumed by other project participants. And despite their limited experience in dealing with such risks, the project consortium inherit them with the process. Unfortunately for them, on the one hand, most of the risk assessment tools described in the literature to date (e.g. decision trees) deal with measurement once risks are identified. That is they require the problem to be fully defined before the solution technique can be applied. On the other hand, tools that assist in defining the problem associated with PPP projects by systematically identifying the potential risks likely to impact the project, throughout all its phases, seem not to exist.

In general, the issues of risk identification, assessment and management have been the focus of much research in recent years. In fact, a number of risk analysis methodologies have been proposed in the literature. However, they are intended to serve the needs of individual, traditional, project participants (i.e. owners, designers or contractors), and focus primarily on the design and/or construction phases of a project.

For example, Al-Bahar and Crandall (1990) developed a risk model entitled "Construction Risk Management System", which allows contractors to identify and classify project risks

(acts of God, physical, financial and economic, political and environmental, design, and construction-related risks were included in this work), primarily in a traditional construction setting, and respond with one of five strategies: risk avoidance, loss reduction and risk prevention, risk retention, risk transfer, and insurance. The model is intended to be employed by construction contractors, possibly as a bidding aid, but focuses only on the design and construction phases and does not cover the entire life-cycle of a PPP project.

Mustafa and Al-Bahar (1991) claim that lack of success in a construction project is frequently due to the failure of contractors to analyze and assess unanticipated risks. They developed a project risk assessment technique using the analytical hierarchy process and used it to analyze and assess risks during the bidding stage of a project. However, they also limited the scope of a project to the construction phase.

Kangari (1988) argues that in order to approach complex problems in construction management, decision-makers should follow a systematic and professional approach in risk management. He claims that existing construction risk management models are not practically implemented and accepted in the industry because these models do not fully include heuristic information, rules of thumb, professional experience and subjective judgments of an expert. He then presents an integrated information management system for risk management, "Expert-Risk", which applies the concept of fuzzy set theory to evaluate overall risk of a typical construction project. Six categories of risks are considered - construction related, contractual and legal, physical aspects, performance and management, general economic factors, and political risks. The system offers a useful method of risk identification for all parties involved in a construction project including contractors, designers or owners, in part because it serves

as a database incorporating past experiences on risk and risk management issues. However, it also focuses only on the construction phase of a project.

Ashley and Perng (1987) reported on the development of an "Intelligent Risk Identification System", which is designed to be an expert system for the identification of construction risks and their potential impact, based on past experience. The system is intended to produce a construction risk influence diagram indicating the potential impact of the risk on project cost and schedule, primarily as a tool for use by the project's design team. See also Ashley, Stokes and Perng (1988), and Ashley and Avots (1984) for more details.

Jaafari (1987) noted that more attention should be paid to the preimplementation phases of a construction project, and proposes a "Management Confidence Technique" to assess a project's overall propensity to succeed or fail. However, further work is needed to identify and formulate a relationship between the project constraints and overall propensity to succeed and fail. Also, the multiple perspectives of project participants are not recognized.

Despite the wide range of techniques and methodologies that currently exist in the literature, they are of limited scope. The much wider scope of PPP projects renders virtually all existing risk management techniques ineffective or at best of limited use, especially since relevant experience with the PPP process is limited. Moreover, Yaworsky and Russell (1991) explain that large engineering projects, such as infrastructure projects, embody a number of special aspects and unique characteristics in comparison to smaller undertakings. They claim that despite the range of currently available risk assessment methods and techniques, evidence can be found that a substantial number of large projects cannot be considered successful in terms

of meeting implementation targets such as time, budget and quality, achieving functionality measures such as commercial and technical, or measured against other more qualitative criteria such as sociopolitical aspects. This, at least in part, is due to the inability of most available risk assessment techniques to treat the full spectrum of risks which characterize large and PPP projects. Such techniques can, however, be used in support of a much needed and more comprehensive risk analysis tool. The goal of such a tool should be to assist in the identification, assessment, and management of all significant risks likely to impact the different phases of these projects in order to assess their candidacy for PPP.

This chapter outlines the features of a tool intended to fill this gap. In the following section, the various risk categories to be accommodated by this tool are defined. This is then followed by a description of the steps involved for identifying, classifying and measuring risks. Having processed all of the risks involved, the chapter concludes with suggested criteria for decision-making.

6.2 RISK DIMENSIONS IN PPP PROJECTS

Yaworsky (1994) provided a comprehensive and detailed framework for qualitatively analyzing large projects which included a holistic process to assist in describing a project in terms of its objectives, constraints, external influences, and so forth. Chapter 5 set out another dimension for describing a large project in terms of its phases, components, and cash flow streams. A classification system for describing risks provides yet another dimension for describing a project. All three dimensions combined are essential for a comprehensive project analysis that considers both the qualitative and quantitative aspects. This section describes the

elements of the latter dimension. The goal is to identify and analyze all risks involved in the project as well as including their impact on each project component.

Each project phase embodies unique risks. The nature of these risks must be fully comprehended if an equitable assignment of roles and responsibilities is to be made between the public and the private sectors for a PPP project. In this section, a description of the various risk categories in the context of this research is presented. Eight risk categories, namely *cost & time*, *technical*, *economic*, *financial*, *environmental*, *political & regulatory*, *organizational & contractual*, and *stakeholder* are considered. These categories appear to encompass all risks identified to date from a thorough review of the literature. The PEI case study presented in Chapter 3, is used, where appropriate, as a backdrop to help explain the significance of each risk category. In addition, reference is made, where appropriate, to the model variables defined in Chapter 5.

6.2.1 Cost & Time Risks

This risk category is introduced to account for potential changes, modifications, and delays in the project process. To illustrate, although the duration of the predesign phase, T_{PD} , can be represented by some maximum and minimum estimates, they are based on an assumed set of activities, and logic linking these activities. Both can change because of external influences. Examples include a political requirement to conduct lengthy environmental tests that have not been discussed before, a need to conduct traffic studies with a much wider scope than originally anticipated, forthcoming elections that will delay the process, certain crucial decisions taking longer than expected, and change in public agenda resulting in postponement

of major milestones. All such issues represent risky events that will have a direct impact on the time and cost of each project phase and therefore which need an assessment of their potential time and cost consequences. In severe situations, such risks may require project proponents to make a decision whether to continue pursuing the project and endure increasing costs in anticipation of some future gains or bail out of the entire process and cut their losses.

Risks of this type were present in abundance for the PEI project. Throughout the protracted duration of the predesign phase, Strait Crossing Inc., the winning consortium, had to comply with ever increasing demands made by the government which were dictated by the evolution of the project environment, especially as influenced by the project's stakeholders. Examples include conducting public hearings, defending the project in lengthy court sessions, compensating affected groups, conducting more environmental studies, securing \$200 million as a performance bond and securing a Letter of Credit for \$73 million as extra protection against cost overruns. All such requirements have dramatically increased both the time and cost of the project. As a result, design of the bridge in its current form started in 1987, but construction didn't start until 1993. In addition, costs during this phase have reportedly ranged between \$15,000,000 and \$20,000,000.

6.2.2 Technical Risks

This category includes characteristics of the project related to site conditions, design, constructibility, operating life, safety issues, quality issues, and so forth. In the context of this research, technical risks in a project are associated with ensuring that the anticipated loads are not exceeded, selecting appropriate methods that perform according to expectations,

predicting material properties and geotechnical conditions, etc. An extensive list of technical risks can be found in the literature (see Al-Bahar & Crandall, 1990; Kangari, 1988; and others).

Technical risks encountered in the PEI bridge include:

- Low temperatures and high wind speeds produce high ice forces, and experts cannot agree on the force that should be designed for;
- The project has a short construction season. Loss of productivity, employing an improper construction method, etc. can have a substantial negative impact on time and cost of construction;
- Variable soil conditions and scour problems represented significant technical problems during design and construction; and
- The bridge had to be designed to last for 100 years. Forecasting the service life of concrete in a hostile operating environment is fraught with uncertainty.

6.2.3 Economic Risks

Economic risks derive from the economic climate in which the project will be conceived, constructed and operated. Model variables in the economic domain include inflation rate (θ), differential inflation rates ($\Delta\theta$), interest rates (i_c and i_p), demand growth rate (θ_v), and rate of drop-off in usage as a function of toll level (λ). Other variables not treated include taxation rates, competitive factors (e.g. new technologies), technological shifts, influences derived from the macro economic climate and which affect the variables in the project model (for example, an increase in oil price may negatively affect usage of the facility), etc. Almost all of

these variables are beyond the control of project participants. Nevertheless all of these variables and the underlying mechanisms that influence their values are of critical importance to a project.

6.2.4 Financial Risks

A key to the successful execution of PPP projects is the ability to assemble the necessary capital when needed. To start with, the project must have a significant potential of profitability in order for a private investor to agree to participate in the project and for financial institutions to agree to lend to the investor. Often, government guarantees are required to attract financing. For example, an undertaking from the government that new restrictions will not be placed on a toll structure at some later date, could be vital for securing finance.

Specifically, financial risks in this research deal with the ability to assemble capital when needed, financial stability of the lenders, the price of capital, its repayment scheme, and the ability of all parties of the project to fulfill the terms and conditions of the financing agreement over its life.

6.2.5 Environmental Risks

This dimension includes the specific characteristics of the project related to its interaction with, alteration of, or impact on the surrounding ecosphere. In this sense, a narrow definition of environment is adopted herein. It excludes other aspects such as the legal, regulatory, social, economic, etc. "environments", which are treated under other headings. The difficulty

of assessing environmental impact lies in how to define an acceptable review procedure, the ability to adhere to this procedure, and the ability to accurately forecast the long and short term effects of the project on the various environmental dimensions. Determining acceptable thresholds of damage or pollution has been always a very controversial issue. Even if such thresholds were agreed upon, the assurance that the project can be built within them or that they will stay constant over an extended period of time in the future is a major concern. In addition, the unwillingness by some groups to accept any risk or damage to the environment may circumvent the entire process. Evidently, negative reactions by communities or environmental groups can cause significant set-backs and additional costs.

Environmental risks are often viewed from their perceived or potential, long term or short term, positive or negative impact, on the atmosphere, water, soil and subsoil, level of noise, fauna, flora, landscape, human health, and land use (Holling, 1978). Their consequences impact the various model parameters that deal with time, cost or scope. For example, the existence of an environmentally sensitive area may require temporary relocation of rare species of fauna, flora, and animals during construction and then their reintroduction after the project is completed. This will affect the cost and time of the project, with compensation ultimately being paid by the end users.

Environmental risk was and is significant in the case of the PEI bridge, where the friends of the island group and other similar groups were fiercely attacking approval of the project and still are challenging it in the courts. These groups believe that the bridge construction will damage the whole fishing industry in the area, and negatively impact the serene way of life on

the island. Although the project proposal was reviewed and approved by panel of experts, the environmental groups were and still are not satisfied.

6.2.6 Political & Regulatory Risks

Political and regulatory risks in large engineering projects are potentially the most significant ones, since they in turn impact every other risk category. It is not uncommon that some construction companies were forced into bankruptcy by a political decision to stop work on a project at a critical stage (Tiong, 1990a).

Political and regulatory risks range from labour unrest, the embargo of construction equipment, through to outright expropriation. Changes in laws and regulations, change in government, dissipation of political commitment to the project, war and civil disorder, revolutions, currency devaluation, requirements for permits and their approval are all examples of political and regulatory risks that impact directly and indirectly on various model parameters. Such impacts may be manifested, for example, in increased construction costs (C_o), increased duration and cost of the predesign phase (T_{PD} and C_{PD}), etc.

Political risks existed in the PEI project in the form of changes in government at both the federal and provincial levels, and the seeming lack of resolve to vigorously advocate the merits of the project. They have also included jurisdictional disputes within the federal government itself, between provinces and between provinces and the federal government.

6.2.7 Organizational & Contractual Risks

Developers of PPP projects usually have to play a number of different roles. Sometimes this situation leads to conflicts of interest and places the developers in a paradoxical position. For example, in the event of a downturn in the market for the completed project's product, the owner half of the developer would favor a reduction in the project size but the contractor half might not as it would reduce its work volume (Tiong, 1990a).

The organizational dimension in this research relates to the strength of the project consortium in terms of the qualifications and profile of each member and as a team, their commitment to the project, their individual and team objectives, potential conflicts in such objectives, and the existence of hidden agendas, etc. Additionally, the overall attitude of the organization, its internal and external communication abilities, its relationship with the government, the politicians and the public, and its financial stability are all issues of significant concern. Moreover, identification of roles and responsibilities for each member of the consortium in terms of legally binding agreements, the commitment and enforcement of such agreements and a similar process linking the consortium and government throughout the project life-cycle are major contractual risks.

The PEI project was no exception. The participants in the project have changed over the last 6-7 years, and the consortia that bid the project reconstituted themselves several times. Moreover, as recent events have unfolded, a major partner in the consortium building the project, namely Morrison Knudsen Corp., is facing a critical financial situation and is teetering on the brink of bankruptcy.

6.2.8 Stakeholder Risks

Large projects often attract considerable opposition from different groups of people, each with their own motives and interests. These groups can range from the political opposition that wishes to be regarded as a champion of the public interest, to contractors who do not want to be excluded from these projects (Tiong, Yeo & McCarthy, 1992). Such groups create changing project dynamics that can be extremely complex and hard to read. Project sponsors, therefore, have to try to avoid the consequences of uninformed actions, or failing to act when faced with a changing condition.

In general, the stakeholder dimension deals with the project's interaction with society's agenda, expectations and perceptions, the existence of "for" and "against" groups, their respective source of power, their goals and objectives, and so forth.

In the PEI project, the proposals of the consortia bidding the project had to satisfy the technical, environmental, and financial requirements set by the client as a first qualification stage. Then for those qualified in the first stage, the commercial aspects of their proposal had to be evaluated in order to choose the lowest bidder. However, winning the bid was just a start. The consortium picked to build the bridge was obligated to hold public hearings to gain support from the environmental groups who continue to fiercely attack the project.

Obviously, the PPP problem is characterized by a vast breadth of issues and risks that must be identified, measured and managed. Ideally, an environment in which experience with regard to existing and potential risks can be systematically catalogued and made accessible would be very beneficial.

6.3 THE RISK ANALYSIS PROCESS

The challenge facing both the public and private sectors, for any PPP project, is identifying risks as they apply to the project at hand. Once they have been identified and measured, the next step is to reduce and/or off-load them through a variety of means, including the use of contingency allowances, insurance, contract conditions, carve-out labour agreements, fixed rates, indexing, special studies, and so forth. Described below is a suggested risk analysis process which is designed to systematically identify and measure all potential risks likely to impact the different project parameters. It is proposed that this process eventually be implemented in the form of a computer-based decision environment. As depicted in Figure 6.1, this process is composed of the following four sequential stages.

- *Stage I : Determining The Relevant Project Parameters*

The objective of this first stage is to determine the relevant project parameters which are project (e.g. bridge versus tunnel) and approach (e.g. traditional versus BOT) dependent.

Usually, the project outlook changes based on the respective project scenario, the views of the project proponents as to what should or should not be included in terms of project phases and components (e.g. the existence of a secondary revenue stream), the assumptions made for undertaking the project in terms of financing schemes, general and differential inflation rates, etc., and the understanding developed of the project environment and constraints. Therefore, in this first step of the process, and based on the acquired understanding of the project and its environment, the project analyst will scan through a comprehensive list of project phases, components, and parameters and select the relevant ones and provide a brief description of

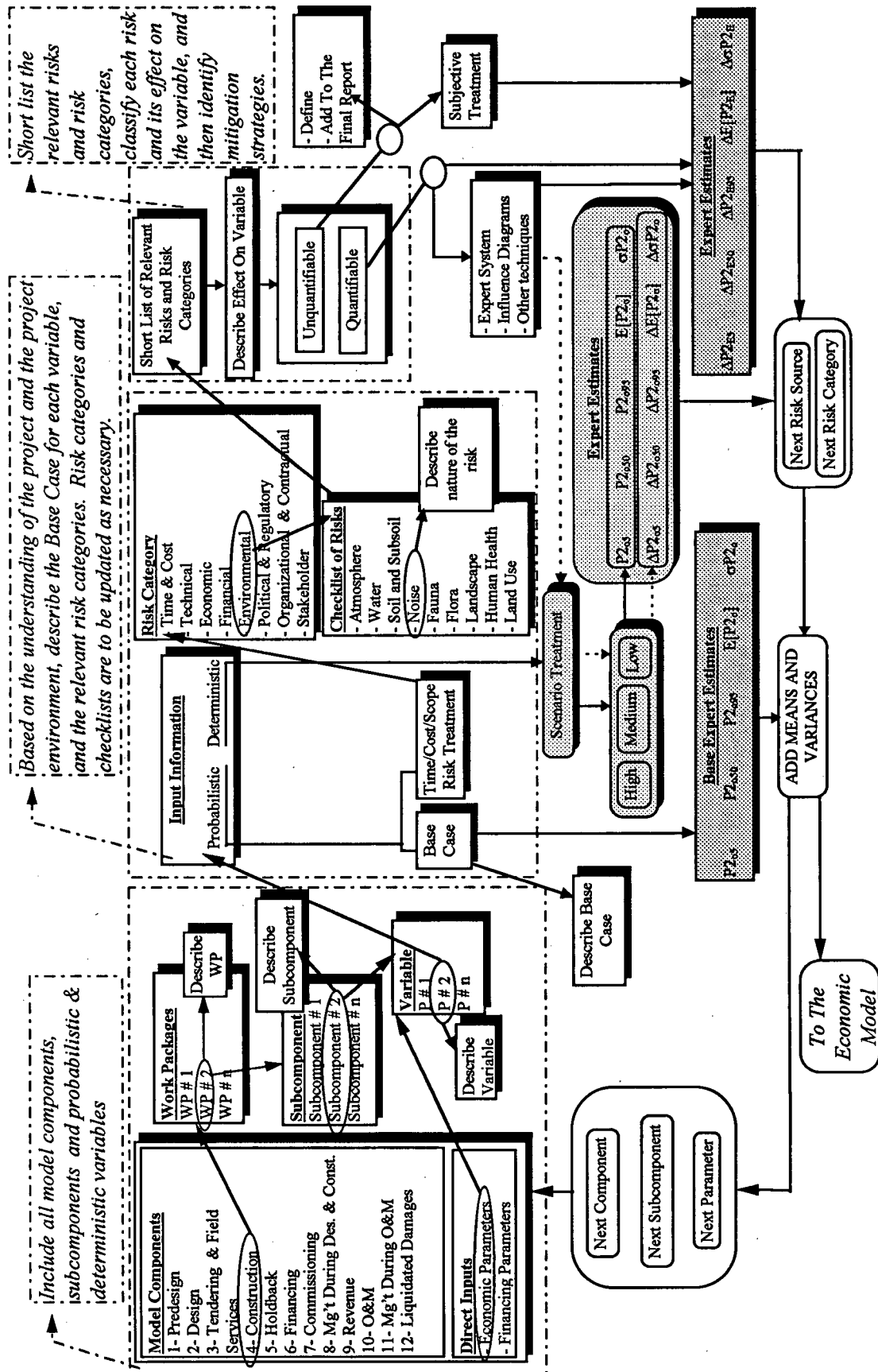


Figure 6.1 Risk Analysis Process For Public-Private Partnership Projects

their relevance to the project scenario being analyzed. This list includes all project phases, such as pre-design, design, etc., economic parameters such as inflation, discount rate, etc., and financial parameters such as interest rates, equity fraction, etc. as described in Chapter 5 (see Table 5.1).

- *Stage II : Identifying Potential Risks*

This stage provides an environment in which to consciously identify all risks likely to impact the various project parameters selected in the previous stage. It involves two tasks. First, each individual variable is classified as a deterministic or probabilistic variable as stated in Chapter 5. *Deterministic variables* are those for which little variation is possible or which are prescribed by legal agreements. In some cases they may be used as strategic variables to control overall project viability. The length of the operating and maintenance phase as prescribed in the concession agreement, minimum attractive rate of return, etc. are examples of such deterministic variables.

Probabilistic variables are those which exhibit uncertainty in their values such as time and cost of construction (T_C and C_0) and design phases, inflation rate (θ), etc. Such uncertainty invariably exists as a result of the potential project risks. This is where the second task in this stage takes place. A base case has to be defined for each probabilistic variable where uncertainty estimates for this base case are meant to reflect the risks traditionally treated (e.g. loss of productivity due to variable work conditions, slippage of schedule, etc.). The analyst then has to consult the available lists of risks and identify, to the best of his/her judgment, relevant potential risk categories (e.g. technical, environmental, economic, etc.) and risk

sources (e.g. in environmental risk category this may include impact on noise, soil and subsoil, fauna, flora, etc.) that will positively or negatively affect each variable, and provide a commentary on how each risk source will affect the variable.

The analyst has to check which if any such special risks were included in the base case to avoid double counting. The value of this task is twofold. First, to make sure that all risks are explicitly investigated. That is, since definition of the base case considered for each variable will include what risks are or are not treated, a second pass in which the impact of individual risk categories and risk sources on the respective variable can be examined, provides for a comprehensive risk identification. Second, it is particularly useful while investigating possible mitigation strategies, since by retrieving such information it can be easily determined which risks contributed to the uncertainty of each project parameter and to what extent.

A direct deliverable of this stage is an analysis tableau that lists all identified issues and risks (see columns 1 through 3 in Table 6.1). Clearly, the more exhaustive and comprehensive this tableau the better the chance for avoiding surprises. A number of risk sources have been cited in the literature in the form of check lists for some of the risk categories identified herein (see Al-Bahar, 1988; Ashley and Perng, 1987; and Holling, 1987). Furthermore, continuous expansion of the risk categories and risk sources under each category lists must be accommodated in order to catalogue experience as it is gained (from the PEI project case study for example).

<i>Stage I</i>	<i>Stage II</i>	<i>Stage III</i>					<i>Stage 5 of The Overall PPP Framework (See Chapter 4)</i>
1	2	3	4	5	6	7	8
Major phase	Performance dimension	Description of conditions/risks	Probability of occurrence	Impact on cost	Impact on time	Impact on scope	Mitigation strategies
Pre-design	Cost & Time performance/risks Technical performance/risks Economic performance/risks Financial performance/risks Environmental performance/risks Political & Regulatory performance/risks Organizational & Contractual performance/risks Stakeholder performance/risks						
Design.....	Cost & Time performance/risks Technical performance/risks Economic performance/risks Financial performance/risks Environmental performance/risks Political & Regulatory performance/risks.....						

Table 6.1 Analysis Tableau For Project Risks Versus Phases & Performance Dimensions

- *Stage III : Assessing All Identified Risks*

Once all significant risks in a project are identified, the next step is to assess them. This is the objective of this stage where all such risks are to be classified as unquantifiable or quantifiable ones, and then the latter quantified.

Not all risks are quantifiable or can be directly treated in models such as the one proposed in this research. For example, loss of political commitment, default of a major party of the consortium, long term environmental impact, etc. are but a few. However, the significance of *Unquantifiable risks* cannot be overemphasized. In fact, some experts are concerned that overlooking the qualitative aspects of risks tends to signal a false sense of confidence and assurance on the outcome. Silverman (1994) explains that to support the decision-making process requires knowledge and heuristics, not just mathematics and flexible model construction environments. Thus, unquantifiable risks have to be identified, and a decision has to be taken as to their treatment in the proposed model. They can be either included in the final project report (as in Table 6.1) subject to further qualitative analysis where potential consequences and mitigation strategies are to be determined, or alternatively, their subjective treatment and inclusion in order-of-magnitude quantifiable form in the model is in some cases possible. For example, a special insurance agreement against unquantifiable political risks such as expropriation can be fed into the model as a monetary value equal to the insurance premium.

Moment analysis is employed in this research to allow for the probabilistic measurement of *quantifiable risks* (see Russell and Ranasinghe, 1992; Ranasinghe, 1994; Pearson and Tukey,

1965; Benjamine and Cornell 1970; and Ang and Tang, 1975). Although moment analysis is only approximate, it has the advantage of providing useful insights into the relative contributions each variable and component makes to the overall risk. Once statistics of the performance measure are estimated, then, for the case of net present value as calculated in equation 5.1 which includes 13 additive terms, by invoking the central limit theorem, one can assert with reasonable confidence that net present value is normally distributed, allowing probabilistic statements to be made.

Use is made of the family of distributions suggested by Pearson and Tukey (1965) to represent all random variables in the model. After comparing most of the formulae available to estimate expected value and standard deviation of a random variable from judgmental estimates, Keefer and Bodily (1983) concluded that the formulae suggested by Pearson and Tukey (1965) are more accurate, often by a wide margin, than their competitors.

Based on this premise, three estimates are required for each such variables - the 5, 50 and 95 percentile values (P_5 , P_{50} and P_{95}). The reasoning behind this choice is explained in Ranasinghe (1994).

Therefore, in this stage, three percentile values should be estimated for the base case of each probabilistic variable P_5 , P_{50} and P_{95} . Similarly, risk impact on the various project parameters in terms of time, cost and scope should be estimated and represented by three percentile values (ΔP_5 , ΔP_{50} and ΔP_{95}) for each risk. Use of these three percentile values permits the estimation of robust measures of the expected value and standard deviation for each risk and ultimately probabilistic input as will be explained in the next stage.

In general, for any random variable X , the formula for the expected value using the three percentile estimates, P_5 , P_{50} and, P_{95} is:

$$E[X] = P_{50} + 0.185 \cdot \Delta \quad (6.1)$$

in which

$$\Delta = P_{95} + P_5 - 2 \cdot P_{50} \quad (6.2)$$

The formula for the standard deviation is:

$$\sigma = \frac{(P_{95} - P_5)}{\max \left[3.29 - 0.1 \cdot \left(\frac{\Delta}{\sigma^*} \right)^2, 3.08 \right]} \quad (6.3)$$

in which

$$\sigma^* = \frac{(P_{95} - P_5)}{3.25} \quad (6.4)$$

In addition, probability of occurrence of risks must also be estimated. Such information are to be fed in columns 4 through 7 in Table 6.1. In so doing, some risks may be perceived as beyond the capacity of the PPP consortium. That is, the project can only be considered if these risks are assumed by or shared with a third party such as the government. Examples of such risks include the high uncertainty of a demand function, requirement for a constitutional amendment which limits the private sector involvement in procurement of public infrastructure (see the PEI bridge case study), etc. These risks and conditions have to be highlighted and subjected to further analysis and negotiation with the government.

It has to be noted that some risks don't have a clear or direct impact on the respective variables. Some environmental risks, such as impact on wild life habitat for example, can fall into this category where a task of relocation of rare species may be required resulting in an impact on project schedule, time and cost. These risks can be treated and quantified by more elaborate schemes as deemed appropriate, such as influence diagrams (Ashley and Avots, 1984), or expert systems (Kangari, 1988), etc. Moreover, several risk sources or categories can interact with each other to produce a certain effect on any one variable. These elaborate schemes may also be used to analyze such relationships. For example, omissions and errors in construction drawings and specifications, in addition to an inexperienced site team and design changes, may individually and collectively result in schedule delay, and increased costs.

Furthermore, in some cases, treatment of different scenarios of risk exposure might be a potential way of treating risks especially when little experience is available as to how the risk consequences can be estimated. For example, and as explained in Chapter 5, general and differential inflation rates, as well as interest rates are assumed to be time invariant. The challenge to the analyst is to estimate an average value for each over the life of the project. To assist in the estimation task, use can be made of scenario building and influence diagrams. Details of such techniques are covered in the literature (Ashley & Avots, 1984; Ashley and Perng, 1987; Howard and Matheson, 1981; and others). As a brief example, Figure 6.2 depicts three scenarios for the long term average inflation rate θ - high, medium, and low.

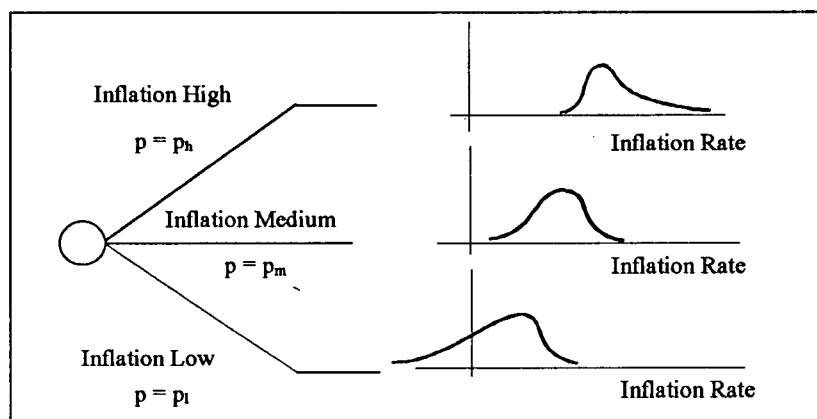


Figure 6.2 Inflation Scenarios

For each scenario, an influence diagram could be constructed to illustrate the conditions which lead to such a scenario, which could in turn be used to assist in estimating the probability of the scenario occurring. Additionally, the consequence of each scenario could be described in terms of a single outcome, or, more realistically, in the form of the three percentile estimates, as described earlier, or a cumulative distribution function, from which estimates of mean and variance can be computed for the scenario. Similar techniques can be used for other probabilistic variables such as interest rates, or to examine the consequences of different risk exposures on probabilistic variables in general.

Special cases of probabilistic variables in this research include the degree of fast-tracking (F), the degree of accelerating construction (A) and degree of overlapping revenue and construction phases (O). They are usually planned for by project management staff to the best of their judgment but their actual values could be different than planned. In actual life the realization of their planned values depends on the skills and experience of the implementation team and is influenced by conditions beyond their control such as loss of productivity due to weather for example. Since these factors represent implementation strategies that are planned

by the project team, they are fed directly into the model without any risk adjustment to their values. Another difference is that while three percentile values are estimated for probabilistic variables to produce mean and variance, the variance of F, A and O is estimated as a fraction of the mean value. For example, the variance of the degree of fast-tracking, F, could be assumed as 10% of the mean (i.e. 10% of the planned degree of fast-tracking) which means the more the degree of fast-tracking the more the uncertainty.

- *Stage IV : Producing The Input Values*

This stage involves producing the deterministic and probabilistic input values for use in the economic model while considering all identified risks and their likely impact on the latter.

A simplifying assumption is made in this stage that all special risks/conditions (Table 6.1) are cumulative and independent. More research is needed in regard to how different risk scenarios may be combined and their independence or correlation determined. Once the different risks are identified in the manner described above, input into the model is made for each variable by adding to the estimated mean and variance of the base case the statistics of the different risks as follows (Bowker and Lieberman, 1972):

$$\bar{X} = \bar{X}_{bc} + \sum_{\text{for all } i} P_{ri} \cdot E_{ri}[\cdot] \quad (6.5)$$

$$\sigma^2_X = (\sigma_{Xbc})^2 + \sum_{\text{for all } i} [P_{ri} \cdot \sigma^2_{Xi} + P_{ri} \cdot E_{ri}[\cdot]^2 - (P_{ri} \cdot E_{ri}[\cdot])^2] \quad (6.6)$$

in which:

\bar{X} is the mean value for the risk adjusted probabilistic parameter X which can be directly used in the economic model,

\bar{X}_{bc} is the mean value of the base case for parameter X,

Pr_i is the probability of occurrence of the i th risk condition for parameter X,

$E_{ri}[\cdot]$ is the mean value of the i th risk condition for parameter X,

σ_X is the standard deviation of the risk adjusted probabilistic parameter X which can be directly used in the economic model,

σ_{Xbc} is the standard deviation of the base case for the parameter X, and

σ_{Xi} is the standard deviation of the i th risk condition for parameter X.

Use can be made to equations 6.1 through 6.4 to calculate mean and standard deviation for each base case and risk profile (i.e. \bar{X}_{bc} , $E_{ri}[\cdot]$, σ_{Xbc} , and σ_{Xi}).

However, equations 6.5 and 6.6 assume only two scenarios per risk condition: the risk is realized with probability Pr_i and a random outcome with a mean $E_{ri}[\cdot]$ and a standard deviation σ_i ; and the risk is not realized with the probability $1-Pr_i$ and a certain outcome of zero. In case of several risk exposures are considered for parameter X, mean and standard deviation for each risk can be treated as follows for a risk condition i , with j exposure profiles each of which has a mean, a standard deviation and a probability of occurrence:

$$\overline{E_{ri}[\cdot]} = \sum_{\text{for all risk exposures } j} Pr_{ij} \cdot E_{rij}[\cdot] \quad (6.7)$$

$$\sigma^2_{xi} = \sum_{\text{for all risk exposures } j} Pr_{ij} \cdot \sigma^2_{xij} + \sum_{\text{for all risk exposures } j} Pr_{ij} \cdot Er_{ij}[\cdot]^2 - \sum_{\text{for all risk exposures } j} (Pr_{ij} \cdot Er_{ij}[\cdot])^2 \quad (6.8)$$

$$\text{while } \sum_{j=1}^j Pr_{ij} = 1.$$

where:

$\overline{Er}[\cdot]$ is the mean value of the i th risk condition for parameter X ,

Pr_{ij} is the probability of occurrence for the exposure j of the i th risk condition,

$Er_{ij}[\cdot]$ is the mean value of the risk exposure j of the i th risk condition,

σ_{xi} is the standard deviation of the i th risk condition for parameter X , and

σ_{xij} is the standard deviation of the exposure j of the i th risk condition.

It should be noted that while the foregoing procedures are equally applicable for treating risks for time variables (e.g. T_{PD} , T_C , T_D , etc.), cost variables (e.g. C_o , C_{oCOM} , etc.) and scope variables (e.g. V_o , θ), care has to be exercised in the case of the time variables. Since the duration of each phase is based on a network of activities, risks have to impact on the critical activities (or the near critical ones) in order for them to be considered for any time variable.

In summary, adjustment of base case estimates in terms of time, cost or scope to include the impact of the identified risks will ultimately result in a mean and variance for each probabilistic variable that will be used in the economic model. As for the deterministic variables, single values can be used to represent them with their variance equal to zero. Several scenarios can

also be used for the deterministic variables to investigate various project possibilities - e.g. long versus short operating period (T_0).

Once estimates for the expected value and standard deviation of each random variable and parameter is available, a first and second moment (mean and variance) approach can be used for estimating the uncertainty surrounding NPV (or any other performance measure, such as IRR, or payback period for example). The first and second moments of NPV are computed as:

$$E[NPV] \cong NPV(\mu_x) + 1/2 \cdot \left\{ \sum_{i=1}^n \frac{\partial^2 NPV}{\partial X_i^2} \cdot \sigma_{x_i}^2 + 2 \cdot \sum_{i=1}^n \sum_{j=i+1}^n \frac{\partial^2 NPV}{\partial X_i \cdot \partial X_j} \cdot \rho_{x_i x_j} \cdot \sigma_{x_i} \cdot \sigma_{x_j} \right\} \quad (6.9)$$

and

$$\sigma_{NPV}^2 \cong \sum_{i=1}^n \left(\frac{\partial NPV}{\partial X_i} \right)^2 \cdot \sigma_{x_i}^2 + 2 \cdot \sum_{i=1}^n \sum_{j=i+1}^n \frac{\partial NPV}{\partial X_i} \cdot \frac{\partial NPV}{\partial X_j} \cdot \rho_{x_i x_j} \cdot \sigma_{x_i} \cdot \sigma_{x_j} + \dots \quad (6.10)$$

in which:

$E[NPV]$ is the mean of the Net Present Value,

$NPV(\mu_x)$ is the Net Present Value evaluated at the means of the input variables,

$\sigma_{x_i}^2$ is the variance of an input variable x_i ,

σ_{x_i} is the standard deviation of an input variable x_i ,

$\rho_{x_i x_j}$ is the correlation between input variables x_i and x_j , and

σ_{NPV}^2 is the variance of Net Present Value.

As explained earlier in Chapter 5, correlation between variables is neglected in this research in order to lessen the estimation burden. In general, this assumption means that the overall project risk will be underestimated. Moreover, higher level moments (e.g. third and fourth moments, which represent skewness and kurtosis respectively) could be calculated given sufficient data (see Russell and Ranasinghe, 1992). Considering only two moments and ignoring higher ones may be viewed as simplification for the moment analysis, but it is commensurate with the overall objectives set forth for this research.

Linear sensitivity coefficients, S_{X_i} , that link fractional change in a dependent variable (NPV) to an independent one (X_i) can be expressed as:

$$S_{X_i} = \left(\frac{\partial NPV}{\partial X_i} \right) \cdot \left(\frac{X_i}{NPV} \right) \quad (6.11)$$

(See Appendices A & B)

Thus, uncertainty in NPV as measured by variance is a direct function of the sensitivity of performance of NPV to changes in input variable and input variable uncertainty. Clearly, management's attention should be focused on those variables that exhibit high sensitivity and high uncertainty. This provides for setting priorities while investigating mitigation strategies for such variables (see column 8 of Table 6.1).

6.4 CRITERIA FOR DECISION-MAKING

It is advocated in this research that in order to assess the candidacy of any project for a PPP approach and/or assess the suitability of one PPP form versus another, it is crucial to

decompose the project into its components and analyze its basic features, risks and opportunities rather than performing some cursory treatment at a global level. It is believed that the insights developed by the former route not only will provide for a well-grounded decision but it will also highlight issues of special concern to the decision makers, provide a means for establishing an equitable trade-off between risk levels and return, help to identify the parties that are most suited to assuming certain risks, and so forth, thereby enhancing the chances of a better relationship between both the public and the private sectors, should they adopt the PPP approach.

Eventually, however, all of the risks, constraints, issues of concern, etc. must be synthesized for purposes of decision-making. In order to provide for a comprehensive view of the project at hand, this synthesis must include both the qualitative and quantitative aspects of the project.

A direct deliverable of the risk assessment described above is the analysis tableau for project phases versus performance dimensions (see Table 6.1). Similar tableaus can be prepared for different project approaches (e.g. traditional versus PPP) or for different potential PPP modes of delivery (e.g. Design-build versus BOT, etc.).

Additionally, several quantitative, performance measures such as NPV, IRR on equity and on total capital, toll levels required, etc. can be derived from application of the model described in Chapter 5. Of particular usefulness are criteria that incorporate the decision makers' attitude towards risk. One traditional approach of establishing such a measure is achieved by formulating a utility function for the project decision makers which represents their attitude towards risk. This function can then be used to evaluate the project potential. However,

formulating such a function for a large group of decision makers with often conflicting objectives and in a situation with complex risks the consequences of which are not easily comprehensible, is a formidable task. Therefore two specific tests of probability of failure are introduced in this section as a practical means for incorporating risk into the decision making process (see Russell and Wahdan, 1994; Wahdan, Russell and Ferguson, 1995).

The first deals with the probability that the project will yield a return on equity capital that is less than what can be achieved for publicly regulated utilities (y_u), the notion being that transportation infrastructure is similar in many respect to telephone services, power services, etc. It uses known rates of return for such projects, as a bench mark against which the potential for the PPP project at hand can be measured. That is, in certain situations governments may endorse certain rates of return for specific projects. However, there is a probability that such rates of return will not be achieved which can be indicated by a negative Net Present Value (NPV) for that discount rate. Such probability can be easily calculated and its acceptable level (ϕ_u) can be assigned by the decision makers to represent the upper bound for such risks, given their attitude toward risk. This test can be written as:

$$\text{Prob}[\text{NPV}_{@y=y_u} < 0.0] \leq \phi_u \quad (6.12)$$

in which $\text{NPV}_{@y=y_u}$ is the Net Present Value calculated with a discount rate y equal to a regulated discount rate, y_u .

The second test deals with the probability that the rate of return on equity capital will be less than the cost of borrowed capital (i), a situation of negative leverage to the project proponents - i.e.

$$\text{Prob}[\text{NPV}_{@y=i} < 0.0] \leq \phi_i \quad (6.13)$$

in which $\text{NPV}_{@y=i}$ is the Net Present Value calculated with a discount rate y equal to the financing rate i .

Similarly, ϕ_i represents an upper bound for an acceptable probability of failure. Values for ϕ_i and ϕ_u adopted will likely differ between the public and private sectors. In the context of a user-pay facility, these two tests can be used to determine the rate of return and hence toll level that is commensurate with the costs and risks involved.

A schematic application of these tests is depicted in Figure 6.3. The significance of these two tests will be further illustrated in the case study in the next chapter. In general, the more risk averse an investor is, as reflected by assuming more stringent criteria for probability of failure, the higher the toll required and the higher the rate of return. These two tests are viewed as much easier to formulate and to fathom than a utility function. Moreover, they provide for a better comprehension of the consequences of risk and the relation between the different risk levels and rates of return.

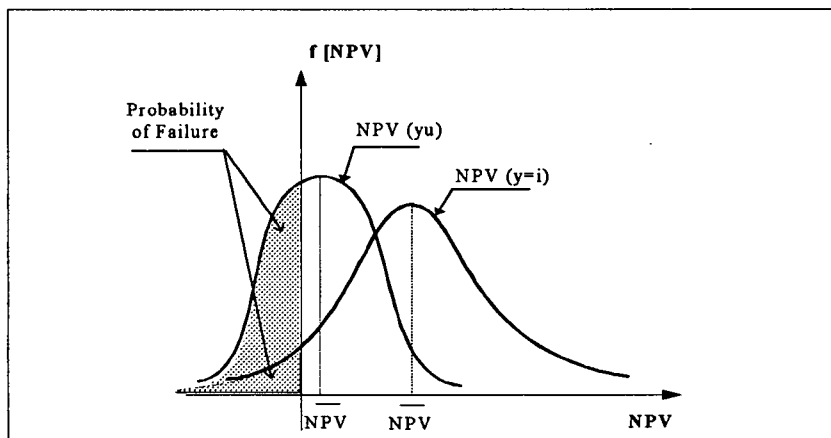


Figure 6.3 Schematic Of Probability of Failure Tests

CHAPTER 7 - EXAMPLE RESULTS

7.1 INTRODUCTION

The developed framework is used in this chapter to analyze a hypothetical case study. It is abstracted from an ongoing project, which is concerned with the rehabilitation/replacement of a major bridge in British Columbia, Canada. A major interest of the owners of this bridge project, namely the Ministry of Transportation and Highways in B.C. (MoTH-B.C.), is to have a means with which to assess the pros and cons of various PPP arrangements for such a project, and to determine how to price out risks for a given assignment of risks. In particular, answers to the following questions are sought:

- 1) Should a public-private partnership approach be used?
- 2) What public-private partnership mode should be adopted?
- 3) What should the roles, responsibilities, and risk assignment be for each partner?

Thus, an opportunity was offered by MoTH to test out the usefulness of the developed analysis framework. It was employed to aid MoTH in finding answers to such questions by providing insights into the anatomy of the project at hand, investigating the relative magnitude of the risks involved, and examining some of the assertions of proponents of PPP.

7.2 OBJECTIVES

A hypothetical case study is used in this chapter to:

- 7.2.1) Illustrate the use of the framework developed in assisting both the private and the public sectors to develop insights into the anatomy of the project being analyzed;

7.2.2) Assess the suitability of an infrastructure project for a PPP mode of procurement as opposed to the traditional one;

7.2.3) Identify the magnitude of risks involved and highlight the use of the developed risk analysis framework; and

7.2.4) Investigate some of the assertions made in the literature dealing with the benefits of adopting implementation strategies such as fast-tracking the design and construction phases and accelerating construction.

Only two project scenarios are investigated in this chapter, namely a traditional approach and a BOT one. The chapter starts by describing a hypothetical case study for the BOT scenario followed by the traditional one. Probabilistic and deterministic analyses are presented for both project scenarios.

7.3 THE CASE STUDY

Table 7.1 presents the data used for the case study. It should be noted that all estimates in this chapter are made by the author to reflect the order-of-magnitude variable values for the bridge project. No expert estimates are used, and original data are suppressed for reasons of confidentiality. Moreover, only base estimates of the uncertainty surrounding each probabilistic variable were made - i.e. only the first phase of the two-step estimation procedure described in Chapter 6 was employed. However, a small example is provided to illustrate application of the second step in the risk assessment process.

7.3.1 The BOT Scenario

As presented, the data in Table 7.1 represents the private proponents viewpoint of a BOT project. All estimates of uncertainty are meant to reflect traditional risks only - i.e. no special risk conditions are involved. The following observations are also important when interpreting the results:

- 1) No government subsidy was introduced and no secondary revenue stream was used.
- 2) Equity is limited to 15% of the total expenditures in design, tendering and design field services, construction, commissioning, holdback and, management during design and construction.
- 3) The loan interest rate during construction is equal to that during debt servicing.
- 4) Costs for operation and maintenance of the existing facility are not considered.
- 5) All acceleration strategies - fast-tracking design and construction, accelerating construction, and overlapping construction and commissioning are applied simultaneously.
- 6) Constant dollar construction costs include estimates of five different components as shown in Table 7.2. These costs refer to the traditional approach. Furthermore, for the BOT scenario, a 25% savings in cost (optimistic) are used to reflect a more efficient implementation by the private sector (i.e. the adoption of a design-build approach as part of the BOT approach is assumed) (see Johannesson, 1990; Anon, 1995; and Anon, 1994). Thus \$108,517,500 is used for the mean of constant construction costs (C_{ob}) in this scenario with a standard deviation of \$5,536,323.
- 7) The demand function used has no inertia region (i.e. $\Gamma_o = 0.0$), and no captive audience (i.e. $v_f = 0.0$) as shown in Figure 7.1.
- 8) A discount rate of 14% was adopted for this approach.

SYMBOL	DESCRIPTION	P5	P50	P95	E[-]	σ
Pre-design						
T_{PD}	Duration in years, of pre-design phase	2.5	3.0	4.0	3.0925	0.47279
C_{PD}	Constant dollar rate per unit time pre-design expenditures	2,000,000	2,500,000	3,000,000	2,500,000	315,195
Detailed Design						
F	Degree of overlap between design and construction	(Probabilistic)			0.4	$0.2 \cdot E[F]$
T_{Db}	Duration, in years, of design phase for traditional, public sector approach	1.25	1.33	1.75	1.3929	0.16234
T_{DF}	Time penalty, in years, for design phase for fast-tracking degree of $F = 1$	0.25	0.5	0.75	0.5	0.15198
T_D	Design duration	$T_D = T_{Db} + T_{DF} \cdot F$				
d_D	Cost of detailed design as a fraction of current dollar construction cost	(Deterministic)			0.06	0.0
E_D	Fraction of detailed design cost paid from equity funds	(Deterministic)			0.15	0.0
Tendering and Design Field Services						
T_T	Time, in years, required for tendering and award of first construction work package	0.167	0.208	0.33	0.22298	0.05292
d_T	Cost of tendering and design field services as a fraction of current dollar construction cost	(Deterministic)			0.09	0.0
E_T	Fraction of tendering and design field services paid from equity funds	(Deterministic)			0.15	0.0
Construction						
T_{Cb}	Construction duration in years for traditional approach	2.5	3.0	3.5	3.0	0.30395
T_F	Construction duration time penalty, in years, for fast-track value of $F = 1$.	0.25	0.5	0.75	0.5	0.15198
T_O	Construction duration time penalty, in years, for construction and commissioning/revenue value of $O = 1$.	0.25	0.33	0.5	0.34665	0.07929
T_C	Duration of construction phase	$T_C = (T_{Cb} + T_F \cdot F + T_O \cdot O) (1 - A)$				
C_{ob}	Constant dollar construction cost for traditional approach	Derived from constituent work packages (Probabilistic)				
A	Degree of acceleration of construction phase	(Probabilistic)			0.2	$0.25 \cdot E[A]$
O	Degree of overlapping of construction and commissioning/revenue phases	(Probabilistic)			0.1	$0.10 \cdot E[O]$

Table 7.1 Case Study Parameters - Private Sector Viewpoint

SYMBOL	DESCRIPTION	P5	P50	P95	E[-]	σ
z	Shape factor for constant dollar expenditure	(Deterministic)			0.0	0.0
w_1	Shape factor for constant dollar expenditure	(Deterministic)			0.3	0.0
w_2	Shape factor for constant dollar expenditure	(Deterministic)			0.4	0.0
C_{oA}	Constant dollar construction cost penalty for $A = 1$.	10,000,000	15,000,000	20,000,000	15,000,000	3,039,510
C_{oF}	Constant dollar construction cost penalty for $F = 1$.	5,000,000	7,500,000	10,000,000	7,500,000	1,519,760
C_{oO}	Constant dollar construction cost penalty for $O = 1$.	1,000,000	1,500,000	2,000,000	1,500,000	303,951
C_o	Constant dollar construction cost	$C_o = C_{oA} + C_{oF} + C_{oO}$				
E_C	Fraction of construction costs paid from equity funds	(Deterministic)			0.15	0.0
$\Delta\theta_C$	Differential inflation rate for construction	(Probabilistic)			0.0	0.0
Commissioning						
T_{COM}	Time in years required for essential commissioning	0.125	0.167	0.333	0.18994	0.06753
C_{COM}	Constant dollar cost of commissioning	1,000,000	1,500,000	2,000,000	1,500,000	303,951
E_{COM}	Fraction of commissioning costs paid from equity funds	(Deterministic)			0.15	0.0
$\Delta\theta_{COM}$	Differential inflation rate for commissioning	(Probabilistic)			0.0	0.0
Management During Design & Construction						
C_{MTRC}	Constant dollar rate per unit of time for management expenditures during design & construction phases	2,000,000	2,500,000	3,000,000	2,500,000	303,951
E_{MTRC}	Fraction of management costs paid from equity funds	(Deterministic)			0.15	0.0
$\Delta\theta_{M1}$	Differential inflation rate for management during D&C	(Probabilistic)			0.0	0.0
Holdback Release						
T_H	Time, in years, when holdback is released after both essential commissioning & construction are completed	41/365	41/365	41/365	41/365	0.0
h	Holdback fraction	0.05	0.05	0.05	0.05	0.0
E_H	Fraction of holdback release paid from equity funds	(Deterministic)			0.15	0.0
Primary Revenue Stream						
T_o	Length of operating phase in years	(Deterministic)			35	0.0
Γ	Fare or user charge per trip at time zero	(Deterministic)			1.00	0.0
Γ_o	Initial inertia toll value in dollars/trip	(Deterministic)			0.0	0.0

Table 7.1 (Cont'd) Case Study Parameters - Private Sector Viewpoint

SYMBOL	DESCRIPTION	P5	P50	P95	E[-]	σ
V_o	Annual volume of trips at start of operation, assuming no tolls.	24,455,000	27,330,000	28,023,000	26,926,300	1,158,440
v_f	Fraction of fixed or captive users	(Probabilistic)			0.0	0.0
λ	Decrease in usage as function of toll level	0.1342	0.2	0.2658	0.2	0.04
θ_v	Growth rate of trips per year	0.0025	0.00426	0.01	0.005	0.00244
g	Fraction of general inflation rate to which tolls are indexed	(Deterministic)			0.9	0.0
Secondary Revenue Stream						
T_{cs}	Duration of secondary revenue Stream					
S_s	Lag, in years, between start of construction and start of secondary revenue stream					
S	Constant dollar rate of secondary revenue stream					
Operating & Maintenance Costs						
M	Constant dollar annual cost of operation and maintenance at time zero	3,000,000	3,500,000	4,000,000	3,500,000	303,951
m	Slope of linear increase in constant dollar operating and maintenance costs	20,000	25,000	30,000	25,000	3,039
R	Constant dollar cost at time zero of major expenditures for repainting/resurfacing	2,200,000	2,500,000	2,800,000	2,500,000	182,371
n	Interval, in years, between major expenditures for repainting/resurfacing	(Deterministic)			10.0	0.0
$\Delta\theta_{O\&M}$	Differential inflation rate for O&M	(Probabilistic)			0.0	0.0
Operating & Maintenance Costs of Existing Facility						
M_{ex}	Constant dollar annual cost of operation and maintenance of existing facility at time zero.	(Probabilistic)			0.0	0.0
EX	Rate of increase in operating and maintenance cost for existing facility	(Probabilistic)			0.0	0.0
$k1$	Time in years for uniform expenditures	(Probabilistic)			0.0	0.0
$k2$	Time in years when costs start to increase.	(Probabilistic)			0.0	0.0

Table 7.1 (Cont'd) Case Study Parameters - Private Sector Viewpoint

SYMBOL	DESCRIPTION	P5	P50	P95	E[-]	σ
Management During Operating Phase						
C_{MGTO}	Constant dollar annual cost for management during operating phase	1,600,000	1,800,000	2,000,000	1,800,000	121,581
$\Delta\theta_{\text{OZ}}$	Differential inflation rate for management during O&M	(Probabilistic)			0.0	0.0
Financing and General Economic Variables						
T_p	Length of time, in years, for amortization of debt	Derived				
T_s	Lag in years between holdback release and start of debt servicing	(Probabilistic)			0.0	0.0
θ	General, long term inflation rate	0.025	0.035	0.0475	0.0354625	0.00687
i_c	Loan interest rate during design and construction	0.09	0.1	0.11	0.1	0.00608
i_p	Interest rate during debt servicing period	0.09	0.1	0.11	0.1	0.00608
y	Pretax minimum attractive return (discount rate)	(Deterministic)			0.14	0.0

Table 7.1 (Cont'd) Case Study Parameters - Private Sector Viewpoint

Work Package	P_5	P_{50}	P_{95}	$E[.]$	σ
The Bridge Structure	88,620,000	93,280,000	107,270,000	95,010,000	6,055,195
Inlet Approach	8,030,000	9,180,000	12,620,000	9,600,000	1,490,260
Outlet Approach	3,920,000	4,350,000	5,660,000	4,510,000	564,935
Toll Plaza	15,750,000	18,000,000	24,750,000	18,830,000	2,922,078
Signaling	14,000,000	16,000,000	22,000,000	16,740,000	2,922,078
Construction Costs				144,690,000	7,381,765

Table 7.2 Constant Dollar Work Package Estimates - Traditional Approach

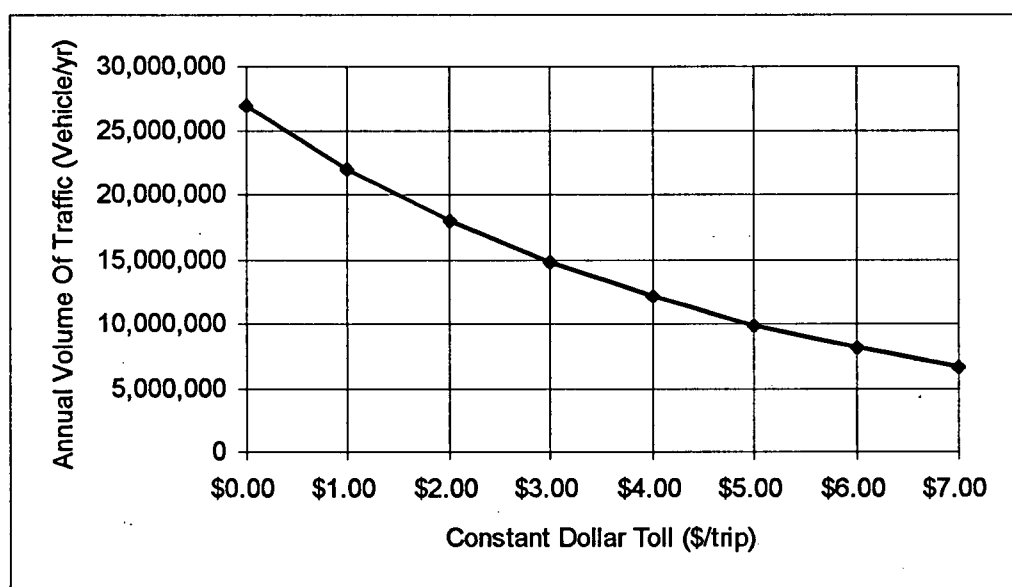


Figure 7.1 Demand Function

7.3.1.1 Deterministic Analysis - BOT Approach

The Net Present Value (NPV) was calculated for this scenario using a \$1.00 user charge. NPV is equal to \$11,222,099, and the internal rate of return on equity is 18.7%. The basis for using a \$1.00 toll is explained in the next subsection. A nonlinear sensitivity analysis was made for the demand function variables (i.e. T_0 , V_0 , θ_v , λ , g and Γ_0) from both an equity

capital and total capital perspective. The results are presented in Table 7.3 and the equity capital case is depicted in non-dimensional form in Figure 7.2. For the variables examined, NPV is found to be most sensitive to the estimate of initial volume of traffic for a zero toll rate V_0 , followed by the rate g with which tolls are indexed to the general inflation rate, the length of concession period T_0 , decay in traffic with increased toll level λ , and growth in traffic volume θ_v . What the foregoing results help illustrate is the significant sensitivity of NPV to changes in revenue function variables, the estimates of which are usually surrounded by considerable uncertainty (note that the sensitivity of NPV to changes in revenue variables is contrasted to the sensitivity to changes in other variables for the traditional case). This may prove to be a very important factor while negotiating a PPP arrangement, since the private proponent, being risk averse, may want the government to share this uncertainty. This notion is examined further in the probabilistic analysis. Also, of note is the significant change in NPV when an inertia region is inserted (i.e. $\Gamma_0 > 0.0$) into the demand function. Little guidance is available in the literature as to how to estimate values for Γ_0 and/or demonstrate that it is indeed zero. What the analysis shows is that the significance of a non-zero value cannot be ignored.

To	Vo	Θv	λ	g	Γ_o	NPV (On Equity)	NPV (On Total Capital)
35	26,926,300	0.005	0.2	0.9	0.00	11,222,099	-14,563,734
25	26,926,300	0.005	0.2	0.9	0.00	4,647,138	-18,234,865
30	26,926,300	0.005	0.2	0.9	0.00	8,597,397	-15,932,220
40	26,926,300	0.005	0.2	0.9	0.00	12,988,471	-13,750,373
45	26,926,300	0.005	0.2	0.9	0.00	14,191,539	-13,266,920
35	24,455,000	0.005	0.2	0.9	0.00	2,055,426	-23,730,406
35	28,023,000	0.005	0.2	0.9	0.00	15,290,034	-10,495,798
35	26,926,300	0	0.2	0.9	0.00	6,423,718	-18,757,955
35	26,926,300	0.0025	0.2	0.9	0.00	8,780,717	-16,700,964
35	26,926,300	0.0075	0.2	0.9	0.00	13,751,773	-12,342,112
35	26,926,300	0.01	0.2	0.9	0.00	16,374,040	-10,031,695
35	26,926,300	0.005	0.1	0.9	0.00	21,726,192	-4,059,640
35	26,926,300	0.005	0.15	0.9	0.00	16,342,871	-13,852,225
35	26,926,300	0.005	0.25	0.9	0.00	6,351,069	-23,424,430
35	26,926,300	0.005	0.3	0.9	0.00	1,717,602	-27,863,319
35	26,926,300	0.005	0.2	0.8	0.00	5,479,538	-23,755,901
35	26,926,300	0.005	0.2	1	0.00	17,349,268	-13,412,904
35	26,926,300	0.005	0.2	0.9	0.25	16,342,871	-13,852,225
35	26,926,300	0.005	0.2	0.9	0.5	21,726,192	-8,694,972
35	26,926,300	0.005	0.2	0.9	0.85	29,729,681	-1,027,583

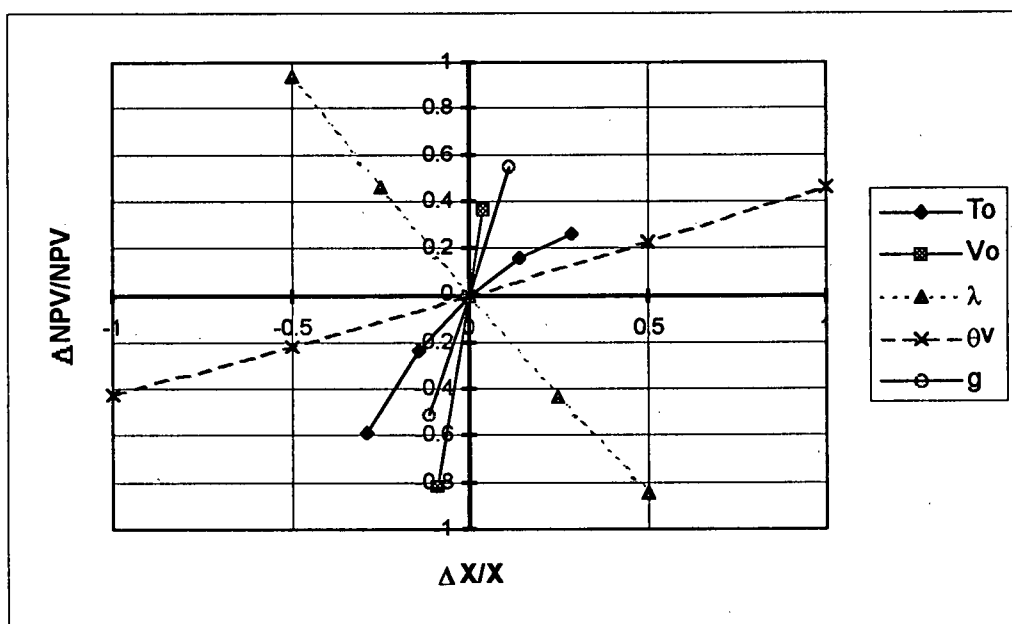
Table 7.3 Data for Sensitivity Analysis ($\Gamma = \$1.00$) - BOT Approach

Figure 7.2 Non-Linear Sensitivity Chart - On Equity - BOT Approach

The influence of fast-tracking and construction acceleration strategies on NPV and time to start of operation is highlighted in Figures 7.3(a), 7.3(b), 7.4(a), 7.4(b) and 7.5. In particular, three scenarios are examined: when no costs or time penalties associated with project speed-up are considered; when time and cost penalties are considered to reflect inefficiencies associated with speed-up and expenditures for shift work, overtime, rework, and so forth; and when the costs of operation and maintenance of the existing facility are included. The latter costs are designed to start relatively early in the design phase and are meant to provide a strong incentive to speed-up the project delivery process. They are assumed to increase exponentially with time as depicted in Figure 7.6 ($M_{ex} = \$10,000,000$; $k_1 = 0$; $k_2 = 3.5$ years; $EX = 0.5$). For the three scenarios studied, acceleration of construction seems more beneficial than fast-tracking, as indicated by the increasing levels of NPV with increased (A) values. Some benefits are obtained from fast-tracking in the hypothetical case of no penalties included (see Figure 7.3(a)). Once cost and time penalties are considered, however, fast-tracking is no longer attractive from an economic perspective and benefits derived from accelerating construction are reduced significantly (see Figure 7.4(a)). Clearly, time to start of operation is also negatively affected when penalties are included (see Figures 7.3(b) and 7.4(b)). In the third scenario, the costs of operation and maintenance of the existing facility outweigh the time and cost penalties for fast-tracking and render it marginally beneficial.

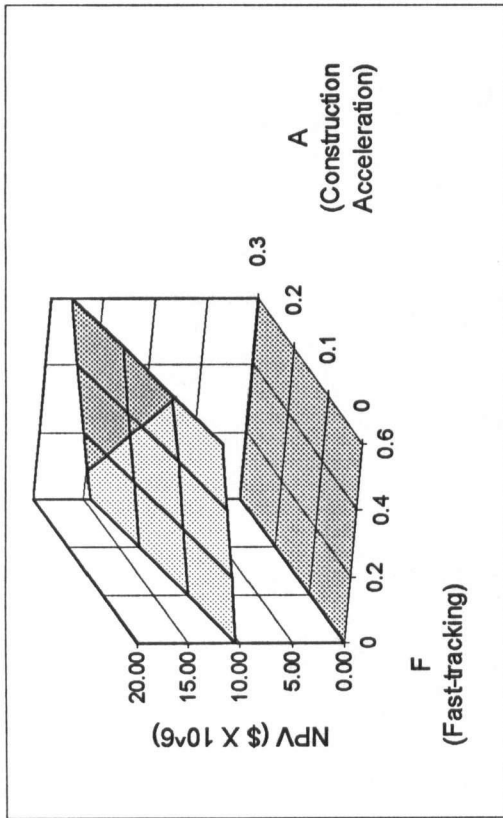


Figure 7.3(a) NPV vs. F and A : No Penalties - BOT Approach

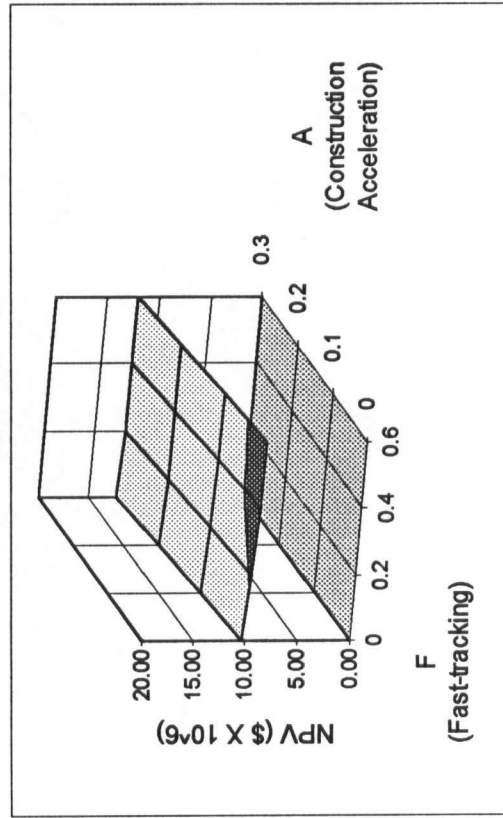


Figure 7.4(a) NPV vs. F and A : Time and Cost Penalties Included - BOT Approach

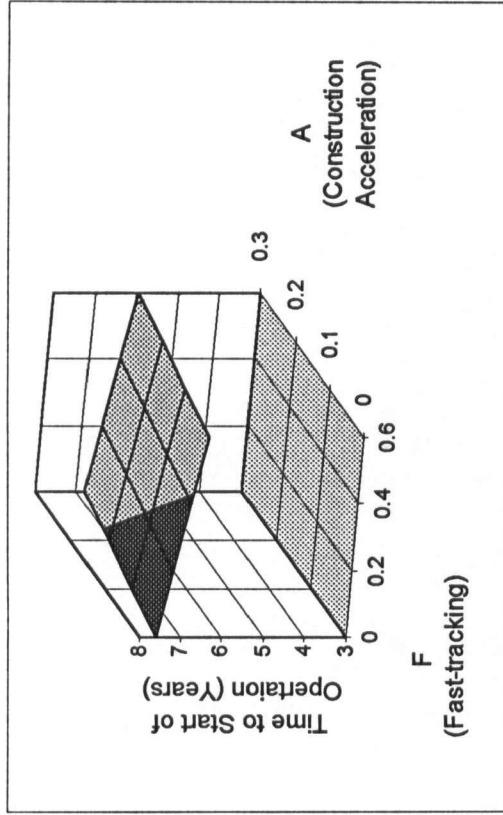


Figure 7.3(b) Time to Start of Operation : No Penalties - BOT Approach

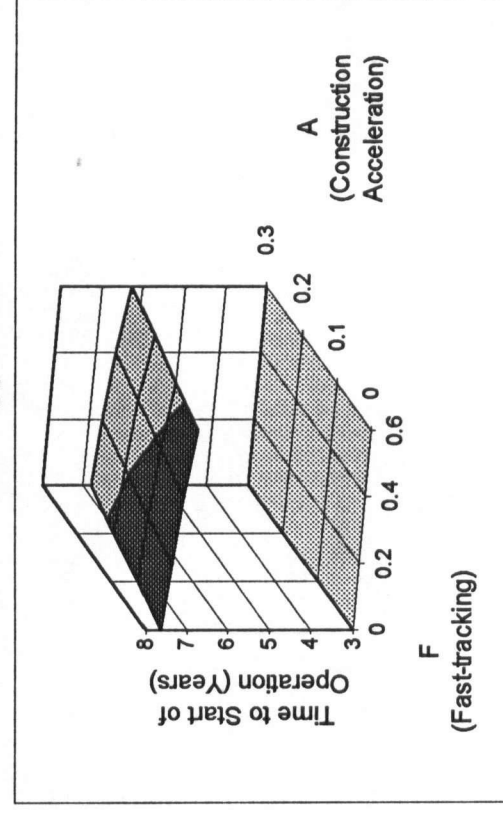


Figure 7.4(b) Time to Start of Operation : Penalties Included - BOT Approach

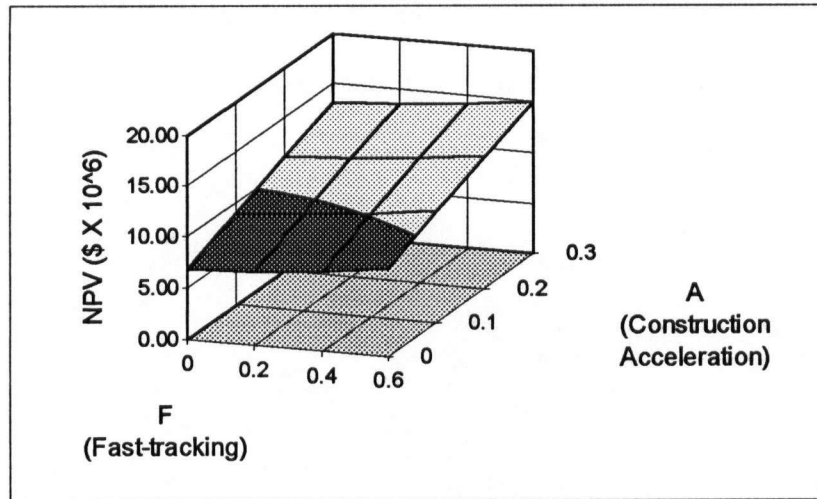


Figure 7.5 NPV vs. F and A : Time and Cost Penalties and Costs of O&M For Existing Facility Included - BOT Approach

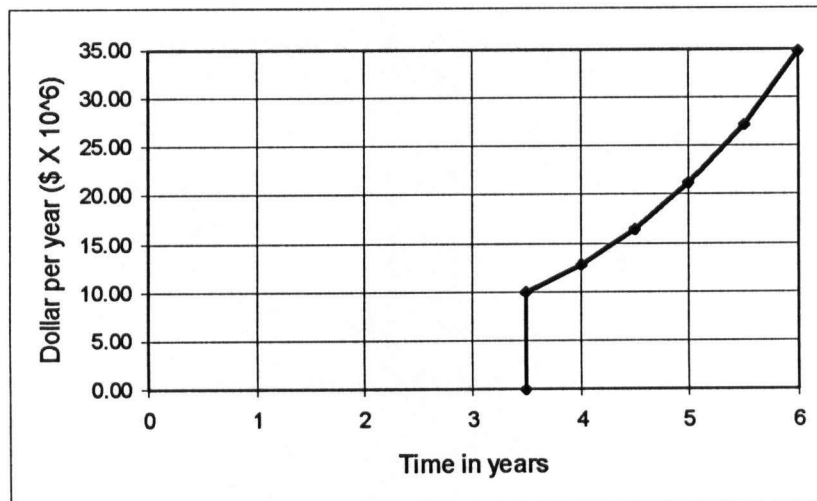


Figure 7.6 Expenditure Function for Operation and Maintenance of Existing Facility - BOT Approach

Shown in Figure 7.7 are NPV and IRR values as functions of the constant dollar toll. This figure highlights the difference between setting tolls based on a cost and risk driven approach versus a market or profit driven one. From a profit maximization viewpoint, constant dollar tolls of approximately \$5.00 would be optimal (a rate of return on equity in excess of 40%). But, the number of vehicles per year using the facility would only be in the neighborhood of 12 million (see Figure 7.1). Such a scheme could result in potentially high political risks and a lack of public acceptance. It has to be noted that, in general, high rates of return are not unrealistic for those assuming all of the risks. Moreover, very high leverage can magnify the returns on equity capital, creating the impression that excessive profits are being made when they are not. Consequently, it is also useful to compute the return on total capital.

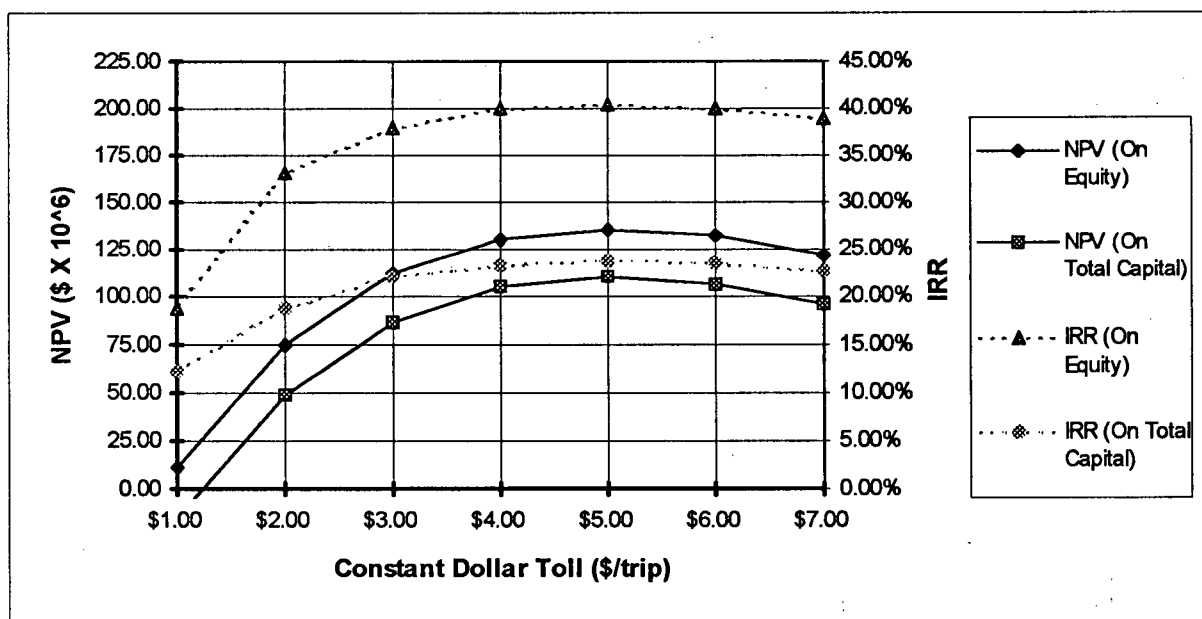


Figure 7.7 Profit Maximization Curves - BOT Approach

7.3.1.2 Probabilistic Analysis - BOT Approach

The two probability of failure tests described in Chapter 6 are used in this case study to set the toll level. Upper bounds are arbitrarily assumed for the private sector as $\phi_u = 12.5\%$ and $\phi_i = 2.5\%$ when $y = 13\%$ (equal to the assumed regulated rate of return) and $y = 10\%$ (equal to the rate of financing) respectively. Figure 7.8 indicates that the second test governs and that \$1.00 toll satisfies both tests. The significance of Figure 7.8 is that it highlights the relationship between different probabilities of failure and the direct toll level commensurate with these probabilities as well as a lower bound on rates of return for the risks assigned. For example, Figure 7.8 indicates that an IRR value of 18.7% is justified for the risks assumed and the assumed risk aversion level. A lower probability of failure threshold (a more risk averse situation), would result in a higher toll rate and, conversely, the less risk averse the less the toll and rate of return. A better understanding of tolerance of risk on the part of the private sector is essential - however, the literature offers very little guidance in this regard.

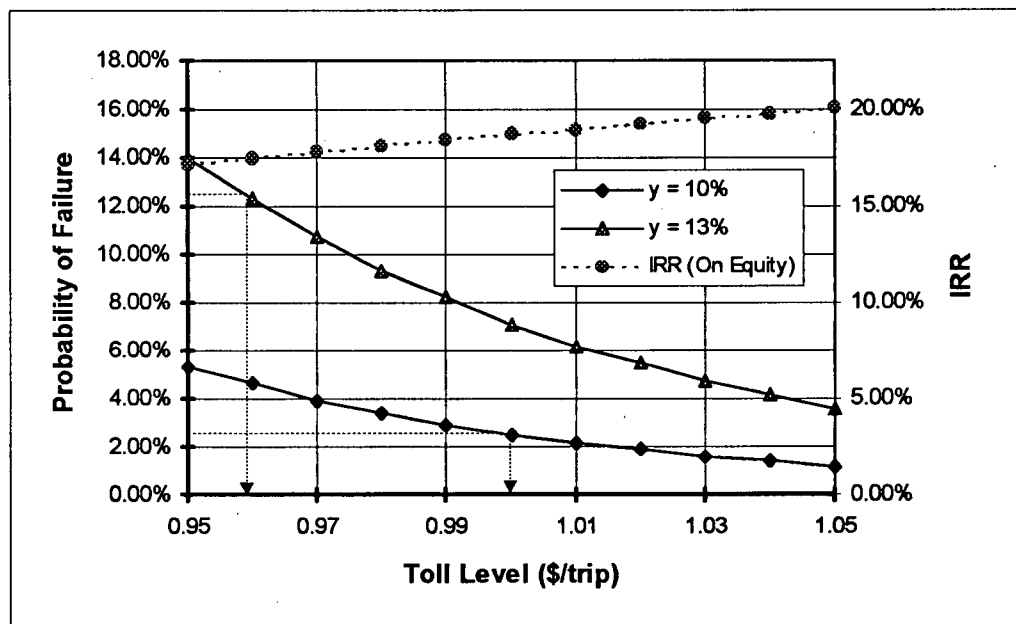


Figure 7.8 Probability of Failure vs. Constant Dollar Toll - BOT Approach

For the equity situation when a \$1.00 toll per trip is applied, NPV has a mean of \$11,747,828 and a standard deviation of \$9,662,997. Compared with the NPV on equity calculated from the deterministic analysis and listed in Table 7.3 (NPV = \$11,222,099), a marginal positive shift of the mean has occurred to NPV. This is due to the uncertainty embedded in the input parameters (see appendix B).

Having determined the toll and the associated probabilities of failure, it is instructive to determine the contribution each variable makes to the overall project risk as measured by variance. This helps in setting priorities for pursuing risk mitigation strategies, and for determining the most equitable assignment of risks. Figures 7.9 and 7.10 indicate the percent contribution each variable's uncertainty makes to the variance of NPV, for the equity and total capital cases respectively. As shown, variables associated with the revenue function, namely V_o , λ and θ_v are responsible for 43% of the total risk. When financing risk is omitted, revenue risks grow even higher and contribute 54% to the overall project risk. This is a clear indication of the need to consider mitigation strategies for the revenue risks.

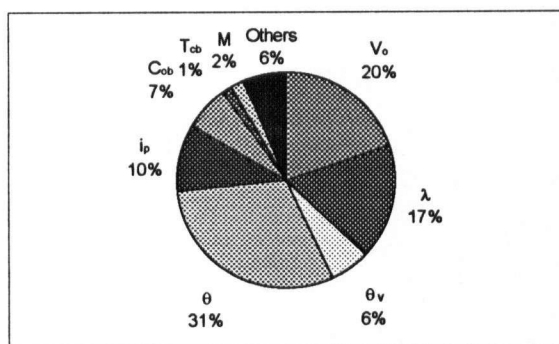


Figure 7.9 Contribution to Uncertainty in NPV On Equity - BOT Approach

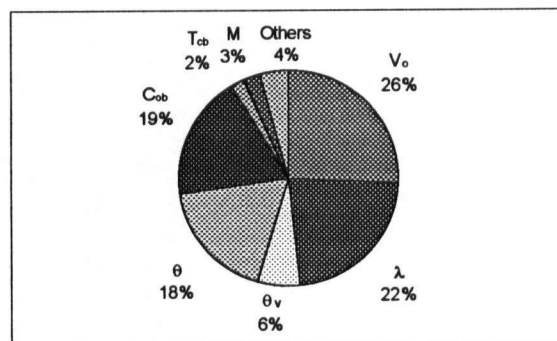


Figure 7.10 Contribution to Uncertainty in NPV On Total Capital - BOT Approach

Since uncertainties in the demand function variables (i.e. V_o , λ and θ_v) constitute major portion of the overall project risk, they are used in what follows as an example to demonstrate the effect of changes in risk assignment on the probability of failure and toll level and, to point out means of dealing with uncertainties by sharing risk with the public sector. The assumption is made that all components of the revenue risk are beyond the control of the private consortium, and a strategy is sought to off-load them to the government. Such a strategy might entail that the government guarantees the parameter values of the demand function - a critical policy issue which has to be negotiated and, if agreed upon, stipulated in the final concession agreement. To illustrate the significance of such a guarantee, mean values are used for V_o , λ , and θ_v (i.e. $V_o = 26,926,300$ veh/year, $\lambda = 0.2$ and $\theta_v = 0.005$), and the standard deviations are all set to zero. The result of such risk sharing strategy is demonstrated in Figure 7.11. Only a \$0.94 toll is required, traffic usage increases to 22,311,528 veh/yr, and the associated rate of return is 16% (instead of \$1.00 and 18.7% - see Figure 7.8).

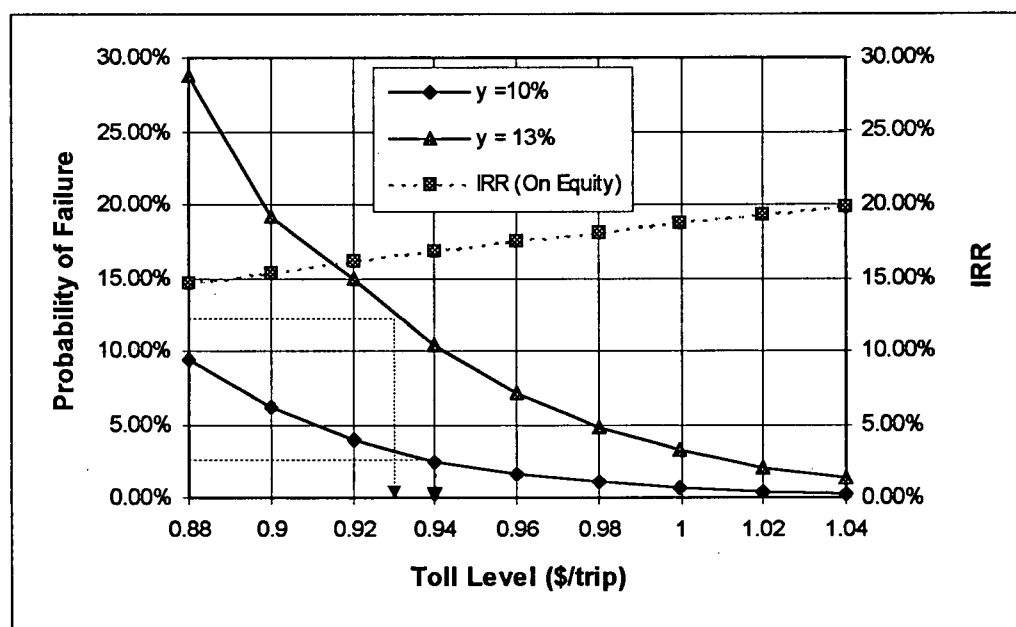


Figure 7.11 Probability of Failure - No Uncertainty in The Demand Function - BOT Approach

With respect to the handling of special risk conditions, constant dollar construction cost (C_{ob}) is used as an example to demonstrate the application of the risk quantification approach described in Chapter 6. The assumption is that a number of special risks are identified and viewed to impact the base constant dollar construction cost (C_{ob}) (e.g. technical, environmental, etc.). Experts estimate of the profiles and probabilities of occurrence of such risks are assumed to be as shown in Table 7.4. Only two outcomes for each risk category are treated. The event is realized with probability Pr_i and a non-zero, uncertain outcome; and the event is not realized, with probability $1-Pr_i$ with no incremental consequences. The risk conditions are assumed to be independent and their influence may be included in the analysis by applying basic principles of statistics as shown in equations 6.5 and 6.6 of Chapter 6.

Risk Category	Probability of Occurrence (Pr)	P5	P50	P95	Er[.]	σ
R1	0.3	2	3	4	3	0.607903
R2	0.25	6	6.5	8	6.685	0.649351
R3	0.1	9	12	13	11.63	1.298701
R4	0.5	1.5	3	4	2.9075	0.769764

Table 7.4 Risk Premiums (in millions) For Constant Dollar Construction Costs

Accordingly,

$$\begin{aligned} \overline{C_{ob}} &= 108,517,500 + 0.3 \cdot (3,000,000) + 0.25 \cdot (6,685,000) + 0.1 \cdot (11,630,000) \\ &\quad + 0.5 \cdot (2,907,500) = \$113,705,500 \end{aligned} \quad (7.1)$$

and,

$$\begin{aligned}
 \sigma \cdot Cob &= \sqrt{(5,536,323)^2 + \{[0.3 \cdot (607,903)^2 + 0.3 \cdot (3,000,000)^2 - (0.3 \cdot 3,000,000)^2] \\
 &\quad + [0.25 \cdot (649,351)^2 + 0.25 \cdot (6,685,000)^2 - (0.25 \cdot 6,685,000)^2] \\
 &\quad + [0.1 \cdot (1,298,701)^2 + 0.1 \cdot (11,630,000)^2 - (0.1 \cdot 11,630,000)^2] \\
 &\quad + [0.5 \cdot (769,764)^2 + 0.5 \cdot (2,907,500)^2 - (0.5 \cdot 2,907,500)^2]\}} \\
 &= \$ 7,475,815.73 \quad (7.2)
 \end{aligned}$$

For this scenario and using the same criteria for the probability of failure, Figure 7.12 indicates that a slightly higher than \$1.05 toll rate is needed instead of \$1.00. The rate of return has also increased from 18.7% to approximately 19.5% for the risk treated case. This example clearly illustrates the usefulness of the framework not only in quantifying risks but also in demonstrating their implications.

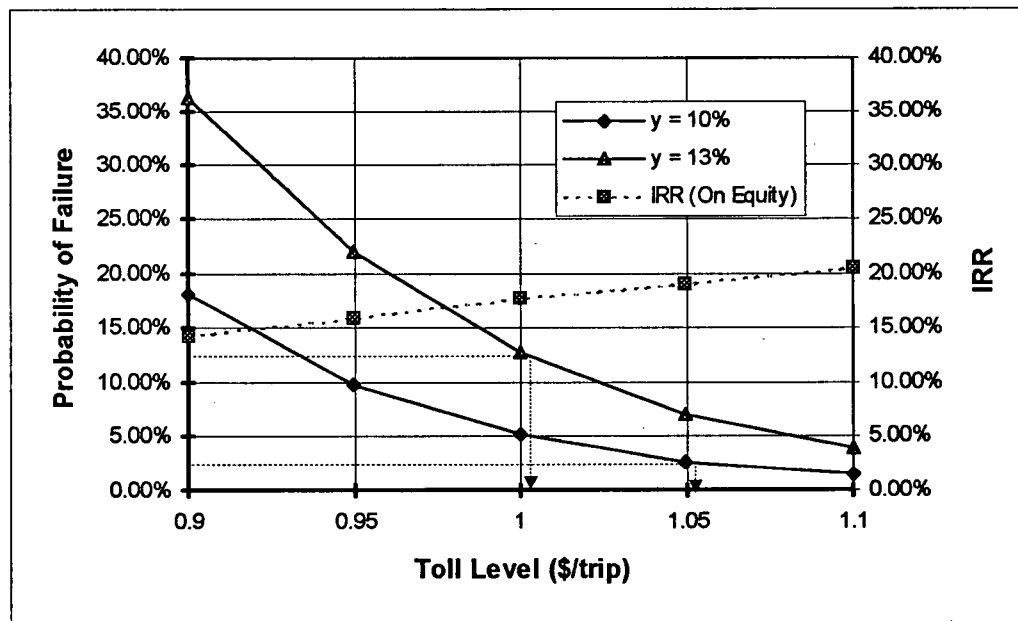


Figure 7.12 Probability of Failure - Risk Treated Case - BOT Approach

Finally, listed in Table 7.5 are several quantitative performance measures which summarize the analysis made for this BOT project. Noteworthy is the effect of inflation on the user charge at start of operation - i.e. at the start of operation, a toll of \$1.24 is to be charged, not the constant toll of \$1.00.

Performance Measure	Units	Expected Value	Standard Deviation
Constant Dollar Toll	\$/trip	1.00	N/A ¹
Current Dollar Toll at start of operation	\$/trip	1.24	N/A
Volume of usage at start of operation	veh/yr	22,045,390	N/C ²
Time to start of operation	yrs	6.79	0.565
Constant dollar design, construction, commissioning costs	\$	126,295,125	5,606,505
Current dollar design, construction, commissioning costs	\$	152,444,157	N/C
Net present value on equity - $y = 14\%$	\$	11,747,828	9,662,997
Internal rate of return on equity	%	18.7	N/C
Internal rate of return on total capital	%	12.3	N/C
Probability that IRR on equity < regulated return	%	7	N/A
Probability that IRR on equity < cost of borrowed capital	%	2.5	N/A

Table 7.5 Quantitative Performance Measures For the BOT Approach

¹ N/A = Not Applicable

² N/C = Not Calculated. These measures are not calculated since they need a highly sophisticated level of calculation, and require modification for the mathematics of the model to be generated.

7.3.2 The Traditional Scenario

Table 7.1 is also applied to this scenario. However, the following modifications are made to reflect the public sector viewpoint in a traditional setting for this user-pay project.

- 1) No secondary revenue stream was used.
- 2) Costs for predesign phase, management during the design and construction phase, management during the operation and maintenance phase, and operating and maintaining costs for the existing facility are assumed to be funded from the regular government budgetary process, and are not required to be recaptured through tolling. Thus, they have been excluded from the analysis.
- 3) Equity input is limited to 100% of the design (i.e. $E_D = 1$). All other phases are assumed to be 100% financed (i.e. $E_C = E_T = E_{COM} = E_H = 0$).
- 4) The loan interest rate during construction is equal to that during debt servicing, and it is lower than the one used in the BOT approach to reflect the government's ability to assemble financing at lower rates. For this scenario, $i_c = i_p = 9\%$ is used.
- 5) The project is sequential and implementation strategies such as fast-tracking design and construction, accelerating construction, and overlapping construction and commissioning are not adopted.
- 6) Constant dollar construction costs correspond to those shown in Table 7.2. Thus constant construction costs (C_{ob}) = \$144,690,000 with a standard deviation of \$7,381,765.
- 7) The demand function shown in Figure 7.1 is used.
- 8) The discount rate is 10%, and reflects the social discount rate typically assumed by governments.

7.3.2.1 Deterministic Analysis - Traditional Approach

The Net Present Value (NPV) for this scenario is calculated to be \$29,343,691 and IRR = 25.6% (on equity) for a toll of \$0.88. Table 7.7 presents the non-linear sensitivity analysis made for the different demand function variables for this scenario. Figures 7.13 and 7.14 present the non-linear sensitivity curves for these variables in graphical form for the equity capital and total capital cases respectively. For the variables examined, NPV is most sensitive to the estimate of initial volume of traffic for a zero toll rate V_0 , followed by the rate g with which tolls are indexed to the general inflation rate, the length of concession period T_0 , decay in traffic with increased toll level λ , and growth in traffic volume θ_v .

T_0	V_0	θ_v	λ	g	Γ_0	NPV (On Equity)	NPV (On Total Capital)
35	26,926,300	0.005	0.2	0.9	0.00	29,343,691	15,591,593
25	26,926,300	0.005	0.2	0.9	0.00	13,036,986	1,545,892
30	26,926,300	0.005	0.2	0.9	0.00	22,401,430	9,687,448
40	26,926,300	0.005	0.2	0.9	0.00	34,501,010	19,873,477
45	26,926,300	0.005	0.2	0.9	0.00	38,340,131	22,979,046
35	24,455,000	0.005	0.2	0.9	0.00	14,314,369	562,271
35	28,023,000	0.005	0.2	0.9	0.00	36,013,321	22,261,223
35	26,926,300	0	0.2	0.9	0.00	19,938,862	6,541,255
35	26,926,300	0.0025	0.2	0.9	0.00	24,536,309	10,979,264
35	26,926,300	0.0075	0.2	0.9	0.00	34,373,071	20,423,245
35	26,926,300	0.01	0.2	0.9	0.00	39,637,304	25,487,151
35	26,926,300	0.005	0.1	0.9	0.00	44,407,067	30,654,970
35	26,926,300	0.005	0.15	0.9	0.00	36,709,709	22,957,611
35	26,926,300	0.005	0.25	0.9	0.00	22,294,751	8,542,653
35	26,926,300	0.005	0.3	0.9	0.00	15,549,240	1,797,142
35	26,926,300	0.005	0.2	0.8	0.00	18,243,394	4,767,167
35	26,926,300	0.005	0.2	1	0.00	41,394,904	27,361,553
35	26,926,300	0.005	0.2	0.9	0.25	37,739,512	23,987,415
35	26,926,300	0.005	0.2	0.9	0.5	46,565,796	32,813,699
35	26,926,300	0.005	0.2	0.9	0.85	59,688,008	45,935,911

Table 7.6 Data for Sensitivity Analysis ($\Gamma = \$0.88$) - Traditional Approach

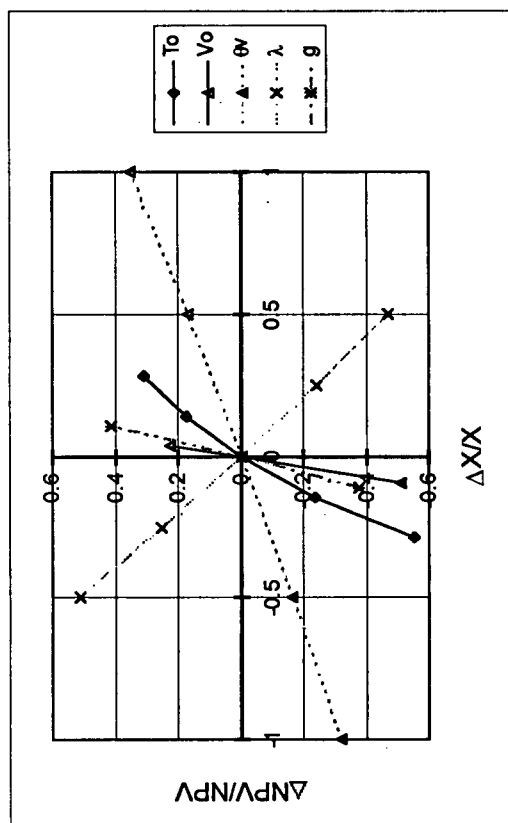


Figure 7.13 Non-Linear Sensitivity Curves For Revenue Variables On Equity - Traditional Approach

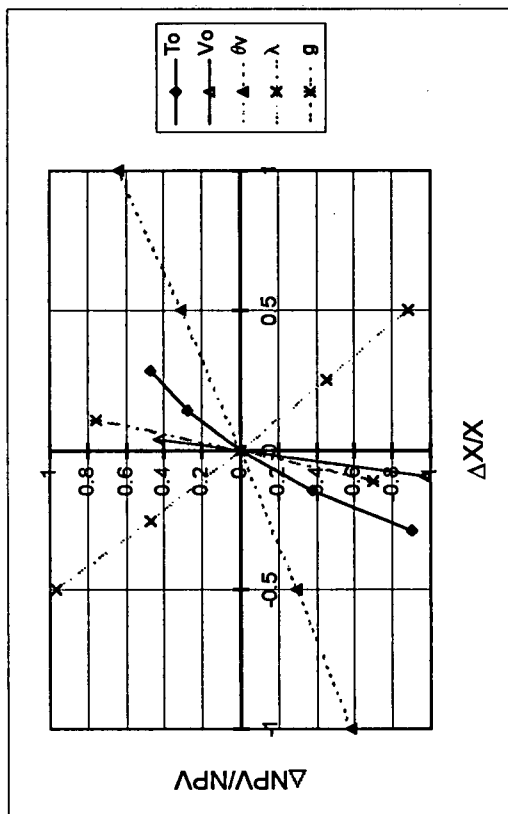


Figure 7.14 Non-Linear Sensitivity Curves For Revenue Variables On Total Capital - Traditional Approach

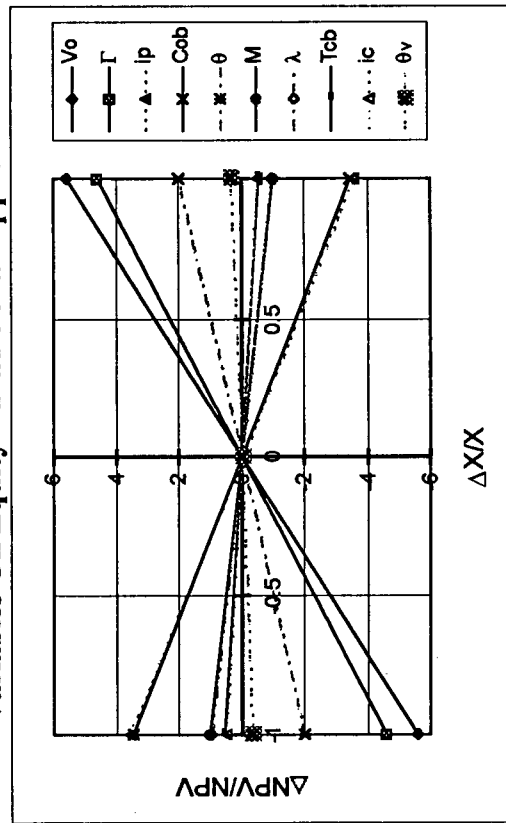


Figure 7.15(a) Linear Sensitivity Analysis - Traditional Approach

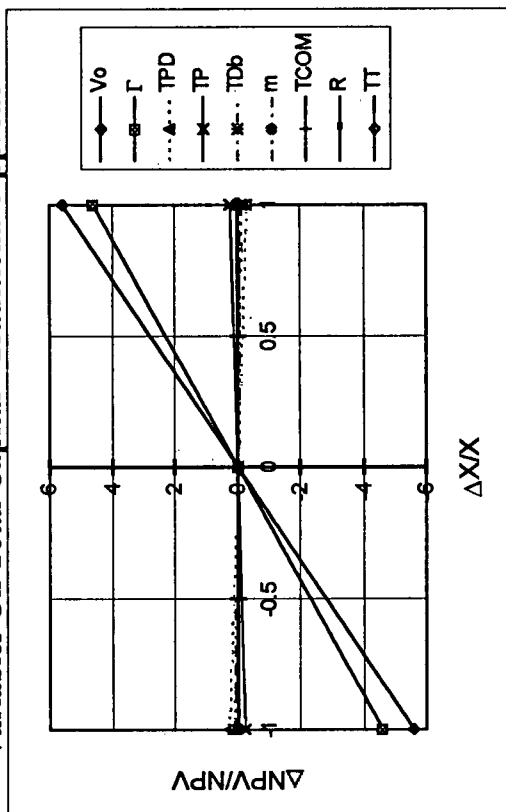


Figure 7.15(b) Linear Sensitivity Analysis - Traditional Approach

Table 7.7 presents the linear sensitivity coefficients for several of the input variables to NPV when equity capital is considered. Figures 7.15(a) & 7.15(b) demonstrate the same findings in a graphical form. The value of linear sensitivity analysis can be illustrated by the following example. Since a BOT approach involves lengthy negotiations, a shorter predesign phase may be achievable in the traditional approach. Thus, the fractional change in the base value of NPV if the duration of traditional predesign phase (T_{PD}) is decreased by 20% would be equal to:

$$\Delta NPV/NPV \cong S_{T_{PD}} \cdot \Delta T_{PD} / T_{PD} = -0.26079(-0.20) = 0.05216 \quad (7.3)$$

where $S_{T_{PD}}$ is the sensitivity coefficient - see Table 7.7.

In other words, a 20% decrease in T_{PD} would result in an approximately 5% increase in NPV - i.e. NPV = \$30,810,875. The result is only approximate since NPV is not in a linear relationship with T_{PD} .

Sensitivity Coefficients (S_x)		Sensitivity Coefficients (S_x)	
$S_{T_{Cb}}$	- 0.5593	S_M	- 0.99437
$S_{T_{Db}}$	- 0.13548	S_m	- 0.08105
S_{T_T}	- 0.02721	S_R	- 0.04831
$S_{C_{ob}}$	- 3.43055	S_θ	1.98561
$S_{T_{COM}}$	- 0.04915	S_{θ_v}	0.3349
S_{COM}	- 0.02737	S_{V_o}	5.58165
$S_{T_{PD}}$	- 0.26079	S_λ	- 0.98237
S_{i_C}	- 0.49757	S_Γ	4.59928
S_{i_p}	- 3.56072	S_{T_p}	0.22673

Table 7.7 Linear Sensitivity Coefficients - Traditional Approach

Shown in Figure 7.16 are net present values and internal rates of return as functions of constant dollar toll. The figure indicates similar results to those shown in Figure 7.7, and a \$5.00 toll would provide for a profit maximization opportunity. Figure 7.3 indicates that such a toll level would result in a dramatic decrease in usage, which may be in conflict with transportation objectives. However, comparing Figure 7.3 with Figure 7.7, the change in NPV and IRR as the toll level increases is much more rapid. This is due to the significant reduction in the front-end costs in the traditional approach, since predesign costs, and all management costs are ignored, despite the fact that constant dollar construction costs are higher.

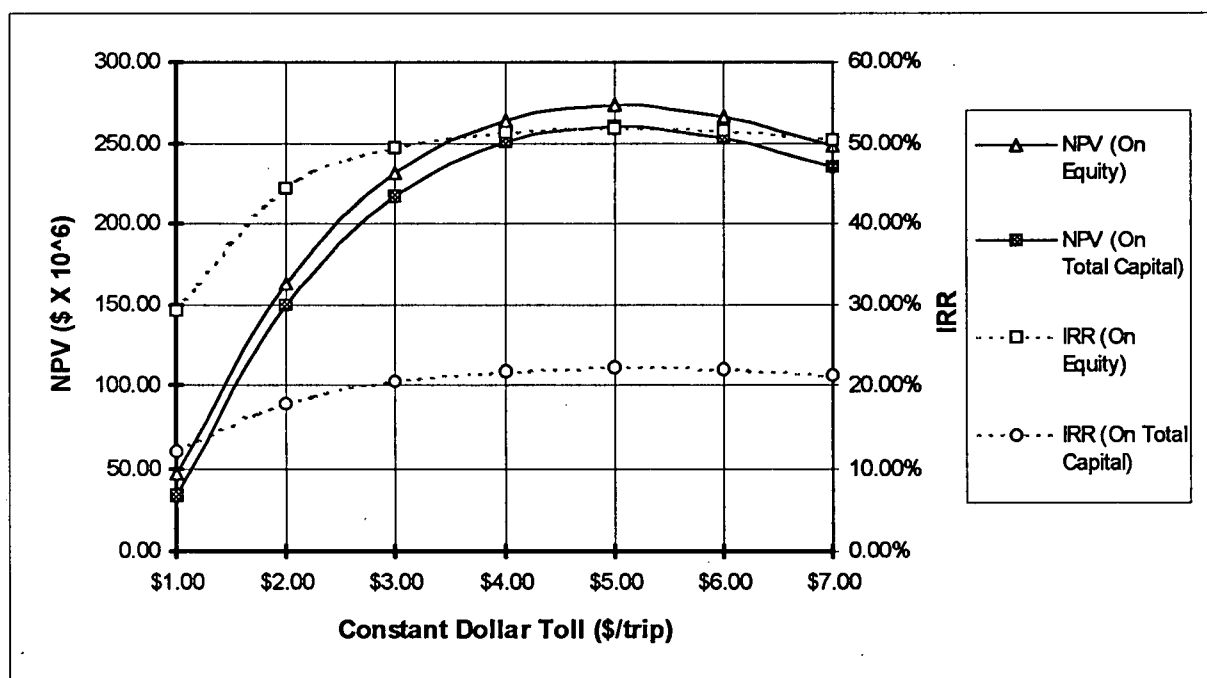


Figure 7.16 Profit Maximization Curves - Traditional Approach

7.3.2.2 Probabilistic Analysis - Traditional Approach

The two probability of failure tests described in Chapter 6 are also used in this traditional

scenario to set the toll level. Failure thresholds are arbitrarily assumed for the public sector as double those used for the private sector case, since the private sector in general is more risk averse. Thus, for the traditional scenario $\phi_u = 25\%$ and $\phi_i = 5\%$ when $y = 13\%$ (equal to the assumed regulated rate of return) and $y = 9\%$ (equal to the rate of financing) respectively. Figure 7.17 indicates that the second test governs and that \$0.88 is the minimum toll level required to satisfy both tests. For this case NPV has a mean of \$30,471,404 and a standard deviation of \$17,923,986, with an internal rate of return $IRR = 24.6\%$.

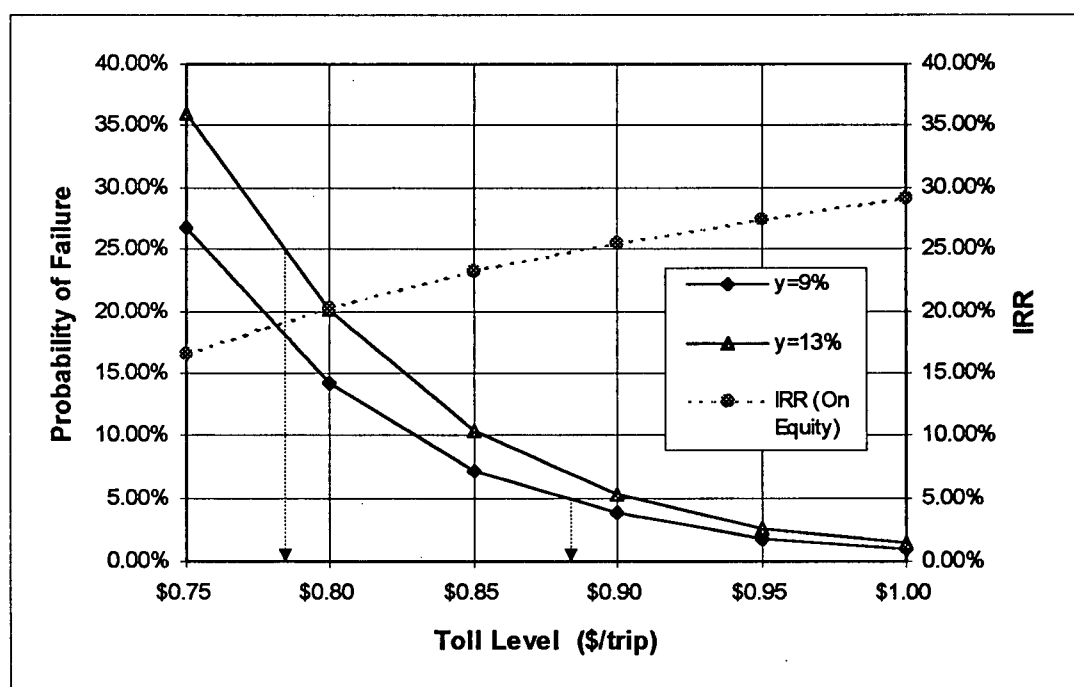


Figure 7.17 Probability of Failure vs. Constant Dollar Toll - Traditional Approach

To demonstrate the effect of increased uncertainty on the probability of failure and toll levels, a 50% increase in the estimates of standard deviation for time, construction costs, commissioning, revenue, maintenance, inflation and interest rate variables was employed. The results are shown in Figure 7.18. Higher estimates of risk lead to considerably higher tolls for the same level of risk aversion. The first test requires a toll of \$0.82, while approximately \$1.03 toll is needed to satisfy the second test with a corresponding internal rate of return equal to 30%. Such results highlight the significance of accurate estimates for the input variables.

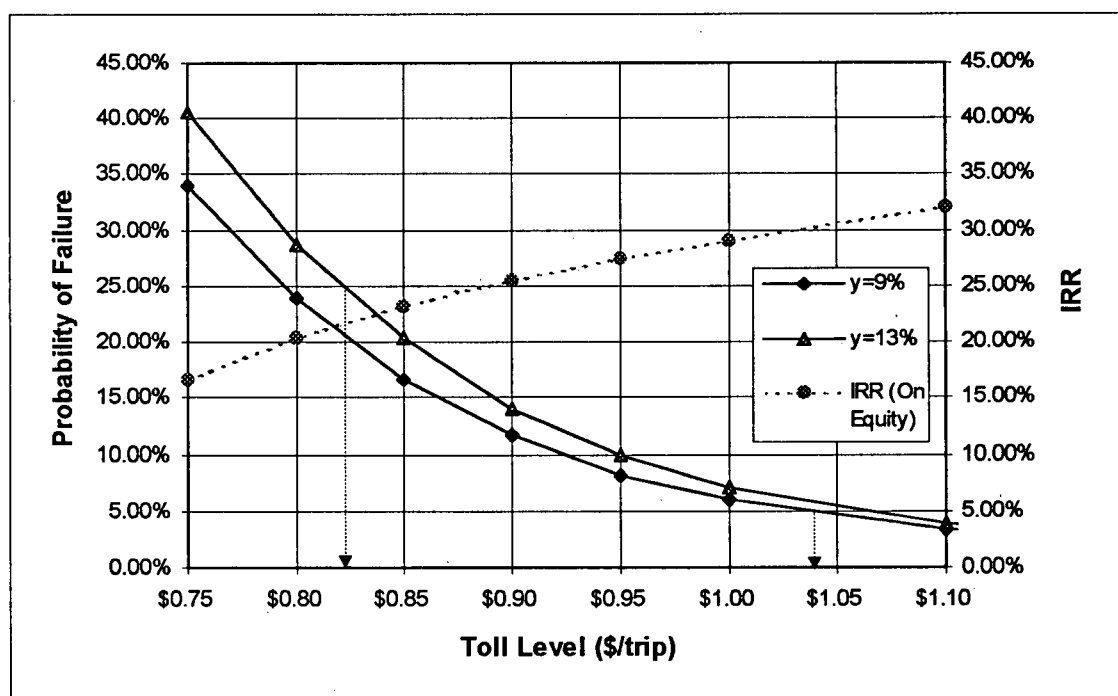


Figure 7.18 Probability of Failure vs. Constant Dollar Toll Level - High Estimates of Risk - Traditional Approach

The contributions of the input variables to the variance of NPV for the basic traditional scenario when the toll is \$0.88 are depicted in Figures 7.19 and 7.20 for the equity and total capital cases, respectively. Since for the latter case, the interest rate risk is not included,

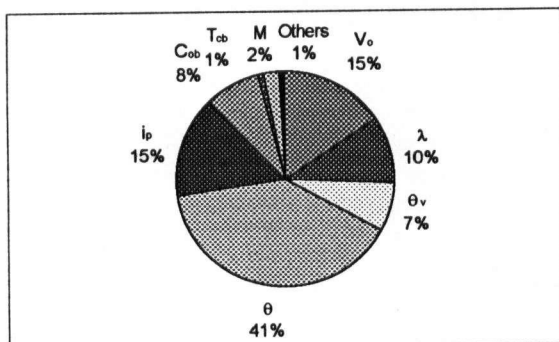


Figure 7.19 Contribution to Uncertainty In NPV On Equity - Traditional Approach

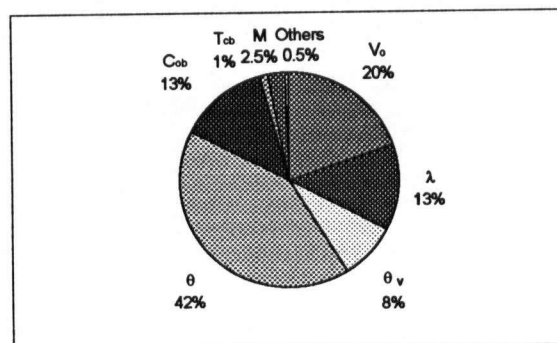


Figure 7.20 Contribution to Uncertainty In NPV On Total Capital - Traditional Approach

higher contributions are shown for the remaining variables. Variables associated with the revenue function, namely V_o , λ and θ_v are responsible for almost 32% of the total risk. Similar to the BOT case, when financing risk is omitted, revenue risks increase to 41%.

In summary, Table 7.8 lists several quantitative performance measures for the traditional case. Compared with Table 7.5, from a user-fee perspective, the traditional approach provides a cheaper solution. However, issues of acceptable levels for the probability of failure, characteristics of the financing scheme adopted in terms of price and equity input requirements, the potential for governmental guarantees (e.g. for the demand function), and so forth, can significantly change the outcome. In addition the adopted approach has to be decided upon in accordance with the objectives defined at the outset for each sector. For example, from a public sector viewpoint, the BOT approach may be viable despite its higher cost to the users if insufficient funds are available to meet current or increasing demands. From a private sector viewpoint, the project outlook will have to be assessed based on the preset criteria for acceptable risk levels and profit potential. Tableaus can be prepared for each approach in conjunction with Tables 7.5 and 7.8 (see Table 6.1), to include all issues

associated with risk and their significance as they impact the various project phases for purposes of a qualitative assessment of the project. In so doing, risk mitigation strategies can be highlighted and pursued. For, example, in a BOT approach the issue of an uncertain demand function can be included therein, and the private proponent may then seek to share such risks with the government.

Performance Measure	Units	Expected Value	Standard Deviation
Constant Dollar Toll	\$/trip	0.88	N/A
Current Dollar Toll at start of operation	\$/trip	1.13	N/A
Volume of usage at start of operation	veh/yr	22,580,879	N/C
Time to start of operation	yrs	7.898	0.611
Constant dollar design, construction, commissioning costs	\$	167,893,500	7,468,751
Current dollar design, construction, commissioning costs	\$	201,540,323	N/C
Net present value on equity - $y = 10\%$	\$	30,471,404	17,923,986
Internal rate of return on equity	%	24.6	N/C
Internal rate of return on total capital	%	11.0	N/C
Probability that IRR on equity < regulated return	%	7	N/A
Probability that IRR on equity < cost of borrowed capital	%	5	N/A

Table 7.8 Quantitative Performance Measures For the Traditional Approach

In conclusion, the case study presented in this chapter illustrates the use of the developed framework for:

- Comparing the consequences of a traditional versus PPP undertaking of a project as indicated by several performance measures;
- Investigating different PPP forms of procurement (e.g. BOT and Design/Build) and identifying the most suitable one(s); and
- Assigning roles and responsibilities amongst the project participants. This was clearly demonstrated in the case study- for example the decreased uncertainty in the demand function results in lower toll and rate of return.

CHAPTER 8 - CONCLUSIONS AND RECOMMENDATIONS

8.1 SUMMARY

In recent years, governments' attention has been directed at increasing the roles and responsibilities of the private sector in the procurement of public infrastructure. Consequently, a spectrum of Public Private Partnership (PPP) arrangements has evolved to suite different government needs and project characteristics. Member forms of this spectrum range from the traditional mode of procurement to the fully private one and include Build-Operate-Transfer (BOT), Design-Build, etc. Several motives and perceived benefits exist for both sectors to engage in such an approach with which they have little experience. However, the extended roles, responsibilities, and the untraditional risks governments would like the private sector to assume make the analysis of PPP projects a complex task. This task is compounded by the fact that the life cycles of PPP projects generally extend far into the future, as does the commitment of both sectors.

The analysis of PPP approaches for procurement of public infrastructure projects is hardly treated in the literature in any objective way. Lacking is a robust analysis framework with which to examine such approaches in the context of special projects, identify the wide range of risks involved, investigate the implications of various risk assignments, determine the compensation warranted by specific risk assignments, and so forth. This research has attempted to address some of these shortcomings.

8.2 CONTRIBUTIONS

This research attempted to achieve a balance between the analysis of PPP projects and the development of a robust analytical tool for use in the early analysis stages of a project. Here is a brief overview of some of the insights gained during the course of this work:

- In cases where no government guarantees are available, revenue risks will most likely represent a major factor in determining the suitability of a project for a PPP approach.
- For projects where direct tolling is adopted, the significance of a non-zero value for the inertia region cannot be ignored - i.e. the toll value which indicates the maximum fare level that yields no drop-off in usage.
- Acceleration strategies such as fast-tracking design and construction and acceleration of construction exhibit only marginal benefits. The greatest benefits of adopting these strategies are expected when penalties are imposed for untimely completion of construction.
- In general, and given the government's capability to acquire financing at a lower price than can the private sector, BOT's could be more expensive from a user-charge perspective, unless savings can be achieved in other project inputs such as capital costs and operating and maintenance costs. However, they can be potentially viable in cases when no funds are available, or for projects that have near monopoly situations.
- Each project is a unique case and has to be assessed based on its merits and constraints. However, the experience gained in every project in terms of risks and rewards is essential for enhancing the scant knowledge base that currently exists.

In order to undertake the analysis of PPP projects and gain such insights, the following contributions are offered in this work:

8.2.1 The Analysis Framework For PPP Projects

An analysis framework for PPP projects is suggested in this research. It assists both the public and the private sectors in quantitatively and qualitatively assessing projects that are candidates for PPP. The usefulness of this framework lies in its ability to assist in developing insights into the anatomy of the project being analyzed, and enhancing the knowledge base of its behavior under different risk exposures and assignments. It allows the analyst to objectively establish the case for and against PPP by examining various project scenarios (e.g. BOT, Design-Build etc.) and implementation strategies (fast-tracking design and construction, accelerating construction etc.) as compared to a traditional mode of procurement. Thus, the suitability of an infrastructure project for a PPP mode of procurement can be assessed and the best fit in the PPP spectrum identified.

An equitable risk assignment is central to achieving a meeting of the minds between both sectors. Two tests for probability of failure are suggested in this research. The developed framework uses these two tests to provide for the risk allocation among both parties. It assists them in establishing the relationship between different risk exposures and commensurate rates of return as well as the impact on user-charges. In so doing, it facilitates the identification of parties in the partnership who are most capable of assuming risks, and, accordingly, the most appropriate assignment of roles and responsibilities.

The framework can also be used as a tool for examining different project constituents in terms of phases, components, and parameters estimates, as well as government guarantees and undertakings (e.g. provision of subsidy, indexing toll to inflation, etc.) needed to make a PPP approach feasible.

8.2.2 The Economic Model

As a subset of the PPP analysis framework, a robust economic model was developed. It is designed for conducting deterministic and probabilistic analyses. The model encompasses the entire project life cycle and includes all significant phases starting from the predesign phase to transfer of the project back to the government. The moment analysis technique was adopted to provide approximate results for a risk analyses.

8.2.3 The Risk Analysis Tool

In order to generate estimates for use in the economic model while considering all significant risks, a structured tool is provided in this research. It consists of a systematic approach for the identification, classification and, quantification of such risks. By way of cataloguing these risks, this tool not only allows for the qualitative aspect of project analysis but it also provides for the management and mitigation of risks. It builds on extracting experts views on particular risk categories and their consequences for different project parameters. In particular, eight risk categories are considered in this research, namely *time & cost*, *technical*, *economic*, *financial*, *environmental*, *political & regulatory*, *organizational & contractual*, and *stakeholder* risks.

8.3 FUTURE RESEARCH REQUIREMENTS

8.3.1 The Framework

8.3.1.1- The framework focuses on the downside of a project for the analysis. Assessment of the upside potential for a project should also be treated.

8.3.1.2- Commercial software such as Mathcad 3.0, Mathcad 4.0 and Microsoft Excel 5.0 were used to perform all calculations in this work. In so doing, some difficulties were experienced in compiling full reports which include input as well as output values for each scenario. Development of a computer program that provides for the automatic storage of input and output values with a commentary on the details of the analyzed scenario should be pursued if the tool is to become a practical one.

8.3.1.3- The functions used in this research to simulate the impact on time and cost while adopting implementation strategies such as fast-tracking design and construction, accelerating construction and, overlapping revenues and construction are only approximate and are not based on any empirical data, as none was found in the literature. To the extent possible, case studies should be undertaken in order to develop a data base.

8.3.1.4- Development of case studies over long periods of time is one area that needs to be considered. A follow up on the PEI case study presented in this work may prove beneficial for enhancing the current experience with regard to the implementation of PPP projects.

8.3.2 The Economic Model

A long term goal for development of this model is to make it as comprehensive as possible.

Modifications proposed for future work on the model are as follows:

8.3.2.1- Multiple financing schemes must be allowed. These should include servicing debts during construction and utilization of bond financing. Different repayment profiles should also be considered. Additionally, time dependent financing rates should be treated.

8.3.2.2- Expenditures for operation and maintenance and inclusion of multiple operation and maintenance items need further assessment.

8.3.2.3- Use of multiple construction packages are required for better treatment of the time dimension. This would help in modeling of fast-tracking and acceleration strategies. In addition, use of a separate cash flow item for indirect construction costs should be considered.

8.3.2.4- A hierarchical break-down of the different tasks and activities included in each phase could help in producing more refined estimates of time and cost. Further, the use of models which are expressed in terms of lower level parameters such as scope and productivity could also result in more accurate estimates of the risks involved.

8.3.2.5- The revenue function treated deals with direct tolling. Consideration of other revenue generation schemes should be included, including congestion pricing.

8.3.2.6- Use of various forms of secondary revenues (e.g. right for land development, government subsidy, and so forth) should be accommodated.

8.3.2.7- Consideration of salvage value, explicit penalty functions, especially liquidated damages and land acquisition costs should be included.

8.3.2.8- After-tax calculations should be included.

8.3.2.9- Consideration should be given to the treatment of correlation.

8.3.3 The Risk Analysis Tool

Enhancements of the developed risk analysis tool are suggested as follows:

8.3.3.1- The assumption of independence amongst special risk conditions should be examined further, as should the assumption of additivity.

8.3.3.2- Integration with other decision tools such as influence diagrams, decision trees, and expert systems to provide for a comprehensive decision support system should be pursued.

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APPENDIX A

DETERMINISTIC MODEL FORMULATION

1- DESIGN DURATION

$$T_D = T_{Db} + T_{DF} \cdot F$$

2- CONSTRUCTION DURATION

$$T_C = (T_{Cb} + T_F \cdot F + T_O \cdot O) \cdot (1 - A)$$

3- DURATION FOR DEBT SERVICING

$$T_P = T_O + T_{COM} + (1 - O) \cdot T_C - T_S - T_H - \max \left\{ \begin{array}{l} (1 - O) \cdot T_C + T_{COM} \\ T_C \end{array} \right. \text{ or } T_C$$

4- PREDESIGN PHASE

$$NPV_{PD} = \int_0^{T_{PD}} C_{PD} \cdot e^{((\Theta - y) \cdot t)} dt$$

5- CONSTRUCTION PHASE

$$\text{Constant Dollar Construction Cost } (C_o) = C_{ob} + C_{oA} \cdot A + C_{oF} \cdot F + C_{oO} \cdot O$$

$$\text{Constant Dollar Construction Cost cash flow during construction phase } (C_{ot}) =$$

$$= \frac{C_{ob} + C_{oA} \cdot A + C_{oF} \cdot F + C_{oO} \cdot O}{T_C}$$

Current Dollar Construction Cost =

$$e^{((\Theta + \Delta\Theta_c) \cdot (T_{PD} + (1-F) \cdot T_D + T_T))} \cdot \int_0^{T_c} C_{ot} \cdot e^{(\Theta + \Delta\Theta_c) \cdot t} dt$$

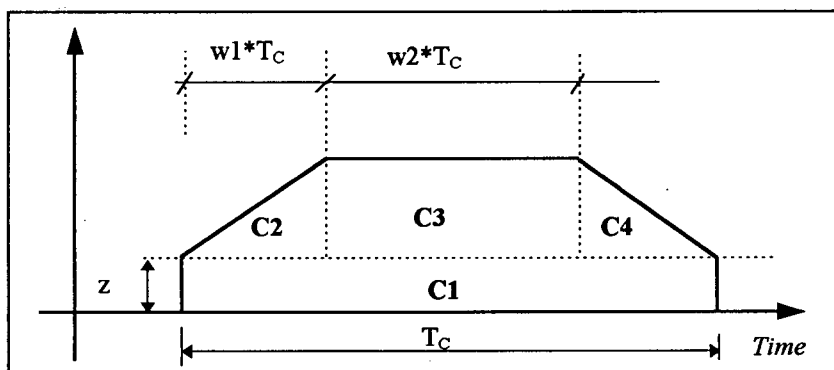


Figure A-1 Constant Construction Costs

5.1.- Net Present Value Formulation

$$z = z \cdot C_{ot}$$

$$NPV_{C1} = e^{(((\Theta + \Delta\Theta_c) - y) \cdot (T_{PD} + (1-F) \cdot T_D + T_T))} \cdot \int_0^{T_c} z \cdot e^{((\Theta + \Delta\Theta_c) - y) \cdot t} dt \cdot E_c \cdot (1-H)$$

$$NPV_{C2} = e^{(((\Theta + \Delta\Theta_c) - y) \cdot (T_{PD} + (1-F) \cdot T_D + T_T))} \cdot E_c \cdot (1-H) \cdot$$

$$\int_0^{w1 \cdot T_c} \frac{C_o - z \cdot T_c}{\frac{T_c}{2} \cdot (1 + w2) \cdot (w1 \cdot T_c)} \cdot t \cdot e^{((\Theta + \Delta\Theta_c) - y) \cdot t} dt$$

$$NPV_{C3} = e^{[(((\Theta + \Delta\Theta_C) - y) \cdot (T_{PD} + (1-F) \cdot T_D + T_T + w_1 \cdot T_C))]} \cdot E_C \cdot (1-H) \cdot$$

$$\int_0^{w_2 \cdot T_C} \frac{Co - z \cdot T_C}{\frac{T_C}{2} \cdot (1 + w_2)} \cdot e^{[(((\Theta + \Delta\Theta_C) - y) \cdot t]} dt$$

$$NPV_{C4} = e^{[(((\Theta + \Delta\Theta_C) - y) \cdot (T_{PD} + (1-F) \cdot T_D + T_T + (w_1 + w_2) \cdot T_C))]} \cdot E_C \cdot (1-H) \cdot$$

$$\int_0^{(1 - w_1 - w_2) \cdot T_C} \frac{Co - z \cdot T_C}{\frac{T_C}{2} \cdot (1 + w_2) \cdot (1 - w_1 - w_2) \cdot T_C} \cdot e^{[(((\Theta + \Delta\Theta_C) - y) \cdot t]} \cdot [T_C \cdot (1 - w_1 - w_2) - t] dt$$

$$NPV_C = NPV_{C1} + NPV_{C2} + NPV_{C3} + NPV_{C4}$$

5.2.- Formulation Of Future Worth Value For Financing

$$FW_{C1} = e^{[(\Theta + \Delta\Theta_C) \cdot (T_{PD} + (1-F) \cdot T_D + T_T)]} \cdot (1 - E_C) \cdot (1-H) \cdot$$

$$\int_0^{T_C} z \cdot e^{[(\Theta + \Delta\Theta_C) \cdot t]} \cdot \max \begin{cases} e^{[(1-O) \cdot T_C + T_{COM} + T_H + T_S - t]} \cdot i \\ or \\ e^{[T_C + T_H + T_S - t]} \cdot i \end{cases} dt$$

$$FW_{C2} = e^{[(\Theta + \Delta\Theta_c) \cdot (T_{PD} + (1-F) \cdot T_D + T_T)]} \cdot (1 - E_c) \cdot (1 - H) \cdot$$

$$\int_0^{w1 \cdot T_c} \frac{Co - z \cdot T_c}{\frac{T_c}{2} \cdot (1 + w2) \cdot (w1 \cdot T_c)} \cdot t \cdot e^{[(\Theta + \Delta\Theta_c) \cdot t]} \cdot \max \left\{ \begin{array}{l} e^{[(1-O) \cdot T_c + T_{COM} + T_H + T_S - t]} \cdot i \\ or \\ e^{[T_c + T_H + T_S - t]} \cdot i \end{array} \right. dt$$

$$FW_{C3} = e^{[(\Theta + \Delta\Theta_c) \cdot (T_{PD} + (1-F) \cdot T_D + T_T + T_c \cdot w1)]} \cdot (1 - E_c) \cdot (1 - H) \cdot$$

$$\int_0^{w2 \cdot T_c} \frac{Co - z \cdot T_c}{\frac{T_c}{2} \cdot (1 + w2)} \cdot e^{[(\Theta + \Delta\Theta_c) \cdot t]} \cdot \max \left\{ \begin{array}{l} e^{[T_c \cdot (1 - w1) - O \cdot T_c + T_{COM} + T_H + T_S - t]} \cdot i \\ or \\ e^{[T_c \cdot (1 - w1) + T_H + T_S - t]} \cdot i \end{array} \right. dt$$

$$FW_{C4} = e^{[(\Theta + \Delta\Theta_c) \cdot (T_{PD} + (1-F) \cdot T_D + T_T + T_c \cdot (w1 + w2))]} \cdot (1 - E_c) \cdot (1 - H) \cdot$$

$$\int_0^{(1-w1-w2) \cdot T_c} \frac{Co - z \cdot T_c}{\frac{T_c}{2} \cdot (1 + w2) \cdot (1 - w1 - w2) \cdot T_c} \cdot [T_c \cdot (1 - w1 - w2) - t] \cdot$$

$$e^{[(\Theta + \Delta\Theta_c) \cdot t]} \cdot \max \left\{ \begin{array}{l} e^{[T_c \cdot (1 - w1 - w2) - O \cdot T_c + T_{COM} + T_H + T_S - t]} \cdot i \\ or \\ e^{[T_c \cdot (1 - w1 - w2) + T_H + T_S - t]} \cdot i \end{array} \right. dt$$

6.- FORMULATION OF HOLDBACK

6.1 - Formulation Of Net Present Value Of Holdback

$$NPV_{H1} = e^{[(\Theta + \Delta\Theta_C) \cdot y] \cdot (T_{PD} + (1-F) \cdot T_D + T_T)} \cdot H \cdot E_H \cdot \max \begin{cases} e^{-y \cdot (T_H + (1-O) \cdot T_C + T_{COM})} \\ or \\ e^{-y \cdot (T_H + T_C)} \end{cases} *$$

$$\int_0^{T_C} z \cdot e^{[(\Theta + \Delta\Theta_C) \cdot t]} dt$$

$$NPV_{H2} = e^{[(\Theta + \Delta\Theta_C) \cdot y] \cdot (T_{PD} + (1-F) \cdot T_D + T_T)} \cdot H \cdot E_H \cdot \max \begin{cases} e^{-y \cdot (T_H + (1-O) \cdot T_C + T_{COM})} \\ or \\ e^{-y \cdot (T_H + T_C)} \end{cases} *$$

$$\int_0^{w1 \cdot T_C} \frac{Co - z \cdot T_C}{\frac{T_C}{2} \cdot (1 + w2) \cdot (w1 \cdot T_C)} \cdot t \cdot e^{[(\Theta + \Delta\Theta_C) \cdot t]} dt$$

$$NPV_{H3} = e^{[(\Theta + \Delta\Theta_c) \cdot y] \cdot (T_{PD} + (1-F) \cdot T_D + T_T + T_C \cdot w_1)} \cdot \max \left\{ \begin{array}{l} e^{-y \cdot (T_H + (1-O-w_1) \cdot T_C + T_{COM})} \\ or \\ e^{-y \cdot (T_H + (1-w_1) \cdot T_C)} \end{array} \right. *$$

$$\int_0^{(w_1+w_2) \cdot T_C} \frac{Co - z \cdot T_C}{\frac{T_C}{2} \cdot (1+w_2)} \cdot e^{[(\Theta + \Delta\Theta_c) \cdot t]} dt \cdot H \cdot E_H$$

$$NPV_{H4} = e^{[(\Theta + \Delta\Theta_c) \cdot y] \cdot (T_{PD} + (1-F) \cdot T_D + T_T + T_C \cdot (w_1 + w_2))} \cdot H \cdot E_H *$$

$$\max \left\{ \begin{array}{l} e^{-y \cdot (T_H + (1-O-w_1-w_2) \cdot T_C + T_{COM})} \\ or \\ e^{-y \cdot (T_H + (1-w_1-w_2) \cdot T_C)} \end{array} \right. *$$

$$\int_0^{(1-w_1-w_2) \cdot T_C} \frac{Co - z \cdot T_C}{\frac{T_C}{2} \cdot (1+w_2) \cdot (1-w_1-w_2) \cdot T_C} \cdot [T_C \cdot (1-w_1-w_2) - t] \cdot e^{[(\Theta + \Delta\Theta_c) \cdot t]} dt$$

$$NPV_H = NPV_{H1} + NPV_{H2} + NPV_{H3} + NPV_{H4}$$

6.2 - Formulation Of Future Worth For Financing

$$FW_{H1} = e^{[(\Theta + \Delta\Theta_c) \cdot (T_{PD} + (1-F) \cdot T_D + T_T)]} \cdot H \cdot (1 - E_H)^*$$

$$\int_0^{T_c} z \cdot e^{[(\Theta + \Delta\Theta_c) \cdot t]} \cdot e^{(i \cdot T_s)} dt$$

$$FW_{H2} = e^{[(\Theta + \Delta\Theta_c) \cdot (T_{PD} + (1-F) \cdot T_D + T_T)]} \cdot H \cdot (1 - E_H)^*$$

$$\int_0^{w1 \cdot T_c} \frac{Co - z \cdot T_c}{\frac{T_c}{2} \cdot (1 + w2) \cdot (w1 \cdot T_c)} \cdot t \cdot e^{[(\Theta + \Delta\Theta_c) \cdot t]} \cdot e^{(i \cdot T_s)} dt$$

$$FW_{H3} = e^{[(\Theta + \Delta\Theta_c) \cdot (T_{PD} + (1-F) \cdot T_D + T_T + T_c \cdot w1)]} \cdot H \cdot (1 - E_H)^*$$

$$\int_0^{(w1+w2) \cdot T_c} \frac{Co - z \cdot T_c}{\frac{T_c}{2} \cdot (1 + w2)} \cdot t \cdot e^{[(\Theta + \Delta\Theta_c) \cdot t]} \cdot e^{(i \cdot T_s)} dt$$

$$FW_{H4} = e^{[(\Theta + \Delta\Theta_c) \cdot (T_{PD} + (1-F) \cdot T_D + T_T + T_C \cdot (w_1 + w_2))]} \cdot H \cdot (1 - E_H) \cdot e^{(i \cdot T_S)}$$

$$\int_0^{(1-w_1-w_2) \cdot T_C} \frac{C_o - z \cdot T_c}{\frac{T_c}{2} \cdot (1 + w_2) \cdot (1 - w_1 - w_2) \cdot T_c} \cdot [T_c \cdot (1 - w_1 - w_2) - t] \cdot e^{[(\Theta + \Delta\Theta_c) \cdot t]} \cdot dt$$

7- TENDERING AND DESIGN FIELD SERVICES

$$\text{Cost of services } (C_s) = \begin{cases} dt \cdot e^{[(\Theta + \Delta\Theta_c) \cdot (T_{PD} + (1-F) \cdot T_D + T_T)]} \cdot C_{ot} \\ \frac{e^{[(\Theta + \Delta\Theta_c) \cdot T_c]} - 1}{\Theta + \Delta\Theta_c} \end{cases}$$

7.1.- Formulation of Net Present Value

$$NPV_T = E_T \cdot e^{[-y \cdot (T_{PD} + (1-F) \cdot T_D)]} \cdot \int_0^{T_C + T_T} \frac{C_s}{T_C + T_T} \cdot e^{(-y \cdot t)} dt$$

7.2.- Formulation Of Future Worth For Financing

$$FW_T = (1 - E_T) \cdot \int_0^{T_C + T_T} \frac{C_s}{T_C + T_T} \cdot \max \begin{cases} e^{[i \cdot (T_T + T_C - O \cdot T_C + T_{COM} + T_H + T_S - t)]} \\ e^{[i \cdot (T_T + T_C + T_H + T_S - t)]} \end{cases} dt$$

8. - DESIGN PHASE

$$\text{Cost of service (C}_D) = \begin{cases} d_D * e^{[(\Theta + \Delta\Theta_c) \cdot (T_{PD} + (1-F) \cdot T_D + T_T)]} \cdot C_{Ot} * \\ \frac{e^{[(\Theta + \Delta\Theta_c) \cdot T_c]} - 1}{\Theta + \Delta\Theta_c} \end{cases}$$

8.1.- Formulation of Net Present Value

$$NPV_D = E_D \cdot e^{(-y \cdot T_{PD})} * \int_0^{T_D} \frac{C_D}{T_D} \cdot e^{(-y \cdot t)} dt$$

8.2.- Formulation Of Future Worth For Financing

$$FW_D = (1 - E_D) \cdot \int_0^{T_D} \frac{C_D}{T_D} \cdot e^{[i \cdot (T_D - t)]} dt * \max \begin{cases} e^{[i \cdot (T_T + (1-O) \cdot T_c + T_{COM} + T_H + T_s - F \cdot (T_D))]} \\ or \\ e^{[i \cdot (T_T + T_c + T_H + T_s - F \cdot (T_D))]} \end{cases}$$

9 - COMMISSIONING PHASE

9.1.- Formulation Of Net Present Value

$$NPV_{COM} = \frac{T_{PD} + (1-F) \cdot T_D + T_T + (1-O) \cdot T_C + T_{COM}}{T_{PD} + (1-F) \cdot T_D + T_T + (1-O) \cdot T_C} \int_0^{T_{COM}} \frac{C_{oCOM}}{T_{COM}} \cdot e^{[(\Theta + \Delta\Theta_{COM}) - y] \cdot t} dt \cdot E_{COM}$$

9.2.- Formulation Of Future Worth For Financing

$$FW_{COM} = e^{[(\Theta + \Delta\Theta_{COM}) \cdot (T_{PD} + (1-F) \cdot T_D + T_T + (1-O) \cdot T_C)]} \cdot (1 - E_{COM})$$

$$\int_0^{T_{COM}} \frac{C_{oCOM}}{T_{COM}} \cdot e^{[(\Theta + \Delta\Theta_{COM}) \cdot t]} \cdot \max \begin{cases} e^{[(T_{COM} + T_H + T_S - t) \cdot i]} \\ e^{[(O \cdot T_C + T_H + T_S - t) \cdot i]} \end{cases} dt$$

10 - REVENUE PHASE

10.1.- Primary Revenue Stream

$$NPV_{PREV} = \Gamma \cdot e^{[(g \cdot \Theta - y) \cdot (T_{PD} + (1-F) \cdot T_D + T_T + (1-O) \cdot T_C + T_{COM})]} \cdot \frac{e^{[(g \cdot \Theta + \Theta_v - y) \cdot T_o]} - 1}{g \cdot \Theta + \Theta_v - y} \cdot [v_f \cdot V_o + (1 - v_f) \cdot V_o \cdot e^{[-\lambda \cdot (\Gamma - \Gamma_o) \cdot T_o]}]$$

10.2.- Secondary Revenue Stream

$$NPV_{SREV} = S_s \cdot e^{[(((\Theta + \Delta\Theta_{RS}) - y) \cdot (T_{PD} + (1 - F) \cdot T_D + T_T + S_s \cdot T_C))]_*}$$

$$\frac{e^{[(((\Theta + \Delta\Theta_{RS}) - y) \cdot T_{OS})] - 1}}{((\Theta + \Delta\Theta_{RS}) - y)}$$

11.- MAINTENANCE AND OPERATION PHASE

$$NPV_{O\&M} = e^{[(((\Theta + \Delta\Theta_M) - y) \cdot (T_{PD} + (1 - F) \cdot T_D + T_T + (1 - O) \cdot T_C + T_{COM}))]_*}$$

$$\left\{ \int_0^{T_O} (M + m \cdot t) \cdot e^{[(((\Theta + \Delta\Theta_M) - y) \cdot t)]} dt + \sum_{j=\frac{T_O}{n}}^{j=1} R \cdot e^{[(((\Theta + \Delta\Theta_M) - y) \cdot j \cdot n)]} \right\}$$

12. - MAINTENANCE OF EXISTING FACILITY

$$NPV_{LD} = \int_0^{k1} M_{ex} \cdot e^{[(((\Theta + \Delta\Theta_{ME}) - y) \cdot t)]} dt$$

$$\int_{k2}^{[T_{PD} + (1 - F) \cdot T_D + T_T + (1 - O) \cdot T_C + T_{COM}] - k2} M_{ex} \cdot e^{[EX \cdot (t - k2)]} \cdot e^{[(((\Theta + \Delta\Theta_{ME}) - y) \cdot t)]} dt$$

13.- MANAGEMENT DURING DESIGN/CONSTRUCTION

13.1.- Formulation of Net Present Value

$$NPV_{MGTC} = e^{[(((\Theta + \Delta\Theta_{G1}) - y) \cdot T_{PD})] * E_{MTGCGC} * \left[(1-F) \cdot T_D + T_T + \max \left\{ \begin{array}{l} (1-O)T_C + T_{COM} + T_H \\ T_C + T_H \end{array} \right\} \right] \int_0^{C_{oMTGCGC} \cdot e^{[(((\Theta + \Delta\Theta_{G1}) - y) \cdot t)]} dt}$$

13.2.- Formulation of Future Worth For Financing

$$FW_{G1} = e^{[(((\Theta + \Delta\Theta_{G1}) - y) \cdot T_{PD})] * (1 - E_{MTGCGC}) * C_{oMTGCGC}$$

$$\max \left\{ \begin{array}{l} (1-F) \cdot T_D + T_T + (1-O)T_C + T_{COM} + T_H \\ (1-F) \cdot T_D + T_T + T_C + T_H \end{array} \right\} \int_0^{e^{[(((\Theta + \Delta\Theta_{G1}) \cdot t)]} * \left(\max \left\{ \begin{array}{l} e^{[(((1-F) \cdot T_D + T_T + (1-O) \cdot T_C + T_{COM} + T_H + T_S - t) \cdot i)]} \\ e^{[(((1-F) \cdot T_D + T_T + T_C + T_H + T_S - t) \cdot i)]} \end{array} \right\} \right)} dt$$

14 - MANAGEMENT DURING OPERATING AND MAINTENANCE

$$NPV_{MGTO} = \int_0^{T_P} \left[T_{PD} + (1-F) \cdot T_D + T_T + (1-O) \cdot T_C + T_{COM} + T_O \right] C_{oMGTO} \cdot e^{[\left((\Theta + \Delta\Theta_{G2}) - y\right) \cdot t]} dt$$

$$\max \left\{ \begin{array}{l} T_{PD} + (1-F) \cdot T_D + T_T + (1-O) \cdot T_C + T_{COM} + T_H \\ \text{or} \\ T_{PD} + (1-F) \cdot T_D + T_T + T_C + T_H \end{array} \right.$$

15 - DEBT SERVICING

$$P_C = \frac{FW_{C1} + FW_{C2} + FW_{C3} + FW_{C4} + FW_D + FW_T + FW_{COM} + FW_{G1} + FGW_{H1} + FW_{H2} + FW_{H3} + FW_{H4}}{e^{[(g \cdot \Theta + \Theta_v - i_p) \cdot T_P]} - 1}$$

$$\frac{g \cdot \Theta + \Theta_v - i_p}{}$$

$$NPV_{DS} = \max \left\{ \begin{array}{l} e^{[-y \cdot (T_{PD} + (1-F) \cdot T_D + T_T + (1-O) \cdot T_C + T_{COM} + T_S + T_H)]} \\ \text{or} \\ e^{[-y \cdot (T_{PD} + (1-F) \cdot T_D + T_T + T_C + T_{COM} + T_S + T_H)]} \end{array} \right. *$$

$$\int_0^{T_P} P_C \cdot e^{[(g \cdot \Theta + \Theta_v - y) \cdot t]} dt$$

16 - NET PRESENT VALUE

$$NPV = NPV_{PREV} + NPV_{SREV} - NPV_{PD} - NPV_D - NPV_T - NPV_C - NPV_{COM}$$

$$- NPV_{MGTC} - NPV_H - NPV_{O\&M} - NPV_{MGTO} - NPV_{DS} - NPV_{LD}$$

APPENDIX B

PROBABILISTIC MODEL FORMULATION

1 - EXPECTED VALUE

$$E[x] = P_{0.5} + 0.185 \cdot \Delta$$

$$\Delta = P_{0.95} + P_{0.05} - 2 \cdot P_{0.5}$$

2- STANDARD DEVIATION

$$\sigma_x = \frac{P_{0.95} - P_{0.05}}{\max \left[3.29 - 0.1 \left(\frac{\Delta}{\sigma_x^*} \right)^2, 3.08 \right]}$$

$$\sigma_x^* = \frac{P_{0.95} - P_{0.05}}{3.25}$$

3 - FIRST DERIVATIVES

$$\begin{aligned} \frac{\partial NPV}{\partial \alpha} = & -\frac{\partial NPV_{PD}}{\partial \alpha} - \frac{\partial NPV_D}{\partial \alpha} - \frac{\partial NPV_T}{\partial \alpha} - \frac{\partial NPV_C}{\partial \alpha} - \frac{\partial NPV_{COM}}{\partial \alpha} - \frac{\partial NPV_{MGTC}}{\partial \alpha} \\ & - \frac{\partial NPV_H}{\partial \alpha} - \frac{\partial NPV_{O\&M}}{\partial \alpha} - \frac{\partial NPV_{MGTO}}{\partial \alpha} - \frac{\partial NPV_{DS}}{\partial \alpha} - \frac{\partial NPV_{LD}}{\partial \alpha} + \frac{\partial NPV_{PREV}}{\partial \alpha} + \frac{\partial NPV_{SREV}}{\partial \alpha} \end{aligned}$$

For all model parameters x.

4 - SECOND DERIVATIVES

$$\begin{aligned}
 \frac{\partial^2 \text{NPV}}{\partial x^2} = & -\frac{\partial^2 \text{NPV}_{\text{PD}}}{\partial x^2} - \frac{\partial^2 \text{NPV}_{\text{D}}}{\partial x^2} - \frac{\partial^2 \text{NPV}_{\text{T}}}{\partial x^2} - \frac{\partial^2 \text{NPV}_{\text{C}}}{\partial x^2} - \frac{\partial^2 \text{NPV}_{\text{COM}}}{\partial x^2} - \frac{\partial^2 \text{NPV}_{\text{MGTC}}}{\partial x^2} \\
 & - \frac{\partial^2 \text{NPV}_{\text{H}}}{\partial x^2} - \frac{\partial^2 \text{NPV}_{\text{O\&M}}}{\partial x^2} - \frac{\partial^2 \text{NPV}_{\text{MGTO}}}{\partial x^2} - \frac{\partial^2 \text{NPV}_{\text{DS}}}{\partial x^2} - \frac{\partial^2 \text{NPV}_{\text{LD}}}{\partial x^2} \\
 & + \frac{\partial^2 \text{NPV}_{\text{PREV}}}{\partial x^2} + \frac{\partial^2 \text{NPV}_{\text{SREV}}}{\partial x^2}
 \end{aligned}$$

For all model parameters x

5- EXPECTED VALUE OF THE NET PRESENT VALUE

Using Taylors Series and assuming no correlation between variables:

$$E[\text{NPV}] = \overline{\text{NPV}} + \frac{1}{2} \cdot \left\{ \sum_{\text{for all } x} \frac{\partial^2 \text{NPV}}{\partial x^2} \cdot \sigma_x^2 \right\}$$

where $\overline{\text{NPV}}$ is The Net Present Value evaluated at the mean of each variable

6- STANDARD DEVIATION OF THE NET PRESENT VALUE

Using Taylors Series and assuming no correlation between variables:

$$\sigma[\text{NPV}] = \sqrt{\sum_{\text{for all } x} \left(\frac{\partial \text{NPV}}{\partial x} \right)^2 \cdot \sigma_x^2}$$

7- SENSITIVITY ANALYSIS

$$\delta x = \frac{\partial \text{NPV}}{\partial x} \cdot \frac{E[x]}{E[\text{NPV}]}$$

8- CONTRIBUTION TO SHIFT OF THE NET PRESENT VALUE MEAN

$$\% \text{Contribution}_x = \frac{\left(\frac{\partial^2 \text{NPV}}{\partial x^2} \cdot \sigma_x^2 \right)}{E[\text{NPV}]}$$

9- CONTRIBUTION TO THE NET PRESENT VALUE VARIANCE

$$\% \text{Contribution}_x = \frac{\left(\left(\frac{\partial \text{NPV}}{\partial x} \right)^2 \cdot \sigma_x^2 \right)}{\sigma[\text{NPV}]}$$