Abstract

Title of Dissertation: Project Performance-Based Optimal Capital Structure For Privately Financed Infrastructure Projects

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Privately Financed Infrastructure (PFI) projects are characterized by huge and irreversible investments and are faced with various risks. Project performance risks, such as project completion time and costs, affect the project value significantly, particularly in project development phase. This is because a major part of the project investments is made during this phase. Due to high uncertainties in managing the project performance risks, the selection of optimal financial structure is a challenge to Project Company sponsors and Lenders. Conventional project performance measurement and valuation methods cannot capture the dynamics of risk variables and their impact on the project value. Without such dynamic performance information, the decision of capital structure may not only be suboptimal, but lead to erroneous results. This research proposes an uncertainty evolution model, with which the dynamics of the project performance risk variables can be predicted at any desired time over the project development phase. A dynamic capital structure model is proposed

that explicitly considers the performance risks and adjusts the capital structure dynamically to counter the impact of performance risks. Numerical results show that such a model can add a significant value to a PFI project.

Two risk-sharing mechanisms are incorporated in the capital structure for a PFI project: active project management (self-support) and government support. An active project management method called *dynamic crashing* is proposed. By dynamically controlling the project performance through dynamic crashing, we show that the project value can be improved and the chances of potential bankruptcies can be reduced. In addition, the significance of government support as a risk-sharing mechanism is also modeled, which may be viewed as another means to protect the Project Company against the potential bankruptcies and improves the project value. Numerical results are implemented to validate the models. Overall, this research contributes an integrated framework to capital structure decisions for projects with performance uncertainties.

Project Performance-Based Optimal Capital Structure For Privately Financed Infrastructure Projects

by

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Dedicated To My Parents

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Chapter 1

Introduction

1.1 Motivation

UNCITRAL (2001) legislative guide on privately financed infrastructure projects defines 'infrastructure' as the physical facilities that provide services essential to the public. In the last decade, there has been an increasing involvement of the private sector in developing and operating infrastructure projects. The infrastructure projects under private participation, called Privately Financed Infrastructure (PFI) projects, involve the development of infrastructure facilities by a new private entity specially established for that purpose. This new entity is called the 'Project Company', constituted by the promoters or sponsors of the project. PFI projects are executed through a 'project agreement', also called a 'concession agreement' or 'concession contract', made between a public Contracting Authority (the Government) and the Project Company. This agreement specifies the terms and conditions for the finance, construction or modernization, operation and maintenance of the infrastructure for the concession period.

PFI projects are predominantly executed through a project financing mechanism, in which risk allocation is a key factor influencing the project success. Considering the uniqueness of using project financing for PFI projects, the importance of effective project management is highly pronounced in project development period. The decision on the determination of appropriate cost of capital and capital structure demands the need for active project management throughout the life of the concession. The Project Company is often held with complexities in choice of debt and equity capital structure, challenges in risk allocation and mitigation strategies and managing performance risks.

1.2 Project Performance Risks and Optimal Capital Structure for PFI Projects

The project performance during the development period has a significant impact on the overall financial feasibility of the project. Project performance risks can be expressed through project completion time (time overrun) and cost risks (cost overrun). Project with high performance risks can affect the project value and capital structure as, time overruns can create business interruption in operation and can create loss of revenues. Similarly, projects with cost overrun can affect the financial feasibility of the project. Depending upon the magnitude, projects with both time and cost overruns can increase the complexity in managing the performance risks and decision on appropriate capital structure.

Optimal capital structure is that structure of debt and equity which satisfies the management objectives of the Project Company. The management objective is to maximize the net present value (NPV) of the project and equity value. To determine such a capital structure is a challenge for the Project Company. The capital structure determination depends on conditions such as access to capital markets, government support and self-support on risk allocation and mitigation by the Project Company's sponsor organizations.

It is common that the interest rates on debt for PFI projects are lower than the expected cost of capital (Myers 2000). In other words, obtaining more debt capital is advantageous than providing equity on the project. In addition, market imperfection boosts the Project Company to have a high leverage by lowering their average cost of capital. In essence, the Project Company would prefer more debt than equity to finance the project, as it shifts the risk to the lenders. But, it is not uncommon to find that high leverage increase the chances of bankruptcy.

If a capital structure is formulated purely based on capital market conditions, then the chances of high leverage and high bankruptcy will be evident. But, such conditions can be prevented by appropriate risk allocation and management within and by the Project Company or risk allocation through suitable government supporting mechanisms such as low interest rate, guarantees, equity participation. However, government has to incur some cost in providing such support. Other risk allocation mechanisms imposed on the Project Company other than government supporting mechanism, would also require minimum equity levels from the sponsors and/or sponsor company guarantees to increase the project value. Keeping other factors such as quality of service aside, the higher the project value is, the higher the debt and equity values are. Therefore, all participants would aim to increase the value of such support reflected in value of the project.

Each support on risk allocation received by the Project Company, whether self or with the government or capital financial market support, would affect the project debt and equity proportions and would change the project value. Therefore, the optimal capital structure is decided by choosing the right mix of risk allocation and support provided by the Government, capital financial markets (insurance and hedging) and by the Project Company themselves.

1.3 Objectives of Research

The main objective of this dissertation is to determine the optimal capital structure using a real options approach for the Project Company for a PFI project. This research specifically considers determining the impact of project performance risks on project value and capital structure through a quantitative model. In addition, the model is extended to include the value of active project management on the capital structure decisions. The formulation also includes determining the optimal capital structure with government support option as a risk allocation mechanism.

1.4 Original Contributions

This dissertation has the following original contributions:

1. The evolution of project performance through performance uncertainties (time-at-completion and cost-at-completion) is modeled in Chapter 4. Furthermore, this research provides an integrated mathematical model which determines the optimal capital structure for a PFI project based on project performance (Chapter 5). Such an quantitative approach has not been attempted before in literature.

2. The flexibility in exercising active project management strategies such as dynamic crashing is a radical approach considered for risk allocation mechanism (Chapter 6). The proposed dynamic crashing approach is also a new concept toward dynamic and active project management.

3. The use of real options in project performance-based capital structure decisions provides an additional value by capturing the value of flexibility in decision making on the capital structure.

4. The mathematical model to analyze the value sharing through government support as an option and their impact on capital structure decision is a relatively new concept for the project financial feasibility analysis. This model is explored in Chapter 7.

5. This research, as a whole, emphasizes the significance and contribution of project management to project financing, especially for PFI projects. The proposed mathematical model links the active management of project performance and its influence on the project value, which is unique and explorative to many future researches.

The determination of a project performance-based dynamic capital structure is a significant improvement over traditional target capital structure models. This will be useful for any future PFI venture. In addition, this research addresses the importance of project performance risks in determining the cost of capital. The concept of providing the government support by limiting the upside and downside risks would be useful for both government and the Project Company. From Project Company's point of view, it protects the bankruptcy and from government's point of view it bounds the high profit expectations of the Project Company.

This mathematical model can be used in situations where government supports are available and the Project Company is given the option to choose among the supports. Since this model aims at choosing a capital structure which maximizes the project value, it would be beneficial to all participants such as the government, Lenders and the Project Company. Overall this model can be used for determining the optimal capital structure for a PFI venture in both developed and developing countries, regardless of the existence of a capital financial market and/or the availability of the government supports.

1.5 Organization of the Dissertation

The organization of this dissertation is as follows. The processes of PFI projects including the discussion on risk allocation and project finance mechanism are discussed in Chapter 2. The need for an integrated project performance-based capital structure model will also be discussed. Related literature is reviewed in Chapter 3. In Chapter 4, a mathematical model will be developed for modeling the evolution of the project performance risks including the time-to-complete and cost-to-complete performance parameters. A generic mathematical model of a dynamic capital structure contingent upon the impact of the project performance risks will be developed and described in Chapter 5. A numerical example will also be solved to validate the model results. In continuation of Chapter 4, the significance of active or dynamic project management and its effect on optimal capital structure will be discussed in Chapter 6. The mathematical model of the generic capital structure in Chapter 4 will be included strategies of mitigating the performance risks through active project management. This can also enhance the value of the optimal capital structure.

PFI project risks are sometimes shared by the Government or the Contracting Authority through provision of government supports. Hence, in Chapter 7, various possible government supports are discussed. A mathematical model will be developed for determining the optimal capital structure on the premise that a mix of government equity supports would be available to the Project Company. In this integrated model, the Project Company is also given an option to choose among the government equity supports. Finally, this dissertation concludes in Chpater 8, in which future research directions will also be identified.

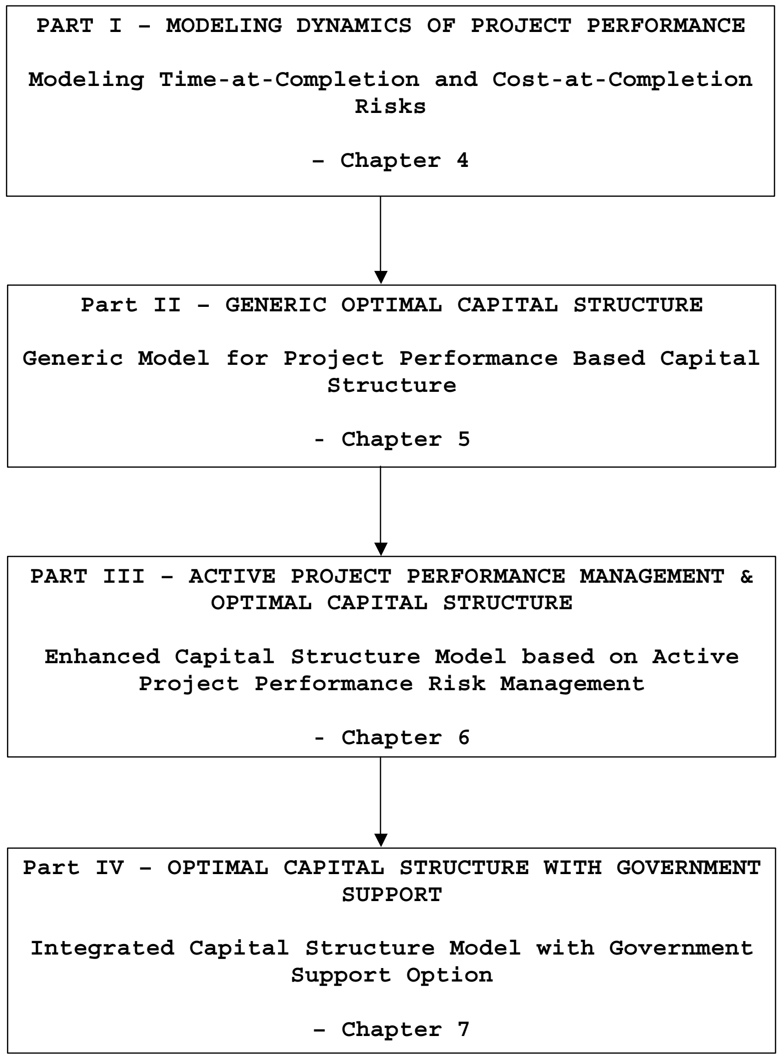


Figure 1.1: Organization of the dissertation

Chapter 2

PFI Projects: An Overview

In this chapter, an overview of privately financed infrastructure (PFI) projects is given. Discussions on various project participants, their contractual relationships, project financing and the significance of project management are presented.

2.1 Participants in PFI Projects

The involvement of the private sector in infrastructure development realm provides an array of participation arrangements. Depending upon the involvement of the private sector, PFI projects can be categorized into various types of delivery systems such as Build-Operate-Transfer (BOT), Build-Transfer-Operate (BTO), Build-Operate-Lease-Transfer (BOLT), Build-Own-Operate (BOO), Build-Own-Operate-Transfer (BOOT). The projects that are typically executed through the PFI schemes include toll roads, power projects, water / wastewater treatment projects, telecommunication projects, and others.

The main participants in the PFI projects are the contracting public authority or concession authority, which is often the host Government, Project Company sponsors, Lenders, Development Financing Institutions, Insurance Companies and other Advi-

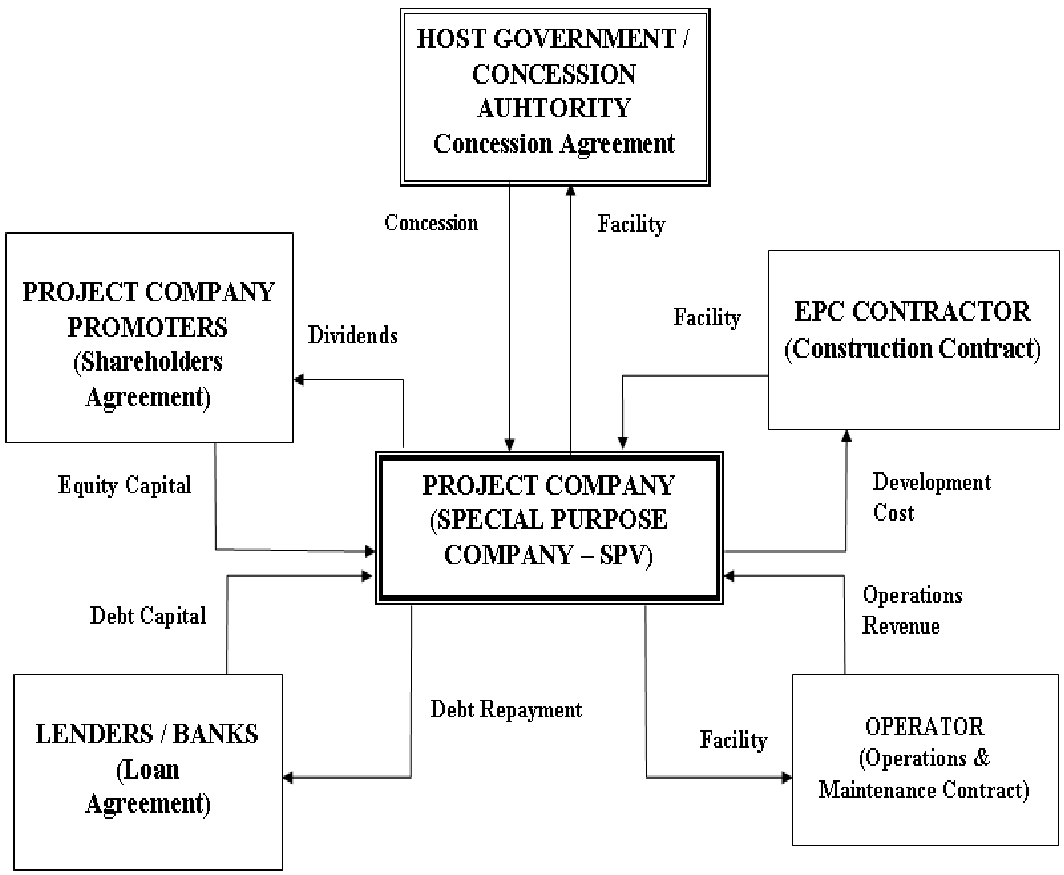


Figure 2.1: A typical PFI project structure

sors and Experts. Figure 2.1 illustrates a typical PFI project organization structure, in which the Project Company has a contractual relationship with the Government / Contracting Authority, the Lenders, the Construction (EPC) contractor and the Operator. In addition, the Project Company has a shareholder agreement within the Project Company sponsors, who provides equity capital and receives dividends from the project revenues.

The Contracting Public Authority (also the main body of the host Government), establishes the project through special legislation and governmental approvals. The authority enters into a project/concession agreement with the project company. Depending upon the sector and project, the authority provides support to the project such as equity contribution and guarantees.

The Project Company's sponsors usually comprise of large engineering and construction firms, supply firms, operation and maintenance companies, etc. They raise finance, build and operate the facility under the conditions of the project agreement.

The Lenders (international development finance institutions, commercial banks, etc) provide the debt capital to the Project Company with repayment conditions stipulated in a loan agreement. Depending upon the project, one or more Lenders can be involved in different phases of the project such as construction and operation. Besides Lenders, insurance companies provides various insurance requirements for the project risks. Similarly, other international financial institutions may also provide risk coverages to political risks and others.

Other participants include development financing institutions, export credit agencies and other investment promotion agencies, which hold the same interests as the lenders. However, they have additional interests in ensuring that the project meets policy objectives, environmental impact and sustainability.

2.2 Project Financing: Debt, Equity and Capital Structure

The Project Company has various sources for financing the infrastructure projects, which include equity contribution by the project company sponsors, debt and subordinated debt through commercial bank loans, financial markets (bonds, shares, etc), institutional investors, export credit agencies and the host government. Unlike the corporate finance, the Project Company, most often a new corporate entity that is constituted by the project company sponsors, do not have an established credit to borrow debts from lenders (UNCITRAL 2001). In such conditions, a 'project financing' mechanism is adopted. In project financing, the project's expected cash flow form the basis for the viability in terms of project existence and loan repayment of the project. Project-specific assets such as toll roads, water treatment plants, power plants, act as the collateral for the loan. Project financing, also practiced as limited-recourse or non-recourse financing, insulates the project risks from the assets and activities of the sponsors, demanding limited or no guarantees from the Project Company sponsors.

Equity capital is generally provided by the Project Company sponsors. Equity capital can also be raised through bonds and shares. By providing equity capital, the Project Company sponsors assume high financial risk and also hold the major share of profit. In some instances, the host government may also provide equity contributions to the project as a form of government support to PFI projects.

Debt capital often represents the key source of funding for PFI projects. Typically, debt capital accounts for two-thirds of the total capital. Debt capital is provided through loans from the Lenders such as international development finance institutions, commercial banks.

Another form of capital is called 'subordinated' loans or 'mezzanine' capital. Subordinated loans have a high priority than equity capital but lower or subordinate priority to debt capital. Subordinated loans are often provided at fixed rates, usually higher than those of the main debt.

Besides, capital financial markets are also used for raising funds through bonds, shares, etc. However, the existence and access to the capital markets and the credit rating of the Project Company decides the level of use of the capital financial markets.

The capital structure of the Project Company is defined by the combination of debt and equity capital assigned for the project. The amount of debt and equity capital is decided based on several factors such as impact of project risks and risk allocation mechanisms, minimum equity level constraints, flexibility in regulatory arrangements, availability and access to capital markets, government support, availability of established financial market hedging and insurances, etc.

The characteristics of a project financing mechanism is pronounced through high-leverage (debt ratio) financing, off-balance sheet treatment, project risk isolation from sponsors activities, tax treatments, subsidies and government support mechanisms. The Project Company, due to high-leverage and risks in project financing mechanism, is also exposed to high chances of bankruptcy.

2.3 Uncertainties and Risk Allocation Strategies for PFI Projects

The PFI projects are subjected to a large number of uncertainties such as product demand, completion cost and time of construction, input price changes, political stability, exchange and interest rate changes, regulatory changes. Such uncertainties affect the risk allocation strategies of the project. For example, risks related to regulatory changes are beyond the influence of the Project Company and such risks have to be allocated to the government. Similarly, project development risks are allocated to the Project Company, who in turn shifts the risk to the construction contractors (see Figure 2.1). Hence the debt and equity amounts depend significantly on the impact of performance uncertainties and the risk allocation mechanism.

In order to determine the amounts of debt and equity that the project can support, the financial methodology of project financing requires a precise projection of the capital costs, revenues and projected costs, expenses, taxes and liabilities of the project. The key feature in this analysis is the identification and quantification of risks. For this reason, the identification, assessment, allocation and mitigation of risks is of utmost importance in project financing from a financial point of view. Following are the major risks identified in PFI projects:

1. **Construction and operation risks** such as completion risks, construction cost overrun risks, operations performance risks, operation cost overrun risks.

2. **Political risks** such as acts of the Contracting Authority, another agency of the government or the host countrys legislature.

3. **Commercial risks** including the situation that the project cannot generate expected revenue due to changes in market prices, demand for the goods, or services it generates.

4. **Interest rate risks** referring to possibile changes in foreign exchange rates and interest rates that will alter the value of cash flows from the project.

5. **Disasters** such as natural disasters (floods, storms, or earthquakes) or the result of human actions (war, riots or terriorist attacks), which are beyond the control of the parties.

The above risks are dynamic in nature when considered for the total life of the concession (usually 20 - 30 years). For example, the demand risk depends on the overall economic growth and varies accordingly with the economic development. Project completion risks depend on the uncertainties in the project performance. Similarly, interest rate fluctuation depends on the stability of the financial markets. For each risk identified and analyzed, how to allocate the risk fairly to all participants is an challenging issue. From the principles of privatization, the Contracting Authority would prefer all major risks be borne by the private sector duly following the notion that the participant best able to manage the risk should absorb the risk. This research concentrates only on the project performance risks during the project development period.

Due to high uncertainties and high cost of performance risk management, the Project Company would prefer getting support internally from the project company sponsors or externally from the Contracting Authority (host government) and / or capital financial markets (insurance and hedging) for the project risks. If the capital market for PFI projects does not exist, which is not uncommon, the Project Company is left with the following two ways of support.

1. Self-support by the sponsoring companies by establishing a dynamic project management system for project development risk management.

2. Government support for project development risk management

The Project Company can also hedge and insure many risks through financial markets, if there exists a market for PFI ventures. Hedging and insurance can also protect the Project Company from downside risks, but are normally costly (insurance premium, etc) to obtain and will eventually increase the cost of capital (Senbet and Triantis 1997). The cost of obtaining such insurances and hedging is often higher than the cost of support obtained from the host government. However, the upside risk effects are not bounded by such mechanisms. This provides the Project Company the advantage of gaining high payoffs, when the project value is high.

Therefore, the Project Company has options to choose for each risk among self-support, government support and financial market (hedging and insurance) for protection against downside risks. However, this research focuses only on the self-support and the government support risk-sharing mechanisms.

2.4 Project Management of PFI Projects

Though the PFI project contractual structure specifies the involvement of the Project Company through project delivery systems such as BOT and BOLT, the management of PFI projects become the primary responsibility of the Project Company during the development phase of the project. In addition, the Lenders (banks) prefer the Project Company to have a good project management system in place for the project, in addition to their ability to invest on equity and self-support on risk impact. Project Companies, often constituted by a combination of several sponsor companies, might not have a uniform project management system for the proposed project. In addition, the uniqueness of PFI projects demands a dynamic project management system, which can link the project development performance and the overall project value. The effect of risks impact and efficiency of performance risk management during the project development period has a huge potential to determine the success of the project. Therefore, the need for a dynamic project management system, which can model the impact of project performance risk on project value, is highly pronounced. An effective project performance measurement technique, that can analyze the project evolution at any given time period becomes a pre-requisite for such a system. Particularly, the need for active time and cost control performance of the project during the development period is emphasized.

2.5 The Need for an Integrated Model

Risk sharing and allocation is the key to success of a PFI project. PFI projects, subjected to uncertainties, face high chances of bankruptcy and failures when risk-sharing mechanisms are not optimally placed. The Project Company would face the challenge to acquire debt and equity capital for the project and to determine which risks would be manageable by them. What is equally important is the decision on choosing the right government support with a constraint on project value sharing.

The traditional project valuation methods such as net present value (NPV) and capital budgeting cannot capture the dynamics of the risk variables. Project performance risks, which can affect the project value during the project development period, need to be explicitly considered in the capital structure decision. Another major disadvantage is the lack of option for obtaining government support during the project development period. In other words, the performance of project development and decision on choosing the support depends on factors such as the probability and impact of performance risk variables on project value at various time periods over the project development phase. Therefore, determination of an optimal capital structure for the entire project requires a model which can integrate the option to choose among available risk allocation mechanisms (self-support or government support) at various time periods and can rebalance the debt and equity to result in a structure that satisfies the management objectives.

The concept of real options can be applied to determine the debt structure dynamically based on the current impact of project performance risks on project value. Clearly, the options for choosing a dynamic capital structure have value. Furthermore, this dissertation also considers the option that the Project Company can switch among different government supporting mechanisms.

2.6 Major Assumptions in the Research

The PFI projects can be executed with a great number of possibilities in terms of obtaining finance (loans, bonds and/or shares), delivery of service (BOT or BTO), with various participants (international financial institutions, development institutions, and export credit institutions). The mathematical model proposed in this dissertation will be restricted to the following major assumptions:

1. The PFI project is financed only through a project financing mechanism and total capital is composed of debt and equity.

2. For the sources of debt finance, only loans/debts from development banks are considered. Bonds and shares are not considered as sources of equity and debt finance for the model.

3. The support options are flexible, i.e., switching among support options is possible.

4. The model considers only the performance risks in the project development period, which includes planning, design, construction and operation phases.

5. The government support includes a mechanism to impose project value sharing constraint.

The detailed assumptions with respect to the mathematical model are discussed in detail in the following chapters.

Chapter 3

Literature Review

In this chapter, a comprehensive review of literature related to Privately Financed Infrastructure (PFI) projects, capital structure, project management and risk management, project financing and real options will be made.

3.1 Privately Financed Infrastructure Processes

Though infrastructure project development and financing is an old concept, the application of project financing in privately financed infrastructure projects is comparatively new. PFI projects encompass multi-sector knowledge and interaction between various disciplines. The key subjects include engineering and construction, project management, project financing, socio-economics, politics, economics, legal etc,. The UNCITRAL legislative guide on privately financed infrastructure (PFI) projects provide a comprehensive legislative principles for PFI projects (UNCITRAL 2001). It discusses the background of PFI projects and discusses in detail the principles of legislative and institutional framework, project risks, selection procedures of the concessionaire, concession and operation procedures and dispute settlements. This guide provides an overall view and legislative recommendation to facilitate PFI projects.

UN/ECE (2000) guidelines on Public Private Partnership for Infrastructure Development outlines the objectives, means, theory and practice of PFI projects. It explains the methods of bid processes, project pre-requisites and selection criteria, negotiations, risk allocation, contract structure and obligations. It also includes the project finance and risk transfer aspects of PFI projects.

The details of concessions for infrastructure is described in a World Bank technical paper (Kerf 1998), that provides guidelines for design and award of concession contracts. This report provides an overview of the types of concessions, their selection and rationale and responsibilities of the Government/Contracting Authority. It provides detailed guidelines for design of concession contract including risk allocation, setting tariffs, regulatory arrangements for price adjustment, other contract conditions and selection processes. It covers the entire bidding and award process including competitive bidding, bid negotiations, rules and procedures. It also delineates the responsibilities of regulatory institutions and the role of government support in risk allocation and sharing mechanisms.

Alexander (1997) emphasizes the importance of regulatory institutions to replicate the competition to improve efficiency in privatization of infrastructure services in the absence of competitive markets. Various factors such as threat of bankruptcy, internal control of infrastructure companies and external actions by the market are considered for attainment of such efficiency. A check-list was developed to consider various options of regulatory and governance systems, and their impact on attainment of efficiency. Merna (2002) provides a comprehensive description on management of infrastructure projects under private participation.

RMC (1998) is a report, that describes the use of World Bank guarantees in bidding for private concessions. It identifies the issues involved in bidding and evaluation. The report stresses on the practice of informal selection of bidders, which leads to an ambiguity over the issue of optimal risk transfer to the private sector. The report also proposes the advantages of guarantees to be integrated into the bidding process for competitive and formal selection process of concession contracts. The World Bank Guarantees Handbook (1997) provides detailed information on the use of guarantees, their operations and management of private sector involvement in infrastructure projects.

Estache (2002) discusses the sector-wide regulatory issues including price, quality and safety regulation for airports, seaports, railways and toll roads. The report also includes performance indicators for each sector, which has been set as a main element in the concession design and award. Baker (2000) emphasize on the service quality and the regulatory instruments required for marinating infrastructure service quality.

Other important selections of literature explaining the process of PFI projects include documents from Privatization Watch from Reason Public Policy Institute, documents from the World Bank and the Inter American Development Bank and several case studies from various international development financial institutions, etc.

3.2 Project and Infrastructure Financing

Project financing has been used widely since 1970 for large scale infrastructure projects worldwide. Statistical evidence shows that the use of project finance investments worldwide has increased from $10 Billion per year in 1980 to $220 billion per year in 2001 (Esty 2003). The classic examples of this use of project finance includes the famous Eurotunnel, Eurodisney, Enron's Dhabol Power project etc. Esty (2002) provides a comprehensive overview of the evolution of project financing in large scale projects. The relationship between the individual asset risk and the project leverage was evident. The importance of project performance on the success of project finance venture have been discussed in detail with statistical information. This paper also stresses the need for research on Project Companies, Project Finance and Project

Performance.

Dailami (1998) addresses the importance of introducing private capital in public infrastructure in developing countries. Private participation and supply of long-term debt capital are considered as the key factors for capital flows in infrastructure sectors. This paper, through an analytical framework, shows risk premium relates country risks and project-specific risks in private infrastructure development projects. Determination of the cost of foreign currency borrowing cost to infrastructure projects shows that the high premiums are charged for countries with high inflation rates.

Standard and Poor's (2002) report on project and infrastructure finance specifies the challenge in obtaining credit for Project Sponsors and utility providers. With increasing project defaults and their associated losses, the Lenders focus on incorporating the loss of defaults in loans. A comprehensive analytical framework for project financing criteria to analyze the impact of project-level risks and external risks on the project cash flow is provided.

Estache (2000) discuss the roles of project finance in the transport sector, their advantages and disadvantages, management of risks and the roles of public sector organizations in project financing deals. Buljevich (1999), Pollio (2002), Nevitt (1995), Yescombe (2002), Finnerty (1996) and Beenhakker (1997) are some of the authors of useful literature concerning the project financing mechanism, financial engineering techniques, risk management, cost of capital and capital structure decisions.

3.3 Risk Management Strategies and Government Support

Project risk management is an inherent knowledge area in project management processes (PMBOK 2000). However, in PFI projects, risk allocation and transfer is the key to project success. Though there are numerous articles available for project risk management, the following are the major relevant pieces of literature which address the uniqueness of PFI projects.

Senbet (1997) provides strategies for risk management through financial contract design. This includes identifying and classifying the risks according to their sources and discusses the rationale for risk management. The use of financial market mechanisms for risk management including hedging and insurance using derivatives for exogenous risks, and incentive contracting for endogenous risks are discussed in detail.

Erhardt(2004) analyzes the impact of infrastructure regulation on bankruptcy and leverage ratios. A model is prepared to identify the impact of government support on project value for various regulatory arrangements. In addition, the policy options towards facing bankruptcy threats are discussed in detail. A discussion of implicit guarantees and possibilities for making bankruptcy a credible threat is also discussed in detail.

INFRISK is a well known computer simulation software system dealing with risk evaluation and management in infrastructure finance transactions (Dailami 1999). INFRISK analyzes different risks such as market, credit and performance to determine the economic viability of PFI projects. Vega (1997) explains the appropriate risk allocation mechanism for major risks that are common to most infrastructure projects. The paper emphasizes the importance of individual project-based risk management solutions for each project. Grimsey (2002) analyzes the principles of risk analysis and management of public-private-partnership projects. Grimsey discusses the complexities in evaluating various risks from the perspectives of the government and private sector and presented a framework for assessing the risks. The framework includes defining, analyzing and evaluating project risks in a practical perspective through case studies.

Tiong (1990) explains the importance of the role of government in PFI projects through supporting mechanisms for risk management. He provides a guideline for negotiations for Project Companies and the assistance and supports which should be required from the Contracting Authority/host government. He also suggested a risk mitigation solution for construction and operation phase risks.

Pindyck (1993) addresses the two major project performance uncertainties, viz., time-to-complete and cost-to-complete for projects with irreversible investment conditions. PFI projects are considered as projects with huge irreversible investments. The projects have very little asset value until they are completed and operated successfully. The proposed model provides simple investment decision rules under conditions of performance uncertainties. In this model, the cost-to-complete $K(t)$ follows a diffusion process with I rate of investment and dz as Weiner Process, is given by

$$dK = -Idt + g(I, K)dz$$

Standard and Poor's (2002) Project and Infrastructure Finance review provides the framework for project finance analysis in terms of a five-level analysis framework for analyzing project risks, which includes project-level risks, sovereign risks, business and legal institutional development risks, force majeure risks and credit enhancements. A further six-steps comprehensive process is enumerated in analyzing the project-level risks.

Lam (1999) provides a very comprehensive risk classification, risk mitigation approaches, residual risks and risk impacts for several sectoral infrastructure projects such as power, expressways, bridge, tunnels, airports, rail systems, telecom and process plants. He also examines the risks faced by private infrastructure projects in major infrastructure sectors, which provides a guideline for future projects.

Dailami (1998) discusses the use and impact of the provision of various government supports for privately financed infrastructure projects in emerging markets. The discussion on supports include guarantees for contractual obligations of government, political risks, financial risks and market risks. The value and charges for types of supports and their inherent problems are discussed. Zayed (2002) proposed a prototype risk assessment model with eight main types of risks such as political, financial, revenue & market, promoting, procurement, development, construction completion and operation risks. A risk index was developed with weights for each risks to be used as a ranking tool for assessment and selection of mitigation process for the project risks.

3.4 Project Valuation Methods, Real Options and Capital Structure Theory

Project valuation methods encompass a wide variety of literature from academics to practice. The following literature are considered more relevant to PFI projects and current research.

Kim (1978) proposed a model for determining debt capacity and optimal capital structure when firms are subjected to bankruptcy costs and taxes. The model provides a debt capacity of the firm before determining the optimal debt ratio. The results reveal that when firms are subjected to bankruptcy costs, their debt capacities are reached before one hundred percent debt. Esty (1999) explains the importance of project finance investments and limitations of constant discount rate methods such as free cash flow (FCF) and equity cash flow (ECF) in valuing Projects. He extended the valuation technique to include quasi-market valuation and real option analysis in valuing large-scale engineering projects.

Shah (1986) proposed a theory of optimal capital structure that links risk, leverage and value. In addition, an economic rationale is suggested for use in project financing for high risk and high leverage projects. The results show that under conditions of equilibrium, firms with high risk choose higher debts. Casey (2000) provided a stochastic framework for investment and risk management, specifying the fact that the investment, finance and hedging activities should be considered together.

Chemmanur (1996) proposed a model to analyze the impact of multiple projects and the effect of corporate financial structure on the overall management ability to control. The model provides interaction between the capital structure and the optimal incorporation of multiple projects and allocation of debt capital across the projects. Babusiaux (2001) formulated after tax weighted average cost of capital (ATWACC) for determination of economic value of the project in consistent with the overall firms target capital structure. This formulation has an advantage because of its independence from any target debt ratios. In addition, another formulation called before tax weighted average cost of capital (BTWACC) was proposed to adapt to any debt ratio similar to the known Arditti-Levy method. It was observed that the former method ATWACC was identified with more advantages for its simplicity as well as adaptability for any differing project debt ratio from the firm's target debt ratio.

Smith (1995) compared different project valuation approaches such as risk-adjusted discount-rate analysis, option pricing analysis, and decision analysis. The paper suggested ways to integrate both the option pricing and the decision analysis methods for valuation. The paper confirms the compatability and consistency of both valuation methods and lies within the same optimal set. In addition, the paper also confirms that in incomplete markets, the integration of both the valuation methods can simplify the analysis by partial hedging.

Ho (2002) provides an option based pricing model for PFI project valuation. The model considers the dynamic risk characteristics of the project and evaluates the impact of government guarantee and negotiations options in determining the project viability. This model considered project value and project cost as the key uncertainties and used a reverse binomial pyramid to compute the BOT equity payoff. This model also considered the chances of bankruptcy and their conditions during the project development period. Ranasinghe (1999) proposed a methodology to analyze the viability of PFI projects based on the consideration of financial risks. This model explictly considers the value of subsidies received from the government, under the conditions of uncertainties in cost estimates, rate of debt and escalation parameter.

Dias (1995) developed a model to determine the debt capacity and optimal capital structure for the project, considering both the possibility of project bankruptcy as well as effect of taxes on the returns. The optimal capital structure is aimed at maximizing either the equity returns or project's NPV. The results explain that the debt levels required for these objectives are less than the debt capacity for the project. Bakatjan (2003) presented a model to determine the optimum equity level for a BOT project, using linear programming aiming at maximizing the equity returns.

The use of real options to value flexibility in managerial decisions has been established for valuing real assets. However, the use of real options in PFI projects has not been substantially made so far. According to Dixit (1994), projects with high uncertainties in payoff increase the value of flexibility. PFI projects are observed with high uncertainties, in which the value of flexibility can be captured efficiently by the real options concept (Esty 1999). Real options in the production and industrial sector has been pronounced with types of options such as to defer, switch, expand or contract, abandon, etc (Trigeorgis (1996) and Kulatilaka (1993)). For more real options references, literatures are referred in the corresponding model development sections. From the understanding of the value of flexibility, the real options concept is applied in this research for dynamic capital structure decisions for the PFI project.

More specific references are being made in the corresponding sections, where proposed models are being discussed.

Chapter 4

Modeling Dynamics of PFI Project Performance Risks

In this chapter, PFI project performance risks are discussed in detail. Specifically, the dynamics of project performance risks on the total project modeled through a project evolution process is explained. This model will provide project performance measurements at any required time period.

4.1 PFI Project Risks and Risk Management

Project risks can be ascertained by their impact on the project value. PFI project risks can have a negative effect on the benefits from the project. As discussed previously, Lenders primarily look at the project's expected cash flow as the source for repayment of debts. The principle of limited-recourse or non-recourse financing is that it insulates the project risks from the assets and activities of the sponsors. Therefore, in case of bankruptcy of the Project Company, the Government and/or Lenders bear the risk of continuing the service. Therefore, it is within all participants' interest to have information and the control on a global risk management process for managing the project risks during project development phase as well as operation phase.

According to Senbet et al. (1997), risks can be classified as endogenous and exogenous to the project. The major risks considered for risk analysis in PFI projects are project performance risks (completion time, completion cost, project quality), economic risks, financial risks, political risks and regulatory risks. In particular, the importance of project performance risk management is highly pronounced in the project development period, since project capital investments are made to a large extent in this period. Therefore, project performance during the development period will have a significant impact on the overall financial feasibility of the project. In this section, the focus is given to developing an efficient measurement process for such project performance risks.

4.1.1 Project performance risk management

Project performance risks can be expressed through project completion time (time overrun) and cost risks (cost overrun). Project completion time, or time overrun risk, deals with the uncertainty of the project to be completed on or before the planned time. Similarly, project completion cost, or cost overrun risk, deals with the uncertainty of the project to be completed on or within budgeted costs. Projects not completed on time are unlikely to start operation and generate revenues on time. Furthermore, this may lead to failure in satisfying the debt obligations of the Project Company. Similarly, projects with actual costs higher than the planned costs may affect the financial feasibility of the project. In addition, high cost overruns increase the project capital cost, which would have to be funded through additional debt and equity. In turn, this would affect the capital structure. Similarly, lengthy time overruns may also lead to early termination of the project. Projects with long delays combined with high actual costs can be disastrous to the Project Company, as there will be cost overrun as well as time overrun. It is also required by the Project Company and often the Lender, to monitor project quality risks of the end product, as these can affect the project to perform as expected on its physical completion.

It is important to the Project Company that the potential problems, that could cause time and cost overruns are identified early and earmarked for their mitigation. It is required that the causes of time and cost overruns, which can be controlled before or during project implementation, be considered for analysis to determine their impact on the overall duration and total cost of the project. However, uncertainties causing time overruns and cost overruns within the project are not uncommon. These uncertainties have been generally considered as the randomness in the duration and estimated cost of the activities. The uncertainties within the completion period can be attributed to various reasons such as the result of defective design and / or construction, use of inadequate technology, land acquisition delays, unforeseen geological conditions, delay in permits, poor workmanship, regulatory changes, escalation etc. Many researchers (Ranasinghe 1994; Pontrandolfo 2000; Etgar et al. 1996) have examined and analyzed risks and uncertainties on project duration. But, no substantial research has been done to specifically address the uniqueness of PFI projects. Project completion time, completion cost and end-product quality in PFI projects have a special significance characterized by additional loss of revenue on delays and failure in satisfying the repayment of debt obligations. Yescombe (2002) discusses the importance of project performance impact on overall project cost.

Impact of performance risks on a PFI Project

To highlight, the performance risks (time overrun and cost overrun) can introduce several upshots in a project listed below.

- **Increase in financing cost(s)**

  This additional financing cost during the delay period is due to the additional interest costs for the debt obtained. Since there will not be revenues in the project development period, the interest cost will be accumulated.

- **Additional increase in cost overrun due to financing cost**
  Due to the increase in financing cost, the total project cost would also increase. This will further increase the cost overrun.

- **Loss of revenue due to interruption in business/operation startup**
  This loss of revenue is due to the delay in starting the operation of the facility. This impact will be very high when the facility operates in a competitive market.

- **Damages and other applicable penalties imposed by the Contracting Authority**
  In case of a delay in starting the operation of a facility, the Contracting Authority (Government) can impose damage and penalties for not providing the facility for the public use in a timely manner.

- **Loss of revenue due to inability/poor quality of the project's end-product**
  The loss of revenue can also happen when the project is unable to provide service due to poor end-product quality. This condition can lead to poor satisfaction of the user demand, which will eventually reduce the revenue.

The completion risks (time and cost overruns) mitigation arrangements are generally accomplished by transferring such risks to the Project Company. This mitigation arrangement is transferred one step further to the design and construction contractor. However, it should be noted that the Project Company is generally assigned wholly responsible for all project-specific risks including the completion risks. This risk transfer commonly relies on fixed-price, certain-date construction contracts for handling completion risks using liquidity damages (Bond 1994; Finnerty 1996; Grimsey 2002;

Kerf 1998; Tiong 1990 and Vega 1997). The Public Private Partnership forum (PPP) of the UK provides a study result in which more than 20% of the PFI projects are faced with cost overruns and 24% of the projects are faced with time overruns in the UK. A report by the International Financial Corporation (IFC) provides information that a study conducted on performance of 233 greenfield projects shows that more than 45% of projects had experienced cost overruns. Another study revealed that out of 48 PFI projects, an average of 22% schedule overrun was observed (Esty 2002).

According to Esty (2002), PFI projects experience severe time and cost overruns. The smallest impact of these project performance risks can reduce the equity returns to the Project Company sponsors, and their worst effect can lead to project bankruptcies affecting both debt and equity returns. Therefore, the impact of project performance risks, irrespective of their magnitude, can significantly affect the equity and debt returns of a PFI project.

Since the most widely used risk allocation mechanism for project performance is only through fixed-price-certain-date contracts, it is believed that most to all of these study projects have relied on these contracts for mitigation of project performance risks. Jaafari (1996) acknowledges the limitations in handling delay risks by using only liquidity damages and warranties. He also proposed a new incentive-based contracting method for an optimum performance outcome. It can be observed from the study results that the need for a better project performance management system is evident.

In addition, these traditional fixed-price-certain-date contracts impose damages based on fixed project milestone performances oftener than those based on a continuous performance measurement. The limitations of such contract conditions to react to impact of project performance risks demands a dynamic/active project management. The impacts of performance risks on the project has to be modeled stochastically such that the current project performance information can be available at any time period for decision making. Therefore, the PFI project development decision making for maintaining or improving project performance should be an ongoing process. Development phase indicates the pre-construction stage tasks such as land acquisition, obtaining permits, design, bid award, and construction and commissioning stages. The evolution of dynamic project performance risks will be modeled in the following section.

4.1.2 The need for a project performance risk based capital structure model

Although many researchers have conducted studies on the integration of risks in capital structure, only relevant papers are discussed here. Ruback (2002) presented a new valuation technique called Capital Cash Flow (CCF) for valuing risky projects, by comparing its equivalence with Free Cash Flow (FCF) and Adjusted Present Value (APV) methods. Leland (1994) provides a methodology for determining optimal capital structure under eternal debt with dividend and bankruptcy conditions. Ho et al. (2002) developed an option pricing based model for evaluating the projects for its viability. This model considers only project value and construction cost as the risk variables, to determine the financial viability of the project using real options pricing method.

Dias *et al.* (1995) developed a model to determine the maximum debt capacity of a PFI project and the relevant optimal financial structure, by considering both bankruptcy and tax benefits and using CAPM method for project valuation. Bakatjan (2003) prepared a model for determining the optimum equity level for a hydroelectric power project under PFI scheme, using linear programming to maximize the return on equity. Esty (1999) explains the limitations of the Discounted Cash Flow (DCF) approach in valuation of large scale engineering projects and employed an approach called Quasi-Market Value (QMV) to value the projects. Esty (1999) also explains the problems with the standard NPV approach with the use of single discount rates for valuation. According to Esty (1999), the use of target capital structure to calculate the discount rates might lead to errors in project financing.

Although many researchers have tried to determine the optimal capital structure in corporate and project finance modality, in the author's opinion, the impact of inherent project performance risks on PFI projects has not been addressed specifically in any of the existing researches. Therefore, the need for an integrated model is evident, which can model the impact of performance risks on project value and determine an optimal capital structure to maximize the project value.

In particular, the Project Company, as a separate legal entity, needs risk management of projects different from corporate financed projects (Yescombe 2002). Traditional capital structure models do not consider the impact of such dynamic performance risks on project value. With the impact of such dynamic project performance risks, determining such an optimal equity and debt capital structure is a challenge for the Project Company.

The traditional project performance management methods fails to provide information on the evolution of performance risk variables. With lack of such information on dynamic performance risk variables, the management decision on performance improvement cannot be effective. In order to determine the impact of performance risks on project value, it would be essential first to model the dynamics of project performance risks over the project development period.

In addition, the determination of an optimal capital structure for the whole project requires a model that integrates both the market and project specific risk profiles and calculates the debt and equity value, which satisfies the management objectives. The integrated model also demands the capability of handling dynamic risk variables. The impact of dynamics of risk variables can be handled using the concept of real options in the valuation of project. The results obtained from this model will capture the value of flexibility in managerial decisions of altering the capital structure during the project development period.

4.2 Model Dynamics of Project Performance Risks

In order to determine the impact of performance risks on the project value, it is essential to model the dynamics of project performance risks at any time period including time-at-completion and cost-at-completion. Time-at-Completion and Cost-at-Completion are the expected total time and cost to complete an activity or a project based on current performance status (PMBOK 2000). The CPM (critical path method) and PERT (program evaluation review technique) are the traditional methods used in determining the project duration through activity networks. While CPM is an activity-oriented networking method that provides a deterministic activity and critical path duration, PERT is a probabilistic approach deals with three time estimates (optimistic time, most-likely time, and pessimistic time) to arrive at an activity duration (Kerzner 2001). But both techniques are not capable of providing information about an activity as how it evolves, or how it approaches toward completion.

In addition, these methods in conventional project management consider work in terms of cost and time required to complete the activity. These methods assume that the rate of work performance is certain over the entire activity duration. This process has deficiencies, because the performance of work done per unit time is never constant in reality, even if resources are available constantly. Fluctuation of work performance may be due to different learning rates, weather, knowledge of workers.

As mentioned, in the traditional techniques for performance measurement, work performance rate is assumed known throughout the duration of the activity, and cost distribution is mostly considered in the shape of an S-curve for engineering projects.

However, this assumption holds good when complete information about the activities such as resources required, constraints, methods are known before the activity starts. In reality, reliable information about the activities are normally very difficult to obtain and hence activity duration and costs have to be treated as random variables.

However, information about the requirements of work in terms of resources required, duration and cost required will be more reliable once the activity proceeds. This necessitates constant attention in determining percentage of work remaining and duration remaining throughout the duration of the activity. Lack of such performance information often leads to wrong or poor estimation and judgment of project performance risks. Any managerial decisions made on such grounds may mislead the project team and its results.

From the project management viewpoint, modeling the evolution of the project performance parameters is of paramount importance. In this section, such a dynamic model will be formulated, that can be used to analyze time and cost completion risks and assist the decision-making for mitigating these risks. The model requirements are stated as follows:

- A stochastic process for measuring performance risks continuously over the total project duration
- Periodic assessments of completion performance parameters such as time and cost at completion
- Integrating time and cost performance

4.2.1 Notation

The notations for parameters and variables used in the model are summarized next.

$j:$ index for activities, $j = 1, \cdots, M$, where M is the total number of activities of the PFI project

$z_{jt}:$ work performed at time t for activity j ($1 \geq z_{jt} \geq 0$)

$\Delta t:$ duration of a time period

$p_j(z_{jt}):$ work performance rate, a function of z_{jt}, for activity j at time t

$\sigma_j(z_{jt}):$ volatility of work rate for activity j at time t

$\epsilon_j:$ a standard normal random variable associated with activity j

$\tilde{T}:$ a random variable indicating the length of project completion period

$T_p:$ contract duration for project development, a fixed duration.

$T_d:$ duration indicating the actual length of project completion period.

$\hat{T}:$ long-stop or termination date for project development, a fixed duration.

$T_c:$ length of concession completion period ($T_c >> T_p$), a fixed duration.

$t:$ index for time ($t = 0, \ldots, \tilde{T}, \ldots, T_c$).

$\tilde{C}:$ a random variable indicating the total project cost.

$c_t:$ a random variable indicating the allocated project cost in time period t, which is shared by equity and debt on equal priority.

4.2.2 Time-at-completion $\tilde{T}(t)$ and cost-at-completion $\tilde{C}(t)$

Because of uncertainties in work performance and other reasons mentioned previously, the estimated project completion time $\tilde{T}$ and cost $\tilde{C}$ may be different from time to time during the project development phase. Therefore, both $\tilde{T}$ and $\tilde{C}$ are time-dependent.

Since a project is composed of many activities and the project completion time ($\tilde{T}$) is not determined by all but *critical* activities only, we first model the performance process at the activity level. Suppose that a project consists of M activities. Consider any arbitrary activity j ($j = 1, \ldots, M$).

Let z_{jt} be the stochastic work performance process of activity j. Conciser the following stochastic process of z_{jt}.

$$z_{j,t+\Delta t} = z_{jt} + (p_j(z_{jt}) + \sigma_j(z_{jt})\epsilon_j)\Delta t \tag{4.1}$$

where

z_{jt} : the state of work completed, takes value between 0 and 1 (=100%), with 0 representing that the activity has not been started, and 1 representing that the activity has been completed.

$p_j(z_{jt}) > 0$: planned worked performance rate, a function of z

$\sigma_j(z_{jt})$: volatility of work (performance) rate

ϵ : a standard normal random variable (process uncertainty)

Work performance rate

The work performance rate $p_j(z_{jt})$ can be defined as the time required to complete a unit amount of work. The work performance rate $p_j(z_{jt})$ is influenced by factors such as complexity of the activity, availability of resources and funds, technology, weather impacts. In addition, the learning process can substantially affect the work performance rate. Badiru (1995) provides a detailed overview of different work performance/production curves. Figure 4.1 provides typical work performance rates along with their description and examples.

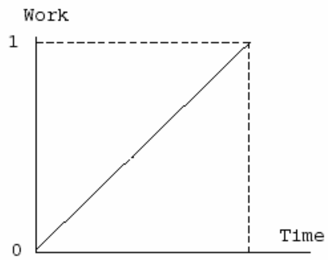
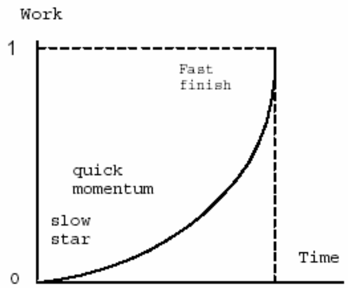
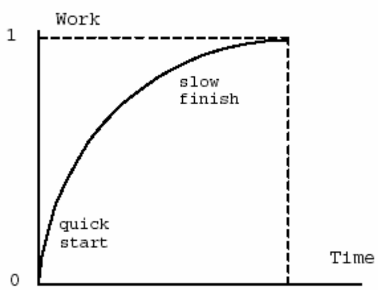
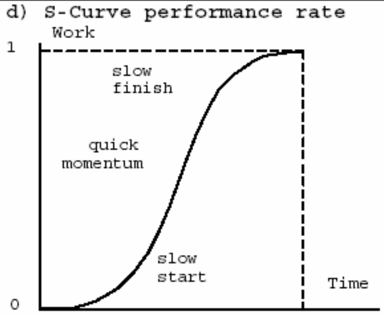
<table>
<tr><th>Work Performance Rate Functions</th><th>Description</th></tr>
<tr><td>a) Uniform or Linear Performance

</td><td>For activities of repetitive in nature, where same information holds good for all. Examples include:
Pipeline installations
Pavement construction</td></tr>
<tr><td>b) Convex performance rate

</td><td>For activities which requires more preparation work as a pre-requisite. However, the work by itself can be completed faster. Examples include:
Concrete Structures
Boring</td></tr>
<tr><td>c) Concave performance rate

</td><td>For activities which requires more testing and operation time to complete, but very less time for installation. Examples include
Equipment (pumps, filters) installation and testing</td></tr>
<tr><td>d) S-Curve performance rate

</td><td>For activities which requires combination of above types of activities. Examples include
Set of Activities
Whole project</td></tr>
</table>

Figure 4.1: Typical performance rate functions

The work performance evolution can follow different profiles, each of which is briefly discussed below.

1. Uniform or linear work performance rate: In this case, the work rate is considered uniform throughout the duration of the activity. This case is often used or implicitly assumed in CPM for calculating the project time. Figure 4.1a corresponds to a linear performance rate.

2. Log-linear work performance rate: In log-linear case, the increase or improvement in work-rate is considered constant. The slope of the logarithm of work rate is constant. The curve will be similar to curve in Figure 4.1a except on a log scale.

3. Convex work performance rate: In this case, the performance rate increases over time, with a slow start and quick momentum. The curve in Figure 4.1b can be referred to for this performance rate.

4. Concave work performance rate: In concave case, the work rate increase over time, with a quick start and slow momentum afterwards. The curve in Figure 4.1c refers to this case.

5. Standard S-Curve work rate: This is a combination of convex and concave curves, in which the work performance rate starts with a convex rate and ends up in concave rate. S-curves are considered often in construction projects to express the time and cumulative cost relationship on an overall project basis. The curve in Figure 4.1d depicts such a case.

6. Other types of curves includes toe-down curves, toe-up curves, leveling-off curves, etc.

Though many types of curves are available to express an activity work performance rate, the selection of any such curve depends on factors such as activity repetitions, effect of changes on work process, working conditions, worker efficiency. Based on these factors, different activities in the project might reveal different performance rates. Managerial decisions on allocating the resources in order to maintain an activity duration and cost is essential to prevent delays and cost overruns. Such allocations will also alter the work performance rate.

We represent the state of completion of work in an ascending order from 0 to 1, with 0 representing the activity that has not been started. When the work performed z_{jt} of the activity reaches 1, the activity is considered completed. The effect of uncertainty depends on the state of work completed. The uncertainty is high before the start of an activity and gets reduced to zero when the activity is completed. The uncertainty is captured by the volatility of the work rate $\sigma_j(z_{jt})$, which satisfies the following condition.

$$\sigma_j(z_{jt}) \to 0 \text{ as } z_{jt} \to 1 \tag{4.2}$$

Note that without $\sigma_j(z_{jt})$ (i.e., set to 0), (4.1) would simply be a difference equation, whose solution captures the evolution of work progress for activity j in the 'ideal' situation (as planned).

It is not uncommon to observe a fluctuation in the work performance rate $p_j(z_{jt})$. Since the work z is influenced by the performance rate $p_j(z_{jt})$, the work performed in any period can also vary from time to time and activity to activity. This uncertainty in the process can be handled by the standard normal variable ϵ_j. Since it is a standard normal distribution it can take both positive and negative values. But under normal circumstances, the work performed (Δz_t) cannot have negative values. This can be handled by employing a truncated normal distribution or setting a nonnegative lower bound to avoid this problem. However, occasionally the work preformance rate does decrease over time due to change of design or construction methods. Furthermore, ϵ_{j_1} and ϵ_{j_2} are mutually independent when $j_1 \neq j_2$.

Process for activity duration.

The duration (denoted by b_j) of an activity (j) can be defined as the first time that the work performed reaches 1, i.e.

$$b_j \equiv \min\{t \mid z_{jt} \geq 1\} \tag{4.3}$$

Equation (4.3) shows that activity j is considered completed when the corresponding work (z_{jt}) reaches 100% for the first time. Subsequently, at time b_j when the activity j is completed, its successor activities can start. At time t given $z_{jt} < 1$, b_j is also a random variable. The expected value of b_j may not have a closed form. However, numerical methods such as the Monte Carlo simulation can be used to determine the value. We assume that at each time t the decision maker will determine $E_t[b_j]$ for each activity j based on available information at time t, where E is the expectation operator and the subscript t indicated that the expectation is made at time t.

Note that the proposed model can be used to estimate activity duration not only before but also after the activity is started. At any time t while the activity is in progress, based on all available information, one can estimate the activity completion time $E_t[b_j]$ based on some projection method. The same process can be continued at different time periods to know the current status of an activity and an estimate of time-to-complete the activity, until the activity reaches its 100 % completion.

4.2.3 Process for project duration evolution

The proposed dynamic model for an activity can be extended to an entire project, which can be composed of several activities. Assuming that the work performance evolution for each activity j follows the relation similar to (4.1), at each time t, an activity is either 'yet to be started' or 'started'. As illustrated in the previous section, in either case an estimated duration for each activity j, i.e., $E_t[b_j]$, can be obtained. Once the work performance information of all activities is known, the expected Time-at-Completion $\tilde{T}$ for the entire project can be obtained using the CPM:

$$E_t[\tilde{T}] = \mathrm{CPM}(E_t[b_1], E_t[b_2], ..., E_t[b_M]), \tag{4.4}$$

where CPM is a module for the CPM that performs analysis of the critical path to determine the project duration, given all activity duration and project network.

Note that in (4.4) several assumptions are implicitly imposed: i) all activity durations are independent; ii) the critical path determined at time t remains critical after t until new information about the work performance is obtained and a new critical path is made. These two assumptions are also made in the PERT. Note that for simplicity, only activities with finish-to-start relationship is considered here. Other relationship between activities, such as start-to-start, finish-to-finish and start-to-finish, can also be easily incorporated into the model.

Figure 4.2 gives an illustration of the proposed method. Assume a constant work rate p_j, the 'ideal' case corresponds to a straight line, depicted by a bold line, with slope p_j. The ideal case corresponds to the estimation of activity duration by the traditional methods such as CPM and PERT. The planned activity duration is $1/p_j$, which is also the expectation at time 0, i.e., $E_0[b_j]$. Therefore, it can be observed that with the information available at time 0, the traditional methods and the dynamic performance measurement methods provide the same estimate for activity duration. However, the actual work performance seldom occurs in a simple straight line as in the ideal case. The actual work process is recorded and depicted by a curved / fluctuating line, which may not be smooth. The underlying reason for not having a smooth line for the actual performance is the uncertainties in the work performance rate and volatility. At time t, based on $z_j(t) < 1$, Figure 4.2 shows that the activity duration is expected to be $E_t[b_j]$.

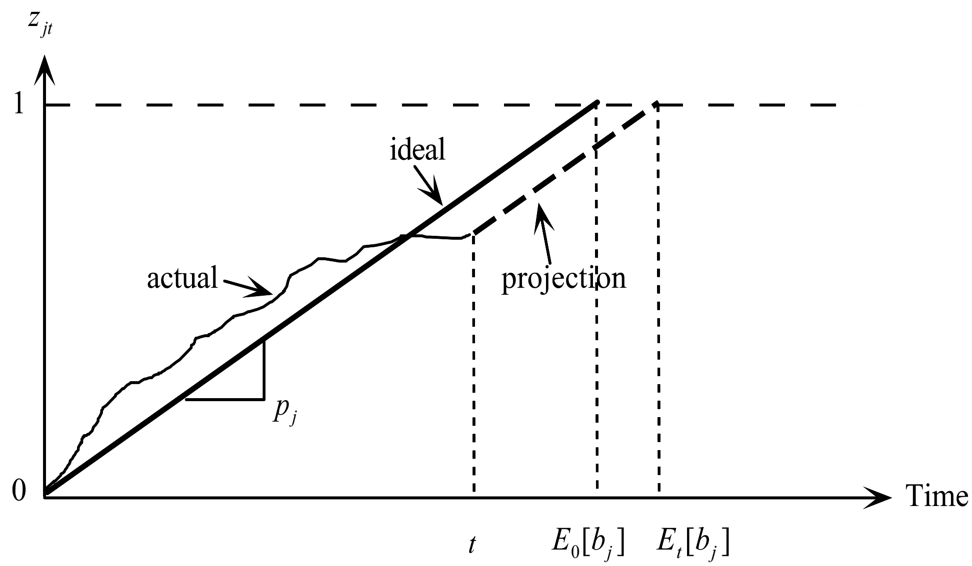


Figure 4.2: An example of activity duration evolution process at time t (assuming constant work rate p_j)

4.2.4 Process for project cost evolution

Assume the cost evolution for activity i follows the following relation:

$$C_{j,t+\Delta t} = C_{jt} + (q_j(z_{jt}) + \varsigma_j(z_{jt})\epsilon'_j)\Delta t, \tag{4.5}$$

where the cost performance rate $q_j(z_{jt})$ is defined as the cost required to complete a unit amount of work. Note that ς_j is the corresponding volatility and has a similar property as σ_j defined in (4.2), and ϵ'_j is a standard normal random variable.

In (4.5), C_{jt} represents the aggregate *inherent* cost up to time t. The inherent cost refers to the cost of resources, direct costs and indirect costs associated with the activity. The total inherent cost for activity j at completion can be projected by the following equation.

$$C_j^{\mathrm{I}} \equiv \{C_{jt} | t = b_j\} \tag{4.6}$$

Therefore, the total project inherent cost is the sum of all C^{I}_j. That is,

$$C^{\mathrm{I}} \equiv \sum_{j=1}^{J} C^{\mathrm{I}}_j \tag{4.7}$$

It should be noted that the inherent cost also includes a cost overrun component, if overrun does occur. This cost overrun can happen due to unprecedented increase in the labor and material costs, inflation and other costs, etc which are beyond the initial estimates and limits of contingencies. This cost overrun will increase the total project cost. As opposed to the inherent cost, a cost of delay occurs when the project is delayed, i.e., when the project duration $\tilde{T}$ is estimated to exceed the contract duration T_p.

$$C^{\mathrm{D}} = \max(\tilde{T} - T_p, 0)\Pi, \tag{4.8}$$

where Π is a constant that represents the financial impact due to the delay, damages and additional interest costs. Finally, at time t, the total project development cost $\tilde{C}$ is determined by

$$\tilde{C} = C^{\mathrm{I}} + C^{\mathrm{D}}, \tag{4.9}$$

and

$$E_t[\tilde{C}] = E_t[C^{\mathrm{I}}] + E_t[C^{\mathrm{D}}]. \tag{4.10}$$

The development cost includes estimates of development fees, project company costs, design, procurement and construction costs, insurance costs, inflation costs, start-up costs, working capital and other contingencies.

From the performance model results, the project completion time $\tilde{T}$ and project development cost $\tilde{C}$ are the time-at-completion and cost-at-completion performance risks, respectively.

4.2.5 Comparison with CPM and PERT models

In comparison with the CPM and PERT techniques, the proposed dynamic model has the following advantages:

- The proposed model explicitly considers the variations in work rate, whereas CPM and PERT do not consider the fluctuation and variability of work and cost performance rate within an activity.

- The proposed model reflects the changing conditions such as change in resources, change in weather through the work performance rate $p(z)$ and cost performance rate $q(z)$. However, CPM and PERT techniques assume that the resources are available throughout the duration at a certain rate, which is hardly true in reality.

- As discussed previously, the proposed dynamic model can provide and support the information required by the CPM and the PERT techniques. However, the converse is not true.

4.2.6 Interdependency of the uncertainties

There are well pronounced interdependencies existing among various uncertainties. For example, mandatory dependencies are common such as having technical feasibility studies completed before the start of detailed design. To model such an interdependency, a correlation can be imposed on the driving random variables, e.g., $\text{cov}(\epsilon_i, \epsilon_j)$ for activities i and j.

4.2.7 Merits of the proposed project performance model

This model is an improvement over the traditional PERT approach, in which the PERT considers the potential uncertainties only by three time probabilistic estimates. Further, these estimates are also depending upon the availability of historical information and human expertise. In addition, PERT assumes all activity duration to follow beta distribution, which is not true for all activities. The calculation to obtain activity duration is also from oversimplification of the actual beta distribution (Kerzner 2001). Any performance assessment based on this duration might not provide any reliable information for decision making. The proposed model does not have such inappropriate simplifications and, in addition, the activity duration is also modeled as an evolution process. The proposed performance model is advantageous over PERT, for the reason that the performance information of project duration and cost can be obtained at any desired time period. Along with the evolution of project duration, the total project cost $\tilde{C}$ can also be computed.

Such observations of current project performance at each time period can increase the managerial flexibility in decision making on performance improvement such as to maintain or reduce project duration and reduce cost overrun over the entire project development period. Such an active project performance decision model will be presented in Chapter 6.

Chapter 5

A Generic Model for Optimal Capital Structure

In this chapter, a generic model for dynamic capital structure based on the proposed project performance risk model is developed. This model obtains the information on project performance risks over the project development period and captures the value of flexibility in making capital structure decision. It is assumed that, keeping other factors aside, the capital structure can be adjusted at each time period based on the impact of project performance risk. A numerical example to verify the model is also presented.

5.1 Performance-Based Dynamic Capital Structure

With the introduction of major uncertainties, such as Time-at-Completion $\tilde{T}$ and Cost-at-Completion $\tilde{C}$ defined in Chapter 4, the Project Company must constantly assess the project value (or utility) and cope with uncertainties with all available managerial decision options.

5.1.1 Model assumptions and discussions

The model for the optimal capital structure is based on a non-recourse project finance with a long-term unsecured debt from the Lenders (banks) and equity from the project company sponsors (Nevitt *et al.* 1995). The following are the assumptions made specifically for this capital structure model.

Project company

(A 1) The Project Company is a special purpose vehicle (SPV), in which the infrastructure project (toll road, water / wastewater treatment plant, etc) is the only business. Therefore, the model considers project and business risks are the same.

(A 2) This model also assumes that the total capital is obtained only through local currency.

(A 3) This model assumes that there are no external supports available to the Project Company. In other words, all project risks are borne by the Project Company through appropriate debt and equity capital.

(A 4) This model assumes that there is a long-stop date ($\hat{T}$) or termination date for the Project Company. This long stop date is a time limit imposed by the host Government for termination of the project, if the project is delayed and the total duration exceeds this long-stop date.

Project risk sharing

(A 5) This model assumes that the Project Company and the Lenders have to participate in a global risk mitigation process instead of their individual risk exposure. The involvement of Lenders is required to determine the appropriate debt amount required for managing the performance risks.

(A 6) The Project Company's debt capacity is assumed as always less than one-hundred debt financing in the presence of bankruptcy. This assumption is in conjunction with the findings of the earlier researches (Dias 1995; Kim 1978), that in a perfect capital market, the debt capacity is always reached before the bankruptcy becomes certain.

(A 7) The model considers no distinction between default, bankruptcy and liquidation. This model assumes that the bankruptcy does occur on conditions other than force majeure, personal default of any sponsors, default of the host government, etc.

Debt, equity, taxes and cost of capital

(A 8) Based on current impact of the performance risks, the leverage ratio can be changed in each period. This model assumes that the decision for the leverage ratio made at each time period will also apply to future periods until the next period when a new leverage ratio is obtained.

(A 9) This model considers that the total capital is obtained only through debt and equity and assumes no mezzanine or sub-ordinate financing and no refinancing. The model also considers a minimum equity level, the Project Company should invest.

(A 10) A constant corporate tax and a fixed interest rate on long-term debt is assumed.

(A 11) The market risk premium is assumed through increasing the rates on equity and debt returns for higher equity and debt amounts. Also the model assumes no time lag between the capital structure decision and availability of the capital (debt and equity).

(A 12) The model determines the optimal capital structure primarily from the Project Company's point of view. But the project finance model is prepared, revised and structured by both the Lenders (banks) as well as the Project Company sponsors. Therefore, the amount of debt and equity drawings are consistent with the objectives of both the Lenders and sponsors. This model assumes no dividend will be given to the sponsors until the debt amount is repaid. This assumption is consistent with the fact that the debt is given priority to be repaid before equity dividends.

(A 13) The net revenue cash flow (equals EBIT) and a constant growth rate from the revenue obtained during the operations period are assumed to be known. However, the start of the operations period is yet uncertain. Since the capital structure will change over time, the corresponding discount rate WACC will also be different from period to period.

5.1.2 Notations

Two major uncertainties $\tilde{T}$, and $\tilde{C}$ representing the time-at-completion and cost-at-completion estimated at time t, have been defined in Chapter 4. Additional standard notation is defined as follows

W : weighted average cost of capital (WACC) or the discount rate.

k_e : cost of equity, i.e., required return on equity.

k_d : cost of debt, i.e., the interest cost.

k_a : rate of return on asset, a constant.

EQ : a random variable indicating the total amount of Equity required at time period t for project completion.

D : a random variable indicating the total amount of Debt required at time period t for project completion.

ϕ_t : cash flow at t obtained from revenues (in the operational period) after deducting the expenses (EBIT).

F : a random variable indicating the present value of revenues from the operation period net revenues at time t.

$V(t)$: project value at any time t.

BC : cost of bankruptcy, a constant.

5.2 Modeling Optimal Capital Structure

The objective of this model is to determine an optimal debt and equity structure based on impacts of the project performance risks at various time periods, in order to maximize the net present value of the project. Figure 5.1 shows a cash flow profile for the whole concession period.

It can be seen that the net revenues (ϕ_t) starts after the completion of the development phase T_d. The project development period has negative cash flows ($c(t)$) where the total capital is invested. The project cost c_t for each period will be shared only between debt d_t and equity e_t drawdown on equal priority, based on the capital structure in period t (A 9). Equal priority refers to drawdown of both equity and debt in each period with respect to the current capital structure.

$$c_t = e_t + d_t \tag{5.1}$$

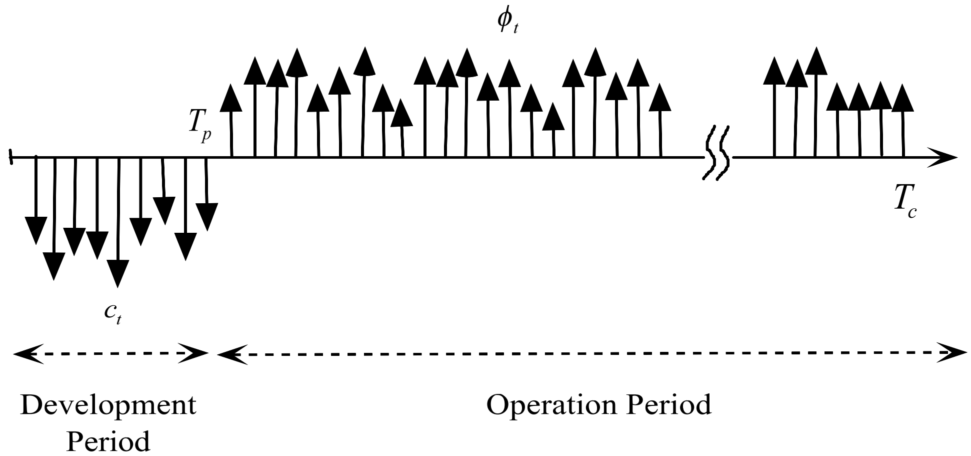


Figure 5.1: Typical cash flow profile for the concession period

It is assumed that there will be no revenues during the construction period and the accrued interest is capitalized at the end of construction period.

The leverage ratio ℓ_t in a period t is defined as the proportion of debt d_t in the total capital in time period t, which, according to (A 8), is also applied to all future time periods after t. Therefore, at time t, the debt amount d_i for any future time period is

$$d_i = \ell_t c_i, \ \forall i \geq t \tag{5.2}$$

In addition, an upper bound for ℓ_t is imposed,

$$\ell_t \leq \ell^{\max} < 1, \ \forall t, \tag{5.3}$$

which implies some minimum equity is necessary (A 9). The minimum equity constraint is imposed on the Project Company, so that it has the incentives to develop the project efficiently.

The total debt at any period $(t; t \leq \tilde{T})$ can be expressed as

$$D = \sum_{i=0}^{t} \ell_i c_i (1+k_d)^{t-i} + \sum_{i=t+1}^{\tilde{T}} \ell_t c_i (1+k_d)^{-(t-i)},\ \forall t \leq \tilde{T} \tag{5.4}$$

and

$$E_t[D] = \sum_{i=0}^{t} \ell_i c_i (1+k_d)^{t-i} + \ell_t \sum_{i=t+1}^{\infty} E_t[c_i](1+k_d)^{-(t-i)} \Pr\{\tilde{T} \geq i\} \tag{5.5}$$

The interest on debt during the construction period is capitalized with the interest cost $(1 + k_d)$. Similarly, the total equity, denoted by EQ, at any period t can be obtained from the difference of the total development cost $\tilde{C}$ and the debt D defined in (5.4) exclusive of the interest cost.

$$EQ = \tilde{C} - (\sum_{i=0}^{t} \ell_i c_i + \ell_t \sum_{i=t+1}^{\tilde{T}} c_i),\ \forall t \leq \tilde{T} \tag{5.6}$$

The net revenue ϕ_t from the operational period is assumed deterministic and known (A 13). However, the start of the operational period (or completion of the development period) $\tilde{T}$ is uncertain. This start date can occur before or after the contract duration (T_p). However, if the time overrun is very high, then the completion period can be extended only upto a long-stop or termination date (A 4). The project value can be obtained from the discounted value of the operational period cash flows (Ho 2002; Beidleman et al. 1990). The present value of the net revenues in the operational phase at time $\tilde{T}$, denoted by Φ, can be calculated as follows.

$$\Phi \equiv \sum_{i=\tilde{T}}^{T_c} \phi_i e^{-(W-\eta)(i-\tilde{T})} \tag{5.7}$$

where W is WACC and η is the growth rate of the cash flows in the operational period. Details for determining W will be discussed in a later section. Similarly, the present value of the cash flows from the operational period at any time period during the development phase $(t \leq \tilde{T})$ can be defined as

$$F = \Phi \cdot e^{-W(\tilde{T}-t)},\ 0 \leq t \leq \tilde{T}. \tag{5.8}$$

Modeling c_t

The project development period will have negative cash flows c_t, where the total capital is invested. The individual period development c_t is obtained generally through budgeting process. The budgeting process allocates the overall estimate to individual project periods. These costs c_t can have different profiles based upon the budgeting techniques. Examples of such profiles are S-curves, J-curves, etc. More details about these curves can be found in standard project management books. In this chapter, for simplicity, we have assumed a uniform profile of budget cost c_t, where the expected total amount $E_t[\tilde{C}]$ less what has been spent is allocated evenly to the remaining periods. To be more precise, at time t given c_1, $c_2 \cdots, c_t$, we assume that $c_{t+1}, \cdots, c_{\tilde{T}}$ are conditionally identical and independent random variables. Therefore, at time t

$$E_t[\sum_{i=t+1}^{\tilde{T}} c_i] = E_t[\tilde{C}] - \sum_{j=1}^{t} c_j. \tag{5.9}$$

Use Wald's equation, since $c_{t+1}, \cdots, c_{\tilde{T}}$ are identical and independent, (5.9) can be reduced to

$$(E_t[\tilde{T}] - t)E_t[c_i] = E_t[\tilde{C}] - \sum_{j=1}^{t} c_j. \tag{5.10}$$

That is,

$$E_t[c_i] = \frac{E_t[\tilde{C}] - \sum_{j=1}^{t} c_j}{(E_t[\tilde{T}] - t)},\ i = t+1, \cdots, \tilde{T}, \tag{5.11}$$

which can be used in evaluating $E_t[D]$ in (5.5). Under the same assumption, we also have

$$\begin{aligned} E_t[EQ] &= E_t[\tilde{C}] - \sum_{j=1}^{t} \ell_j c_j - \ell_t(E_t[\tilde{T}] - t)E_t[c_i],\ i = t+1, \cdots, \tilde{T}, & (5.12a) \\ &= (1 - \ell_t)E_t[\tilde{C}] + \sum_{j=1}^{t} (\ell_t - \ell_j)c_j, & (5.12b) \end{aligned}$$

where (5.12b) is obtained by plugging (5.11) to (5.12a). Similarly, $E_t[F]$ can be derived and evaluated.

Project valuation - conventional approach

In an imperfect market with taxes and bankruptcy costs, the project value of a levered firm V^L at time t can be obtained by the following relation

$$\text{Value of Project (levered) } V^L(t) = V^U(t) + V^\tau(t) - BC, \tag{5.13}$$

where V^U is present value of all-equity financed firm or unlevered firm, V^τ is present value of tax-shields, and BC is present value of financial distress (Belkaoui 1999).

Considering the conventional valuation approach for a levered Project Company, the taxable income should equal to the difference of the net revenue (ϕ_t) and the interest paid on debt in the operational period. Therefore, the interest on debt component of the levered Project Company increases the cash flow when compared to the all-equity financed firm (Beenhakker 1997). This increase in the net revenue is considered as the value of tax shield (V^τ) from debt.

In addition to the value of tax shields, the project value V^L is affected by the cost of bankruptcy. The bankruptcy condition at any time is

Generic bankruptcy condition Project value $V^L(t) <$ Total outstanding debt at t

The cost of bankruptcy is considered inclusive of the cost of financial distress (A 7). It includes the court fees, other administrative costs, etc. It should be noted that, in case of bankruptcy the project value is reduced by the cost of bankruptcy BC. The cost of bankruptcy is assumed to be a constant BC in this chapter.

In the conventional valuation approach, the project value increases with use of more debt until an optimum debt level is reached, where the value of tax shield exceeds the value of bankruptcy costs. Though higher debt amounts can produce improved cash flow for a levered firm through the value of tax shield, it may also create bankruptcy. The benefit of the tax shields and the risk of bankruptcy must be accounted to yield an optimal level of debt. That is, the balance between the value of tax shields and the cost of bankruptcy will determine the optimal ratio for the capital structure. The optimal capital structure is used as the target capital structure with a constant weighted average cost of capital W for the entire project development period.

Project valuation - dynamic approach

As discussed previously, the performance risks, time-at-completion $\tilde{T}$ and cost-at-completion $\tilde{C}$, can change from period to period depending upon the performance of that current period. These changes will affect the total project and capital cost and the start of the operations period. Therefore, the present value of the cash flows in the operational phase $F(\tilde{T})$, the total debt required D, total equity required EQ and cost of capital W vary from time to time. For example, an increase in the total project cost can increase the debt required at any time period. This increased debt requirement at time t can be fulfilled by obtaining more debt from the Lenders/Banks. When this debt level is very high, this additional debt required at time t can trigger a possible bankruptcy in the project development phase. This trigger can protect the Lenders from provision of any additional debt to the Project Company. In situation of bankruptcy, the Project Company will not be able to meet its debt repayment obligation (debt service).

Although the value of project (V^L) can be obtained by the conventional valuation method, it generally ignores the value of flexibility in managerial decisions in handling the impact of project performance risks. The conventional approach does not consider explicitly the impact of the project performance risks and the associated chances of bankruptcies. In addition, the evolution of the project value at any time period t ($t \leq \tilde{T}$) during the project development period depends on several factors such as the uncertainties in the total project cost, completion time, chance of bankruptcy, and debt and equity decisions chosen by the Project Company. The impact of these factors on the project value cannot be ascertained by conventional valuation methods. By not considering the potential bankruptcies due to the performance risks, the value obtained from the conventional valuation method can lead to erroneous results for a PFI Project Company. This chapter specifically considers the impact of the performance risks on project value and reduces the chances of bankruptcies.

The new valuation method developed in this chapter can be referred to as a project performance-based dynamic capital structure method. By explicitly considering impact of the performance risk on the project value, the Project Company would be able to maximize their value by making decisions on capital structure during the project development period.

This model considers the possibility of bankruptcy in the project development period (A 7). However, the condition for bankruptcy can be defined based on the information available at time t. The Project Company can be considered bankrupt at time t, when the present value of project net cash flows is less than the outstanding debt D (Ho 2002). Therefore, the condition for bankruptcy stated in (5.14) can be expressed as

Bankruptcy condition at time t

$$E_t[F] < E_t[D], \quad t \leq \tilde{T} \tag{5.14}$$

The managerial decision alternatives available in conditions of possible bankruptcy are either to declare bankruptcy or to continue the project by adjusting the capital structure. If the decision is to declare bankruptcy, the equity value will be zero and the

Project Company has no return from the project (A 3). Alternatively, the adjustment of capital structure can be made possible through different debt requirements at each time period. The managerial decision depends on the alternative which maximizes the project value at time t. As assumed in (A 5), the Bank and the Project Company both would be willing to participate in risk mitigation process by adjusting the capital structure in order to maximize the project value.

The project value at any time t, denoted by $V(t)$, during the development phase $(0 < t \leq \tilde{T})$ can be obtained by solving the following stochastic program, denoted by (P_1).

$$(P_1) \qquad V(t;\ell_{t-1}) = -c_t + \max_{\ell_t}\{u_t E_t[V(t+1;\ell_t)e^{-W(\ell_t)}] - (1-u_t)BC\} \tag{5.15}$$

where u_t is a binary variable indicating whether bankruptcy occurs at time t or not.

$$u_t = \begin{cases} 1, & \text{if the bankruptcy condition (5.14) holds} \\ 0, & \text{otherwise} \end{cases} \tag{5.16}$$

Note that the project value $V(t)$ apparently, in this dynamic setting, also depends on the debt level ℓ_{t-1}, made previously. Therefore, in (5.15) ℓ_{t-1} is added as a parameter, separated from the variable t. In the sequal, when the focus is not on the debt level but the value itself, we will simply use the notation $V(t)$. It should also be noted that, in comparison with the conventional model, the project value $V(t)$ includes the value of the tax shields. In other words, $V(t)$ is composed of both the values of an unlevered firm and the tax shields.

The maximization of project value V depends on the impact of performance risks ($\tilde{T}$ and $\tilde{C}$) and the decision of capital structure ℓ_t to be made in time period t. By dynamically adjusting the capital structure at each period based on the impact of the performance risk, the project value can be maximized by choosing an appropriate leverage ratio. The boundary condition is set such that the value of the project $V(\tilde{T})$

be equal to the present value of the net revenue from the operational phase of the project exactly at the start of the operational phase $\tilde{T}$. That is,

$$V(\tilde{T}) = \Phi, \tag{5.17}$$

where Φ is defined in (5.7). The value of project at time 0, $V(0)$, is the NPV of the project.

$$V(0) = -c_0 + \max_{\ell_0}\{u_t E_t[V(1;\ell_0)e^{-W(\ell_0)}] - (1-u_t)BC\} \tag{5.18}$$

Solving the above optimization will give an optimal leverage ratio ℓ_0^* at time $t = 0$, which maximizes the project value. The above formulation takes account both the intrinsic and flexibility value of the project at each time period in the development phase. The flexibility value of the project can be observed as the difference in value between this dynamic capital structure valuation ($V(0;\ell_0)$) approach and the conventional target capital structure (V^L) approache.

$$\text{Flexibility value of the dynamic capital structure} = V(0;\ell_0^*) - V^L(0) \tag{5.19}$$

This flexibility value is attributed to the assumption that the capital structure can be adjusted over time. Note that the value of the tax shield corresponding to the optimal capital structure ratio can be calculated as

$$V^\tau(0) = V(0;\ell_0^*) - V^U(0) \tag{5.20}$$

WACC, cost of equity and debt

The WACC W is the discount rate or cost of capital expressed as the proportion of values of debt and equity to the project (Copeland 1988). As explained previously, the optimal capital structure is determined by the proportion of debt and equity that maximizes the value of the firm or minimizes the WACC (W)(Copeland 1988; Myers 1999). For sake of simplicity, we use the book value for debt and equity to calculate the discount rate. The weighted average cost of capital WACC (W) is given by the following relation

$$W = k_e \frac{E_t[EQ]}{E_t[EQ] + E_t[D]} + k_d(1-\tau)\frac{E_t[D]}{E_t[EQ] + E_t[D]} \tag{5.21}$$

It should be noted that the debt $E_t[D]$ is a function of the leverage ratio (ℓ_t). In general, to maximize the NPV of the project value is equivalent to minimizing the WACC (W). The WACC (W) depends on the decision on proportion of debt (ℓ_t) in the capital structure. The higher use of the debt proportion can lead to bankruptcy. The trade-off between the tax advantages on higher use of debt proportion and the cost of bankruptcy determines the minimum WACC. Considering the Project Company's debt capacity is always less than 100% debt financing in the presence of bankruptcy (A 6) and also constrained by (5.3). Upon observing the impact of performance uncertainties, the decision of debt proportion is made by increasing the leverage ratio (ℓ_t) until it reaches the point where either the condition of bankruptcy is imposed (5.14) or the minimum equity constraint is reached (5.3). Therefore, the decision of the leverage ratio (ℓ_t) is constrained by both (5.3) and the bankruptcy condition, whichever occurs earlier. It should be noted that the WACC, $W(\ell_t)$, is also time-dependent and may not be monotone. In fact, based on our observation, $W(\ell_t)$ behaves like a convex function with an interior minimum point.

The cost of debt (k_d) is the return expected (expected interest rate) by the Lenders (banks) for the debt financed. The interest rate for the long-term loan is assumed fixed. Though there are several methods (CAPM, OPM, etc) to calculate the cost of debt, for sake of simplicity, this chapter assumes that the cost of debt is an increasing function of debt. A parameter λ is used to represent the market risk premium for higher debt requirements (A 11). The minimum rate of interest is assumed as $k_d^{\min}$, which is consistent with interest rates of project finance loan transactions.

$$k_d = \max(\ell_t \lambda, k_d^{\min}) \tag{5.22}$$

Similarly, the Cost of Equity (k_e) is the rate of return expected by the equity providers (Project Company Sponsors) for the equity financed. In this chapter, a constant tax rate is assumed for the debt amount (A 10). This chapter considers imperfect markets, with corporate taxes (τ) as the imperfection, and accordingly the cost of equity is calculated by the following relation

$$k_e = k_a + \frac{E_t[D]}{E_t[EQ]}(k_a - k_d)(1 - \tau) \tag{5.23}$$

where k_a is the rate of return on asset. The rate of return on asset k_a is assumed to be a constant. From (5.22) and (5.23), it can be seen that, without the taxes, the value of W remains unchanged for all debt proportions.

Procedures for solving (P_1)

Solving the optimal dynamic capital structure problem defined in (P_1) is not trivial. It is a difficult multi-stage stochastic program. The inherent challenging task is that it has a boundary condition (5.17) where the boundary ($\tilde{T}$) is uncertain. Although in theory one can apply existing numerical methods for valuing path-dependent American options such as the least squares Monte Carlo method (Longstaff and Schwartz 2001), validating these methods is equally challenging. In this chapter, we propose a simulation-based heuristic approach, which is sensible. Although the obtained project value is suboptimal, it provides a reliable lower bound.

To describe the basic idea of our heuristic method, first consider a deterministic special case at time $t = 0$ (assuming all project costs and duration are known for certain).

The NPV of the project value V_0 is a function of the choice of the debt level ℓ_0.

$$V_0(\ell_0) = \sum_{i=0}^{\tilde{T}} -c_i e^{-W(\ell_0)} + \sum_{i=\tilde{T}+1}^{T_c} \phi_i e^{-(W(\ell_0)-\eta)(i-T_d)} \tag{5.24}$$

Since all cash flows (ϕ_i) are independent of ℓ_0, apparently maximizing V_0 is equivalent to minimizing $W(\ell_0)$. Motivated by this fact, we develop a heuristic method based on the Monte Carlo simulation. The simulation approach mimics real-time decision making. At each time period, the Project Company updates the information of project status, including evaluating $E_t[\tilde{T}]$ and $E_t[\tilde{C}]$, and then minimizes $W(\ell_t)$ to determine the optimal debt level. If with this optimal debt level and its corresponding expected net revenue, the Project Company cannot afford the expected debt, bankruptcy is declared. The detailed algorithm is presented next. In the algorithm, the variable n denotes the index for the simulation and N denotes the maximum number of simulation runs set for the algorithm.

Simulation Algorithm 5.1

Data: The maximal number of simulation runs $N > 0$ is given; The long-stop date $\hat{T}$ is also given.

Step 0: Set $n \leftarrow 0$, $t \leftarrow 0$.

Step 1: If $n > N$, go to Step 7. Otherwise, set $V^{(n)} \leftarrow 0$.

Step 2: If the project is completed, set the project duration $T_d \leftarrow t$ and go to Step 5. Otherwise, update the work progress for each activity using (4.1) and (4.5). Then, determine $E_t[\tilde{T}]$ and $E_t[\tilde{C}]$ for the project.

Step 3: Solve $\min\{W(\ell_t)|\ell_t \leq \ell^{\max}\}$ to determine the debt proportion at time t. Let the optimal solution to be ℓ_t^*. If $E_t[D(\ell_t^*)] > E_t[F(\ell_t^*)]$, bankruptcy is declared, set $T_d \leftarrow t$ and go to Step 5.

Step 4: $t \leftarrow t + 1$, go to Step 2.

Step 5: Calculate the NPV of the project value $V^{(n)}$: if there was no bankruptcy,

$$V^{(n)} = \sum_{i=1}^{T_d} -c_i e^{-W(\ell_i^*)i} + \sum_{i=T_d}^{T_c} \phi(i) e^{-(W(\ell_i^*)-\eta)(i-T_d)}; \tag{5.25a}$$

if there occurs a bankruptcy at any time t, then the value is reduced only to the actual costs incurred upto time t.

$$V^{(n)} = \sum_{i=1}^{t} -c_i e^{-W(\ell_i^*)i} \tag{5.25b}$$

Step 6: $n \leftarrow n+1$ and go to Step 1.

Step 7: NPV $= \frac{1}{N}\sum_{n=1}^{N} V^{(n)}$

The NPV of the project can be obtained from Step 7. This algorithm simulates the project value forward in time during the project development phase. At each time t, the Project Company makes decision on the optimal leverage ratio ℓ_t, that maximizes the project value $V(t+1;\ell_t)$ for the next period. The project cost is deducted from the project value at each time period. The process continues until the project reached its completion ($\tilde{T}$). As explained previously, at each time period, based on the performance uncertainties $\tilde{T}$ and $\tilde{C}$, the Project Company can maximize the project value by dynamically adjusting the leverage ratio in the total capital.

5.3 Numerical Results

This section provides an illustrative example to determine the optimal capital structure for a PFI project. The proposed method has been applied to a PFI project. The advantages of this model against a conventional capital structure model are explained through the model results.

Table 5.1: Project specific data

Total Estimated Project Cost (C_p)	\$400M
Total Estimated Project Duration (T_p)	4 Years
Length of Concession (T_c)	30 Years
Liquidated Damages Imposed (ω)	\$50,000 per Month
Long-stop / Termination date ($\hat{T}$)	6 Years
Loss of Revenue (Cash flow) Π	\$50000 per Month
Projected Cash flow at Year 5 (ϕ)	\$60M
Cash flow Growth (η)	5%

Project overview

Universal Water Inc. is a special purpose vehicle (SPV) Project Company created by a combination of three different sponsoring companies. The Project Company is to undertake the financing, building and operating a Wastewater Treatment Plant under the concession agreement for 30 years from the local government.

The Project Company obtains revenue from the operation period (up to 30 years) to repay the debt and provide an equity return to the sponsors. On completion of the concession period (30 years) the facility has to be returned to the host government. The Project's financial viability studies provide a cash flow stream from year five (5) and at a growth rate (η) of 5% for rest of the years up to the end of the concession period. The project specific details are the initial estimates made as given in Table 5.1.

The government authority can impose a liquidated damage of \$50,000 per month for the overrun period, if the Project Company fails to complete the project within 4 years. In addition, the government authority has also set a long-stop/termination date of 6 years. The Project Company also incurs loss of revenue, if it could not complete the project within 4 years.

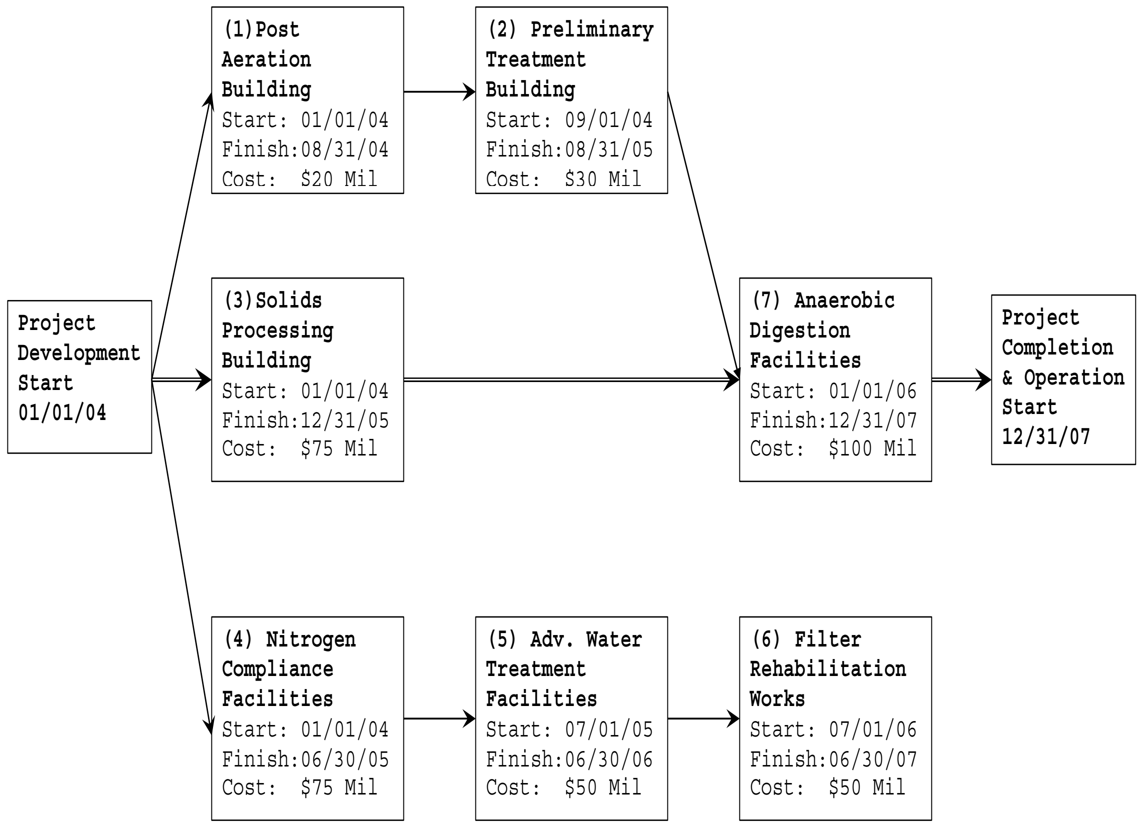


Figure 5.2: Project network diagram (double line shows the critical path)

The Project Company observes that there is a high uncertainty in completing the project construction within the budgeted cost and planned duration. From the simulation result of the proposed performance model, the mean values of time-at-completion and cost-at-completion are observed to be 58 months and \$463M, indicating serious time and cost overruns. The Project Company has decided to use non-recourse project financing modality for financing the project. A development bank (Infra Bank Ltd) has agreed to finance the debt portion of the project based on the project's financial viability.

The Project Company and the Lender has to prepare and review the financial model for the project to determine the capital structure. The Project Company and the Lenders believes that a conventional (target) capital structure models would provide incorrect results due to the expectations of high uncertainties in project performance. Therefore, the Project Company and Lenders agrees to develop to a dynamic capital structure model to incorporate the project and market specific uncertainties. In this dynamic model, the capital structure is decided based upon the current impacts of project performance risks.

The Project Company sponsors are imposed with an additional constraint for a minimum equity of \$40M for the project. The total debt at time period t can be obtained from (5.4). The mean value of the total debt is obtained as \$408M. Similarly the mean value of the total equity is obtained as \$55M, which satisfies the minimum equity constraint. It is identified that the target capital structure approach uses a debt amount of only \$393M and a higher equity amount of \$70M for the same conditions of project. This debt amount does not include the interest accumulated during the project development period. In the dynamic model, the total debt amount at any time t is divided into two components such as the actual debt based on past debt amounts and projected future debt requirements upto the end of project development period. Hence, for an increase in the leverage ratio at any time t, the amount of debt will be higher in the dynamic capital structure method. This is consistent with the definition of k_d (5.22). It can be identified that k_d increases with respect to the leverage ratio only beyond $k_d^{\min}$.

The cost of debt (k_d) and cost of equity (k_e) are the returns expected by the Lenders / Banks and the Project Company Sponsors respectively for their debt and equity investments. The cost of debt (k_d) is given by the relation $\max(\ell_t\lambda, 8\%)$, in which λ is a constant having a value of 13.5. The product $\ell_t\lambda$ represents the equivalent market risk premium. The value of λ is chosen such that the cost of debt (k_d) is close to the rate in reality. The cost of equity (k_e) is given by (5.23). The rate of return on asset (k_a) is assumed to be a constant (14%). The WACC w can be obtained for each time period using (5.21) based on the current leverage ratio, cost of debt and equity. It can be shown that, without the taxes, the cost of capital (W) remains constant for all leverage ratios.

From the known cash flow stream and the growth rate in the operational period, the present value of net revenues at the start of operational period can be obtained by (5.7). Similarly, the value (F) of cash flows at any time during construction period can be obtained by discounting using weighted average cost of capital W using (5.8). The condition of bankruptcy is defined in (5.16). This condition acts as a trigger representing the potential bankruptcy, if the current leverage ratio continue to exist for rest of the development period. In such condition, the Project Company can either declare bankruptcy or adjust the capital structure to avoid the potential bankruptcy. The cost of bankruptcy is assumed to a constant ($40M). The project value (V_t) during construction period can be obtained from (5.15). This recursive equation considers different leverage ratios at each period in order to maximize the value of project.

A sensitivity analysis has been done to identify the changes in NPV. The constraint on minimum equity has a significant impact on the capital structure and the project value. Figure 5.3 shows the difference in project values between the target and dynamic capital structure approach. It can be seen that, with the increase the minimum equity requirement, the advantage of using flexible capital structure reduces. The higher the minimum equity is imposed, the lesser the flexibility is to choose high debt amount and leverage ratios (ℓ_t). This would result in a higher cost of capital and lower project value. It can be seen from Figure 5.3 that the project value decreases as the minimum equity value increases. In particular, the value from dynamic capital structure at one point becomes equal to the target capital structure, as there will be limited flexibility in dynamically adjusting the capital structure.

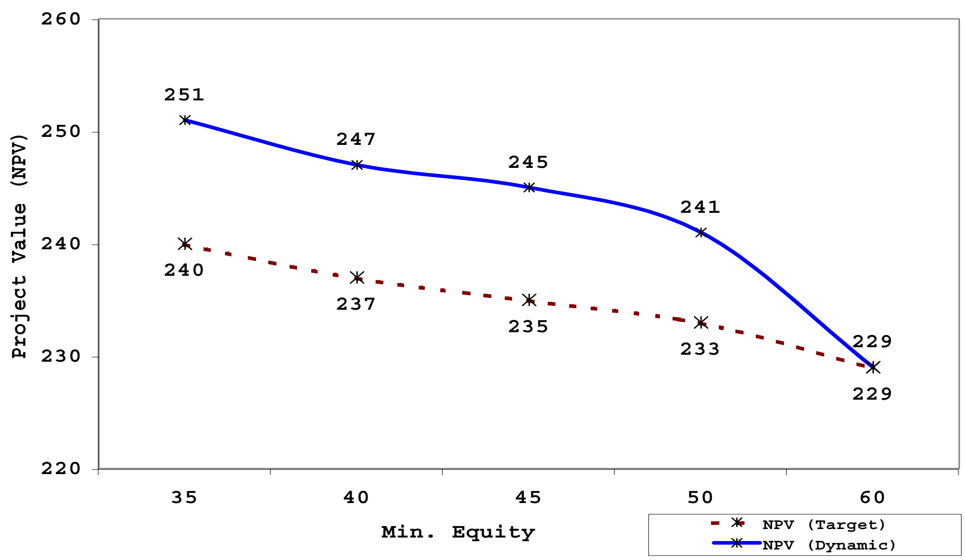


Figure 5.3: Effect of minimum equity constraint on NPV

Considering different corporate taxes, the changes in the NPV is illustrated in Figure 5.4. The NPV from the dynamic capital structure approach provides an increase in value for different tax rates. In this approach, the WACC (W) gets reduced for incremental increase in the tax rate. The performance based capital structure approach captures this tax benefits to increase the project value. However, it can be seen from the figure that lower values of tax rates, the flexibility of adjusting capital structure reduces due to lesser advantages of tax benefits. The debt repayment period has a significant contribution to the NPV, as the present value of interests and value of tax shields are affected by this. The higher the debt repayment period is, the higher the interest costs will be. But the principal return will be lowered. As the model considers leveled annuity repayment, increase in the debt return period can increase the present value from the net cash flows and in turn can reduce the chances of potential bankruptcy occurrences for the same debt level. Figure 5.5 illustrates the

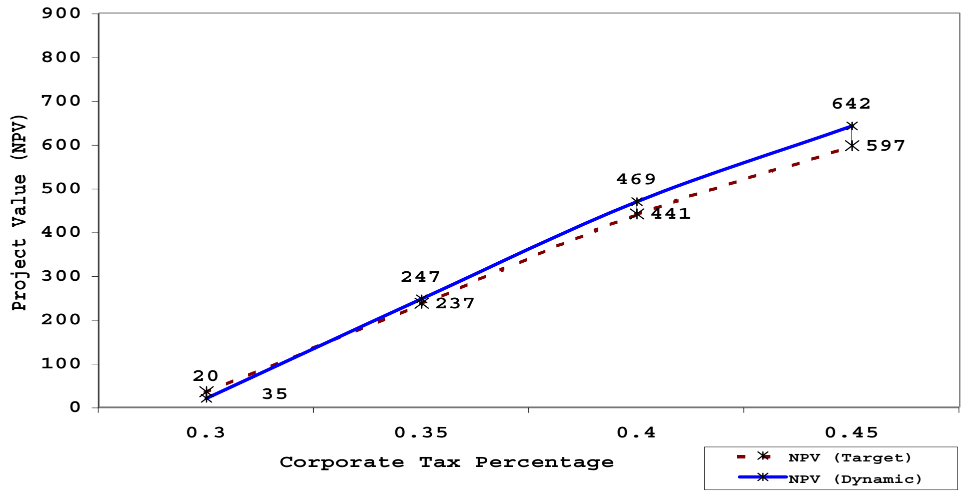


Figure 5.4: Effect of corporate taxes on NPV

effect of debt repayment period on NPV.

The effect of long-stop or termination date is illustrated in the Figure 5.6. As discussed previously, that if the delay in completion continues beyond the long-stop or termination date, the Government has the authority to terminate the project. In this example, termination date is set as 6 years and the contract duration is set as 4 years. It can be noticed that the Project Company can continue the project with loss of revenues and penalties upto this period and can still obtain an NPV. However, once the termination date is reached, the Project Company will get zero value from the project. It can be noticed from the following figure that, once the long-stop duration gets reduced, the NPV also gets reduced. This impact is of high significance, when the uncertainties in project completion are very high. .

From the numerical result, it can be seen that the NPV of the project using a fixed or target capital structure with a leverage ratio 0.82 is \$237.74M. But with such target capital structure, the average number of the iterations that encounter bankruptcy in the simulation is 2 times as high as in the dynamic case. However, by using the dynamic capital structure method, the model gives an NPV of \$246.67M

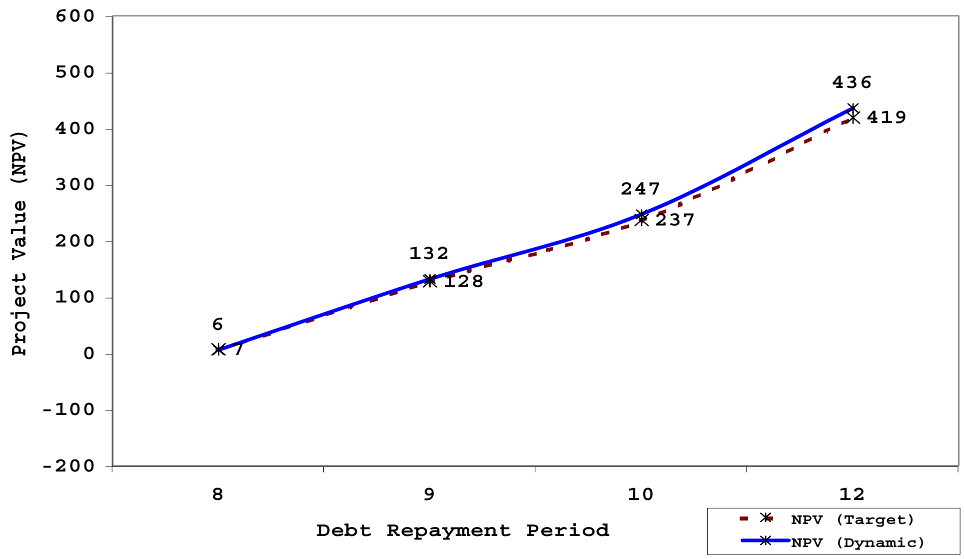


Figure 5.5: Effect of debt repayment period on NPV

with a mean leverage ratio of 0.8531. As stated previously, by adjusting the structure to maximize the project value at every time period, the Project Company could obtain more debt than the target capital structure approach. The average number of potential occurrences of bankruptcies has been found same as the target capital structure approach. However, the adjustments made in the leverage ratios according to the performance uncertainties in each period has improved the project value.

Overall, the performance-based capital structure model reveals a higher project value (NPV) of 4.05% over the target capital structure model. This value addition or increase can be considered as the value of flexibility in adjusting the capital structure based on the current impacts of project performance risks. This model also helps trigger a potential bankruptcy possibility to the Project Company, which in turn can make decisions on changing the capital structure. The lenders (banks) would also be aware of such bankruptcy possibility and can adjust the debt amount at any time period.

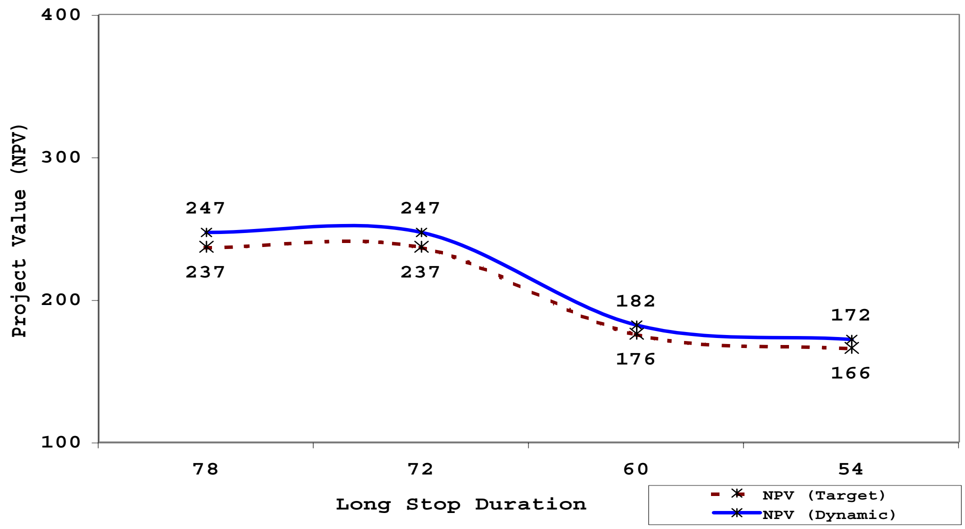


Figure 5.6: Effect of length of termination period on NPV

5.4 Conclusion

This model provides a quantitative framework for determining the optimal capital structure, which is of importance for both the Lenders as well as the Project Company. Another key contribution of this chapter is that the model also triggers the potential bankruptcy possibility so that the Project Company can make optimal decisions at every time period to continue or declare default. The numerical results prove the validity of the model and the value addition over and above the target capital structure models. However, this model does not consider the uncertainties of the cash flows in the operational period, which will be considered in future research.

Chapter 6

Optimal Capital Structure Model with Active Project Performance Management

In this chapter, the significance of active (or dynamic) project management and its effect on optimal capital structure will be discussed. In Chapter 4, a model that determines the project performance measurements at any time within the project development period has been developed. The impact of project performance uncertainties on the project value was identified and modeled. This chapter will further show how performance uncertainties can be mitigated through active project management. An active project performance management model, that can control the project performance will be introduced. By improving the project performance, the project value can be improved. Additional values obtained through such active management also include enhancement of feasibility of financial decisions such as the capital structure.

As discussed in Chapter 2, the project specific risks are managed primarily by the Project Company. Consistent with the principle of sharing and allocation of risks, the management of performance risks over the project development period can be undertaken by the Project Company. The performance risks can be managed either by the Project Company through self-support or support from the Government. With the use of the self-support, the project resultant equity value $(V - D)$ will be owned by the Project Company, where V and D are the project value and the debt value, respectively, as defined in Chapter 5. The self-support case will be discussed in detail in this chapter, whereas, the use of government support will be presented in Chapter 7.

6.1 Project Time-Cost Tradeoff Decisions

Kerzner (2001) explains the importance of project performance trade-off as an active project management exercise throughout the project development period. The well-known "time-cost-quality triangle" is a concept in project management wherein the time, cost and quality are interrelated and any decision made on improving or maintaining any one parameter can have a pronounced effect on others. Hence, the project management decision-model must follow a systems approach. In the following section, we will introduce to a decision process called *dynamic crashing*, which will be used to expedite project progress and mitigate some project risks. For simplicity, the proposed model does not consider the quality issue and will be confined to the other two performance uncertainties, completion time and cost.

Crashing is a project management concept, in which trade-off decisions between reducing project duration and its cost impact are analyzed. The decision maker considers among alternatives that can provide the maximum amount of time reduction or compression for the least incremental cost (PMBOK 2000). Often, several feasible alternatives are executed exogenously.

The parameters used in project crashing include *normal duration*, *normal cost*, *crash duration*, and *crash costs*. The normal duration and normal cost represents the scheduled time and estimated cost under normal (without crashing) conditions. These are often the original or initial planning results. Crash duration and crash costs are the feasible set of options under which normal duration can be reduced with additional costs. The determination of choosing the activity to be crashed in the critical path can be based on the crash ratios of individual activities. The crash ratio is defined as

$$\text{crash ratio} = \frac{(\text{crash cost} - \text{normal cost})}{(\text{normal duration} - \text{crash duration})} \tag{6.1}$$

Crash ratio can also be referred to as the slope of crashing in a figure that depicts crash cost and crash duration relation, e.g., Figure 6.1. The activity which has the least crashing ratio (or slope) and is critical can be chosen first for performing the crashing. Subsequently, other critical activities are chosen in the order of increasing crash slopes. This process is continued until all feasible crash options for duration reduction have been completed. In addition, an upper limit to the additional cost can be set such that the crashing operation could be performed only upto this limit. Figure 6.1 represents a typical crashing profile, where the horizontal axis shows the crashing duration and the vertical axis represents their associated crashing costs.

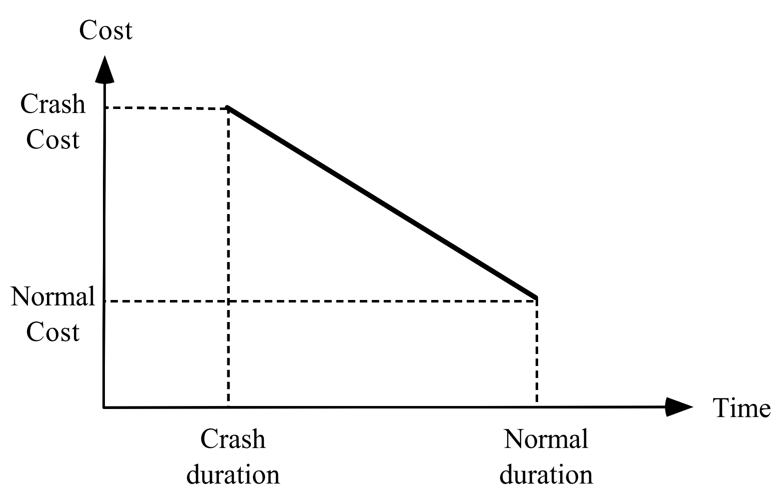


Figure 6.1: Typical time-cost tradeoff profile for an activity

However, the information required for crashing such as normal and crash duration and costs are generally obtained from the conventional CPM and PERT models. The limitations of these techniques, discussed in Chapter 4, often provide inaccurate estimation of time and cost options for crashing. To highlight, the deficiencies of conventional crashing are briefed below:

- The decision of choosing a crashing option is independent of the overall project value. The optimality in time-cost tradeoff is considered only within the purview of critical path duration and project cost. Hence, the optimal crashing decision made for performance improvement need not lead to an optimal capital structure.

- The dynamics of performance risk variables cannot be handled by the conventional crashing mechanism. In addition by improving the project performance through conventional crashing, the possibility of preventing potential bankruptcies (project performance induced bankruptcies) is not clearly defined.

- Lack of efficient mechanism to capture the dynamics of performance risk variables, the use of conventional crashing process might provide erroneous results in project valuation and capital structure decisions.

The stochastic performance measurement model from Chapter 4 captures the dynamics of project performance variables at any time period. Therefore, the same stochastic model can be further extended to accommodate dynamic crashing operations.

6.2 Dynamic Activity Crashing

Dynamic project crashing can be referred to as the operation of project crashing using stochastic performance measurements. Recall the uncertainty models for work evolution z_{jt} in (4.1) and cost evolution C_{jt} in (4.5) for activity j, which are repeated below.

$$\frac{z_{j,t+\Delta t} - z_{jt}}{\Delta t} = p_j(z_{jt}) + \sigma_j(z_{jt})\epsilon_j \tag{6.2}$$

and

$$\frac{C_{j,t+\Delta t} - C_{jt}}{\Delta t} = q_j(z_{jt}) + \varsigma_j(z_{jt})\epsilon'_j. \tag{6.3}$$

Crashing decisions will increase the project cost by employing additional resources. These additional resources required for crashing will change the work performance rate (p_j) and cost performance rate (q_j). Subsequently, the total project duration ($\tilde{T}$) will be changed if the activity crashing is performed properly, so will the total project cost ($\tilde{C}$). Since the project performance uncertainties ($\tilde{T}$ and $\tilde{C}$) are time-dependant, the crashing operation is also time-dependant. Therefore, it is essential to capture the dynamics of the performance uncertainties for making optimal crashing decisions.

Consider an activity j at time t, define a crash option m ($m = 1, \cdots, M$) available to j at the time as a vector θ^m_{jt}:

$$\theta^m_{jt} \equiv [p^m_{jt}(\cdot), \sigma^m_{jt}(\cdot), q^m_{jt}(\cdot), \varsigma^m_{jt}(\cdot)],\ m = 1, \cdots, M, \tag{6.4}$$

where $(p^m_{jt}, \sigma^m_{jt})$ are the new work performance rate and volatility if the crash option m is adopted at time t. Similarly, $(q^m_{jt}, \varsigma^m_{jt})$ applies to the cost performance rate model. Note that the crash costs have been embedded in $(q^m_{jt}, \varsigma^m_{jt})$ and are not shown explicitly.

Upon observing a potential delay in the project duration at time t, the Project Company can make a crashing decision to expedite the project, which, as will be shown later, may have a significant impact on the value of a PFI project and may reduce the possibility of bankruptcy. Consistent with the conventional crashing model, this model assumes that these options are exogenously determined and are made available to the project team.

Figure 6.2 depicts two available crash options, denoted by (i) and (ii), and their impacts on time and cost. At time 0, it is assumed that both the time performance rate p_j and the cost performance rate q_j are constant. Therefore, the ideal evolution of z_j and the evolution of cost (versus z_j) are all linear. At time t with $z_{jt} = A$, the activity apparently has a time overrun and a cost overrun concerning expected time-at-completion $E_t[b_j]$ and (inherent) cost-at-completion $E_t[C_j^{\mathrm{I}}]$. Crash Option (i) is more effective than Option (ii) in terms of time improvement, but is much more expensive. From Figure 6.2, it can be seen that both crash options (m=(i) and (ii)) have a bigger p_j^m and a smaller p_j^m/q_j^m than p_j and p_j/q_j, respectively.

For duration crashing, additional resources or new technology may be employed, that will increase the work performance rate p_j. However, the volatility σ_j may not necessarily increase. Intuitively, if more resources are employed, σ_j may increase; but if a newer and safer technology is used, σ_j may even decrease. Note that the model developed here only considers activities with finish-to-start relationships. Similar to the work performance rate modification, the cost performance parameters (q_j, ς_j) will also be modified when crashing takes place.

6.3 Capital Structure using Dynamic Project Crashing

As mentioned previously, efficiently crashing the critical activities may reduce the project duration. Although crashing incurs additional costs, in this section, it can be shown that it may increase the value of a PFI project. In this section, the focus will now be shifted to the project level (instead of the activity level, recognizing that crashing decisions are made at the activity level.) Consider at time t, the Project

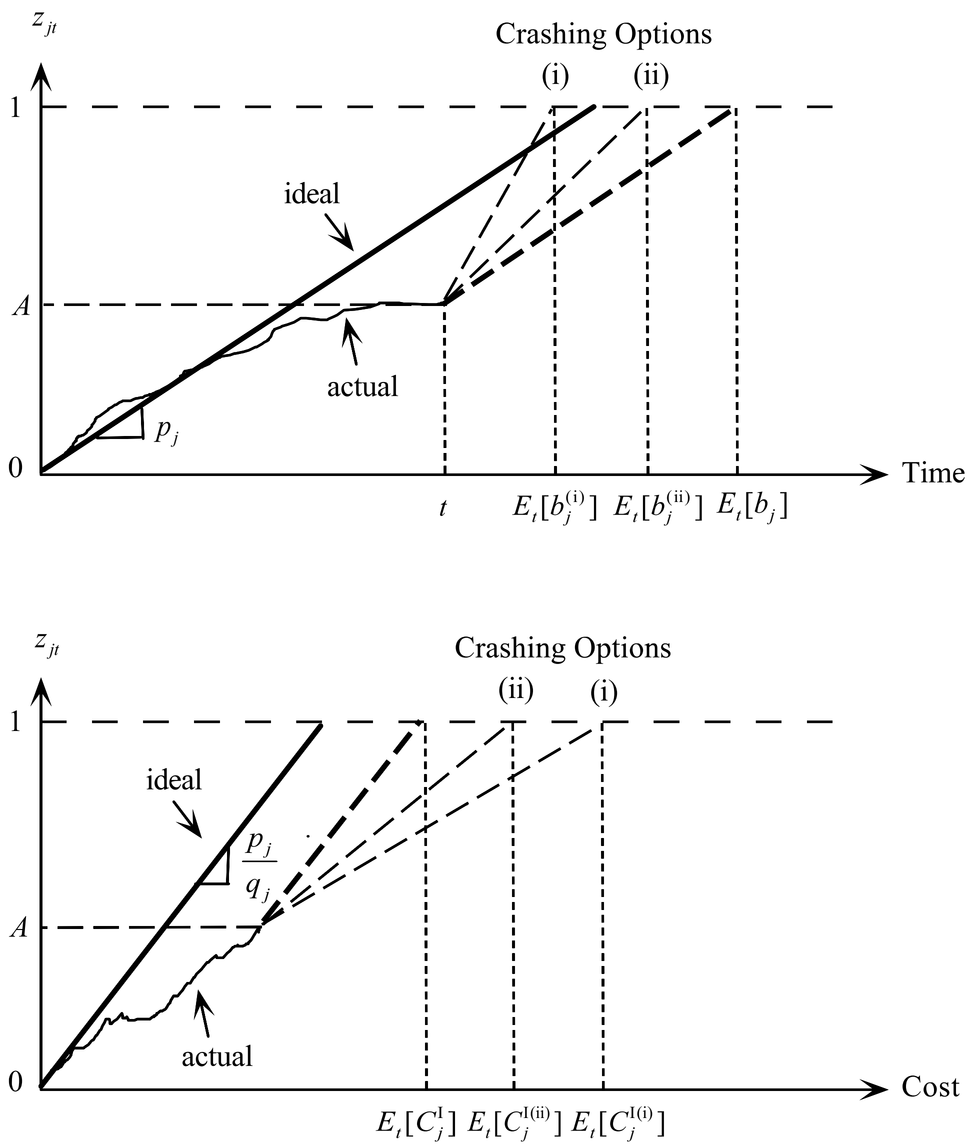


Figure 6.2: Example of two crashing options and their corresponding time and cost behaviors

Company is provided with a set of feasible crashing options Θ_t.

$$\Theta_t \equiv \{\theta_{jt}^m | m \in M_j(t), j \in J_c(t)\}, \tag{6.5}$$

where $M_j(t)$ is the index set of crash alternatives available to activity j and $J_c(t)$ is the index set for critical activities at time t. That is, if $\theta_{jt} \in \Theta_t$, then crash alternative $m \in M_j(t)$ is available to a critical activity $j \in J_c(t)$ at time t.

The Project Company's selection of the crashing option depends on the impact of performance uncertainties and the occurrence of potential bankruptcy. The value of dynamic crashing in the determination of optimal capital structure will be modeled in this section, all of which is based on the following assumptions:

(C 1) Consistent with the conventional crashing mechanism, the feasible set of crashing options are determined exogenously and made available for crashing decisions.

(C 2) There is no lead time required for implementing a crash alternative. That is, a crash alternative can be implemented immediately after the crash decision is made.

(C 3) It is assumed that, keeping other reasons aside, bankruptcy is triggered only due to the uncertainties in project performance.

(C 4) A ceiling on total equity is assumed, such that the Project company can only perform a limited amount of activity crashing.

(C 5) For sake of simplicity, the cost of additional equity capital also follows the same relation (5.23) as the initial cost of equity capital (k_e).

Notation

Various notations required for the model formulation have been defined in Chapters 4 and 5. Additional standard notation specific to this model is defined as follows.

W_c : weighted average cost of capital (WACC) with the crashing option.

θ_{jt}^{m} : crashing alternative m for activity j at time t.

Θ_t : set of all feasible crashing alternatives (for all applicable critical activities) at time t.

EQ_c : a random variable indicating the total amount of equity required with crashing option at time period t for project completion.

$EQ_c^{\max}$: a constant indicating the maximum amount of equity for crashing, which can be provided by the Project Company sponsors .

In conditions of bankruptcy (5.14), the available managerial options are either to adopt dynamic crashing or to declare bankruptcy, depending on the resultant value of the project after crashing. As previously discussed, the additional cost of implementing dynamic crashing is obtained through additional equity as a self-support risk-sharing mechanism from the Project Company sponsors. This additional equity can alter the capital structure to avoid bankruptcy. However, the additional equity can also increase the cost of capital and reduce the project value. The mechanism of crashing and effects on capital structure is explained as follows.

- Each crash option tends to decrease the project duration and increase the project cost by altering the performance rates p_j and q_j respectively. Therefore, each feasible crashing option can alter the capital structure of the project through duration reduction and additional cost (C 1).

- The reduction in project duration can allow the project to start the operation earlier and obtain revenues. The additional revenue from early start of operation period can increase the present value of revenues. In addition, the loss of revenue for delays, penalties, liquidated damages and other delay costs could also be avoided by earlier start of operation period. All these factors will improve the project value. This increased project value must, however, be offset by the crash costs incurred.

- The increase in project cost has to be acquired through additional equity by the Project Company as a self-support risk management method. This increased equity requirement will alter the debt requirement, increase the cost of equity and in turn increase the overall cost of capital (W_c). This increased cost of capital will reduce the project value obtained before.

- In general, the optimal crashing option is one that reduces the chances of bankruptcy and provides maximum increase in net project value.

As explained above, the decision of crashing option which reduces the bankruptcy and maximizes the resultant project value after crashing would be of interest to the Project Company. With the introduction of major uncertainties obtained from the stochastic project performance risk model, such as time-at-completion $\tilde{T}$ and cost-at-completion $\tilde{C}$, the Project Company must assess the occurence of potential bankruptcy (C 3).

Because of crashing, the additional indirect cost and the increased total project cost would demand additional equity. The additional equity should be self-supported by the Project Company and should be included when calculating the project equity EQ_c. The total equity required after crashing can be modified from (5.6) as follows.

$$EQ_c = \tilde{C} - (\sum_{i=0}^{t} \ell_i c_i + \ell_t \sum_{i=t+1}^{\tilde{T}} c_i), \ \forall t \leq \tilde{T} \tag{6.6}$$

and

$$E_t[EQ_c] = E_t[\tilde{C}] - \sum_{j=1}^{t} \ell_j c_j - \ell_t(E_t[\tilde{T}] - t)E_t[c_i],\ i = t+1, \cdots, \tilde{T} \tag{6.7}$$

Depending upon the requirement for additional equity from each crashing option, the equity amount (EQ_c) will vary. But, the Project Company will often be restricted with a maximum equity amount ($EQ_c^{\max}$), which they can invest in the project.

$$E_t[EQ_c] \leq EQ_c^{\max} \tag{6.8}$$

Though, there can be many crashing options in the feasible set, only those crashing options that satisfy (6.8) will be used.

The cost of capital (W_c) with crashing can be expressed as

$$W_c = k_e \frac{E_t[EQ_c]}{E_t[EQ_c] + E_t[D]} + k_d(1-\tau)\frac{E_t[D]}{E_t[EQ_c] + E_t[D]}, \tag{6.9}$$

where the $E_t[EQ_c]$ and $E_t[D_t]$ are the expected values of total equity and debt required at time t with crashing. These can be obtained from (6.7) and (5.5) respectively.

The optimization problem for performing dynamic crashing on the dynamic capital structure is modeled as the following stochastic program, denoted by (P_2).

(P_2)

$$V_c(t; \ell_{t-1}, \Theta_{t-1}) = -c_t + \max_{\ell_t, \theta \in \Theta_t} \{u_t E_t[V_c(t+1; \ell_t, \Theta_t)e^{-W_c(\ell_t)}] - (1-u_t)BC\}, \tag{6.10}$$

Although (6.10) looks similar to (P_1) in Chapter 5, the crash decision θ can implicitly affect $\tilde{T}$, $\tilde{C}$, EQ_c and W_c (WACC), which makes the problem more complex than problem (P_1). Again, u_t is used as a bankruptcy indicator.

$$u_t = \begin{cases} 1 & \text{if } E_t[F] > E_t[D(\ell_t)] \\ 0 & \text{otherwise} \end{cases} \tag{6.11}$$

In general, the following relations hold.

- Activity crashing reduces $\tilde{T}$, which potentially can avoid the loss of revenue, damages, additional interest costs.

- Activity crashing increases the inherent project cost C^{I}, but may avoid the delay cost C^{D}. Since $\tilde{C} = C^{\mathrm{I}} + C^{\mathrm{D}}$, crashing does not necessarily increase $\tilde{C}$ especially when the project is already behind schedule.

- Activity crashing increases the equity level EQ_c and also increases the cost of equity capital K_e, which leads to a higher WACC, i.e., $W_c \geq W$.

The above relations describe the trade-off using dynamic crashing. Therefore, the optimal decision of selecting crashing option (θ) and selecting the debt level (ℓ_t) will have a tradeoff between the value reduction due to additional cost of crashing and the value increase from the duration reduction, as long as potential bankruptcy is prevented.

The maximization of project value V depends on the decision of capital structure ratio (ℓ_t) to be made in time period t and the project crashing decisions (θ) made in that same period. The value of the project at time 0, $V(0)$, is the NPV of the project with crash options. Solving the above optimization will give an optimal leverage ratio (ℓ_0^*) at time $t = 0$, which maximizes the project value. A detailed solution procedure and an algorithm for the process is explained below.

6.4 Solution Procedure for Solving (P_2)

Similar to Chapter 5, in this section, a simulation-based heuristic approach is proposed. Although the obtained project value is suboptimal, it provides a reliable lower bound. As crashing options may be made at each time period, we implicitly assume that crashing operation is used as a risk management tool and is adopted only on occurences of bankruptcies. An equivalent interpretation is that the crashing options are normally costly and are economical only when the project is close to bankruptcy.

An extension of the heuristic method from Chapter 5 is discussed here. At each time period t, the Project Company assess the impact of performance uncertainties $E_t[\tilde{T}]$ and $E_t[\tilde{C}]$. Based on the impact, if a bankruptcy condition is triggered, the following optimization problem, denoted by (X), will be solved to determine an optimal crashing option and debt level.

(X)

$$\min_{\ell_t, \theta \in \Theta_t} \{W_c(\ell_t, \theta)\} \tag{6.12}$$

subject to

$$E_t[D(\ell_t)] \leq E_t[F(\ell_t)] \tag{6.13}$$

$$E_t[EQ_c] \leq EQ_c^{\max} \tag{6.14}$$

Again, solving (X) is motivated by the fact that minimizing the WACC is equivalent to maximizing the project value in the deterministic case. The following simulation algorithm is very similar to Simulation Algorithm 5.1 in Chapter 5, except employing crashing options when bankruptcy is declared.

Simulation Algorithm 6.1

Data: The maximal number of simulation runs $N > 0$ is given; The long-stop date $\hat{T}$ is also given.

Step 0: Set $n \leftarrow 0$, $t \leftarrow 0$.

Step 1: If $n > N$, go to Step 7. Otherwise, set $V^{(n)} \leftarrow 0$.

Step 2: If the project is completed, set the project duration $T_d \leftarrow t$ and go to Step 5. Otherwise, update the work progress for each activity using (4.1) and (4.5). Then, determine $E_t[\tilde{T}]$ and $E_t[\tilde{C}]$ for the project.

Step 3: Solve $\min\{W(\ell_t)|\ell_t \leq \ell^{\max}\}$ to determine the debt proportion at time t. Let the optimal solution to be ℓ_t^*. If $E_t[D(\ell_t^*)] \leq E_t[F(\ell_t^*)]$, go to Step 4. Otherwise, solve (X). If (X) is infeasible, bankruptcy is declared, set $T_d \leftarrow t$ and go to Step 5.

Step 4: $t \leftarrow t+1$, go to Step 2.

Step 5: Calculate the NPV of the project value $V^{(n)}$: if there was no bankruptcy,

$$V^{(n)} = \sum_{i=1}^{T_d} -c_i e^{-W(\ell_i^*)i} + \sum_{i=T_d}^{T_c} \phi(i) e^{-(W(\ell_i^*)-\eta)(i-T_d)}; \tag{6.15a}$$

if there occurs a bankruptcy at any time t, then the value is reduced only to the actual costs incurred upto time t.

$$V^{(n)} = \sum_{i=1}^{t} -c_i e^{-W(\ell_i^*)i} \tag{6.15b}$$

Step 6: $n \leftarrow n+1$ and go to Step 1.

Step 7: NPV $= \frac{1}{N}\sum_{n=1}^{N} V^{(n)}$

6.5 Numerical Example

This section continues the same numerical example in Chapter 5 to show how active project performance management can affect the capital structure. Although dynamic crashing may be applied at any time within the project development phase, for simplicity we assume that the Project Company only considers using it at bankruptcy. That is, upon identification of bankruptcy, the Project Company will either declare bankruptcy or apply dynamic crashing to mitigate the project performance risks.

Table 6.1: Crashing option information

Crashing Option m	p_j^m/p_j	σ_j^m/σ_j	q_j^m/q^j	$\varsigma_j^m/\varsigma_j$
0	1	1	1	1
1	1.05	1	1.08	1
2	1.10	1	1.15	1
3	1.15	1	1.22	1
4	1.20	1	1.30	1

For simplicity, we also assume that the available crashing options are independent of time. Consider a crashing option m for activity j such that θ_j^m is given as follows.

$$\theta_j^m = [p_j^m, \sigma_j^m, q_j^m, \varsigma_j^m], \tag{6.16}$$

Assume that when θ_j^m is applied, the project performance parameters are (p_j^m, σ_j^m, q_j^m, ς_j^m). Table 6.1 records the information of the crash options. It can be seen from Table 6.1 that the dynamic crashing is assumed not to change the volatilities for the performance processes (for both work and cost) but the performance rates. Crashing option 0 is the status quo. Assume that each activity can only be crashed once before it is completed. Once the activity is crashed, depending on when option is used, both the corresponding performance rates at that time are multiplied by a factor given in Table 6.1. Five test cases (numbered from 0 to 4) are solved with respect to the feasible set of crashing options Θ^n, $n = 0, \cdots, 4$, respectively, where

$$\Theta^n = [\theta_0, \cdots, \theta_n], \; n = 0, \cdots, 4. \tag{6.17}$$

Since $\Theta^0 \subset \Theta^1 \cdots \subset \Theta^4$, apparently as the case number increases, more crashing options are available to expedite the project.

Table 6.2: Summary of test results

Case no. m	0	1	2	3	4
Project value ($M)	247	249	252	255	255
Total Project Cost ($M)	473	488	503	523	553
Probability of bankruptcy	28.2%	22.6%	17.5%	13.2%	13.2%

Simulation Algorithm 6.1 is applied repeated to solve (P_2) with respect to Θ^n, $n = 0, \cdots, 4$. In each case, 1000 simulation runs are performed. The probability of bankruptcy is obtained by the number of the simulation runs that cannot complete due to bankruptcy divided by the total number of simulation runs. The result of the numerical test is summarized in Table 6.2.

Apparently, the project value increases as the feasibility set of crash options becomes bigger. However, both Cases 4 and 5 yield a same result, which implies that θ^4 is a costly crashing option, never been used though available. The numerical example is also tested with various sensitivity tests, which are illustrated below.

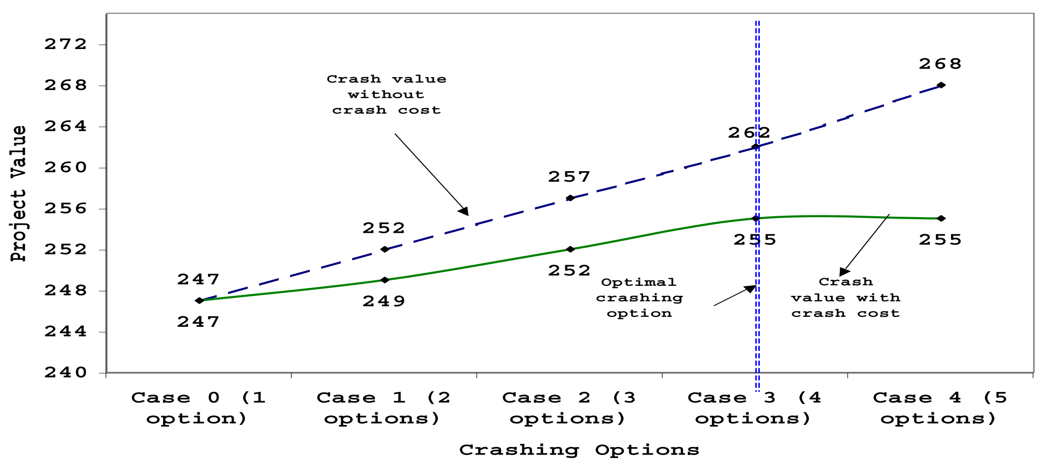


Figure 6.3: Effect of crashing cost on project value

Figure 6.3 shows that the project value increases as more crash options become available. The increased value is attributable to the early start of the operation period and the early collection of the associated revenue. In addition, the relieve from loss of revenues, liquidated damages and other additional costs also augments the operation revenues to increase the project value.

However, each crash duration is associated with a crashing cost. The total project cost increases as more activities are crashed (so the project duration is shortened). The informationof the totoal project costs is also summarized in Table 6.2. The crash costs have to be incurred by the Project Company through additional equity as a self-support risk management. This increase will also modify the capital structure ratio and will alter the project value.

The solid line in the bottom in Figure 6.3 represents the project values with crash options. It can be seen that the project value initially increases (for Θ^0 to Θ^3) then stays the same (for Θ^4). The intial increase in the project value is due to the more choices for crash options; while the latter stagnancy of the proejct value implies that the additional crash options provided by Θ^4 are too costly to be incorporated.

To determine the impact of varying crashing costs to the project value, a sensitivity analysis is peroformed and the result is given in Figure 6.4. In this test, the costs of the crash options in Θ^1 are increased ranging from 1.08 to 2.0 times. It can be seen from Figure 6.4 that with increasing crash costs, the project value decreases. This is quite obvious for the fact that for any particular crash duration, the higher the crash cost, the lower the value obtained. As discussed before, the crashing cost can vary due to changes in the availability and cost of resources at different time periods. Based upon the availability of resources and its costs, the crashing costs and the optimal crashing option decision can also vary.

Through this numerical test, we show that not only the project is enhanced due to active project management, the probability of bankruptcy is reduced significantly. The potential of the active project management using the dynamic crashing is justi-

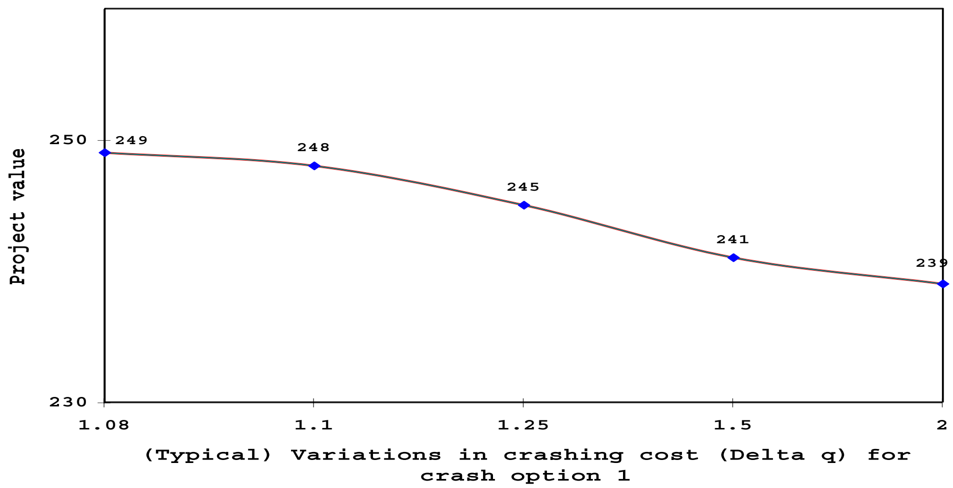


Figure 6.4: Impact of variations in crash costs on Project value

fied.

6.6 Limitations of Dynamic Crashing

Though the dynamic crashing method proves to be a valuable method for the project team to influence the performance variables, the model provides the following limitations.

- The resources and technology required for obtaining crashing options could be difficult to obtain when required by the Project Company.
- Although crashing options could increase the project value, the additional equity required to bear the additional project cost may be difficult to obtain.
- The equity payoff $(V - D)$ for the Project Company has to be determined for each crashing option, in addition to the net present value. As long as the debt ratio is not modified with the crashing option, the optimal crashing options has also to be determined for maximizing the equity returns.

- As mentioned, the active performance management requires constant managerial attention in influencing the performance variables. This might increase the indirect costs to the project.

6.7 Conclusion

This dynamic crashing model provides a quantitative framework for determining the optimal capital structure with crashing options, which improves the project performance and reduces the chances of bankruptcy. The significant contribution of this model is that it provides an upstream control of the performance variables (time-to-complete and cost-to-complete). Unlike other participants, the Project Company within the project development period, has the highest influence to control the project performance variables. In addition, the Project Company also gets to make decisions on investing additional equity. This flexibility modeled in this chapter proves to give an additional value to the project. The numerical results also prove the significance of the model through increase in the project value.

Chapter 7

Optimal Capital Structure with Government Support Option

In Chapter 6, active performance management was discussed. A model was formulated to determine the effect of active performance management on the capital structure. As mentioned, it is an upstream control mechanism of uncertain performance variables through self-support of the Project Company sponsors. Due to its limitations discussed in Section 6.6, the applicability of active performance management as a risk sharing method is restricted. Similarly, government support can also be advocated as a risk sharing mechanism.

In this chapter, an overview of various possible government support will be discussed. The requirement for dynamic government support for sharing project performance risks will be discussed in detail. A quantitative model will be developed to determine the optimal capital structure under provision of government support for project performance risk sharing during the project development phase.

This chapter considers two different cases of using government support. The first case considers the government equity as a rescue mechanism at bankruptcy, whereas, the second case considers government equity as a negotiable option to choose proactively in conditions of potential bankruptcy.

7.1 Introduction to Government Support

The project risk management measures are generally made through contractual risk-allocation arrangements by means of allocating and sharing the risks to each project participant. However, as discussed in Chapter 4, such contractual arrangements may not be sufficient to mitigate the risks of projects with high uncertainties. The lack of appropriate mechanisms for risk allocation and for determining the risk impact on the project can lead to high complexity in investment decisions for the Project Company. To avoid such situations, government support, economic or financial in nature, may be needed to enhance the attractiveness of private investment in infrastructure projects in the host country. Many countries have adopted a flexible approach for dealing with the issue of governmental support (UNCITRAL 2001).

The impact of absorbing risks such as performance risks, political risks, interest rate fluctuation risks can lead to high leverage and in turn high probability of bankruptcy. The projects in bankruptcy can lead to disruption of service for which it is intended. In order to prevent such service disruption, government can sometimes rescue the project against bankruptcies through the government support. Such support is common, when PFI projects render essential services to the public.

7.2 Forms of the Government Support

The government support can be provided in terms of economic and/or financial support. Though various forms of the government support can be possible, the main supports are discussed in the following sections.

7.2.1 Loans and guarantees

The government can provide loan guarantees for the repayment of loans taken by the project company. The purpose of loan guarantees are to protect the Lenders against default by the project company. The government can limit the provision of loan guarantee by a fixed amount or a percentage of total investment. Sometimes, the government can specify conditions such as, risk impact outside the control of Project Company, regulatory changes, etc under which the guarantees are *contingent liabilities*. However, the loan guarantees cannot protect the Lenders completely against the risk of default by the project company. In some projects such as toll roads, the provision of guarantees can be extended to minimum revenue guarantees. Minimum revenue guarantees provide a minimum operating income or minimum demand for the product.

7.2.2 Equity participation

The government can provide direct or indirect equity in the Project Company, by specifying their limits of involvement in case of default. The cost of the government equity is often less than cost of equity provided by Project Company Sponsors. The rationale for equity participation is to achieve a favorable financial structure.

7.2.3 Subsidies

Subsidies are used to supplement the project revenues when infrastructure provisions for a targeted population are required in conditions of low demand or high operational costs. Subsidies usually take the form of direct payments to the Project Company, either lump-sum payments or payments calculated specifically to supplement the Project Companys revenue. Subsidies can also be provided in terms of low interest rates rather than available in commercial markets to reduce the cost of debt capital.

7.2.4 Tax and customs benefits

The government can also provide some form of tax and customs exemption, reduction or benefit. Typical tax exemptions or benefits include exemption from income or profit tax or from property tax on the facility, or exemptions from income tax on interest due on loans and other financial obligations assumed by the Project Company. Such benefits can include duty exemptions on equipment imports.

7.2.5 Protection from competition

Protection from competition may be regarded by the Project Company and the Lenders as an essential condition to foster the investment confidence. This support prevents competition arising from other similar services by retaining the benefits only for this project. For example, the government can protect (PFI based) toll roads by preventing non-tolled roads from being built in adjacent areas that can serve alternative routes for the toll roads.

7.2.6 Other supports

Other support shall be in the form of concession term extension, providing ancillary revenue sources, etc. The Project Company also has the option to receive a mix of the government support encompassing some or all of the types of support mentioned above.

7.3 Effects of Government Support

In general, the Project Company would prefer obtaining government support for most of the risks. The reason for this can be attributed to low cost of risk absorption by the government. It also has the advantages of bolstering credibility in the

Lender's view of the Project Company. However, from the government's perspective, the provision of support increases the cost to the government. In addition, with bankruptcy-shy governments, this can lead to assuming the risks by the government itself. Such situations might defy the very assumption of risk transfer to the private sector in PFI project investments. This supporting mechanism can sometimes defy the very purpose of risk allocation if the supports are provided only implicitly by the government. Such conditions can be considered as providing implied supports or implied guarantees to the Project Company. The effect of such implied supports is discussed below:

Implied guarantees / support

The government support for a particular risk as a risk sharing approach can be effective when the government is truly willing to let the Project Company bear the full consequences of other unsupported risks. If the Project Company is highly levered, which is not uncommon, the high chance of bankruptcy can lead to chances of service disruption or the provision of poor quality services in case of bankruptcy. It is not atypical that the government would try to avoid such service disruption or poor quality service of the infrastructure facility. Therefore, even without an explicit provision of support in the concession agreement, the government would rescue/support the Project Company against declaring bankruptcy (Erdhardt 2004). This situation can be referred to as a provision of implied support or guarantee by the government, which makes the risk sharing principle generally illusory. This could result in multiple losses to the government, since:

1. If the project value is not affected by the impact of project risks, the Project Company receives all the benefits.

2. Otherwise, the government absorbs the risk by providing rescue (implied) sup-

ports, which would protect the Project Company against declaring bankruptcy.

In order to prevent such losses and to have an efficient risk sharing, the government, in the concession agreement, must explicitly make the supporting arrangements available to the Project Company. But, even such explicit support can also lead to the above multiple losses to the government, unless and until the Project Company and the government recognize the support only as a facilitating mechanism for risk-sharing. However, the provision of explicit supporting arrangements might reduce the incentives for the Project Company to improve their efficiency. In order to prevent this, the government can specify a balance in the risk-transfer through a mechanism of sharing the project value (Ehrhardt, 2004). The proposed research in this dissertation concentrates on such a mechanism for risk allocation strategies. In the proposed mechanism, government support is provided with a constraint by sharing the additional project value along with the Project Company.

The significance of the proposed method is that the equity value from the project (payoff to the Project Company) will have limits. The advantage is that it reduces risk to the Project Company, while preserving a reasonable level of incentives for efficiency. By providing such a mechanism for protecting the Project Company's downside risk, it reduces the risk of bankruptcy, and also restricts the limit of payoff (profits) to the Project Company.

7.4 Dynamic Government Support

It is recommended that the terms and conditions of government support as a risk-sharing mechanism be explicitly stated in the concession agreement. This is possible if all information about the project risks is available. However, from the discussions and results of Chapters 4 and 5 where the impact of dynamics of risk variables were emphasized, such dynamic risk management requires the government support different from the conventional support arrangements. For example, the impact of the project performance risks on the project value has been observed as highly dynamic in nature, which requires constant managerial attention in making decision on the risk sharing. The choice of use of the government support will be contingent on the occurrence of bankruptcies. Therefore, the decision to choose the government support requires determining the impact of project performance risks on the project value at each time period.

In this research, government equity participation is considered as a form of government support. The rationale for use of the government's equity is to help achieve a favorable capital structure. In equity participation by the government, it is considered that the use of such equity by the project sponsors is purely a facilitating arrangement to supplement their equity. Therefore, the use of government's equity has to be justified in terms of reducing the chances of risk impact. Consistent with the effects of government support risk-sharing arrangements discussed above, the project value sharing mechanism can be adopted as part of the government support provision.

7.4.1 Optimal capital structure with dynamic government support

By receiving the government support for project performance risks, potential bankruptcies can be avoided. However, by introducing a project value sharing constraint, the additional project value obtained from government support (G) will also be shared by the government. The details of the value sharing constraints pertaining to the equity participation support will be explained in the following section. Such constraint will restrict the high profits of the Project Company and the net equity value will be $(V - D - G)$. Therefore, the Project Company has to assess dynamically the impact of obtaining the government support and the resulting value in case of occurrences of bankruptcy. This assessment and decision making cannot be made just by using the conventional valuation models or the generic model developed in Chapter 5. This situation demands a dynamic stochastic decision model to determine at each time period the value of the project under the contingent government support and the project value sharing constraint. Such a model is formulated in the following section.

7.4.2 Basic assumptions

The key assumptions made in the dynamic capital structure model with government support are as follows:

(D 1) The equity from government is purely a facilitating arrangement under the concession contract, which can be used by the Project Company within the project development period. However, the use of such equity is subjected to a maximum amount set by the government.

(D 2) The government also sets a minimum equity level, which the Project Company has to invest in the project.

(D 3) The provision of government equity is contingent on the occurrence of potential bankruptcies. However, at any time period, the choice of the option and amount of government equity is decided by the Project Company.

(D 4) The cost of government equity is lesser than the cost of the Project Company's equity but higher than the (Lenders) cost of debt.

(D 5) In case of government equity as an option, the Project Company can negotiate with the government for a lesser cost of government equity.

7.4.3 Notation

In addition to the notations given in the Chapters 4 and 5, the additional notation used in this chapter is listed below.

g_t : proportion of government equity in the project cost at time t.

W_g : weighted average cost of capital with government support.

$W^{\min}$: lower bound weighted average cost of capital set by the government for value sharing purposes.

k_g : cost of government's equity ($k_e \geq k_g \geq k_d$).

$\hat{k_g}$: cost of government's equity with negotiable option ($\hat{k_g} \leq k_g$).

β : negotiable discount factor for $\hat{k_g}$

G_t : total amount of government equity required at time period t for project completion.

γ : value sharing ratio set by the government on additional value gained from the government support.

$V_b(t)$: project value with government equity at bankruptcy at time t.

$V_g(t)$: project value with government equity at any time period t.

$V_r(t)$: project value with optional government equity at any time period t.

7.4.4 Modeling optimal capital structure

In Chapter 5, the generic model provides the basis for determining the dynamic capital structure based on the impact of project performance risks. In this section, the use of government equity is introduced in the capital structure model. The provision of the government equity will facilitate a favorable capital structure. The capital structure model with the use of government equity can be formulated by extending the generic model.

In the generic model in Chapter 5, the project cost c_t for each period had been shared only between debt d_t and equity e_t without government support. However, with the use of government support, the project cost will also be shared by the government's equity g_t. Equation (5.1) can be modified as

$$c_t = e_t + d_t + g_t \tag{7.1}$$

The use of government equity g_t at any time period t is contingent upon the requirement for additional capital to prevent the bankruptcy. Since it is assumed that the bankruptcy is induced only by the effect of performance uncertainties, the requirement for government equity can also vary from time to time. Consistent with the assumption made for the debt (A 4), a government equity ratio η_t at time t is also assumed to be applied to all the future time periods after t. That is, at any time t, the government's equity amount g_i for any future time period is determined by

$$g_i = \eta_t c_i, \ \forall i \geq t \tag{7.2}$$

Based on the above, the total requirement for government equity G at any period in the development phase with $\tilde{T}$ as completion time and $\tilde{C}$ as completion cost, can be assumed similar to equation (5.4) in Chapter 5. The total government equity at time t can be expressed as below:

$$G = \sum_{i=t_0}^{t} g_i c_i + \eta_t \sum_{i=t+1}^{\tilde{T}} c_i, \ \forall t \leq \tilde{T} \tag{7.3}$$

and

$$E_t[G] = \sum_{i=t_0}^{t} g_i c_i + \eta_t \sum_{i=t+1}^{\infty} E_t[c_i] \Pr\{\tilde{T} \geq i\}, \tag{7.4}$$

where t_0 is the time when the government equity is adopted. The timing t_0 for use of the government equity in (7.3) should be determined based on the impact of performance uncertainties and the induced bankruptcies. Since the cost of government equity k_g is less than the cost of Project Company's equity k_e, it is obvious that the requirement for expected government equity will be high, according to (D 4). Such conditions can increase the need for more government equity which will eventually defy the fundamental issue of involvement of the private sector. To avoid such situation, the government can set a maximum limit $G^{\max}$ for government equity investment as assumed in (D 1). In addition, the government also maintains the minimum equity constraint for the Project Company sponsors as assumed in (D 2). This minimum equity constraint can provide a basis for improving the efficiency and commitment of the Project Company.

In order to determine the effect of the government support in the capital structure, this research considers two different cases. The first case (Case 1) considers that the government equity comes as a rescue mechanism when the project is met with a bankruptcy. In the second case (Case 2), the Project Company has the option to choose the use of the government equity pro-actively in conditions of potential bankruptcy. In Case 2, the Project Company can negotiate for a cost of government equity lesser than Case 1. Both cases are modeled in detail in the following sections.

7.4.5 Case 1: Government support as an explicit rescue mechanism at bankruptcy

In this case, it is assumed that the government equity is infused in the project only when bankruptcy is triggered. Although the consideration of performance risks is only in the project development period, any bankruptcy in the development period will inevitably affect its intended service. Depending upon the timing and impact of such service disruption, the government can impose an additional penalty on the Project Company. The penalty will be determined exogenously depending on the service that the project is supposed to provide. The penalties are included in the liquidated damages, which the government imposes on the Project Company for performance failures. To relieve the project from such service disruption, the government can rescue the Project Company by providing government equity. The government equity will bolster the Project Company's equity and reduce the requirement for debt such that the bankruptcy is removed. Case 1 conforms to the conventional government support mechanisms.

The choice and amount of government equity at each time depends on the bankruptcy indicators (5.16) induced by the current impact of performance uncertainties. Depending upon the occurrence of bankruptcy, the government equity can be used at any time period upto the actual completion of project development period (T_d) or upto the maximum limit ($G^{\max}$), whichever reaches first. Based on the dynamic characteristics of performance uncertainties and the induced bankruptcy, the use of government equity could be higher or lower, since the need for government equity arises only when a bankruptcy is triggered.

The rational for choosing government equity only at bankruptcy is that the value sharing might be limited, as long as the chances for occurrence of bankruptcy is lesser. The details of value sharing for the dynamic government equity support is explained in the following section. However, on occurrence of bankruptcy, the government equity required will be higher in order to relieve the impact of bankruptcy and continue the project. It should also be noted that the government equity need not be used when a bankruptcy is not triggered. In such cases, the equity value could be higher than if government equity were used prior to the occurrence of bankruptcy. The need for a stochastic decision model is emphasized here, as government support at bankruptcy at any time t will be based on the dynamic nature of performance uncertainties. The details of the model are discussed below.

At each time period, the performance uncertainties $\tilde{T}$ and $\tilde{C}$ are observed from the performance model. The Project Company must assess the condition of bankruptcy under the current impact of performance uncertainties. If a bankruptcy is triggered, the government equity (g_t) will be placed as a rescue support. Similar to the recursive relation for project value V in (5.15), the project value (V_b) with the use of government support at bankruptcy can be expressed from the following stochastic program, denoted by (P_3):

(P_3)

$$V_b(t; \ell_{t-1}, g_{t-1}) = \begin{cases} V_g(t; \ell_{t-1}, \eta_{t-1}), & \text{if (5.14) holds} \\ V(t; \ell_{t-1}), & \text{otherwise} \end{cases} \tag{7.5}$$

where V is defined in (5.15). If the bankruptcy condition (5.14) is not met, the government support will not be used, i.e., $\eta_t = 0$, and this case is no different from the generic model defined in Chapter 5. However, if the bankruptcy condition (5.14) is met, the problem is switched to the following stochastic program of V_g, which represents the project value with government equity.

$$V_g(t; \ell_{t-1}, g_{t-1}) = -c_t + \max_{\ell_t, \eta_t} \{ y_t E_t[V_g(t+1; \ell_t; \eta_t) e^{-W_g(\ell_t, \eta_t)}] - (1 - y_t) BC \} \tag{7.6}$$

subject to

$$E_t[G_t] \leq G^{\max} \tag{7.7}$$

where y_t is a binary variable indicating whether bankruptcy occurs at time t or not.

$$y_t = \begin{cases} 1 & \text{if } E_t[F] < E_t[D(\ell_t)] \\ 0 & \text{otherwise} \end{cases} \tag{7.8}$$

and cost of capital with government equity (W_g) can be defined similar to (5.21), as

$$W_g = k_e \frac{E_t[EQ]}{E_t[EQ] + E_t[D] + E_t[G]} + k_d(1 - \tau) \frac{E_t[D]}{E_t[EQ] + E_t[D] + E_t[G]} +$$

$$k_g \frac{E_t[G]}{E_t[EQ] + E_t[D] + E_t[G]} \tag{7.9}$$

The cost of government equity (k_g) is assumed as a constant set by the government. It should be noted that even after obtaining the government equity, bankruptcies ($y_t = 1$) may still be possible. This is because that the cost of capital with government equity W_g is higher than the one without W, the one without the need for additional equity, as long as $k_g > k_d$ and no additional equity is invested by the Project Company. This can reduce the present value of net revenues (F). With the same debt level (D), the chance of bankruptcy is evident.

Value sharing constraint

As explained previously, the government would impose a value sharing constraint for use of the government support. The value sharing constraint could be imposed by the government by first setting a lower bound $W^{\min}$ for the cost of capital. The cost of capital would be higher, if the government equity proportion were also assumed to be incurred by the Project Company. As $W^{\min}$ corresponds to the total equity investment only by the Project Company, the government would prefer setting $W^{\min}$ as a pre-determined constant generally corresponds to some industry benchmark (PWC 2002, Ehrhardt 2004). The additional value obtained from lower cost of capital will be shared proportionally between the government and the project company as assumed in (D 3). The sharing of the additional project value gained from the government support, between the government and the Project Company is determined based on the amount of government equity used in the project. If the Project Company uses the government equity upto its maximum ($G^{\max}$), then an equal sharing ratio will be assumed. Similarly, proportional sharing of the additional value is considered.

With the use of the value sharing constraint, (7.6) should be modified as follows.

$$V_g(t; \ell_{t-1}, g_{t-1}) = -c_t + \max_{\ell_t, \eta_t}\{y_t E_t[V_g(t+1; \ell_t, \eta_t), e^{\max(-W_g(\ell_t,\eta_t), -W_s)}] - (1 - y_t)BC\}, \tag{7.10}$$

where W_s is the imposition of value sharing constraint expressed as

$$W_s = W^{\min} - \gamma(W^{\min} - W_g) \tag{7.11}$$

In (7.11), γ represents the proportionate amount of government equity used against the maximum limit of government equity ($G_t/G^{\max}$). For example, if the government equity is not used, then only $W^{\min}$ will be applicable, which corresponds to the case that the total equity is only through the Project Company's equity. This represents that the government support value sharing constraint allows the Project Company to have the value restricted to $W^{\min}$ minus the proportionate γ additional value gained from the government support.

Keeping the same boundary condition (5.17) for the above recursive equation, the value at time zero $V_g(0)$ at time 0 can be considered as the NPV of the project with government support. The NPV obtained will also be owned by the government, in addition to the Project Company and the Lenders.

The simulation algorithm for (P_3) is very similar to Simulation Algorithm 6.1 and is skipped here. Basically, use Simulation Algorithm 5.1 until bankruptcy is triggered, which means the government equity will be introduced. Problem (P_3) is essentially the same as (P_1), except that the WACC is defined differently. A modified version of Simulation Algorithm 5.1 is then used after the government support has been adopted.

7.4.6 Case 2: Government support is an option

In this case, instead of considering the government support as a rescue mechanism as in Case 1, we will consider the government support as a negotiable option available to the Project Company. The focus of this case will be to provide information about possibilities of preventing bankruptcies. However, the decision on use of government equity is contingent on the occurrence of "potential" bankruptcies (D 3).

The trigger for the "potential" bankruptcy is governed by the uncertainties in the project performance. Since the performance variables ($\tilde{C}$ and $\tilde{T}$) are highly dynamic in nature, the bankruptcy trigger also can be dynamic and is difficult to predict. The trigger for the potential bankruptcy can be modeled as follows.

Potential bankruptcy condition

$$x_t = E_t[F] < \alpha E_t[D], \;\; t \leq \tilde{T} \tag{7.12}$$

where $\alpha > 1$ is a potential bankruptcy factor. Compared with (5.14), (7.12) is more stringent in the sense that it triggers before bankruptcy takes place.

With the use of factor α to prevent the potential bankruptcy, the need for earlier use of government equity is warranted. With the earlier use of government equity, the cost of government equity (k_g), a higher cost of capital W_g than W is introduced earlier. This will in turn reduce the project value and discourage the use the government equity. On the other hand, the chance of bankruptcies may be significantly reduced with the government equity, which will be advantageous to the government. Therefore, we assume that the Project Company can negotiate with the government to reduce the cost of government equity by a discount factor (D 5).

$$\hat{k}_g = \beta k_g \tag{7.13}$$

where $\beta < 1$ is a government equity discount factor. This negotiation occurs for a lesser rate of cost of government equity ($\hat{k}_g \leq k_g$).

The focus of this section will be to determine the functional relation between the two factors α and β that defines the existence condition of a "Pareto" point, where the project value remains the same as if the government equity were not used. That means the project value obtained in the generic case in Chapter 5 will be used as the benchmark value. The values of α and β in this functional relation that are close to 1 will be the values for the factors that both the Project Company and the government are likely to accept. As we will show that the main incentive behind this is the significant reduction of the chance of (real) bankruptcies.

The formulation that the government equity is an option is modeled as the following stochastic program, denoted by (P_4):

(P_4)

$$V_r(t;\ell_{t-1}) = -c_t + \max_{x_t\in\{0,1\}}[(1-x_t)A + x_tB] \tag{7.14}$$

where,

$$A = \max_{\ell_t} E_t[V_r(t+1;\ell_t)e^{-W(\ell_t)}] \tag{7.15}$$

$$B = \max_{\ell_t,g_t} E_t[V_g(t+1;\ell_t,g_t)e^{-W_g(\ell_t,g_t)}] \tag{7.16}$$

$$x_t = \begin{cases} 1 & \text{if (7.12) holds} \\ 0, & \text{otherwise} \end{cases} \tag{7.17}$$

In (7.14), $x_t = 1$ if the potential bankruptcy condition is satisfied. Then the government support option is exercised and $\hat{k}_g$ in (7.13) is used to calculate W_g using (7.9) with k_g replaced by $\hat{k}_g$. In this case, the project value is equal to V_g defined in (P_3). Otherwise, $x_t = 0$ implies a status quo.

The simulation algorithm is similar to that in Case 1, except that now the government equity is triggered by (7.12) and W_g is calculated using (7.9) with k_g replaced by $\hat{k}_g$ in (7.13).

7.5 Numerical Tests

The numerical example in the generic model in Chapter 5 is used here to observe the impact of adopting the government equity support. In addition to the data given in Table 5.1, the constant cost of government equity (k_g) is assumed to be 12%.

For Case 1, it is observed that the average NPV is \$243M, less than the project value \$247M obtained in Chapter 5. This is because that the cost of capital with the government equity (k_g) is higher. However, the chance of bankruptcy is reduced from 28.2% to 25%. More details about the simulation result are given in Table 7.1.

In Case 2, the focus is to obtain the functional relation between $\alpha > 1$ and $\beta < 1$ such that the project value matches the benchmark value \$247M, obtained in Chapter 5. This functional relation is depicted in Figure 7.1. It can be seen that a larger α indicating a more stringent bankruptcy measure requires a bigger discount factor β for the cost of government equity to maintain the same project value. This result is intuitive.

The probabilities of bankruptcies are also given in Figure 7.1. It can been seen that earlier adoption of the government equity does result in a lower chance of bankruptcy. From the numerical test, it can be observed that, the use of government equity as a negotiable option reduces the bankruptcy significantly. As preventing the bankruptcy is advantageous to both the Project Company and the government, Case 2 provides a valuable model for negotiations and decision-making.

In order to determine the impact of other variables on the project value, a sensitivity analysis was done. In particular, the variables such as maximum government

Table 7.1: Summary of the result for Case 1

Debt ratio (ℓ_t^*)	0.8264
Equity ratio (e_t^*)	0.11
Government equity ratio (g_t^*)	0.064
Cost of capital (W_g^*)	9.96%

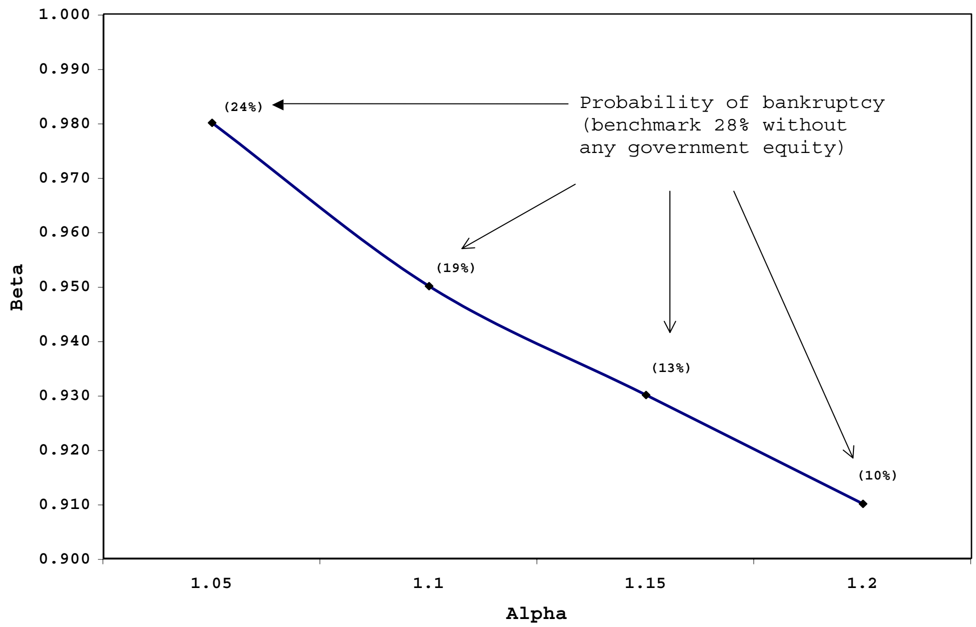


Figure 7.1: Functional relation between $\alpha > 1$ and $\beta < 1$ such that the project value matches the benchmark \$247M, obtained in Chapter 5

equity ($G^{\max}$) and constraint on cost of capital ($W^{\min}$) has a significant impact on the project value. A sensitivity analysis was done to verify the impact of maximum government equity ($G^{\max}$) and the results are illustrated below.

Figure 7.2 shows that for higher government equity amounts, the value obtained could increase. It can be noticed that the case 2 (α - 1.1 and β - 0.95) provides more value than Case 1 for higher amounts of government equity. The fact that, with stringent condition on determination of potential bankruptcies, the availability of more government equity can increase the value of flexibility to decide on government equity, is evident. In contrary, Case 1 would need the government equity only in case of bankruptcy. Hence, the government equity beyond the need for avoiding the bankruptcy as a rescue support might not add value to the project. This can be seen

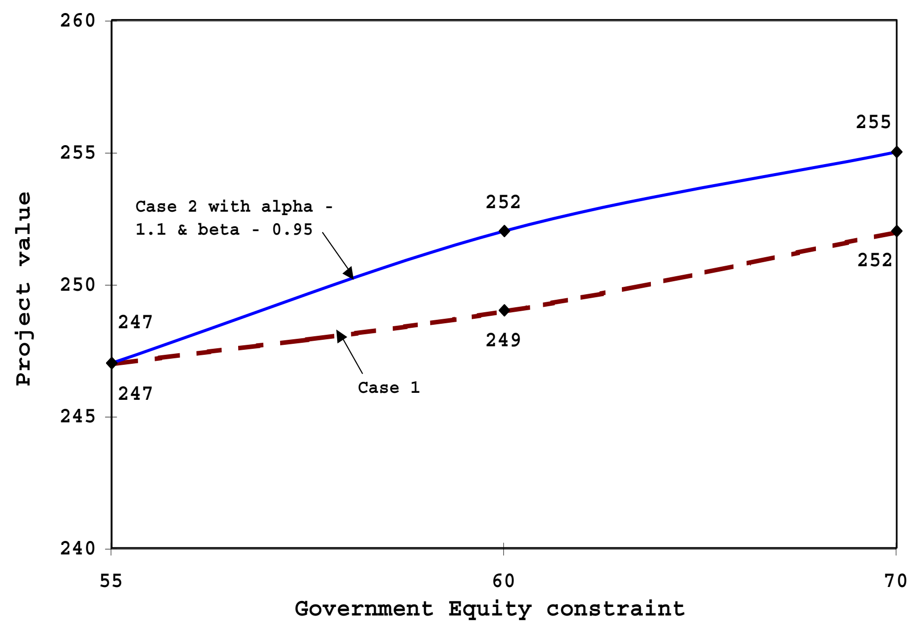


Figure 7.2: Effect of maximum government equity on project value

in the curve corresponding to Case 1, as the project value increases at a slower rate than Case 2.

As the cost of capital constraint is a variable set by the government, it is essential to determine its impact on project value. Similar to maximum equity constraint, the effect of cost of capital constraint ($W^{\min}$) is explained through Figure 7.3.

Note that from Figure 7.3, the project value decreases with the constraint on cost of capital. This is quite obvious that constraint with higher values of cost of capital would minimize the project value. The fact that the requirement of higher government equity on occurrence of bankruptcy results in a lesser value in Case 1 than Case 2. However, it should be noted that for higher values of constraint, the rate of decrease of value in Case 2 is higher than that of Case 1. This is due to the fact that the additional value of flexibility from Case 2 will be offset by the loss in

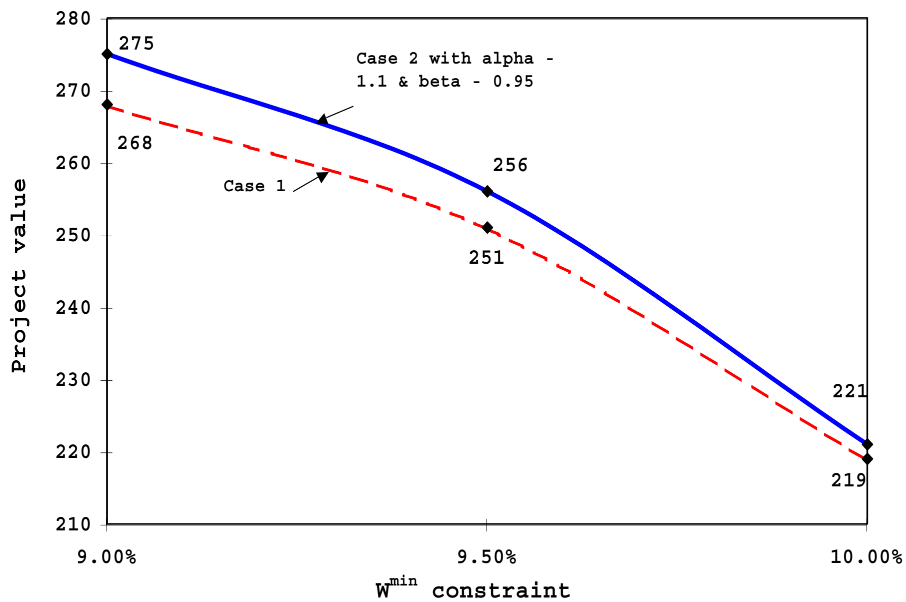


Figure 7.3: Effect of cost of capital ($W^{\min}$)constraint on project value

value sharing for higher levels of cost of capital constraint.

7.6 Conclusion

PFI projects provide public services, which, the government would prefer not to have any disruption in service. Two models were proposed to show how the government equity can be introduced to reduce the chance of bankruptcy. In Case 2, where the government equity is a negotiable option, we show that the flexibility in choosing the government equity pro-actively can provide a favorable capital structure and capture additional value, while satisfying the fundamental purpose of providing government equity.

Overall, the proposed pro-active strategy in Case 2 can improve the financial feasibility of the project, since it reduces the bankruptcy, prevents the legalities, cost and other effects of bankruptcy, and thus provides uninterrupted project service. In addition, unlike the conventional government support, the use of government support exclusively as a risk-allocation mechanism for projects with dynamic performance uncertainties proves to be a value addition to the project.

Chapter 8

Summary and Future Directions

In this dissertation a stochastic performance model has been developed, which captures the dynamics of performance risk variables, determines their impact on project value and helps make optimal capital structure decisions. In addition, the research also recommended methods for value addition to projects through active risk management and dynamic government support. The research advocates a radical approach to consider the relevance of bankruptcy condition, pro-actively in the project development stage, where the actual capital is being invested.

Chapter 4 models the dynamics of performance risk measurements. In this chapter, a dynamic model was formulated, which can be used to analyze time and cost completion risks and to assist the decision-maker to mitigate these risks. The stochastic performance risk model has advantages over conventional models, for the reason that the performance information of project duration and cost can be obtained at any desired time period. The validity of the model can be verified with more documented performance from real-world project data, in future research.

From the performance risk measurement obtained, their impact on the project value is modeled in Chapter 5. This generic model provides a quantitative framework for determining the dynamic capital structure on each period based on the current impact of performance risk variables. The optimal capital structure is determined by a heuristic strategy that maximizes the NPV of the project. A numerical example was developed to validate the model. It has been observed that the model improves the project value. The assumptions such as constant interest rates, considering only debt and equity to form the financial structure can be relaxed in future research.

An active performance risk management method, referred to as dynamic crashing, was introduced in Chapter 6, that can control the project performance risks. A project performance dynamic-decision model was developed, on a heuristic strategy, to model the relationship between the active project management decisions and its significance on the decision on capital structure. This model proves that the project value could be improved and potential bankruptcies could be prevented by controlling the performance variables. The applicability of dynamic crashing can also be verified through reviewing real-world project information.

Chapter 7 considers government equity participation as a risk-sharing mechanism, in which government participated in providing equity to prevent bankruptcy. Two cases with government equity support were considered, one as a rescue mechanism at bankruptcy and the other as an option to prevent potential bankruptcies. The latter case provides a significant reduction in the probability of bankruptcies.

In this dissertation, the capital structure decisions were obtained via heuristic methods. That is, the project values obtained were sub-optimal. In future research, rigorous numerical methods that can solve the multi-stage stochastic programs with uncertain boundary conditions to optimality may be developed. Such methods may incorporate the state-of-the-art path-dependent option valuation methods. Furthermore, more uncertainties in the financial side, such as interest rates, may also be incorporated in determining the optimal capital structure. It is expected that a even more positive outcome would be reported if all these improvements are included.

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