A REAL OPTIONS MODEL FOR THE FINANCIAL VALUATION OF INFRASTRUCTURE SYSTEMS UNDER UNCERTAINTY

A Dissertation
Presented to
The Academic Faculty

by

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In Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy in the
School of Building Construction

Georgia Institute of Technology
May 2012

A REAL OPTIONS MODEL FOR THE FINANCIAL VALUATION OF INFRASTRUCTURE SYSTEMS UNDER UNCERTAINTY

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Date Approved: March 14, 2012

Dedicated
To
My Mother Nahid
and
My Father Ahmad

ACKNOWLEDGEMENTS

I would like to express my gratitude to my advisor, Dr. Baabak Ashuri, for his insightful guidance, encouragement, dedication and patience throughout my graduate studies. Working with him has been an invaluable lifetime experience for me. His technical and editorial advice was essential to the completion of this dissertation and has taught me innumerable lessons and insights on the workings of academic research in general.

I would like to thank the members of my doctoral examination committee, Dr. Daniel Castro-Lacouture, Professor Kathy Roper, Dr. Keith Molenaar, Dr. Adjo Amekudzi and Mr. Darryl VanMeter. They provided many valuable comments that helped me improve the contents and presentation of this dissertation.

The friendship of Jian Lu, Mohsen Shahandashti and Kia Mostaan is much appreciated and has led to many interesting and good-spirited discussions relating to this research.

Thanks are also extended to all the faculty members at the School of Building Construction. Thanks are also due to Lorie Wooten, Jacquelyn Strickland and Brenda Morris for their administrative support.

Finally, I would like to thank my parents, Nahid and Ahamd, for all their love and encouragement. They raised me, taught me, loved me and supported me in all my pursuits. They receive my deepest gratitude and love.

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GLOSSARY OF KEY TERMS

AADT	Annual Average Daily Traffic, total volume of vehicles passing through a highway in a year divided by 365
BOT	Build-Operate-Transfer, a project delivery method
Greenfield Project	A new project, a project that is not an extension, an upgrade or a change to an existing project
Minimum Revenue Guarantee	Or MRG, a mechanism that guarantees a minimum traffic revenue value
PPP	Contractual agreements formed between a public agency and a private sector entity that allow for greater private sector participation in the delivery and financing of infrastructure projects
Project Volatility	Measures the uncertainty about project value over time
Revenue Risk	Risk associated with the adverse possibility that the project may not generate revenue that is adequate to pay the project costs, service the debt, and generate the investors' expected rate of return
Traffic Revenue Cap	Or TRC, a mechanism for sharing surplus traffic revenue when the traffic demand grows significantly beyond the projected levels

SUMMARY

Many governments confront a gap between the rising demand for transportation infrastructure systems and the financial resources that they have historically used for meeting this demand. They are seeking innovative solutions to close this growing gap between the cost of much needed transportation infrastructure systems and their available financial resources. The Public-Private Partnership (PPP) model is growingly adopted by governments in order to achieve these objectives.

Build-Operate-Transfer (BOT) is a form of PPP model that is commonly used for financing, development, and operations of transportation projects. In a BOT project, the private partner, known as the concessionaire, has the responsibility to finance, design, build and operate a facility for a specific period of time under a concession contract. The concessionaire typically raises return on its investment through the user charges.

During their life cycle, BOT projects are subject to a variety of risks. The effective mitigation of these risks is a key factor in successful delivery of BOT transportation projects. Private investors consider traffic revenue risk, which is stemmed from the uncertainty about the future traffic demand, as one of the most important factor when they assess the feasibility of a BOT transportation project. They often demand that the government partially assume the traffic revenue risk and compensate them if the traffic demand falls short of the projections. In order to encourage private investments in BOT transportation projects, governments typically agree to provide revenue risk sharing mechanisms such as Minimum Revenue Guarantee. In addition to Minimum Revenue Guarantee, a mechanism known as Traffic Revenue Cap may also be negotiated between

the concessionaire and government. It makes the government entitled to a share of revenue when it grows beyond a specified threshold. The combination of the Minimum Revenue Guarantee and Traffic Revenue Cap provisions creates a risk and revenue sharing mechanism between the government and the concessionaire.

BOT participants need a proper valuation method to determine the market value of Minimum Revenue Guarantee and Traffic Revenue Cap mechanisms and avoid under- and over-investments in transportation projects The conventional valuation methods are not capable of integrating the uncertainty about future traffic demand in the valuation of BOT projects. They also have no capacity to determine the impact of Minimum Revenue Guarantee and Traffic Revenue Cap mechanisms on the financial value of the BOT project and establish the market value of these mechanisms. This situation presents a research opportunity to create new valuation methods that provide the participants in BOT projects with proper tools for structuring appropriate risk and revenue sharing instruments such as Minimum Revenue Guarantee and Traffic Revenue Cap. Recognizing the need, this research focuses on the creation of a real options valuation model that can capture the traffic demand uncertainty and accurately price the Minimum Revenue Guarantee and Traffic Revenue Cap options in BOT projects.

The body of knowledge on the application of real options in transportation infrastructure management is still growing. Prior research has focused on the definition and analysis of various kinds of options on transportation projects. However, after analyzing the literature on the application of real options in transportation infrastructure management, it was concluded that the existing models are subject to significant limitations.

The current literature on the application of real options in transportation infrastructure management does not provide a systematic method for estimating the project volatility, which is the most critical input to real options valuation models and measures the uncertainty about project value over time.

Moreover, when it comes to the valuation of real options in transportation projects, it is typically impossible to estimate the correct risk-adjusted discount rate that reflects the market risks, unique project risks and asymmetric benefit patterns of options. The existing literature on the application of real options in transportation infrastructure management does not address this problem. Due to these limitations, the application of current real options models to the valuation BOT investments under traffic demand uncertainty does not lead to the determination of market value of real options.

Furthermore, the current real options models do not determine the concessionaire's financial risk profile under traffic demand uncertainty. Finally, the current models cannot characterize the impact of Minimum Revenue Guarantee and Traffic Revenue Cap options on the concessionaire's financial risk profile.

The primary objective of this research is to apply the real options theory in order to explicitly price Minimum Revenue Guarantee and Traffic Revenue Cap under the uncertainty about future traffic demand. This research objective is achieved through the creation of an investment valuation model for BOT transportation projects under traffic demand uncertainty. This model characterizes the long-term traffic demand uncertainty in BOT projects and determines the concessionaire's financial risk profile under uncertainty about future traffic demand. Moreover, it utilizes a novel method for estimating the project volatility for real options analysis. Further, the model uses a market-based option

pricing approach to determine the value of Minimum Revenue Guarantee and Traffic Revenue Cap options. Finally it presents the appropriate procedure for characterizing the impact of Minimum Revenue Guarantee and Traffic Revenue Cap options on the concessionaire's financial risk profile. In order to illustrate the proposed model and highlight its capabilities of the model presented in this research, it is applied to the Incheon International Airport Highway (IIAH) project in the Republic of Korea.

This research contributes to the body of knowledge on the application of real options in transportation infrastructure management. It presents an approach that combines Monte Carlo simulation and the stochastic processes, and can be used for estimating the project volatility. Moreover, it presents a market-based risk-neutral option pricing approach in order to determine the fair value of Minimum Revenue Guarantee and Traffic Revenue Cap mechanisms in BOT projects.

The proposed model can help public and private sectors better analyze and understand the financial risk of BOT projects under traffic demand uncertainty. The private sector can use this model to make better entry decisions to BOT highway projects considering their expectations about the costs and risks of the project as well as the level of revenue guarantee provided by the government. The government can use this model to identify the appropriate Minimum Revenue Guarantee and Traffic Revenue Cap thresholds that encourage the private investments without compromising its future budgetary strength.

CHAPTER 1   INTRODUCTION

Research Background

Modern and efficient transportation infrastructure systems are necessary

preconditions for successful and sustainable economic growth. In many countries, a

significant part of the financial resources required for the development and modernization

of transportation infrastructure systems has traditionally been provided by the

government. However, the ability of most governments to meet the rising demand for

infrastructure is becoming more and more constrained. Governments have limited

financial resources and typically face restrictions on their ability to raise debt in order to

provide the funding required for development of new projects and modernization and

maintenance of existing transportation infrastructure systems.

In the United States, for instance, the needs for expanding and repairing the

Nation's network of roads, bridges, and tunnels have been constantly escalating over the

past decades (Office of Policy and Governmental Affairs 2007). According to the Report

Card for America's Infrastructure (ASCE 2009), 33% of America's major roads are in

poor or mediocre condition and 36% of the nation's major urban highways are congested.

As a result, more than 4.2 billion hours a year are wasted in traffic, at a cost of $78.2

billion per year. The Federal Department of Transportation (DOT) and State DOTs are

unable to keep up with the rapidly rising demand for transportation infrastructure by

relying on their traditional sources of funding. A variety of issues such as changing

economic conditions, a delayed federal transportation reauthorization bill, and the

declining value of the fuel tax, have affected the ability of transportation agencies to

provide adequate budget for building new capacity and performing the necessary

maintenance on existing infrastructure (Rall et al. 2010). In other words, there is a growing gap between the costs of preserving, modernizing, and expanding the transportation infrastructure and the funding available to transportation programs. According to National Surface Transportation Infrastructure Financing Commission (2009), the surface transportation system in the U.S. is in financial crisis and the annual average funding gap between 2008 and 2035 is expected to be approximately $138 billion. Likewise, in many countries worldwide, the governments' traditional funding sources are insufficient in providing steady, reliable investment budgets that can finance construction, maintenance and expansion of the highway systems (Davies and Eustice 2005).

The economic costs of inadequate transportation infrastructure systems are enormous. Transportation infrastructure systems are important components of the economy impacting the development and welfare of populations. When transportation systems are efficient, they provide economic and social opportunities and benefits that result in positive multipliers effects such as better accessibility to markets, employment and additional investments. When transport systems are deficient in terms of capacity and reliability, they can have an economic cost such as reduced or missed opportunities (Rodrigue et al. 2009).

The Public-Private Partnership (PPP) model can help close the growing gap between the costs of preserving and expanding the transportation infrastructure and the funding available to transportation programs by increasing the involvement of the private sector in the delivery of transportation infrastructure and services. The Federal Highway Administration (2008) defines PPP as "contractual agreements formed between a public

agency and a private sector entity that allow for greater private sector participation in the delivery and financing of transportation projects." Through this agreement, the skills and assets of each sector (public and private) are shared to deliver the service or facility to the public. In addition to resources, each party shares the inherent risks of PPP projects. The PPP method has been used in both the developing and developed countries for delivering transportation projects.

According to the World Bank's Private Participation in Infrastructure Projects Database (2012), the private investment commitment to transportation projects in developing countries has been growing on average since 1990. Figure 1.1 shows the annual flow of private capital into the transportation projects in developing countries.
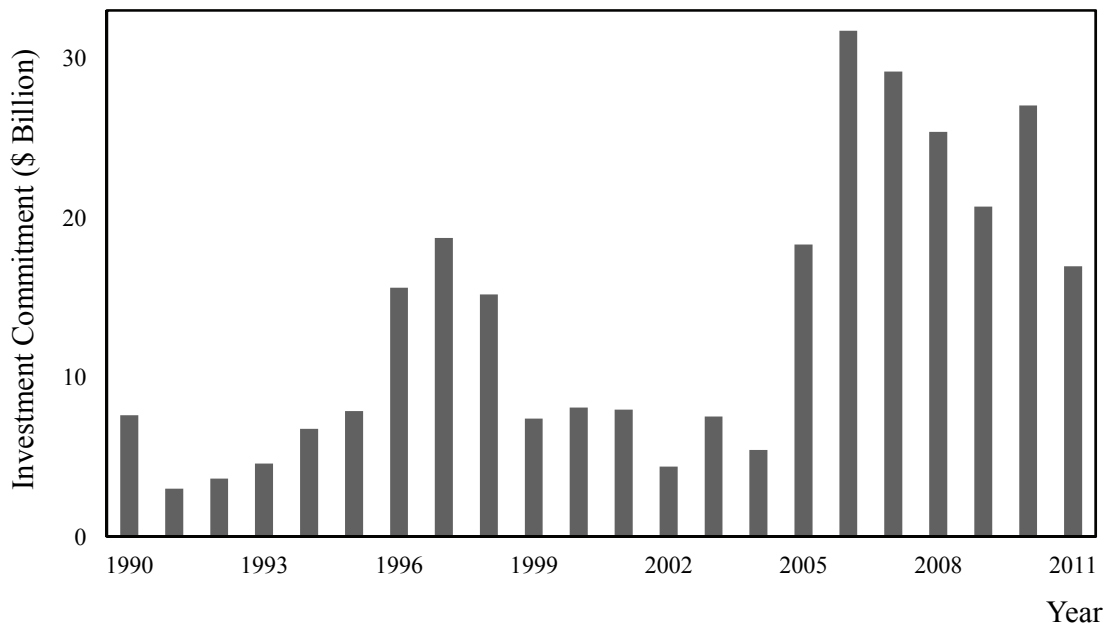
Figure 1.1 Transport project investments by private sector in developing countries
(Source: World Bank)

The use of PPP model is not limited to the developing countries. Some developed

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countries such as the United Kingdom, Australia, Canada, and the United States have also

utilized the PPP model for delivering the transportation projects. For instance, in the

United States, the Transportation Infrastructure Finance and Innovation Act (TIFIA),

which was enacted in 2000, encourages new revenue streams and private participation for

the infrastructure development. The act was in order to leverage limited federal resources

and stimulate private capital investment by providing credit assistance in the form of

direct loan, loan guarantees, and standby lines of credit to projects of national or regional

significance (United States Department of Transportation 2002).

A common form of implementing PPP in transportation is the Build-Operate-

Transfer (BOT) method. The major aim of BOT is to utilize the private sector's financing

resources as well as operations expertise in the delivery of public services. Through the

BOT model the government, and a private entity, called the "concessionaire", enter into

an agreement where the concessionaire is responsible to finance, design, build, operate

and maintain a transportation project on behalf of the government for a predetermined

period of time that is called the "concession period". At the end of the concession period,

the concessionaire transfers the ownership rights back to the government. The

concessionaire covers its costs and also makes a return on investment, either from a

revenue stream generated by the project (e.g., traffic revenue) or from the compensation

by the government.

Instead of corporate loans, the concessionaire typically finances a BOT project

through project finance (Yescombe 2002). This implies that the lenders play a key role in

the delivery of transportation projects using the BOT model. The key BOT participants

have different stakes in the BOT project. The government is mostly concerned with the

political and socio-economic feasibility of the project; the concessionaire is mostly concerned with the financial viability of the project while the lenders are only concerned with appraises the concessionaire's capacity to service its debt. Therefore, in the BOT model, the interrelationships among different participants are very complex. The critical success factor for a BOT project is the efficient and effective allocation of project risks and returns among different project participants (Lu et al. 2000).

Despite the promising features of the BOT model for developing transportation infrastructure, its implementation has not been without trouble. There are numerous examples of the financial failure of BOT transportation projects. One of the most infamous cases of failure occurred in Mexico, where the Mexican government had to take over 23 troubled BOT road projects. The Mexican government paid approximately $5 billion in outstanding debt to Mexican Banks and approximately $2.6 billion to construction companies (Hodges 2006). Similar instances have occurred in many other countries including Hungary and Thailand (Cuttaree 2008). These failures may diminish the willingness of governments and private investors to participate in BOT transportation projects and create a "lose-lose" situation. In this situation, governments lose the opportunity to expand, modernize, or rehabilitate the transportation infrastructure systems, while private sector participants (e.g., contractors, lenders, management companies) miss the opportunity to create value for their shareholders.

The financial failure of many BOT projects during the operations phase is generally attributed to two major issues (Cuttaree 2008; Queiroz 2007):

1. Improper consideration of the significant uncertainty about future traffic demand in the financial valuation of BOT projects; and

2. Inefficient traffic risk and revenue sharing mechanisms between the public and private sectors.

These issues can be traced to the methods used for the financial valuation of BOT projects. Traditionally, Discounted Cash Flow (DCF) techniques and most notably the deterministic Net Present Value (NPV) analysis have been used for estimating the value of investment in the assets that are not actively traded in the markets including highway projects (Cheah and Garvin 2009). These conventional methods work only when the uncertainties and risks across the lifespan of an investment remain relatively stable. Therefore, they are unable to properly evaluate BOT transportation projects since they do not explicitly capture and treat the evolving project uncertainties including the uncertainty about future traffic demand, which has been identified by several researchers as the significant source of revenue risk during the operations phase of BOT projects (Brandão and Saraiva 2008; Chiara et al. 2007; Cuttaree 2008; Garvin and Cheah 2004; Ho and Liu 2002; Lu et al. 2000; Zhao et al. 2004). There are increasing concerns about the validity of results and the reliability of using a conventional NPV analysis approach for financial evaluation of BOT highway projects. If the NPV approach was used as a basis of decision-making for a BOT project, the financial solvency of the project and creditworthiness of the concessionaire could results in project failure. Hence, Kaka and AlSharif (2009) indicate that there is a pressing need for developing nondeterministic methods for the proper valuation of BOT transportation projects.

One of the most significant risks in a BOT transportation project is the revenue risk which is stemmed from the uncertainty about the future traffic demand. Revenue risk is defined as the adverse possibility that the project revenue from traffic may not be

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sufficient to cover the project costs, to service the debt, and to generate the concessionaire's expected return on investment. Considering the uncertainty about future traffic demand, the private investors often request government support instruments that are designed to mitigate the revenue risk.

One of the most common forms of government support instruments is Minimum Revenue Guarantee. By offering Minimum Revenue Guarantee, the government guarantees a specific level of revenue for the concessionaire during the concession periods and covers some or all of revenue shortfall when, due to insufficient traffic demand, the traffic revenues are lower than projected levels (Mandri-Perrott 2006). Hence, Minimum Revenue Guarantee is a mechanism for sharing the revenue risk between the concessionaire and government. In cases that the government shares the revenue risk with the concessionaire, a mechanism can be applied to share the surplus traffic revenue when the traffic demand grows significantly beyond the projected levels. This mechanism is often referred to as Traffic Revenue Cap (TRC).

Since traffic revenue risk can prevent the successful implementation of a BOT project, proper risk mitigation through appropriate risk and revenue sharing mechanisms such as Minimum Revenue Guarantee and Traffic Revenue Cap has strategic relevance for both the government and private investors in a BOT project. BOT participants need a proper valuation method to determine the market value of Minimum Revenue Guarantee and Traffic Revenue Cap mechanisms and avoid under- and over-investments in transportation projects. The conventional valuation methods are not capable of integrating the uncertainty about future traffic demand in the valuation of BOT projects. They also have no capacity to determine the impact of Minimum Revenue Guarantee and

Traffic Revenue Cap mechanisms on the financial value of the BOT project and establish the market value of these mechanisms. This situation presents a research opportunity to develop new valuation methods that provide the participants in BOT projects with proper tools for structuring appropriate risk and revenue sharing instruments. Recognizing the need, this research focuses on development of a real options valuation model that can capture the traffic demand uncertainty and accurately price the Minimum Revenue Guarantee and Traffic Revenue Cap mechanisms in BOT projects.

State of Knowledge

The body of knowledge on the application of real options in transportation infrastructure management is still growing. Prior research has focused on the definition and analysis of various kinds of options on transportation projects in order to only demonstrate that the application of real options analysis in transportation infrastructure development and management can lead to valuable outcomes. Ho and Liu (2002) present an option pricing model for evaluating the impact of the government's guarantee and the developer's negotiation option on the financial viability of privatized infrastructure projects. Zhao et al. (2004) develop a multi-stage stochastic model for decision-making in highway development, operations, and rehabilitation, which considers three sources of uncertainty, namely, future traffic demand, land price, and highway deterioration, as well as their interdependencies. Garvin and Cheah (2004) use an option pricing model to capture the strategic value of project deferment for The Dulles Greenway project. Cheah and Liu (2006) use Monte Carlo simulation methodology to evaluate government guarantees and subsidies as real options and apply it to the case of the Malaysia-Singapore Second Crossing. Huang and Chou (2006) develop a compound option pricing

formula for the Taiwan High-Speed Rail Project. Minimum Revenue Guarantee options combined with the option to abandon in the pre-construction phase are evaluated as a series of European style call options in their work. Chiara et al. (2007) model governmental guarantees on BOT projects as one of three discrete-exercise real options: European, Bermudan, and simple multiple-exercise (Australian) options, and expand the least-squares Monte Carlo technique to value these guarantees. Brandao and Saraiva (2008) present a real options model for evaluating highway projects with minimum traffic guarantees, and apply it to the 1000 mile BR-163 toll road project that links the Brazilian Midwest to the Amazon River. The real options model proposed in this study upon and contributes to this body of knowledge by overcoming the key limitations of the current real options model.

Gaps in Knowledge

The appropriate application of real options analysis to valuation of investments in transportation projects is conditioned upon overcoming the specific limitations of the existing real options models. These limitations are discussed below.

Estimation of the Project Volatility for Real Options Analysis

Uncertainty is the key driver of the value of real options (Benaroch et al. 2006; Bräutigam et al. 2003). Thus, one of the most critical inputs to any real options valuation models is the project volatility that measures the uncertainty about project value over time. For investments in transportation infrastructure projects, it is very difficult to estimate the project volatility directly or using proxies. Transportation infrastructure

projects are unique and there is no relevant data on historical or current market prices of the transportation projects that can be used as the basis for project volatility estimation. The current literature on the application of real options in infrastructure management does not provide a systematic method for estimating the project volatility and often prescribes the use of assumptions. Therefore, the application of the current real options models to the valuation of investments in BOT projects under the uncertainty about future traffic demand can lead to an erroneous valuation. There is a pressing need for a method that can systematically estimate the project volatility for pricing real options such as Minimum Revenue Guarantee and Traffic Revenue Cap in BOT transportation projects.

Finding the Market Value of Real Options in Transportation Project

In order to determine the price of an option, the benefits resulted from exercising the option should be discounted at an appropriate risk-adjusted rate. The risk-adjusted discount rates for options vary widely depending on a several factors including the volatility of project due to various market and project risks. When it comes to the valuation of real options in transportation projects, it is typically impossible to estimate the correct and exact risk-adjusted discount rate that reflects the market risks, project risks that are unique to these projects and asymmetric benefit patterns of options (Brigham and Ehrhardt 2011; Ford et al. 2002). The existing literature on the application of real options in transportation infrastructure management does not address this problem and typically suggest the use of approximate discount rates for real options valuation. This approach can lead to the inaccurate pricing of real options. There is a need for an

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appropriate method that can overcome this challenge and determine the market value of options such as Minimum Revenue Guarantee and Traffic Revenue Cap in BOT projects.

Characterizing the Concessionaire's Risk Profile under Uncertainty

Existing real options models do not address several critical questions when it comes to the valuation of investments BOT project under traffic demand uncertainty. These models do not determine the concessionaire's financial risk profile under uncertainty about future traffic demand in a BOT project. Existing models cannot characterize the impact of Minimum Revenue Guarantee and Traffic Revenue Cap options on the concessionaire's financial risk profile. Also, current models do not determine the likelihood of Minimum Revenue Guarantee payment to the concessionaire as well as the likelihood of Traffic Revenue Cap payments to the government. There is a need for an appropriate real options valuation model that can characterize concessionaire's risk profile under traffic demand uncertainty and, also, enhance the understanding about the impact of Minimum Revenue Guarantee and Traffic Revenue Cap mechanisms on the concessionaire's investment value.

Research Objectives

The primary objective of this research is to apply the real options theory in order to price Minimum Revenue Guarantee and Traffic Revenue Cap risk and revenue sharing mechanisms under the uncertainty about future traffic demand. The specific research objectives that will be addressed in this research are as follows:

1. Model the long-term traffic demand uncertainty in BOT projects;

2. Devise an appropriate method for estimating the project volatility for real options analysis;

3. Devise an appropriate method for finding the market value of Minimum Revenue Guarantee and Traffic Revenue Cap options in BOT projects; and

4. Create a procedure for characterizing the impact of Minimum Revenue Guarantee and Traffic Revenue Cap options on the concessionaire's financial risk profile.

Organization of Dissertation

In order to achieve the objectives of this research, the rest of this dissertation is organized as below.

Chapter 2 provides a review of relevant literature. The comprehensive literature review covers two main research threads: PPP and specifically BOT model for delivering transportation infrastructure and options theory.

Chapter 3 describes the research methodology, discusses theoretical foundation of the proposed approach and explains the real options model creation approach. The unique features of the proposed real options model that differentiate it from existing models are also discussed.

Chapter 4 presents the application of proposed real options valuation model to Incheon International Airport Highway (IIAH) project in Republic of Korea. The valuation processes are illustrated in this chapter and a summary of results are provided.

In Chapter 5 limitations of the proposed real options model and implementation barriers to its application are discussed and recommendations for further research in order to overcome these limitations and barriers are presented.

Chapter 6 provides the conclusion of this research and highlights its contributions.

CHAPTER 2   LITERATURE REVIEW

The relevant topics covered in the literature review are the Public-Private Partnership (PPP) model, investment valuation and real options theory. The literature review starts with an introduction to the concept of Public-Private Partnerships. Several potential benefits of transportation PPPs for the public sector as well as the public interest are discussed. Moreover, some of the potential concerns related to transportation PPP projects are briefly reviewed. The commonly-used sources of financing and the general patterns for financing PPP project are introduced next. In addition, a brief description of the most common types of PPP contracts is provided in this chapter. Public-Private Partnership transportation projects typically have a BOT type of arrangement. Therefore, an overview of structure of BOT transportation projects along with a brief introduction to BOT key participants is presented. During its life cycle, a BOT transportation project is exposed to various risks. Different categories of BOT these risks are introduced and the traffic revenue risk, which is one of the most significant risks in a BOT transportation projects, is highlighted. Minimum Revenue Guarantee, which is a mechanism for sharing the traffic revenue risk between the government and the concessionaire, is also introduced in this chapter. In the cases that the government shares "downside" traffic revenue risk with the concessionaire through a Minimum Revenue Guarantee mechanism, an arrangement for sharing the "upside" potential between the concessionaire and the government may also be negotiated. This can be achieved by considering a Traffic Revenue Cap. There is need for an appropriate method to price these mechanisms. The limitations of conventional valuation methods in pricing

Minimum Revenue Guarantee and Traffic Revenue Cap mechanisms are specified. These limitations can be overcome by using a different approach for evaluating investments under uncertainty that is called Real Options. An analysis of the literature on the application of real options in transportation infrastructure systems is provided and the limitations of existing real options models are identified.

Public-Private Partnership (PPP)

Concept of Public-Private Partnership

Across the globe, many public authorities face constant demand for developing new transportation infrastructure projects and for funding the renewal, maintenance and operation of existing transportation systems. Competition for securing the financial resource in order to satisfy the transportation infrastructure demand is very intense. Transportation infrastructure projects should not only compete with each other to secure funds, but they should also compete with other projects that demand public sector finance. This creates large and growing gap between transportation infrastructure needs and the resources that governments can invest in maintaining, expanding and modernizing these systems. Many countries confront this transportation infrastructure deficit that is demonstrated by evidences such as congested roads and bridges in urgent need for rehabilitation and repair.

These problems in turn impose considerable costs on the society and a cause a variety of issues from lower productivity and reduced competitiveness to an increased number of accidents (Rodrigue et al. 2009). This has forced the governments to explore alternative approaches to finance transportation infrastructure systems (Latham and

Trombka 2010). Since the late 1980s, Public-Private Partnerships (PPP) have attracted

much attention in various countries as a possible means that the governments can utilize

to close infrastructure gaps, contribute to the economic integration, accelerate economic

growth and sustainable development, and expand local access to international markets

(Office of Policy and Governmental Affairs 2007). Numerous examples of PPP

transportation projects exist worldwide. In the United States, 24 states and the District of

Columbia have so far used PPP process to help finance and deliver at least 96

transportation projects worth a total $54.3 billion (Reinhardt 2011). The use of PPP

model has expanded the range of capital sources that can be used for financing

infrastructure transportation projects (Figure 2.1).
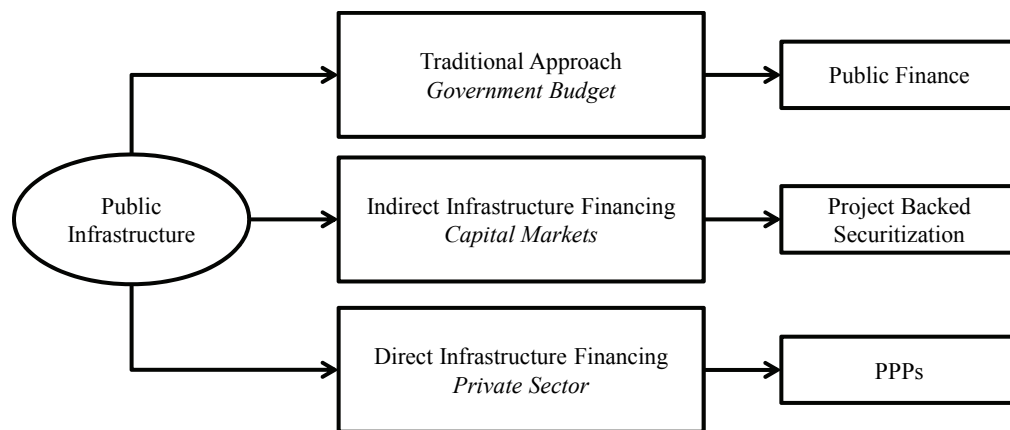
Figure 2.1 Capital sources currently utilized for financing transportation infrastructure

The Federal Highway Administration (2008) defines PPP as "contractual

agreements formed between a public agency and a private sector entity that allow for

greater private sector participation in the delivery and financing of transportation

projects." Through this agreement, the resources and capabilities of the private sector

such as financial assets, efficient management, propensity to innovative and entrepreneurship are combined with the resources of the public sector in order to achieve efficiency levels that are superior to an entirely public or entirely private project (Valila 2005).

PPP contracts are generally long-term contracts with duration increasing with the level of financial involvement of the private sector in the provision of investments. In addition, PPP projects are often large in magnitude and face complex risks beyond the scope normally experienced in typical construction projects. To ensure the success of a PPP, the project risks should be borne by the party that can manage it best. For this reason, in PPP projects many of the risks traditionally borne by the government are transferred to the private investors. The private investors want to be assured that the PPP project can provide competitive rates of return commensurate with a financial rate of return similar to alternative projects of comparable risk. Therefore, before entering into contractual arrangements, they appraise the risks involved in the project. If the level of such risks are very high and appropriate risk mitigation mechanisms are not available, they will likely withdraw from the project (Esty 2003; Yescombe 2002). In other words, participation of the private investors in PPP projects is conditioned upon the appropriate mitigation of the project's risks. This implies that risk management and risk mitigation play a central role in initiation and successful realization of PPP infrastructure projects.

Potential Benefits of Public-Private Partnerships

Public-Private Partnerships present numerous advantages both for the public partner and the private partner. Through PPP projects, the private sector can get access to new investment opportunities in various sectors, increase the business activities, enjoy better margins and get more long-term revenues (Shaoul 2009). The implications for governments have been getting much more attention in the literature (Alexandersson and Hultén 2010). By using PPP arrangements governments can address the common issues often associated with public sector procurement including constrained budget, high construction costs, time overruns, operational inefficiencies, poor design and community dissatisfaction (Feigenbaum 2011; Latham and Trombka 2010; Mustafa 1999). The advantages for the public partner may be summarized into the following broad areas:

Project Funding

Public-Private Partnerships offer alternative ways to fund and deliver the projects that otherwise would not be built due to the limitation of funding available through conventional sources (Feigenbaum 2011). PPPs provide the potential to utilize the private sector capabilities to provide more favorable financing options and to secure such financing in a much quicker timeframe (National Council for Public-Private Partnerships 2003). Therefore, governments can use PPPs to deliver much needed transportation infrastructure, control their borrowing, and maintain the sustainability of their financial position (Heller 2005; The World Bank 2005). In addition, PPP contracts sometimes stipulate a large upfront payment that local officials can use to close budget gaps or free up resources for other needs(Partnerships British Columbia 2003).

Public-Private Partnerships enable better allocation of public resources over time. Using PPPs, the costs of various infrastructure investments can be spread over the lifetime of the assets. This allows infrastructure projects to be delivered years earlier compared with the pay-as-you-go financing typical of many infrastructure projects (Alexandersson and Hultén 2010; Deloitte Research 2011). Finally, it is expected that the involvement of private sector in the financing of transportation infrastructure systems will increase fiscal accountability and transparency, reduce corruption and create incentives for the prudent management of public expenditure (Shaoul 2009; United Nations 2000).

Quality

By using the Public-Private Partnership contracts, governments can utilize the private sector expertise, innovation and efficiency in the development of infrastructure systems (Shaoul 2009). Transportation infrastructure projects are typically complex; the private sector carries special expertise that can be utilized effectively in order to improve the project quality. PPP arrangements can also provide the potential to maximize the use of innovative technology and the ability to select the best materials in order to improve the quality of a project (Latham and Trombka 2010). The government can regulate the level of service quality that the facility provides to the public by incorporating satisfaction metrics and performance-related payments into the contract. These measures incentivize the private partner to improve the service quality and maintain the asset according to highest standards (Alexandersson and Hultén 2010; Shaoul 2009). Finally, during the operation phase, the competition for higher market share creates additional incentives for improved quality by means of entrepreneurial development and innovation

(Emecheta 2010).

Project Costs

Typically, PPP contracts encompass a wide range of activities including financing, design, construction, and operations and maintenance provision. When there is a single point of responsibility for these activities, there are opportunities to achieve better overall solutions and exploit economies of scale in order to reduce the costs (Emecheta 2010; Hart 2003). In addition, government may occasionally encounter specific types of project that need specialized knowledge or technology. In such cases, the cost reduction may also be achieved through the use of specialized technology, knowledge and expertise held by the private sector firms regarding these projects.

Risk Sharing

Project contracts should be designed so that each risk associated with the project is allocated to the partner best suited to handle it. Compared to the public sector, the private sector is typically more capable of managing most of the project risks (Latham and Trombka 2010; Shaoul 2009). By using the Public-Private Partnership model, a government can reduce its exposure to these risks by transferring them to the private sector, which will act vigorously to safeguard the profitability of the project (Emecheta 2010). Nevertheless, specific risks such as policy changes and natural disaster can still be better managed by the public sector. There are also some risks that neither the government nor the private sector can fully control. These risks are typically shared by both partners including the demand risk (Alexandersson and Hultén 2010). Allocating risk to the party best able to manage it reduces the likelihood that each project risk will

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materialize, thus reducing the overall project risk. In addition, the up-front consideration of risk in a PPP agreement may also facilitate less costly and timely risk mitigation (Rall et al. 2010).

Project Delivery Schedule

Public-Private Partnerships have a solid track record of on-time as well as on-budget delivery (Deloitte Research 2011; HM Treasury 2003; Price 2000; Shaoul 2009). The results of research on 12 completed, large-scale (greater than $100 million) PPP transportation projects in North America indicate the schedule overruns for the PPP sample averaged -0.44%, compared to 11.04% schedule overruns for design-build projects and 4.34% schedule overruns for publicly funded large-scale design-bid-build highway projects (Chasey et al. 2012). Also, according to a British study, only 24% of all new PPP projects are running late, compared to 70% of the public projects (National Audit Office 2003).

The reason is that, in a PPP project, there is a single point of responsibility for activities such as design and construction. Therefore, these activities may be carried out in parallel rather than sequentially in order to shorten the project's completion time (Alexandersson and Hultén 2010). Incentives such as the possibility of generating revenues from operating the completed facility as well as other contractual mechanisms may also provide motivations to expedite the project delivery.

Life-cycle Efficiency

Public-Private Partnerships can lower the cost of infrastructure systems by reducing overall life-cycle costs (Latham and Trombka 2010; Rall et al. 2010). Using

PPP model facilitates an integrated approach to project delivery in which a single entity is responsible for multiple project phases such as design, construction, operations and maintenance. In theory, this gives the private investors the incentive to reduce costs across a facility's entire lifecycle through a variety of means such as innovative design that reduces construction costs, high-quality project delivery that lowers the cost of maintenance and improvements, or maintenance that avoids costly rebuilds and rehabilitations during the facility lifecycle.

Moreover, since the private sector is often responsible for the design, construction and future service of a project, the public can be assured that the project goals are reached and kept in line with the price agreed upon at the time of signing the contract (Partnerships British Columbia 2003). This can reduce the possibility for large unexpected cost increases across a facility's entire lifecycle. In fact, evidence suggest that, compared to the projects executed by the public sector, PPP projects stay within their estimated budgets far more often (Alexandersson and Hultén 2010).

Concerns Related to the Utilization of Public-Private Partnerships

Public-Private Partnerships projects are typically complicated projects. Typically, these projects are long-term investments with two distinct phases in their lives; the development phase and the operation phase. These two phases are very different in character and may involve different challenges. Experts have identified several potential concerns related to the utilization of PPP for delivering transportation infrastructure systems. Some of these concerns pertain to the increased private sector involvement in various aspects of the project. Many of these concerns can be addressed by well-crafted

enabling legislation and contract terms, or through meticulous project evaluation and selection, procurement, and oversight.

Loss of Public Control and Flexibility

Typically, Public-Private Partnerships contracts require the long-term commitments of the involved public and private parties. No contract can be crafted well enough to predict the public's long-term demand and contingencies. Therefore, many experts warn that PPP agreements may reduce the government's flexibility to make necessary policy adjustments since there is a concern that such changes may affect the PPP project. In addition, some critics are concerned that the long-term commitment of the government to the PPP contract can be exploited strategically by the private investors seeking renegotiation or contract termination. Another issue that raises concerns about potential loss of public control is the non-compete clauses that sometimes incorporated in the PPP contracts. These clauses prohibit or limit the potential for developing new transportation facilities that may draw traffic from the PPP project. They can place the government in a potentially disadvantageous position by limiting its ability to develop the infrastructure system in response to the changes in demand over time (Alexandersson and Hultén 2010; Emecheta 2010; Rall et al. 2010).

Private Profits at the Expense of Public

Critics have also expressed concerns that private sector participants in Public-Private Partnership projects may seek a profit at the expense of public. The concern is that the private partner may skip required maintenance and repairs to boost profits or force compensation for lost revenues due to competing public transportation facilities.

There are also concerns that the PPP contracts give private partners too much discretion to raise toll rates and enforce high fees. Another related concern is related to the unsolicited PPP project. There is a concern that unsolicited bids encourage public agencies to give higher priority to projects that are more profitable to private investors rather than those projects that are the most beneficial to the public (Rall et al. 2010)..

Risk of Bankruptcy or Default

There are also concerns about the way the private partner's default affects the government. Problems can arise in cases where the government is owed money at the time of default or the cases where the government is at financial risk since it has guaranteed the private investors' loans (Emecheta 2010; Rall et al. 2010).

Transparency

Transparency is mostly concerned with providing the legislators and the general public with adequate opportunities to review the project and actively participate in the decision-making process. The challenge is to keep a balance between maintaining confidentiality during the proposal review process in order to protect the proprietary information provided by bidders and providing adequate information to stakeholders regarding the implications of accepting each proposal (Priemus and Flyvbjer 2008; Rall et al. 2010)

Environmental Issues

There are concerns that Public-Private Partnerships may not sufficiently safeguard the environment. For instance, one concern is that the private entities may choose less costly construction and maintenance methods that may be harmful to the environment.

There are also concerns that the use of private financing may exempt the PPP projects from environmental protections laws and regulations such as the National Environmental Policy Act (NEPA) in the U.S. that are only enforceable to publicly-funded projects (Rall et al. 2010).

Sources of Financing in Public-Private Partnership Projects

Public-Private Partnership projects typically involve financing from various sources in some combination of equity and debt. This section presents a brief overview of the main sources of financing in PPP projects.

Debt

Debt financing involves borrowing the funds required for the project. The investment return for debt holders is limited to the interest earned on the principal. Debt can be obtained from many sources, including commercial lenders, institutional investors, export credit agencies, bondholders and sometimes the government. Though the returns for debt holders are limited to the interest, they have a senior claim to income and assets of the company or project. Different rights or claims to cash flow may also exist among different debt holders. Subordinated debt holders are junior to general or senior creditors and will only be paid once they have been satisfied (The World Bank 2011). Repayment of debt is generally tied to a fixed or floating rate of interest and a program of periodic payments. Below are some of the most common forms of debt financing.

1. *Bonds*: Bonds are long-term interest bearing debt instruments generally purchased by individual or institutional investors through the public capital markets. Therefore,

bond financing provides the ability to raise debt directly from investors in public capital markets, rather than using commercial lenders as intermediaries. There are many different institutional investors that purchase these bonds including pension funds, insurance companies, and fund managers. Typically, there is a manager that assists the borrower with the process of marketing the bonds. There is also trustee that holds rights and acts on behalf of the investors, stopping any one investor from independently declaring a default. Due to restrictions on investment mandates, many institutional investors may require a credit rating for the project from an independent credit rating agency(Gawlick 2007). Therefore, rating agencies often assess the riskiness of the project, and assign a credit rating to the bonds which will signal to bond purchasers the attractiveness of the investment and the price they should pay. Bond financing generally provides lower borrowing costs, if the credit rating for the project is sufficiently strong. Therefore, rating agencies are usually consulted to maximize the credit rating for the project. Bond financing provides a number of benefits to projects including lower interest rates, longer maturity and more liquidity(Gawlick 2007; The World Bank 2011).

2. *Commercial loans*: Commercial loans are funds that are lent by commercial banks and other financial institutions. Typically, these loans are securitized by the PPP project's underlying assets. While the financial strength of the borrower (i.e., project company or concessionaire) is often the principle basis for making decision on the structure of the loan, for PPP projects many financial institutions give greater consideration to a project's expected cash flow(Gawlick 2007). Commercial loans are usually considered as senior debt. Therefore, in the case of default, commercial loans

have the rights to project assets and cash over equity and subordinated debt holders.

3. Subordinated loans: Subordinated loans are secondary (subordinated) to commercial loans or other senior debt holders in their claim on assets but have the priority over equity. As a result, the rate of return on subordinated loans is higher than commercial or senior debt as the perceived risk is higher (Gawlick 2007).

Equity

Equity financing is long-term capital provided by an investor in exchange for shares, representing ownership in the company or project. Typically, the equity contributors to a PPP project are the project participants, the government, and third party private investors such as institutional investors and other governments. The equity contributions are typically in form of share capital and other shareholder funds. A key feature that distinguishes equity from debt is the holder's claim to assets. Equity contributors hold the lowest priority compared to other funding contributors to the project. Therefore, other contributors such as lenders will have the right to project assets and revenues before the equity contributors can obtain any return (Gawlick 2007; The World Bank 2011). In other words, in the event of default, equity holders' claim on the income and assets is secondary to debt holders. Equity contributors bear the highest risk. However, in exchange for taking higher risks, equity holders have unlimited potential returns compared to debt holders whose investment returns are limited to the interest earned on the debt.

Mezzanine

Placed somewhere between equity and debt in the capital structure of a PPP

project, mezzanine contributions are accorded lower priority than senior debt but higher

priority than equity (Gawlick 2007; The World Bank 2011). The utilization of mezzanine

contributions, which are typically characterized as quasi‑equity, allows the project

company to maintain greater levels of debt to equity ratio in the project, although at a

higher cost than senior debt (Gawlick 2007). Mezzanine financing can be received from

shareholders, commercial lenders, and institutional investors. Mezzanine contributors

will be compensated for the added risk they take either by receiving higher interest rates

on loans than the senior debt contributors and/or by receiving partial participation in the

project profits or the capital gains achieved by project equity (The World Bank 2011).

Examples of mezzanine contributions are subordinated agreements and preferred shares.

Subordination involves a lender agreeing not to be paid until another lender to the same

borrower has been paid, whether in relation to specific project revenues or in the event of

insolvency. Subordination can be achieved either by contract or through corporate

structuring. Preferred shares have a fixed rate dividend similar to a debt instrument

however, unlike debt, payment ultimately rests at the discretion of management and

failure to pay dividends will not force a company into default. However, dividends to

preferred shareholders must be paid out prior to any distributions to holders of equity. In

case of default, holders of preferred shares are junior to debt holders, but senior to

ordinary equity shareholders(Gawlick 2007).

Innovative Financing Mechanisms

In many cases, in addition to the commonly-used financing mechanisms available

in capital markets, various innovative financing mechanisms exist that can be utilized in

PPP projects. For instance, in the United States, innovate financing mechanisms such as

Transportation Infrastructure Finance and Innovation Act (TIFIA) federal credit

assistance, private activity bonds and state infrastructure banks provide the private

investors in transportation projects with access to low-interest or tax-exempt debt. These

mechanisms are intended to reduce the financing costs for private investors to levels that

are more competitive with state and municipal financing rates. Table 2.1 provides an

overview of the innovative finance mechanisms that can be utilized in PPP transportation

projects.

Table 2.1 Innovative financing mechanisms that can be utilized to support PPP
transportation projects (Source: AASHTO and FHWA)

Innovative Financing Instruments	Examples

Federal-Aid Fund Management Tools	• Advance Construction (AC) and Partial Conversion of Advance Construction (PCAC)
	• Federal-Aid Matching Strategies
	    Flexible Match
	    Tapered Match
	    Toll Credits (Soft Match)
	    Program Match
	    Third-Party Donations
	    Using Other Federal Funds as Match

Federal Debt Financing Tools	• Grant Anticipation Revenue Vehicles (GARVEEs) • Private Activity Bonds (PABs)
Federal Credit Assistance Tools	• Transportation Infrastructure Finance and Innovation Act (TIFIA) • State Infrastructure Banks (SIBs) • Section 129 Loans
Public-Private Finance Mechanisms	• Pass-Through Tolls / Shadow Tolling • Availability Payments
Other Mechanisms	• Non-Federal Bonding and Debt Instruments • Value Capture Arrangements such as Tax Increment Financing (TIF) • 63-20 Public Benefit Corporations

General Patterns of Financing Public-Private Partnership Projects

A significant portion of funds required for a PPP project is typically obtained through project financing. The term project financing essentially means "to finance a particular economic unit in which a lender is satisfied to look initially to the cash flows and earnings of that economic unit as the source of funds from which a loan will be repaid and to the assets of the economic unit as collateral for the loan" (Nevitt and Fabozzi 2000). The definition highlights three important features of project financing. First, the financing is carried out through an economic unit. In other words, project financing involves an organizational decision to create an economic entity that will assume the ownership of project. Second, debt service depends upon the cash flows generated through the operation of the project by the economic unit. This implies that all the relevant contracts are important to ensure the realization of anticipated cash flows. Third, liquidation is limited to the assets of the economic unit and, thus, debt financing is based on a non- or limited recourse basis (Ye 2009).

There are three patterns of financing PPP projects: financing based on a single-entity organizational structure, financing based on a two-entity organization structure and financing based on multiple-entity organization structure.

Financing Based on a Single-Entity Organizational Structure

In a single-entity structure for financing infrastructure projects, a single-purpose economic entity (e.g., project company or concessionaire) is established. The sole purpose of this economic entity is to develop the project. This entity, which acts as the client for both financing and management of the project, can be in form of an

incorporated company, a contractual joint venture, a partnership or a trust.

This economic entity enters into contracts with different project participants for the financing, design, construction and operation of the project. For instance, it may enter into a loan agreement with lenders in order to finance the project. Also, depending on the complexity of project and capabilities of the economic entity, the project can be operated by the economic entity or a specialized operator that is hired for this purpose. The majority of transportation projects are developed by companies that have the capabilities required for operating the project once the construction is over (Ye 2009).

Financing Based on a Two-Entities Organizational Structure

In a dual-entity structure, two economic units are established to carry out different tasks or different parts of a project (Figure 2.2). Various situations may force the utilization of a dual-entity structure. One of the common instances is when a project involves a lot of lenders/investors with different requirements. In these cases, one of the economic units will be responsible for financing (e.g. a trust borrowing vehicle) while the other will be responsible for managing the project (e.g. a project company). An economic entity is specially established as a borrowing vehicle to raise funds for the project so that the project company can avoid dealing with a lot of lenders/investors directly. Then the project company enters into a loan agreement with the borrowing vehicle. Similar to the mono-entity structure, the project company in a dual-entity structure may act as an owner– operator company or an owner company (Ye 2009).
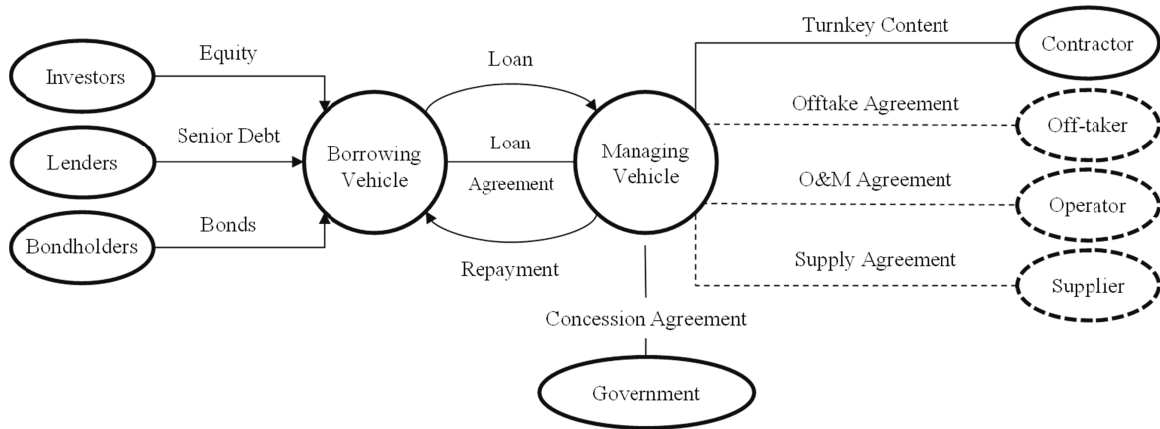
Figure 2.2 Financing based on a two-entities organizational structure (Source: Ye (2009))

Financing Based on a Multiple-Entity Organizational Structure

In the multiple-entity structure, more than two economic entities are established: one for financing and the others for managing different parts of a project respectively, or each entity for developing one part of the project. For example, a PPP project can be developed using three separated economic units: one for financing, one for leasing and the other for managing the project (Smith 2009; Ye 2009). Another case is when a project is complex or very large in size, it is broken down into more than two parts, which are be developed by different entities.

Miller's Quadrant Framework

Public-Private Partnership contracts can take different forms. They come in a wide variety of arrangements, representing a broad spectrum of private and public sector cooperative involvement in the various phases of project finance, design, construction, and operations and maintenance (Benett et al. 1999; Office of Policy and Governmental

Affairs 2007).

A framework proposed by Miller (2000) can be used to define different types of PPP model and compare and contrast them against traditional models for funding and delivery of infrastructure projects such as Design-Bid-Build (DBB). In this framework, project delivery and project finance methods are distinguished and compared as interdependent variables (Figure 2.3).

The metric that is used for project delivery methods is the degree to which the project elements (i.e., design, construction, and operations and maintenance) are separated from each other. Accordingly, there are two general choices regarding the project delivery methods.

1. Segmented: The three key elements of infrastructure projects are delivered separately from each other. In this case, distinctions remain between capital budgets for the initial delivery of projects and the operating budgets for long term operations and maintenance; and

2. Combined: The three key elements of infrastructure projects are delivered together – integrated with each other. Distinctions between capital budgets and operating budgets for these projects are eliminated. All "Public Private Partnerships" use combined delivery methods.

The metric that is used for project finance methods is the degree to which the government assumes the direct financial risk for delivering the project. Accordingly, there are two general sources of financing for projects.

1. Direct financing: Government pays for projects by using public resources such as taxes, user fees, or funds borrowed based on its credit-worthiness; and

2. Indirect financing: The funding required for the project will be provided by the

private sector investors. In this case, funds required for the design and construction of

the project are generally acquired based on the ability of project to produce revenue

that is sufficient to pay the project costs, service the debt, and generate the expected

rate of return for the investors.

Miller's framework is comprised of two perpendicular axes. The horizontal

axis represents the continuum of delivery methods measured by the degree to which

typical elements are segmented or combined with one another. The vertical axis

represents the continuum of financing methods measured by the degree of which

government assumes the financial risk for producing, operating, and maintaining the

project throughout its life cycle. Figure 2.3 illustrates the placement of different types of

PPP arrangements as well as more traditional approaches to the delivery of infrastructure

projects on Miller's proposed framework. As it is clear, various types of PPP projects are

included in quadrant II where the project development, finance, design, construction,

maintenance, and operation are performed by a single entity. In addition, for most PPP

models, the private participants themselves assume all the risk and take the responsibility

for financing the project throughout most of its lifecycle.
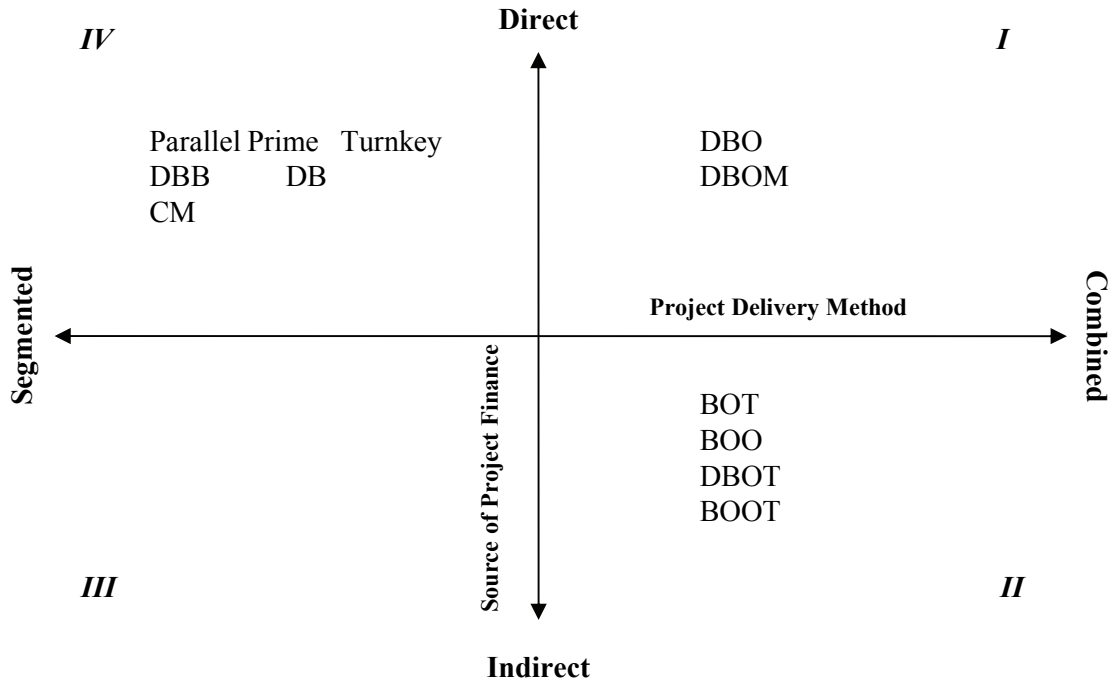
Figure 2.3 Miller's framework (Source: Miller (2000))

Types of PPP Contracts

Estache and Serebrisky (2004) provide a holistic definition of Public-Private Partnerships that encompasses all types projects with private participation in provision of infrastructure systems. In their view, the level of private sector involvement in infrastructure systems delivery might range from a purely service provision, without recourse to public facilities, through service provision based on public facilities usage, up to the ownership of a publicly-used facility (Figure 2.4). For each project, the appropriate type of PPP contract should be selected based on a variety of issues such as: the degree of control desired by the government; the government's capacity to provide the desired services; the capacity of private parties to provide the services; the legal framework for

monitoring and regulation; and the availability of financial resources from public and private sources (Gentry and Fernandez 1998). The most common types of PPP contracts are discussed below.

New Projects
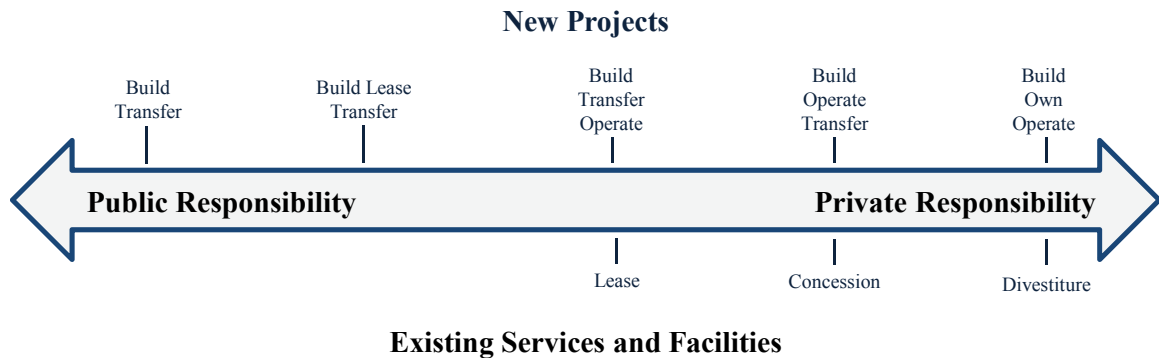
Figure 2.4 Different types of PPP contracts (Source: National Council for Public-Private Partnerships (2011))

Lease

Under this model, the government grants a private entity a leasehold interest in a publicly financed existing facility for specified time. Usually the private sector pays an upfront fee in return for future generated revenue. The private sector operates and maintains the facility in accordance with the terms of the lease (Latham and Trombka 2010; National Council for Public-Private Partnerships 2011).

Concession

The government grants a private entity the exclusive rights to operate and maintain an existing facility over a long period in accordance with performance requirements set out in the concession agreement. The public sector retains ownership of

the asset, but the private operator retains ownership over any improvements made during the concession period(Estache and Serebrisky 2004).

Divestiture

The government transfers all or part of a publicly financed facility to the private sector indefinitely. Generally, the government includes certain conditions on the sale to require that the asset be improved and services be continued (Deloitte Research 2011; National Council for Public-Private Partnerships 2011).

Build-Transfer-Operate (BTO)

Under the Build-Transfer-Operate (BTO) model, a single contract is awarded for the design, construction, and operation of a facility (National Council for Public-Private Partnerships 2011). Once the facility is completed, the title for the new facility is transferred to the government, while the private partner operates the facility for a specified period (Deloitte Research 2011). This is contrary to the BOT model where the transfer of the title for the facility takes place at the end of the concession period. The private partner must meet all agreed upon performance standards relating to physical condition and service quality. The potential benefits of the BTO approach are the increased incentives for the delivery of a higher quality plan and project because the private sector partner is contractually responsible for the performance of facility for a specified period of time after construction is completed.

Build-Own-Operate (BOO)

Under the Build-Own-Operate (BOO) model, the design, construction, operation, and maintenance of a facility is the responsibility of the private partner. The major

difference between the BOO model and BTO or BOT models is that the private partner

retains the ownership of facility. Therefore, the potential benefit associated with a BOO

approach is that the contractor is assigned all operating demand risk and any surplus

revenues for the life of the facility (National Council for Public-Private Partnerships

2011; Office of Policy and Governmental Affairs 2007).

Build-Operate-Transfer (BOT)

Under the Build-Operate-Transfer (BOT) model, the private project team, which

is also known the "concessionaire", is primarily responsible for the financing, design,

construction, and operation of the facility for a specified time under a long-term contract.

the concessionaire, is typically a consortium of private companies with resources and

expertise in different functions such as design, construction, financing, operations, and

maintenance (Federal Highway Administration 2008; Office of Policy and Governmental

Affairs 2007). The major aim of BOT is to utilize these resources and expertise in the

development of infrastructure systems. The concessionaire retains ownership of the

facility and operates it for a specified period of time according to the concession contract.

The revenue generated from the operation of the facility is typically retained by the

concessionaire and is expected to be sufficient for both repaying the debt and to

providing the required return on investment (National Council for Public-Private

Partnerships 2011). The concessionaire transfers the facility to the government at the end

of the concession lifetime under the agreed terms in the contract (Federal Highway

Administration 2008; Office of Policy and Governmental Affairs 2007). A potential

benefits of using a BOT approach is the increased incentive for the delivery of a higher

quality plan and project since the concessionaire is contractually responsible for the

operation of the facility for a specified time period after construction (Office of Policy and Governmental Affairs 2007). Another potential benefit of the BOT approach is the transfer of the project risks to the private sector partner. Figure 2.5 illustrates the contractual structure of a typical BOT project.

Shareholders
(Shareholders'
Agreement)

Shareholding

Lenders

Government

Lending
Agreements

Concession
Agreement

Concessionaire

O & M
Agreement

Construction
Contract

Operator

Construction
Contractor
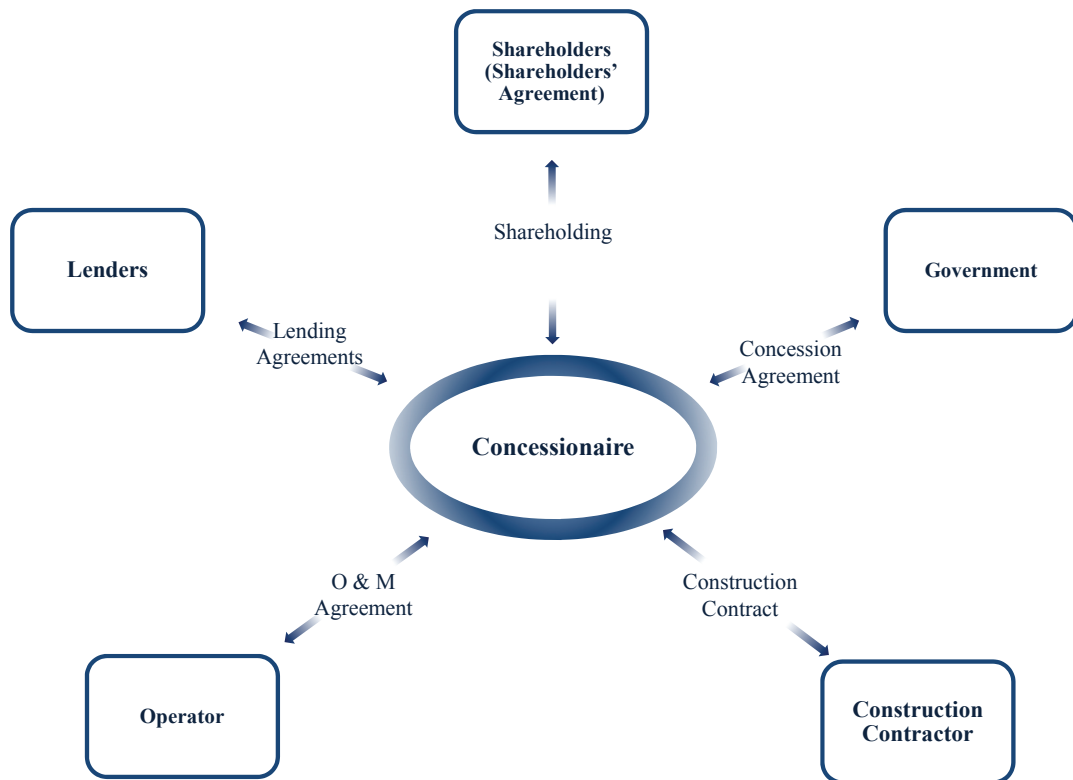
Figure 2.5 Contractual structure of a typical BOT project (Source: World Bank (2011))

The BOT model is one of the most common forms of implementing PPP in transportation projects. From 2001 to 2006, BOTs made two-third of private highway investments ($18 billion) in developing countries (Queiroz and Izaguirre 2008). Common characteristics of the BOT transportation projects are discussed below.

BOT Transportation Projects

Public-Private Partnership transportation projects often have a BOT type of arrangement, which is designed to attract private participation in financing, design, construction, and operation of transportation infrastructure systems. BOT transportation projects are typically large-scale and complex structures comprising multiple interdependent agreements among the various participants. These agreements can be seen as risk-management mechanisms, which have been designed to optimally allocate the BOT risks by shifting them to those parties best able to appraise and control them (Brealey et al. 1996).

Key Participants in a BOT Transportation Project

As shown in Figure 2.5, there are various parties involved in a BOT transportation project. These participants are identified below.

Concessionaire

The concessionaire is usually comprised of a group of companies interested in undertaking the design, construction and operation and maintenance of the infrastructure project or facility. The concessionaire also has an equity stake in the project. The concessionaire holds the responsibilities for the operation of facility during the specified concession period wherein the private investors try to recover their investments and earn profits (Llanto 2007). The concessionaire covers its costs and makes a return on investment, either from a revenue stream generated by the project (e.g., traffic revenue) or from the compensation by the government. Government compensation arrangements such as shadow tolls include regular payments by the government to the private partner

based on traffic levels, capacity provided by the project, or other performance measures as defined by contract. In these cases, the private partner typically does not charge the end users any direct user fees or tolls (Irwin 2003; Rall et al. 2010). In many other situations, the revenue stream generated by form direct user fees and tolls are the primary sources for recovering the private sector investment.

Contractor

BOT transportation projects involve large-scale building and construction activities. In some cases, the concessionaire hires a contractor through a fixed-price design-build contract and uses it services to construct the facility. In other instances, the contractor is part of the consortium that forms the concessionaire. In order to facilitate financing, the contractor takes responsibility of the design risk, by assuming risks for longer period of time as opposed to standard construction contracts of shorter life (Llanto 2007). The contractor also hires subcontractors, suppliers and consultants.

Operator

The concessionaires generally use the services of an operator, which has the required knowledge of the business and the local environment, in order to manage and operate the facility. Usually, the operator is required to maintain at certain performance and service quality level and produce the maximum revenue from the operation of facility. The operator can be one of the entities forming the concessionaire.

Lenders

Usually, the equity contribution from the shareholders of concessionaire constitutes a limited part of the financing required for the transportation projects. In

addition to the shareholders, there are two other broad categories of equity providers that may contribute to the financing of the project:

1. Those that have a direct interest in the operation of the project such as contractors, operators or the government itself, and

2. Those that are solely involved as equity investors such as public shareholders and other institutional investors (Llanto 2007).

Often, institutional investors act as lenders and provide the majority of the funding needed for the project. Lenders are typically commercial banks, insurance companies, multilateral lending institutions, and similar institutional investors. They create a syndication that provides credit financing to the concessionaire. Before lending money, lenders need to be very confident that the project can be completed on time and on budget, capable of operating as designed, and able to generate enough net cash flow to completely service the debt. As a result, the concessionaire may negotiate with the government for certain guarantees or credit enhancements to make the project attractive to the lenders. In addition, the concessionaire may allow lenders assume an active role not only in the financial arrangement but also in the planning and execution of the BOT projects (Merna and Njiru 2002).

Suppliers

Manufacturers and suppliers, provide raw material and equipment required for the project through a supply contract. In some cases, the manufacturers and suppliers of raw materials and equipment participate in the financing of a BOT project. The equity contribution to the project could be beneficial for the suppliers in achieving the goal of selling their products. The suppliers generally assume the supply risk for the material and

equipment necessary for the development and operation of the project. Therefore, the concessionaire is protected against the risk that the project will not risk its intended goals due to the lack of essential materials and equipment input. Not all BOT projects require a form of supply contracts since in many cases, concessionaires can rely on market availability of required materials and equipment (Delmon 2005).

Insurance

It is helpful to have insurance advisors to consider when insurance can be used to mitigate some of the project risks. The government also needs insurance advisors to determine if there are risks that need insurance coverage.

Risks in BOT Projects

Although it is theoretically assumed that BOT projects will bring many benefits to the public and private participants, evidence suggest that the financial expectations of BOT investors are not always fulfilled (Cuttaree 2008; Erhardt and Irwin 2004; Queiroz 2007). The financial success of a BOT project relies on the ability of project to service the debt and generate the expected equity rate of return. Therefore, it is imperative that any risks that can endanger the project's profitability are assessed and eventually mitigated (Hoffman, 2001).

Risk can be defined as the probability of occurring of an event during a specific period of time that causes the project outcomes to deviate from the expected values (Mandri-Perrott 2010). Therefore, three essential elements of risk are the probability of occurrence, the consequence of event and time of exposure. Risk is associated with

uncertainty. Uncertainty is the state of shortage of certainty with implies the lack of adequate information. A risk occurs when either the consequence of an activity or decision is uncertain in terms of probability, impact or time (Boothroyd and Emmett 1996). Therefore, risk modeling of is primarily concerned with investigating and treating the uncertainty (Akintoye et al. 2003).

The BOT transportation projects are particularly subject to a variety of financial risks due to the large initial costs, high irreversibility (sunk costs), extended contract duration, and high contract complexity due to the involvement of several parties with different objectives and constraints (Checherita and Gifford 2007). For BOT transportation projects, appropriate mitigation of the financial risks by the project participants is one of the most critical success factors (Arthur Andersen and Enterprise LSE 2000; Chiara and Garvin 2007; Grant 1996; Hardcastle et al. 2005; Qiao et al. 2001). In fact, many BOT projects fail due to high levels of risks and the inefficient risk sharing mechanisms between the public and private sectors (Cuttaree 2008; Queiroz 2007).

Several methods for classifying project finance risks have been proposed. These methods classify project finance risks in variety of ways including: inherent or external risks, controllable or uncontrollable risks, unique (diversifiable) or market (non-diversifiable) risks, upside and downside risks, dependent or independent risks, corporation or project-related risks, and management-related or technical risks. In a BOT project, risks can also be classified according to timing of their occurrence in the BOT project life-cycle. Based on this categorization, the BOT highway risks are classified into three categories, 1) Risks that exist in the design and construction phase of BOT project; 2) Risks that exist in the operation phase on BOT project; and 3) Residual risks that exist

throughout the BOT project life-cycle.

Yescombe (2002) takes a different perspective and classifies the risks according to the environment from which they stem. In this approach risks are divided into three categories: Macro-economic risks, Political risks and Commercial risks.

Macro-economic risks

Macro-economic risks are the risks related to the external economic factors not directly related to the project. Examples of these factors are inflation, currency exchange rates and interest rate.

Political risks

Political risks, which are also known as country risks, are the risks related to the effects of government actions or political force majeure events such as war and civil disturbance. The political risks can impair the ability of project to generate earning. Examples of political risks that impact BOT projects include cancelling the concession unilaterally, imposing new taxes or regulations that seriously reduce the project value for investors, refusing to accept the tolls agreed in the concession agreement; and prohibiting investors from taking revenue out of the country.

Commercial risks

Commercial risks, which are also known as project risks, are the risks specific to the project itself and the market in which it operates. Therefore, an investor that undertakes two projects with different characteristics (location, scope, organization, duration, and industry) in the same country and under the same market conditions is not necessarily subject to same commercial risks. The BOT projects are generally subject to

various types of commercial risks that concerned with a variety of issues as described below (Checcherita and Gifford 2007; Grimsey and Lewis 2002).

Commercial Viability: Does the project make overall sense from commercial standpoint?

Regulatory/political Support: Is there a need for more recourse or supportive policies to the sponsors?

Contractual mismatch: Does the contractual structure of the project work properly?

Environmental risks: Can the project face any adverse environmental impacts, constraints and hazards during the construction and operation phases?

Input supply risks: Can raw materials and other necessary input be obtained at the projected costs?

Completion risks: Can the project be completed on time and on budget?

Force majeure risk: How can the project cope with force majeure events?

Operating risks: Will the project be capable of operating at the expected performance levels and costs?

Revenue risk: Will the project generate traffic revenues as projected?

The revenue risk, which is stemmed from the uncertainty about future traffic demand, is one of the most significant risks in a BOT transportation project. The investors consider the revenue risk an extremely important factor when they assess the feasibility of a BOT project.

Traffic Demand Uncertainty and Revenue Risk in BOT Transportation Projects

In general PPP projects require a huge initial outlay in exchange for a stream of

income in future that has a great degree of uncertainty associated with it (Cheah and Garvin 2009). For the private investors, a BOT transportation project is viable only if a reliable, long-term traffic revenue stream can be generated during the operation phase of project. Therefore, for BOT transportation projects, a critical question is whether the traffic demand, and consequently the traffic revenues, is high enough to cover the project costs, service the debt, and generate the investors' expected return on investment. However, the investors often face a difficult challenge in answering this question especially at the early stages of the project.

Traffic demand projections are essential inputs for the appraisal of the viability of a BOT transportation project. The projections are typically done based on the notion that the extent of traffic demand depends primarily on the performance of the economy, the users' response, and the competition with other means of transport (Vassallo, 2006). The challenge is that regardless of the efforts that are made, long-term traffic demand projections are subject to high levels of uncertainty.

In a study by J.P. Morgan (1997), the predictive accuracy of traffic forecasts prepared for 14 constructed toll roads in the United States was evaluated. For each toll road, the actual early-year performance was compared against the original forecasts. Among all evaluated projects, only one exceeded its original revenue forecast. Three forecasts were found to be optimistic by up to 25%. Finally, for four of the projects revenue was lower than 30% of the forecasts. Another extensive work by Flyvbjerg et al. (2006) based on 183 transport infrastructure projects in 14 nations showed that for 50% of the studied road projects the difference between actual and forecasted traffic was more than ±20%. In addition, the data on 14 toll motorway concessions in Spain showed that,

on average, actual traffic during the first 3 years of operation was overestimated by approximately 35% (Vassallo and Baeza 2007). Furthermore, an international survey of over 100 privately-financed toll roads, bridges and tunnels in 2005 projects suggest that traffic forecasts are characterized by large errors and considerable optimism bias. As Figure 2.6 shows, the study revealed that on average traffic forecasts were optimistic and on average 23% higher than actual traffic demand and the error that was measured through the standard deviation was 0.26 (Bain 2009). Finally, a series of studies by Standard & Poor's (S&P) have shown that a majority of toll roads (almost 90 percent of new toll roads in 8 states) failed to meet revenue expectations in their first full year. By year 3, 75 percent remained poor performers. These studies alluded to the existence of an "optimism bias" in traffic and revenue forecasts, with an over-estimation of early years traffic by 20-30 percent that is likely to evolve as the time passes (Prozzi et al. 2009).

Global Toll Road Sample (2005)
Normal (0.77, 0.26), _n_ = 104
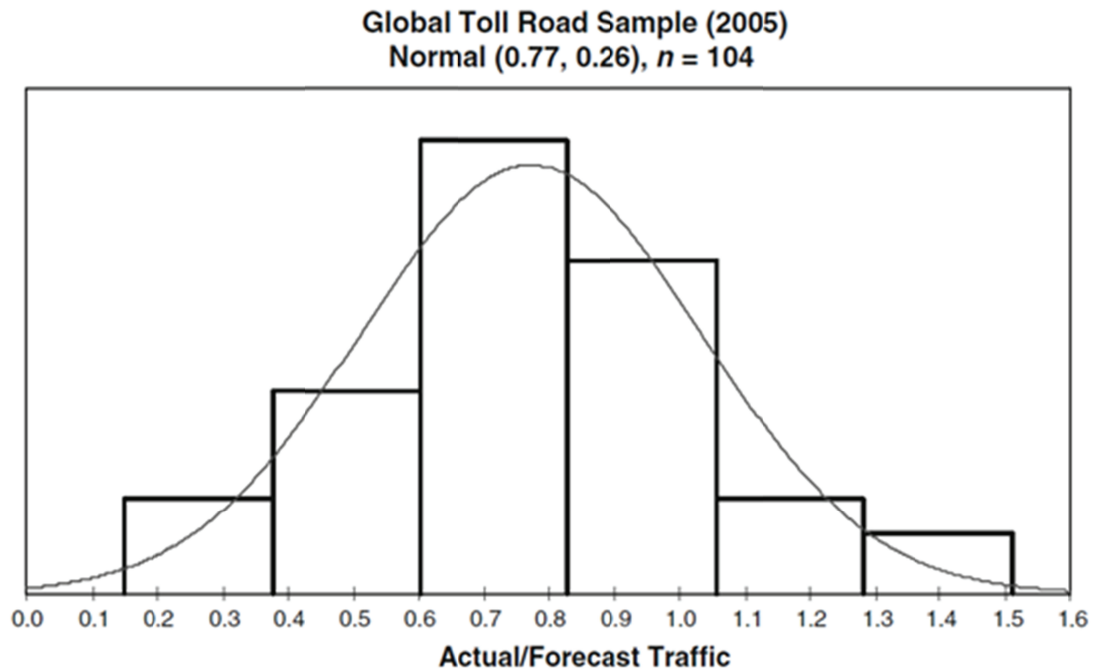
Figure 2.6 Performance distribution of traffic demand forecast based on comparison of actual/forecast (Source: Bain (2009))

These evidence highlight the inherent difficulty associated with projecting the future traffic demand and traffic revenue. It constitutes a major risk in BOT highway projects that can be referred to as traffic revenue risk. Traffic revenue risk is, thus, defined as the risk that the projected traffic demand are not materialized during the operating phase of the BOT project. The consequence of this event is that the revenue generated from the toll collection will be lower than the projections used in the assessment of a BOT project's feasibility. The revenue shortfall can negatively affect concessionaire's ability to meet its financial obligations and lead to the failure of project. Due to its impact on the commercial viability of BOT projects, the traffic revenue risk is often considered to be the most critical risk during the operations phase of BOT projects. The proper management of the traffic revenue risk plays a vital role in the success of a

BOT highway project.

Traffic Revenue Risk Allocation in BOT Highway Projects

In some sense, BOT agreements can be viewed as mechanisms for sharing of the

risks, which are traditionally borne by the public sector, between the public sector and the

private investors (Wibowo and Mohamed 2008). Thus, BOT agreement should be

developed based on the findings of a process which is aimed at determining which party

or parties should bear the consequence of each specific project risk. Throughout this

process, the ultimate goal is to create an arrangement that reduces the risk of loss and

satisfies the stakeholders' goals in enhancing their value (Ward and Sussman 2006).

It is often difficult to establish ideal amount of risk that should be transferred to

each stakeholder in the BOT agreement. Nevertheless, there are some generally accepted

rules regarding the allocation of the risks. Based on these rules, a particular risk should be

retained by the party that a) is best able to assess, control, and manage that risk; or b) has

the best access to hedging instruments; or c) has the greatest ability to diversify the risk;

or d) assumes the risk at lowest cost (Kerf et al. 1998). Therefore, the parties to the BOT

contract should be relieved of the risks that are believed to be better managed by other

parties.

Unlike some other risks such as construction or regulatory risks, which are clearly

controllable by the project participants, the traffic revenue risk cannot be fully controlled

by any of the BOT participants. The traffic revenue risk in the BOT highways is also

difficult to hedge due to the lack of a liquid insurance market. As a result, the proper

management of the traffic revenue risk has often been one of the greatest challenges in

designing and implementing BOT highway concession contracts (Vassallo 2006).

Private investors are specifically interested in limiting their exposure to the downside traffic revenue risk. This reduces the overall project risk and allows the investors to enjoy the benefits of having higher leverage and lower interest rates. Private investors are also interested in controlling the upside traffic revenue risk. The BOT transportation projects are usually highly leveraged and the investors look forward to realizing traffic revenue that is higher than the expectations (upside risk) as it compensates for the possibility of losing all their capital (Brealey et al. 1996). Moreover, the complete transfer of the traffic revenue risk to the concessionaire may lead to asymmetrical behavior by the concessionaire. If ultimately the traffic is higher than expected, the concessionaire will reap excess profits, whereas if the traffic is lower, the concessionaire will incur losses, and may attempt to force a renegotiation with the government (Vassallo 2006).

The negative consequences of failing to manage traffic revenue risk have prompted governments to identify and utilize appropriate mechanisms for mitigating the traffic revenue risk. In general, by utilizing these risk mitigation mechanisms, the governments seek two objectives:

1. Increasing the completeness of concession contracts to reduce the potential for renegotiations; and

2. Establishing more equitable rules for sharing gains or losses between the BOT concessionaire and the government (Vassallo and Baeza 2007).

Concession Extension, Revenue Enhancement, Shadow Tolls and Minimum Revenue Guarantee are examples of the mechanisms typically used for mitigating traffic

revenue risk in BOT highway projects.

It should be noted that, apart from the mechanisms that are specifically defined for mitigating the traffic revenue risk, the government and the concessionaire may also negotiate other forms of guarantees such as exchange rate, debt and equity guarantees (Fishbein and Babbar 1996). These guarantees are designed to enhance the concessionaire's ability to develop, operate and maintain the facility to the desired standard while maintaining the tolls at levels affordable to users.

Minimum Revenue Guarantee

A potential mechanism for mitigating the traffic revenue risk is Minimum Revenue Guarantee. By offering this mechanism, the government partially assumes the traffic revenue risk and compensates the concessionaire in cash if the actual revenue generated by the project falls below the guaranteed minimum level or threshold. Hence, Minimum Revenue Guarantee is a mechanism for sharing the "downside" traffic revenue risk between the concessionaire and the government during the operation phase of a project.

For many BOT transportation projects, the private sector' participation is conditioned upon the inclusion of a Minimum Revenue Guarantee mechanism in the contract. An example of such case is the Costanera Norte project in Chile in 1998 in which the government initially refused to offer revenue guarantees deemed necessary by the private investors. Consequently, no bids were submitted for the project due to the private investors' concerns about the imminent failure of the project. The private sector investors showed interest in the project only after the Chilean government offered to assume some of the traffic revenue risk through a Minimum Revenue Guarantee

agreement (Brandão and Saraiva 2007).

Minimum Revenue Guarantee is the frequently chosen mechanism by government for mitigating traffic revenue risk in BOT transportation projects (Irwin 2007). For instance, Colombia (Lewis and Mody 1997), the Dominican Republic (Luis 2004), Malaysia (Fishbein and Babbar 1996), South Africa (Irwin 2007), Spain (Gómez-Ibáñez and Meyer 1993), and Chile (Gómez Lobo and Hinojosa 2000) have all offered Minimum Revenue Guarantee for the road concessions. The Minimum Revenue Guarantee offered by the Chilean government typically ensures that the concessionaire gets revenue equal to 70 percent of the estimated present value of its costs, including the costs of investment, operations, and maintenance; the guaranteed revenue might be spread over 20 years, providing as much as 85 percent of forecast revenue in early years and less later on. So far, the government has attracted a great deal of investment without having to pay much because of these guarantees (Irwin 2007).

Similarly, in the Republic of Korea, the government offers to guarantee infrastructure firms specified fractions of their projected revenue (Irwin 2007). Typically, the government guarantees the projected revenue only for the first 15-20 years of concession. Moreover, the guarantee levels decline over time. Typically, the government guarantees up to 90 percent of the projected revenue in the early years of concession period and less later on. Finally, the government typically pays nothing if revenue is less than 50 percent of the forecast. This approach reduces the investors' concerns about the traffic revenue risk and also encourages them to perform a comprehensive evaluation of the project before becoming involved in BOT projects.

Traffic Revenue Cap

In the cases where the government shares "downside" traffic revenue risk with the private investors by offering a Minimum Revenue Guarantee mechanism, an arrangement for sharing the "upside" potential between the concessionaire and the government may also be negotiated. This can be achieved by considering a Traffic Revenue Cap for splitting the surplus traffic revenue resulted from the excessive growth of the demand beyond the anticipated levels. The concessionaire retains 100 percent of revenues up to a certain Traffic Revenue Cap threshold level, and the government receives a percentage of any revenues above the threshold (Fishbein and Babbar 1998). For instance, in return for offering a Minimum Revenue Guarantee, the government in the Republic of Korea demands a share of surplus traffic revenue during the first fifteen years of concession.

Combining the Minimum Revenue Guarantee and Traffic Revenue Cap contractual creates a "risk and revenue sharing" mechanism between the government and the concessionaire.

Pricing Minimum Revenue Guarantee and Traffic Revenue Cap Options

It is clear that, by offering Minimum Revenue Guarantee on BOT projects, the government becomes responsible for the future liabilities that these supports may cause (Brandão and Saraiva 2007; Fishbein and Babbar 1996). This can become very burdensome for the government if the risks involved are not adequately analyzed and quantified. The failure of the Mexican toll road concessions after the 1994 Mexican crisis eventually cost $8.9 billion respectively to the government (Brandão and Saraiva 2007;

Fishbein and Babbar 1996). Thus, the thresholds for Minimum Revenue Guarantee as well as Traffic Revenue Cap must be set based on appropriate valuation that establishes the government's level of exposure to the traffic revenue risk. The importance of proper valuation of these risk and revenue sharing mechanisms (i.e., Minimum Revenue Guarantee and Traffic Revenue Cap) is that it allows the government to define the levels of guarantee that make the project economically feasible and financially attractive for the private sector while limiting its financial exposure and burden. Thus, pricing the Minimum Revenue Guarantee and Traffic Revenue Cap mechanisms helps the government avoid overinvestment or underinvestment in the BOT transportation projects.

Likewise, the valuation of Minimum Revenue Guarantee and Traffic Revenue Cap mechanism helps the private investors make better choices about investing in the project based on their expectation about the project costs, the extent of traffic revenue risk and the level of guarantees offered. Naturally, they commit to the BOT project only if the offered risk and revenue sharing mechanism improves the likelihood that their investment will be profitable.

Current Investment Valuation Models for BOT Projects

While the concept of using risk and revenue sharing mechanisms such as Minimum Revenue Guarantee and Traffic Revenue Cap for BOT projects is appealing, measuring the exposure of the concessionaire and the government to the traffic revenue risk and establishing the correct price of these mechanisms is very challenging. Currently, no appropriate method that can serve this purpose is available. Traditionally, methods such as payback, discounted payback, internal rate of return (IRR), and net present value (NPV) have been applied for the valuation of investments in built environment. Many

Survey studies indicate payback, internal rate of return, and net present value are the most frequently used valuation methods by practitioners (Brigham 1975; Graham and Harvey 2001; Jog and Srivastava 1995; Klammer and Walker 1984). Among these, NPV analysis is the method traditionally used for valuation of BOT transportation projects (Cheah and Garvin 2009; Infrastructure Partnerships Taskforce 2003). In the following section, the NPV method will be examined in details.

Net Present Value Analysis

Traditionally, a concessionaire evaluates a BOT transportation project using the deterministic NPV analysis approach. The first step in this approach is to outline the concessionaire's cash inflows and outflows. Table 2.2 shows an example of the concessionaire's cash flows over the investment lifetime of a BOT project. The concessionaire's cash outflows consist of different project cost components including construction costs, operations, maintenance, and rehabilitation costs, and debt payment plan. Construction costs are the initial expenses to build a BOT project. Operations, maintenance, and capital improvement costs are annual expenses required to keep the highway project within the acceptable service level. The debt payment plan summarizes the principal and interest payments of construction-related loans or other costs related to financing such as public bonds. The annual concessionaire's cash inflows start after the project is completed and the project opens for traffic. The projected concessionaire's operating revenue is primarily based on the tolls collected from the traffic. The toll rates for various kinds of vehicles are predetermined in the initial concession agreement and may be subject to revision thereafter. The annual concessionaire's net cash flows are

computed as the net difference between the annual cash inflows and outflows over the

project lifetime. These project net cash flows are also shown in Table 2.2.

Table 2.2 An example of the concessionaire's cash flow table over the investment lifetime of a BOT project

Year	1995	1996	1997	1998	1999	....	2030
Financing Activities Inflows	34.9	209.7	385.4	351.7	240.1	....	
Equity	34.9	209.7	131.9			....	
Debt			253.6	351.7	240.1	....	
Financing Activities Outflows							
Construction Cost	-34.9	-209.7	-385.4	-351.7	-240.1	....	
Operations Revenue						....	882.5
Operations & Maintenance						....	-373.7
Investor's Net Cash Flow	-34.9	-209.7	-131.9	0.0	0.0	....	508.8

These net cash flows are discounted back to the beginning of the project to

calculate the concessionaire's NPV. The choice of discount rate in the NPV analysis

approach is often subjective and, therefore, challenging in the BOT project valuation. The

discount rate represents the rate of return that the concessionaire expects from investing

in the BOT project, i.e., the discount rate is the risk-adjusted cost of capital for the

concessionaire. The Weighted Average Cost of Capital (WACC) and the Capital Asset

Pricing Model (CAPM) are two methods, which have been frequently used in the

identification of the discount rate for BOT projects. Using the concessionaire's choice of

discount rate and the BOT project net cash flows, the NPV analysis can be conducted

according to the following formulation:

$$NPV = -\sum_{i=0}^{n} \frac{CC_i}{(1+\rho)^i} + \sum_{j=n+1}^{N} \frac{(PR_j - OC_j)}{(1+\rho)^j} \qquad (2.1)$$

Where n is the length of construction period in years; N is the total concession length in years from the initial construction to the return of the highway asset to the government; $CC_i \quad i = 1, 2, \ldots, n$ are the annual construction costs from the beginning of the project until the end of construction period; $OC_j \quad j = n+1, n+2, \ldots, N$ are the annual operations, maintenance, and rehabilitation costs from the first year after the project is completed until the end of concession period; $PR_j \quad j = n+1, n+2, \ldots, N$ are the forecasted annual traffic revenues from the first year after the project is completed until the end of concession period; and ρ is the discount rate.

Limitations of the NPV Analysis Approach

The advantage of NPV analysis approach is that it provides clear and consistent decision criteria that applicable to all projects. These decision criteria are relatively simple, widely taught and generally accepted. Moreover, the results of the NPV analysis are not influenced by the risk preferences of the investors. Finally, the NPV analysis results are easy to understand and interpret. A positive NPV means that the project is financially viable (Vandoros and Pantouvakis 2006). However, the NPV method is subject to major limitations when it comes to the proper evaluation of BOT projects.

The future traffic demand for BOT transportation projects, which drive the concessionaire's revenue cash inflows, is subject to considerable uncertainty. This is due to the inability of current traffic models to accurately determine the behavior traffic demand over the concession period (TRANSYT 2007). As a result, there is an adverse possibility that the project cash flows may not be sufficient to cover the project costs, service the debt, and generate the investors' expected return on investment. The NPV analysis approach does not have the capability to capture and treat the uncertainty about future traffic demand. Moreover, there is no standard systematic approach in the

conventional NPV analysis to describe how the discount rate should be adjusted to reflect the uncertainty about future traffic demand and the traffic revenue risk. The choice of an exogenous discount rate is critical for the proper evaluation of BOT projects since the project NPV is very sensitive to changes in the value of discount rate.

The NPV analysis approach is also unable to address the impact of Minimum Revenue Guarantee and Traffic Revenue Cap on the financial value of investments in BOT transportation projects. Moreover, the NPV analysis approach is unable to determine the correct market value of these risk and revenue sharing mechanisms and cannot be used for establishing the appropriate Minimum Revenue Guarantee and Traffic Revenue Cap threshold. The poor choice of Minimum Revenue Guarantee and Traffic Revenue Cap can lead to the inappropriate risk-sharing between the government and the private investors and impact the financial solvency of project. This can eventually result in the default by the concessionaire or the failure of a BOT project. These failures can have significant implications for the public and private investors. Specifically, default by a private partner can create huge unexpected costs for the government and reduce its flexibility to invest in other required infrastructure projects.

Real Options

The described limitations of the NPV analysis approach BOT projects can be overcome by using a different approach for evaluating investments under uncertainty that is called Real Options. The Real Options Analysis is an emerging state-of-the-art financial engineering methodology that provides an integrated formwork to evaluate investment opportunities under dynamic market uncertainty (Dixit and Pindyck 1994).

Option Concepts

Based on the options theory an option is defined as the right, without an associated symmetric obligation, to buy (or sell) a specified asset under specified terms. Usually there a specified price and a specified period of time over which the option is valid (Luenberger 1998). By providing the opportunity to exercise the option only if it is in the option's holder benefit to do so, an option creates a beneficial asymmetry that is essential to its value (Trigeorgis 1996). The option theory studies how to model and price the opportunity created by an option, which is often present either in form of a contractual right or an embedded flexibility. If the option can be exercised before maturity, it is called an American option; if only at maturity, a European option.

Options Theory

An area of work that concentrates on the theoretical valuation of an option is called option pricing theory. Financial option theory was first developed by the French mathematician Louis Bachelier in 1900 and became a mature science in the 1970's thanks to the seminal Nobel Prize winning research by Merton, Black, and Scholes (Black and Scholes 1973; Merton 1973). There are several approaches the valuation of options that are based on different assumptions about the market, the dynamics of underlying asset (e.g., stock) behavior and individual preference (Luenberger 1998; Trigeorgis 1996). However, the common valuation concept of option pricing theory is that an option can be priced based on the construction of a portfolio of a specific number of shares of an underlying asset, and that one can borrow against the shares at a risk-free rate to replicate the return of the option in a risk-neutral world (Copeland and Antikarov

2001; Trigeorgis 1996). A brief introduction to the option pricing theory and valuation of options is presented below. This introduction, which is developed based on Luenberger (Luenberger 1998; Trigeorgis 1996), focuses on the development of the option pricing theory for a single-period option. A single step of a binomial process is going to be for this purpose. The discussion about multi-period valuation process will be presented later.

Suppose that the initial price of a stock is S. At the end of the period, the price will either be uS with probability P or dS with probability $1-p$. It is assumed that $u > d > 0$. Also, it is possible to borrow and lend at a common risk-free interest rate r. Let $R = 1 + r$; to avoid arbitrage opportunities, the condition $u > R > d$ must always hold (Luenberger 1998). Now suppose also that there is a call option on the stock with the exercise price X that expires at the end of the period. The no-arbitrage argument can be used to find the value of this option.

In Figure 2.9, the binomial lattices for the stock price, the value of the risk-free asset and the value of option are presented.
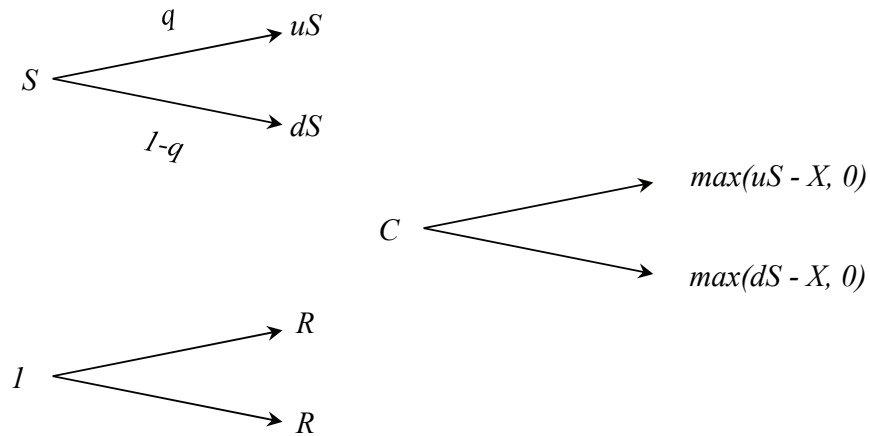
Figure 2.7 Binomial lattices for stock price, value of the risk-free asset and value of option

All three of the lattices above all move together along the same path. For instance, if the stock price moves along the upward path, the risk-free asset and the call option both move along the upward path of their lattices as well. The value of risk-free asset is deterministic (i.e., the return at the end of period will always be R), however, the risk-free asset is treated as if it were a derivative of the stock by making the value at the end of each arc the same. If the stock price S is known, all other values of these lattices are known except the value of the call option C. The patterns corresponding to the outcomes of option can be constructed by combining various proportions of the stock price and risk-free asset lattices. Let's denote that

$$C_u = \max(uS - X, 0)$$
$$C_d = \max(dS - X, 0)$$

(2.2)

To duplicate the two outcomes shown above, y dollars' worth of stock and b

dollars' worth of the risk-free asset must be purchased. This portfolio that duplicates the outcome of the option is often referred to as a replicating portfolio. At the end of period, depending on the patch that stock is taken, this replicating portfolio will be worth either $uy + Rb$ or $dy + Rb$. To match the option outcomes the following equations must hold

$$uy + Rb = C_u$$
$$dy + Rb = C_d$$
(2.3)

By solving these equations, it can be concluded that

$$y = \frac{C_u - C_d}{u - d}$$
$$b = \frac{C_u - uy}{R} = \frac{uC_d - dC_u}{R(u - d)}$$
(2.4)

By combining these two elements, the value of replicating portfolio is found to be as

$$x + b = \frac{C_u - C_d}{u - d} + \frac{uC_d - dC_u}{R(u - d)}$$
$$= \frac{1}{R}\left(\frac{R - d}{u - d}C_u + \frac{u - R}{u - d}C_d\right)$$
(2.5)

The no-arbitrage argument can be used to establish that value $y + b$ is the value of the call option C since the constructed replicating portfolio produces exactly the same outcomes as the call option. If the cost of this portfolio were less than the price of the

price of the call, the call option will never be purchased. Indeed, arbitrage profits by buying this portfolio and selling the call for an immediate gain and no further consequences. If the prices are unequal in the reverse, the same argument can be done in reverse direction. Thus, it can be concluded that the price of the call is

$$C = \frac{1}{R}\left(\frac{R-d}{u-d}C_u + \frac{u-R}{u-d}C_d\right) \qquad (2.6)$$

There is a simplified way to view the above equation. The quantity q can be defined as

$$q = \frac{R-u}{u-d} \qquad (2.7)$$

From the relation $u > R > d$ that was assumed to hold earlier, it can be concluded that $0 < q < 1$. Therefore, q can be considered to be a probability. Equation (2.6) now can be re-written as

$$C = \frac{1}{R}\left[(qC_u) + (1-q)C_d\right] \qquad (2.8)$$

Equation (2.8) implies that the value of option C can be found by taking the expected value of the option using the probability q, and then discounting this value according to the risk-free rate. Thus, the probability q can be considered a risk-neutral

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probability that would prevail in a risk-neutral world where investors are indifferent to risk and can be used for valuation of all securities.

An important feature of the pricing Equation (2.6) is that it is independent of the probability p of an upward movement in the lattice. This is because no trade-off among the probabilistic events is made. The value is found by perfectly matching the outcomes of the option with a combination of stock and the risk-free asset. Probability never enters the matching calculation.

The solution method discussed above can be extended to multi-period options by working backward one step at a time.

A two-stage lattice representing a two period call option is shown in Figure 2.8. As in the case for single-period option, it is assumed that the initial price of the stock is S. This price is going to change by the up and down factors u and d while moving through the lattice.
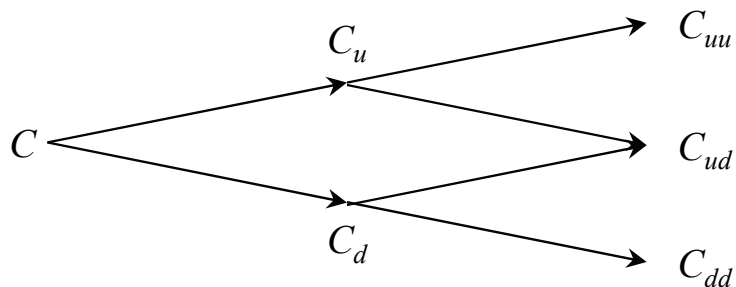
Figure 2.8 Two-stage lattice representing a two period call option

The values shown in the lattice belong to the corresponding call option that has the strike price X and the expiration time corresponding to the final point in the lattice.

The value of options is known at the final point in the lattice. Specifically,

$$
\begin{aligned}
C_{uu} &= \max\left(u^2 S - X, 0\right) \\
C_{ud} &= \max\left(udS - X, 0\right) \\
C_{dd} &= \max\left(d^2 S - X, 0\right)
\end{aligned}
\tag{2.9}
$$

The risk-neutral probability is defined the same as above (i.e., $q = \dfrac{R-u}{u-d}$) where

R is the one-period return on the risk-free asset. Assuming that the option is not exercised

early, the values of C_u and C_d can be calculated using the single-period equation

presented above. Specifically,

$$
\begin{aligned}
C_u &= \frac{1}{R}\left[\left(qC_{uu}\right) + \left(1-q\right)C_{ud}\right] \\
C_d &= \frac{1}{R}\left[\left(qC_{ud}\right) + \left(1-q\right)C_{dd}\right]
\end{aligned}
\tag{2.10}
$$

By applying the risk-neutral discounting formula, C can be calculated as

$$
C_u = \frac{1}{R}\left[\left(qC_u\right) + \left(1-q\right)C_d\right]
\tag{2.11}
$$

The same procedure can be used for lattices with more periods. Starting from the last

period and working backward toward the initial time, the single-period risk-free

discounting should be done for every node at the lattice.

Black and Scholes Formula

When expanded the option valuation approach presented above can appropriately

solve most option problems. There is however, a continuous version of the theory and

extension of the lattice theory that leads to new financial insights, allows the

consideration of more complex derivative securities, provide alternative computation

methods, and prepare the way for more complete theory of investment (Luenberger 1998).

In the continuous view, the stock prices or project gross values are assumed to

follow a stochastic process thus their values change over time in an uncertain manner. A

particular type of stochastic process is the Markov process, where only the present state

of the process (i.e., the asset value) is relevant for the prediction of the future while the

past history is irrelevant. A particular type of the Markov process is the Weiner process

or Brownian motion. If a variable $z(t)$ follows a Weiner process, then changes in z (Δz)

over small time intervals (Δt) must satisfy two essential properties:

1. Δz over small and non-overlapping time intervals are independent. That is, the

   process can be thought of as the continuous limit of a discrete random walk; and

2. Δz are normally distributed, with mean $E(\Delta z) = 0$ and a variance that increase

   linearly with the time interval. In other words, $Var(\Delta z) = \Delta t$ and $\Delta z = \sqrt{\Delta t}\, \tilde{\varepsilon}_t$, where

   ε_t is a normally distributed random variable with zero mean and standard deviation of

   1. In continuous time as $\Delta t \to 0$, the increment of a standard Weiner process becomes

   $dz = \sqrt{dt}\, \tilde{\varepsilon}_t$, with $E(dz) = 0$ and $Var(dz) = dt$.

   Nevertheless, prices changes are not normally distributed. In fact, they are closer

to being log-normally distributed. Thus, the more reasonable assumption is that the

natural logarithm of stock prices follows a Weiner process. Evidence also suggests that the stocks have non-zero drift and volatility that is not necessarily equal to 1. Therefore, a more generalized Weiner process is often used to present the asset dynamics. It is generally written as

$$ds = \mu(S,t) + \sigma(S,t)dz \tag{2.12}$$

Where dz is the increment of a standard Weiner process with mean 0 and variance dt, $\mu(S,t)$ and $\sigma(S,t)$ are the drift and variance coefficient expressed as the functions of current state and time. The continuous-time stochastic process is called and Ito Process with mean $E(dS) = \mu(S,t)dt$ and variance $Var(dS) = \sigma^2(S,t)dt$.

In the seminal paper, Black and Scholes (1973) showed that the continuous application of a dynamic portfolio replication strategy under certain assumptions results in a fundamental partial differential equation that must be satisfied by the value of the European call option (Trigeorgis 1996). Therefore, the logic behind the Black-Scholes approach is conceptually identical to what was used for the binomial lattice. It implies that at each given moment, to assets can be combined to construct a portfolio that replicates the behavior of the option (Trigeorgis 1996).

Let's assume that the asset price dynamics is described by a special case of generalized Weiner process which is called the Geometric Brownian Motion (GBM) with drift, or the standard diffusion Weiner process where $\mu(S,t) = \mu S$ and $\sigma^2(S,t) = \sigma^2 S^2$. This can be presented by

$$dS = \mu S dt + \sigma S dz \qquad (2.13)$$

Where z is standard Brownian motion or a Wiener process. Suppose that there is a risk-free asset (e.g., a bond) carrying an interest rate of r over $[0,T]$. Thus, the value B of this bond satisfies

$$dB = rBdt \qquad (2.14)$$

Consider a security that is derivative to S, which means that its price is a function of S and t. Let $f(S,t)$ denote the price of this security at time t when that stock price is S. The derivative of this security has a price $f(S,t)$, which satisfies the partial differential equation (Luenberger 1998)

$$\frac{\partial f}{\partial t} + \frac{\partial f}{\partial S} rS + \frac{1}{2} \frac{\partial^2 f}{\partial S^2} \sigma^2 S^2 = rf \qquad (2.15)$$

Although it is usually impossible to find an analytical solution to the Black-Scholes equation, it is possible to find such solution for a European call option. This analytical solution has great practical and theoretical use.

Consider a European call option with strike price X and expiration time T. If the underlying stock pays no dividends during the time $[0,T]$ and if interest is constant and continuously compounded at rate r, the Black-Scholes solution is $f(S,t) = C(S,t)$, defined by (Luenberger 1998) as

$$C(S,t) = SN(d_1) - Xe^{-r(T-t)}N(d_2) \qquad (2.16)$$

Where

$$d_1 = \frac{\ln(S/X) + (r + \sigma^2/2)(T-t)}{\sigma\sqrt{T-t}} \qquad (2.17)$$
$$d_2 = d_1 - \sigma\sqrt{T-t}$$

And where $N(x)$ denotes the standard cumulative normal probability distribution, C denotes the current value of the European call option, S denotes the current price of underlying stock, and r is the risk-free interest rate

Real Options Concept

Options can be associated with investment opportunities that are not financial instruments. For instance, if one acquires a piece of land, one has the option to drill for oil, and then later the option of extracting oil if it is found. Such options are often termed as real options to emphasize that they involve real activities or real commodities as opposed to purely financial commodities such as stock options (Luenberger 1998).

The term "Real Options" was first introduced by Myers (1977) as reference to the application of options pricing theory and methods from finance to the assessment of non-financial or "Real" investment opportunities. Since then, the field of real options analysis has gone through a transition from a topic of a modest academic interest in 1980s and 90s to one that now receives considerable, active academic and industry attention (Borison

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2005). Many researchers have contributed to the expansion of real option theory (Amram and Kulatilaka 1999; Copeland and Antikarov 2003; Dixit and Pindyck 1994; Trigeorgis 1996). de Neufville made a major contribution by categorizing real options based on their nature into real options "on" and "in" projects. In de Neufville's view, real options "on" projects are mostly concerned with the valuation of investment opportunities, while real options "in" projects are mostly concerned with design of flexibility (Wang and Neufville 2005).

In the mid-1990s, real options began to attract attention from industry as a potentially important tool for investment valuation and strategy. In the application context, real options approach was primarily applied to decision-making elated to corporate investment projects and corporate valuation as the state-of-the-art financial engineering methodology that provides an integrated formwork to evaluate investment opportunities under dynamic market uncertainty (Dixit and Pindyck 1994). It also allows companies to examine programs of capital expenditures as multi-year investments, rather than as individual projects (Copeland and Antikarov 2003). This is crucial since strategic decisions are rarely one-time events, particularly in investment-intensive industries. Leslie and Michaels (1997) argue that NPV analysis is inferior to the real options analysis since it recognizes only two of crucial factors that the real option valuation approach captures: the present value of expected future cash flows and the present value of fixed costs. Therefore, NPV can mislead whenever there is uncertainty and flexibility to respond to uncertainty over the rate of cash flow growth, because it incorporate only two key levers of value criteria. Figure 2.9 presents a comparison between a traditional NPV analysis and real options analysis.
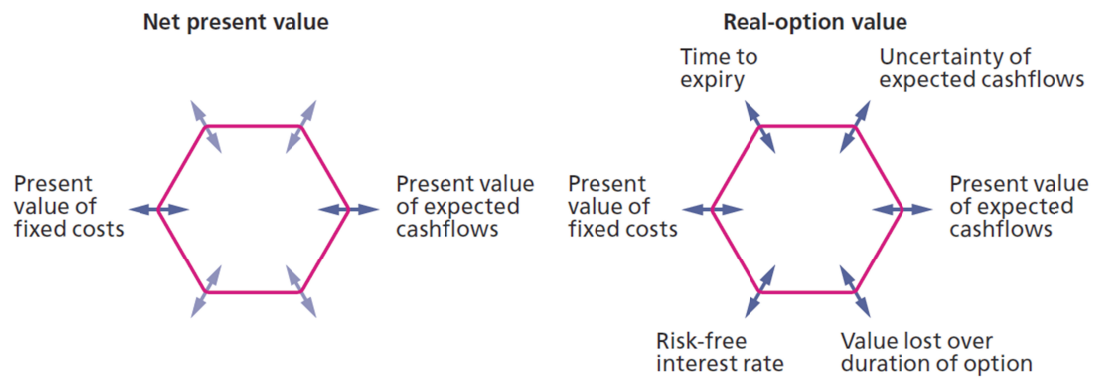
Figure 2.9 Comparison of NPV and real options methodologies (Source: Leslie and Michaels (1997))

The oil and gas industry was principally the first to apply real options analysis and was followed by a range of other industries that began to apply real options tools intermittently (Borison 2005). Other notable applications of real options methodology are in technology assessment (Shishko et al. 2004), research and development (Bodner and Rouse 2007), retail (Ashuri et al. 2008), mining (Mayer and Kazakidis 2007), manufacturing (Bengtsson 2001), healthcare (de Neufville et al. 2008), corporate real estate (Ashuri 2010), architecture (Greden and Glicksman 2005), building technology (Greden et al. 2006), construction engineering and management (Ford et al. 2002), etc.

Real Options in Transportation Infrastructure Systems

The body of knowledge on the application of real options in transportation infrastructure management is still growing. Prior research has focused on the definition and analysis of various kinds of options on transportation projects in order to demonstrate that the application of real options analysis in transportation infrastructure development and management can lead to valuable outcomes.

- Ford et al. (2002) present a real options approach in order to proactively utilize strategic flexibility and capture project values hidden in dynamic uncertainties and apply it to evaluate and select strategies for a toll road project proposal.

- Ho and Liu (2002) present an option pricing model for evaluating the impact of the government's guarantee and the developer's negotiation option on the financial viability of privatized infrastructure projects.

- Zhao and Tseng (2003) present an option pricing model for assessing design flexibility in infrastructure projects. The proposed real option model is applied to assess the expansion option of a public parking garage.

- Zhao et al. (2004) develop a multi-stage stochastic model for decision-making in highway development, operations, and rehabilitation, which considers three sources of uncertainty, namely, future traffic demand, land price, and highway deterioration, as well as their interdependencies.

- Garvin and Cheah (2004) propose the use of option pricing model in order to enhance traditional project evaluation and capture the strategic value hidden in flexibility to defer infrastructure projects. They apply the proposed valuation method to assess the deferment option value of the Dulles Greenway project.

- de Neufville et al. (2006) present a spreadsheet model for valuing flexibility in engineering systems. The proposed approach is employed to assess the expansion options for a multistory parking garage.

- Cheah and Liu (2006) use Monte Carlo simulation methodology to evaluate government guarantees and subsidies as real options and apply it to the case of the Malaysia-Singapore Second Crossing.

- Huang and Chou (2006) develop a compound option pricing formula for the Taiwan High-Speed Rail Project. Guarantee options combined with the option to abandon in the pre-construction phase are evaluated as a series of European style call options in their work.

- Chiara et al. (2007) model governmental guarantees on BOT projects as one of three discrete-exercise real options: European, Bermudan, and simple multiple-exercise (Australian) options, and expand the least-squares Monte Carlo technique to value these guarantees.

- Brandão and Saraiva (2008) present a real options model for evaluating highway projects with minimum traffic guarantees, and apply it to the 1000 mile BR-163 toll road project that links the Brazilian Midwest to the Amazon River.

Gaps in Knowledge

After analyzing the literature on the application of real options in transportation infrastructure systems management, it was concluded that the existing models are subject to significant limitations. These limitations are discussed below.

Estimation of the Project Volatility for Real Options Analysis

Uncertainty is the key driver of the value of options. One of the most critical inputs to options valuation models is the volatility. Volatility measures the uncertainty about investment value over time. Financial options derive their price from the value of their underlying financial assets, such as stocks. Therefore, option volatility can be estimated by either using historical movements of asset market prices, or by calculating

the implied volatility from the Black-Scholes model based on the current market price of an option. Estimating the volatility of a real option in transportation infrastructure projects is much more difficult since these projects are unique and there is no relevant data on historical or current market prices of the transportation projects that can be used as the basis for volatility estimation. The current literature on the application of real options in transportation infrastructure management does not provide a systematic method for estimating the project volatility. In the existing real option models, the project volatility values that are used as inputs to the model are assumed values. Therefore, the application of the current real options models to the valuation of investments in BOT projects under the uncertainty about future traffic demand can lead to an erroneous valuation. There is a pressing need for a method that can systematically estimate the project volatility for pricing real options such as Minimum Revenue Guarantee and Traffic Revenue Cap in BOT transportation projects.

Finding the Market Value of Real Options in Transportation Project

In order to determine the price of an option, the benefits resulted from exercising the option should be discounted at an appropriate risk-adjusted rate. The risk-adjusted discount rates for options vary widely depending on a several factors including the volatility of project due to various market and project risks. When it comes to the valuation of real options in transportation projects, it is typically impossible to estimate the correct and exact risk-adjusted discount rate that reflects the market risks, project risks that are unique to these projects and asymmetric benefit patterns of options (Brigham and Ehrhardt 2011; Ford et al. 2002). The existing literature on the application of real options in transportation infrastructure development does not address this problem

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and often suggest the utilization of approximate discount rates for real options valuation. Therefore, the application of the current real options models to the valuation BOT investments under traffic demand uncertainty does not lead to the determination of correct market value of real options. There is a need for an appropriate method that can overcome this challenge and determine the market value of options such as Minimum Revenue Guarantee and Traffic Revenue Cap in BOT projects.

Characterizing the Concessionaire's Risk Profile under Traffic Demand Uncertainty

Current real options models also do not address several critical questions when it comes to the valuation of investments BOT project under traffic demand uncertainty. Existing models do not determine the concessionaire's financial risk profile under uncertainty about future traffic demand in a BOT project. These real options models cannot characterize the impact of Minimum Revenue Guarantee and Traffic Revenue Cap options on the concessionaire's financial risk profile. Also, existing real options models do not determine the likelihood of Minimum Revenue Guarantee payment to the concessionaire as well as the likelihood of Traffic Revenue Cap payments to the government. An appropriate real options valuation model is required to enhance the current understanding of the impact of Minimum Revenue Guarantee and Traffic Revenue Cap mechanisms on the concessionaire's financial risk profile.

Research Objectives

The primary objective of this research is to apply the real options theory in order

to explicitly price Minimum Revenue Guarantee and Traffic Revenue Cap under the

uncertainty about future traffic demand. The specific research objectives that will be

addressed in this research are:

1. Model the long-term traffic demand uncertainty in BOT projects;

2. Devise an appropriate method for estimating the project volatility for real options

    analysis;

3. Devise an appropriate method for finding the market value of Minimum Revenue

    Guarantee and Traffic Revenue Cap options in BOT projects; and

4. Create a procedure for characterizing the impact of Minimum Revenue Guarantee and

    Traffic Revenue Cap options on the concessionaire's financial risk profile.

    The proposed real options model, which is created in order meet the above

objectives, is described in the next chapter.

CHAPTER 3   REAL OPTIONS MODEL FOR THE FINANCIAL VALUATION OF INFRASTRUCTURE SYSTEMS UNDER UNCERTAINTY

The literature review indicated that BOT transportation projects are subject to a variety of risks that can be divided into three categories: Commercial risks, Macro-economic risks and Political risks. The BOT agreements serve as a mechanism for effective sharing of these risks between the government and the private sector investors. The success of the BOT projects depends on whether these risks are allocated effectively to the project stakeholders.

The traffic revenue risk is one of the most significant risks in a BOT transportation project. The traffic revenue risk is the adverse possibility that the project may not generate sufficient cash flows to cover the project costs, service the debt, and generate the investors' expected return on investment. Unlike some other risks such as construction or regulatory risks, which are clearly controllable by some stakeholders, the traffic revenue risk which is stemmed from the uncertainty about the future traffic demand cannot be completely controlled by any of the public or private stakeholders involved in BOT transportation project. It is also difficult to hedge due to the lack of an established insurance market. Therefore, the proper allocation of the traffic risk has become one of the greatest challenges in designing highway concession contracts. Many governments have considered traffic revenue risk mitigation mechanisms to encourage the private investment in crucial transportation projects. The Minimum Revenue

Guarantees (Minimum Revenue Guarantee) is the frequently used mechanism for mitigating the traffic revenue risk in BOT transportation projects. In general a minimum revenue guarantee is a contract based on which the government partially assumes the traffic revenue risk and compensates the concessionaire in cash if the traffic revenue falls below a specified minimum level or threshold. Hence, Minimum Revenue Guarantee is a mechanism for sharing the "downside" revenue risk between the concessionaire and government in the operation phase.

In many cases where the government shares "downside" risk with the private investors by offering Minimum Revenue Guarantee, an arrangement for sharing the "upside" potential between the concessionaires and the government may also be negotiated. This approach can be achieved by considering a mechanism for splitting the surplus revenue resulted from the excessive growth of the demand beyond the anticipated revenue levels. This mechanism is called Traffic Revenue Cap (TRC). The concessionaire retains 100 percent of revenues up to the Traffic Revenue Cap threshold level, and the government receives a pre-determined percentage of any revenues above the threshold. The combination of Minimum Revenue Guarantee and Traffic Revenue Cap creates a risk and revenue sharing mechanism between the government and the concessionaire involved in a BOT transportation project.

It is critical for the project stakeholder to measure their exposure to the traffic revenue risks in the presence of these risk and revenue sharing mechanism and determine the market value of such mechanisms. It helps the private investors make better choices about investing in a BOT project based on their expectation about the project costs, the extent of risks and the level of guarantees offered. Pricing the combined Traffic Revenue

Cap and Minimum Revenue Guarantee mechanism also helps the government avoid overinvestment or underinvestment in the BOT transportation projects. In this research, the real options theory is used to create the investment valuation model that characterizes the long-term traffic demand uncertainty in BOT projects and determines investors' financial risk profile under this uncertainty. This model presents a novel method for estimating the project volatility for real options analysis. This model also devises a market-based option pricing approach to determine the value of Minimum Revenue Guarantee and Traffic Revenue Cap options. An appropriate procedure is created for characterizing the impact of Minimum Revenue Guarantee and Traffic Revenue Cap options on the investors' financial risk profile.

Figure 3.1 shows an overview of the proposed real options model consisting of the following major steps:

1. Establish input data requirements, e.g., cost data related to the BOT project, the concessionaire's capital structure, and future traffic demand;

2. Model uncertainty about long-term traffic demand

    a. Develop a binomial lattice model to characterize uncertainty about future traffic demand;

    b. Generate random future paths for future traffic demand using Monte Carlo simulation technique;

3. Conduct life cycle cost and revenue analysis for the BOT project under each random traffic path and characterize the concessionaire's financial risk profile for the case that Minimum Revenue Guarantee and Traffic Revenue Cap are not offered; and

4. Price the Minimum Revenue Guarantee and Traffic Revenue Cap options

    a. Estimate the project volatility

b. Adjust the binomial lattice model of future traffic demand based on the risk-neutral option valuation approach

c. Repeat steps (2) and (3) and adjust the annual revenues based on the Minimum Revenue Guarantee and Traffic Revenue Cap options pay-offs. Calculate the market value of Minimum Revenue Guarantee and Traffic Revenue Cap, and characterize the concessionaire's financial risk profile with Minimum Revenue Guarantee and Traffic Revenue Cap options.

Establish Information Requirements

Year	1995	1996	1997	1998	1999	2000	2001	2002	....	2030
Financing Activities Inflows	34.9	209.7	385.4	351.7	240.1	279.8			....	
Equity	34.9	209.7	131.9						....	
Debt			253.6	351.7	240.1	279.8			....	
Financing Activities Outflows							-1.9	-56.1	....	
Construction Cost	-34.9	-209.7	-385.4	-351.7	-240.1	-277.8			....	
Operations Revenue						45.3	208.3	240.6	....	882.5
Operations & Maintenance						-47.2	-185.7	-186.3	....	-373.7
Investor's Net Cash Flow	-34.9	-209.7	-131.9	0.0	0.0	0.1	20.6	-1.9	....	508.8

Model Uncertainty about Long-term Traffic Demand
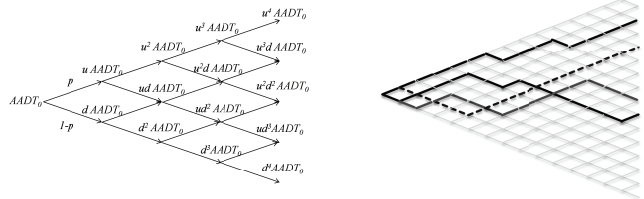
Conduct Lifecycle Cost and Revenue Analysis under Traffic Demand Uncertainty
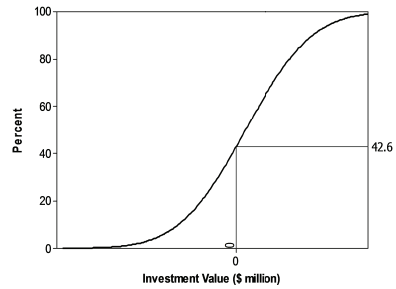
Price MRG and TRC Options
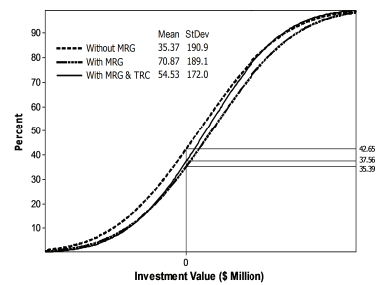
Figure 3.1 Overview of the proposed real options analysis model

Establish Information Requirements

The proposed model requires certain data as inputs. The first dataset is concerned with the BOT project life cycle costs that include several components. The construction cost is the first item contributing to the project lifecycle. It includes the costs of constructing the physical asset based on the specified standards as well as the cost of survey, design, right of way acquisition, management fee, interest, tax, and any other necessary cost item.

In a BOT transportation projects, the concessionaire has the responsibility to operate the facility during the concession period and maintain a certain performance and service quality level. These performance and service quality level requirements are generally set by the government considering the "user costs". User costs are delay, vehicle operating, and crash costs incurred by the users of a facility. User costs are heavily influenced by current and future roadway operating characteristics (Walls and Smith 1998). Therefore, governments typically regulate the level of service quality that the facility provides to the public by incorporating satisfaction metrics into the contract. These measures require the private partner to improve the service quality and maintain the asset according to the specified standards by conducting regular maintenance, frequent rehabilitations, and emergency maintenance projects (Alexandersson and Hultén 2010; Shaoul 2009). The O&M costs capture the costs associated with these activities. It also includes tax, enforcement costs and other overhead costs associated to operation of the infrastructure.

The second dataset is concerned with the concessionaire's capital structure. It consists of the cash flow resulted from raising the required capital for the project through

equity and debt. Another component of this dataset is the debt payment plan and the concessionaire's cost of capital. The debt payment plan includes a series of principal and interest payments to the lenders over a certain period of time, which is commonly known as debt services. Debt services, which take the next priority after O&M costs, should be paid from the project revenues. This dataset also includes the payments to equity providers. Another component of this dataset is the cost of capital that is the minimum rate of return that the concessionaire needs to compensate for bearing risks and waiting for returns. This rate is specific to the concessionaire and will be used as the discount rate in project valuation.

The third dataset is concerned with the cash inflow resulted from the operation of the BOT project during the concession period. In most BOT highway projects, the major source of revenue is the toll collected from the road users. Projections of this operating revenue are generally provided in traffic and revenue studies which are typically conducted by special consultant groups. A typical traffic and revenue study provides the Annual Average Daily Traffic (AADT) values over the concession lifetime. AADT is the total volume of vehicles passing through a highway in a year divided by 365 days. From a modeling point of view, BOT projects have two primary characteristics. First, little or no historical data is available on the future traffic demand. Second, the concession period for these projects is predetermined, and it typically ranges from 10 to 40 years. The transport models that are generally used in traffic and revenue studies, predict the AADT for a single scenario or a limited number of scenarios (e.g., low and high growth, etc.). Therefore, their predictions are mostly point estimates, and, even when produced for several scenarios, do not directly provide insight into the uncertainty that exists around

the future traffic demand.

The model created in this research treats the uncertainty about future traffic demand in a stochastic manner. It uses the projections provided by the traffic study report in order to determine the projected initial traffic demand for the BOT project. The traffic study report is also used to determine the expected annual growth rate of AADT. This expected annual growth rate may change over the project lifetime depending on the traffic study assumptions. Suppose $AADT_j$ j = n+1, n+2, …, N are the most-likely forecasts of AADT from the first year after the project is completed (n+1) until the end of concession lifetime (N). These N-n data points in time, spanning over N-(n+1) periods, are going to be used in order to compute the expected annual growth rate of AADT – denoted by α – as follows (Luenberger 1998):

$$\alpha = \frac{1}{N-(n+1)} \ln \left[\frac{AADT_N}{AADT_{n+1}} \right] \tag{3.1}$$

The expected annual growth rate of AADT is not sufficient to characterize the uncertainty about future traffic demand. In order to describe the uncertainty about future traffic demand the annual volatility of AADT is also required. Annual volatility or parameter σ hereafter refers to the standard deviation of the expected annual growth rate of AADT. It provides a valuable measure for understanding and quantifying the risk of underestimating/overestimating the future traffic growth over the concession lifetime. The choice of annual volatility of AADT is often not easy since the BOT project is yet to be built. Three ways are suggested to determine σ in BOT projects:

1. Use historical AADT data of similar existing highway projects to estimate the
   volatility of the new BOT project (Irwin 2003);

2. Use the forecasted annual volatility of Gross Domestic Product (GDP) of the region
   where the BOT project is built as a surrogate measure for the annual volatility of
   AADT (Banister 2005); and

3. Refer to the subject matter experts' opinions to estimate the annual volatility of the
   AADT of a new BOT project (Brandão and Saraiva 2008).

The concessionaire can use one or a combination of the above approaches to provide an appropriate estimate for σ of AADT. Sensitivity analysis should, however, be conducted to account for the risk of improper estimation for the volatility of AADT.

Model Uncertainty about Long-term Traffic Demand

The uncertain nature of traffic demand implies that an appropriate stochastic model should be conceived in order to determine how the traffic demand evolves over time. There are four basic stochastic processes: Geometric Brownian Motion (GBM), mean-reversion process, barrier long-run process, and jump-diffusion process (Mun 2006). Many recent engineering economic analyses have relied on an implicit or explicit assumption that value of an underlying asset (e.g., stock) that changes over time with uncertainty follows a GBM process (Marathe and Ryan 2005). The GBM model has also been used to represent future demand in capacity studies. For instance, Whitt (1981) studies capacity utilization over time assuming demand followed a GBM. This assumption is indirectly validated by Lieberman (1989) who, through an empirical study show that the actual capacity utilization matches the predictions of GBM model. Also,

Ryan (2004) assumes demand for services in rapidly growing industries follows a GBM. In all cases, the demand is assumed to follow aGBM process given by

$$dS = \mu S dt + \sigma S dz \qquad (3.2)$$

Where μ is the constant drift rate, σ the constant variance rate, and dz the increment of a standard Weiner process, i.e., $dz = \varepsilon_t \sqrt{t}$ where ε_t is $N(0,1)$ and for $t \neq s$, $E(\varepsilon_t \varepsilon_s) = 0$. A discrete approximation to this underlying stochastic process can be developed to provide a transparent and computationally efficient model for valuation problems (Brandão et al. 2005).

The most recognized example of this approach is the binomial lattice model. A binomial lattice may be viewed as a probability tree with binary chance branches, with the unique feature that the outcome resulting from moving up and then down in value is the same as the outcome from moving down and then up. Thus, binomial lattice is recombining with numerous paths resulting in the same outcomes. The main advantage of using this method is that from each time step to the next, the number of possible outcomes increases linearly (at time 0 there is one possibility, at time 1 two possibilities, and so on). This linear increase from each period to the next allows for a wide array of possibilities to be handled in convenient fashion (Chambers 2007). Another characteristic of binomial lattice is that the values projected on the lattice follow a lognormal distribution, with only non-negative values shown. The binomial lattice model was originally developed by Cox et al. (1979) as a mathematically intuitive tool to accurately approximate solutions from the Black-Scholes-Merton continuous-time option valuation

model.

In this research, the binomial lattice model is used to characterize uncertainty about future values of AADT. The binomial lattice is powerful yet flexible model for representation of uncertainty about AADT. In economics and finance, the binomial lattice is an appropriate random walk model to capture uncertainty about a variable that grows over time plus random noise (Dixit and Pindyck 1994; Copeland and Antikarov 2001). The modeling choice of binomial lattice is consistent with the general body of knowledge in real options analysis (Hull 2008; Luenberger 1998). It has been used by several researchers such as Garvin and Cheah (2004), and Ho and Liu (2002) to characterize uncertainty about future traffic demand.

A basic period length of one month is considered to define a binomial lattice for future traffic demand, i.e., $\Delta t = 1$ month $= 1/12$ year. According to the model formulation, the current traffic demand $AADT_0$ is known. In this model, it is assumed that $AADT_0$ is chosen randomly from a triangular distribution for which the lowest, most likely and highest values are the pessimistic, most likely, and optimistic forecasts of the initial traffic demand, respectively. These forecasts are typically specified in the traffic and revenue study report.

The AADT at the beginning of each period is assumed to take just one of the two multiples of the AADT at the previous period: a multiple u for the upward movement and a multiple d for the downward movement where both u and d are positive values with u>1 and d<1. The probabilities of upward and downward movements are $0 \leq p \leq 1$ and $0 \leq 1-p \leq 1$, respectively. These binomial lattice parameters can be determined using the expected annual growth rate of AADT (α) and the annual volatility of AADT (σ) as

formulated in Equation 3.3 (Hull 2008):

$$u = e^{\sigma\sqrt{\Delta t}}$$

$$d = e^{-\sigma\sqrt{\Delta t}} \qquad\qquad (3.3)$$

$$p = \frac{e^{\alpha\Delta t} - d}{u - d}$$

Figure 3.2 shows the binomial lattice for future values of AADT. The initial AADT is $AADT_0$. It is the expected AADT at the beginning of the first year after the project is completed. The AADT at the beginning of the second month will be either $u \times AADT_0$ with probability p or $d \times AADT_0$ with probability 1-p. This variation pattern continues for subsequent months until the end of the concession lifetime. The probability of upward movement from any node in this lattice is p and the probability of downward movement from any node is 1-p. The recombining feature of this binomial lattice implies that an upward movement followed by a downward movement is identical to a downward movement followed by an upward movement.

$$u^4\,AADT_0$$

$$u^3\,AADT_0$$

$$u^2\,AADT_0 \qquad u^3 d\,AADT_0$$

$$u\,AADT_0 \qquad u^2 d\,AADT_0$$

$$p \qquad ud\,AADT_0 \qquad u^2 d^2\,AADT_0$$

$$AADT_0$$

$$d\,AADT_0 \qquad ud^2\,AADT_0$$

$$1\text{-}p \qquad d^2\,AADT_0 \qquad ud^3\,AADT_0$$

$$d^3\,AADT_0$$

$$d^4\,AADT_0$$
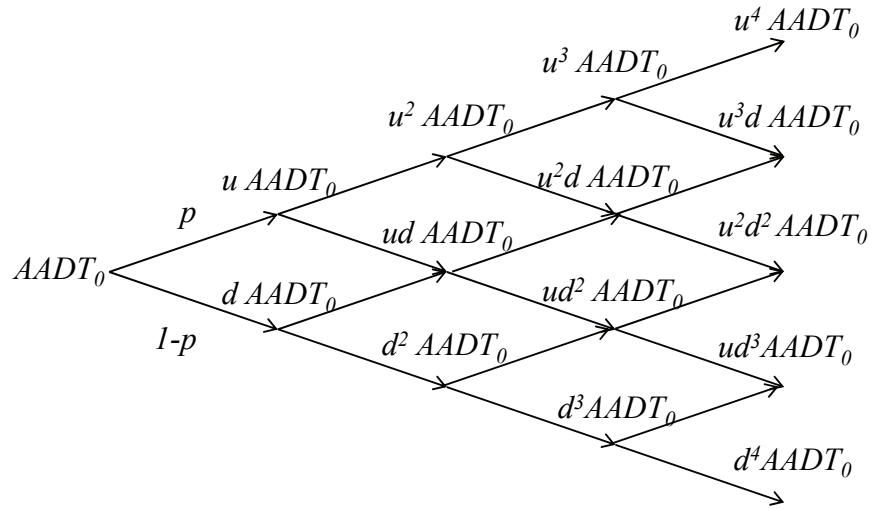
Figure 3.2 A binomial lattice to model uncertainty about future traffic demand

A slight modification in this binomial lattice model is necessary to ensure that infeasible, large future traffic demand is not generated for AADT. A highway is operationally adequate for providing satisfactory services to a specific maximum number of vehicles (Transportation Research Board 2000). This maximum capacity can be used as the cap for AADT values in this binomial lattice. Thus, in this binomial lattice model, the AADT values over this cap will be changed to the maximum AADT.

This lattice model is a flexible and powerful tool for capturing the dynamic uncertainty about future traffic demand in an approximate fashion. Particularly, if the period length is relatively small (e.g., 1 month), many AADT values are possible after several short time steps (Hull 2008; Luenberger 1998). This AADT binomial lattice will be used as a basis to generate random paths for future traffic demand in the BOT project as described in the next section.

Generate Random Traffic Demand Paths

Monte Carlo simulation technique can be used to generate several random paths for future traffic demand along the binomial lattice from the first year after the project is completed until the end of the concession lifetime. The Monte Carlo simulation method is essentially a method for evaluating an integral

$$\Psi = E_{\pi}\{U(X)\} = \int U(x)\pi(x)\,dx \qquad (3.4)$$

where $E_{\pi}(\ )$ is the expectation with respect to the probability density π and $U(\ )$ is some response function, e.g., a utility function. It involves generating random draws $X = x^{(j)}$ from the target distribution π and then estimating ψ by

$$\hat{\psi} = \frac{1}{k}\{U(x^{(1)}+\ldots+U(x^{(k)}\} \qquad (3.5)$$

Monte Carlo method is a numeric approach for evaluating the above integral. In addition, if the random draws $x^{(j)}$ are independent, an estimate of the error of the approximation using the Central Limit Theorem can be easily obtained (Fishmann 1996).

Monte Carlo simulation can be used to value complex real options whose payoffs are dependent on a project's cash flows. This technique uses repeated random sampling from the probability distributions for each of the crucial primary variables underlying the cash flows of a project to arrive at output probability distributions. (Trigeorgis 1996).

In Chapter 2, it was shown that the binomial method is consistent with the Black-Scholes-Merton framework. Therefore, the binomial lattice can be considered as the combination of all possible paths for the underlying asset movements. On the other hand, the standard Monte Carlo method has the capability to simulate all the possible movements of the underlying asset. Therefore, for the purpose of valuation under uncertainty, it is possible to generate sample paths through the binomial lattice instead of implementing the generic Monte Carlo method that randomly samples from the continuous stochastic process for the traffic demand. This is the idea behind the method that has been used in this study in order to model evolving traffic demand uncertainty and generate random paths of future traffic demand. These random paths will be used for pricing the Minimum Revenue Guarantee and Traffic Revenue Cap options.

Considering the binomial lattice formulation, AADT at the beginning of the *(j)th* year $j = n+1, n+2, …, N$ is a random variable that follows a discrete binomial distribution. There are several upward and downward movements that are needed to reach any node in this lattice from the root. The initial AADT at the beginning of the *(n+1)th* year is $AADT_0$, which represents the respective AADT value of the root node in the binomial lattice model. The possible values of AADT at the beginning of the *(n+2)th* year, *(n+3)th* year, …, *(N)th* year are summarized in the binomial lattice nodes of the *12th* month, *24th* month, …, *(12×(N-(n+1)))th* month, respectively.

Take any node in month l = 12, 24, …, 12×(N-(n+1)). This node can be reached from the root node by 0≤k≤l upside and 0≤l-k≤l downside movements along the lattice. The AADT at this node, then, becomes $AADT_0 \times u^k d^{l-k}$, which has the following binomial distribution:

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$$\text{Pr(AADT at the Beginning of the } (l)th \text{ month } = AADT_0 \times u^k d^{l-k}) = \begin{bmatrix} 1 \\ k \end{bmatrix} p^k (1-p)^{l-k} \quad (3.6)$$

This binomial distribution is used to generate random binomial variables as AADT values over the project lifetime. The Monte Carlo simulation engine for binomial random variables is then applied to generate a large number of random AADT paths across the binomial lattice as shown in Figure 3.3. This simplicity is an important feature of the proposed model for characterizing uncertainty about future traffic demand. In the next section, this model will be utilized to generate random traffic revenue streams for the concessionaire.
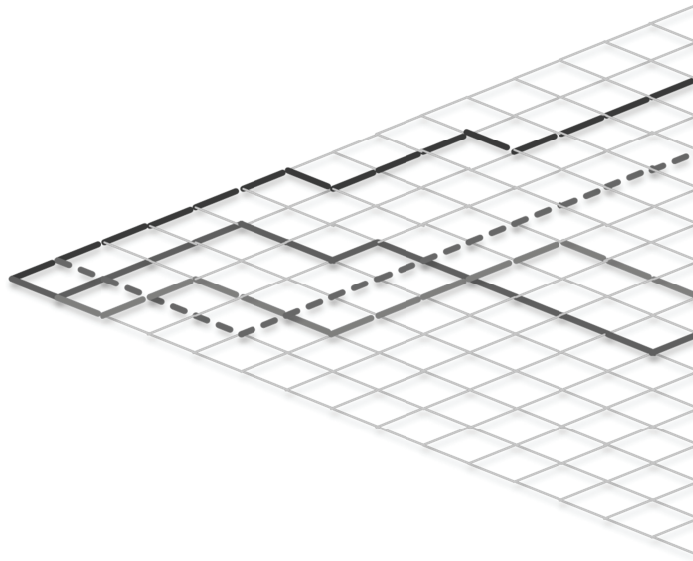
Figure 3.3 Randomly generated traffic demand paths along the binomial lattice

Conduct Lifecycle Cost and Revenue Analysis under Traffic Demand Uncertainty without Real Options

Each generated random AADT path can be used to create another path that represents a possible traffic revenue stream for the concessionaire. The annual operating revenue from the first year after the project is completed until the end of concession lifetime, i.e., OR_j $j = n+1, n+2, ..., N$ can be calculated for each generated random AADT path as follows:

$$OR_j = AADT_j \times 365 \times Scheduled\ Toll\ Rate_j \quad j = n+1, n+2, ..., N \tag{3.7}$$

Thus, through each simulation run, random paths of the concessionaire's future revenues from the operation of the BOT project are generated. These randomly generated revenue streams will then be used to calculate the concessionaire's NPV based on the following equation.

$$NPV = -\sum_{i=0}^{n} \frac{CC_i}{(1+\rho)^i} + \sum_{j=n+1}^{N} \frac{(OR_j - OC_j)}{(1+\rho)^j} \tag{3.8}$$

Where n is the length of construction period in years; N is the overall concession length in years from the initial construction to the return of the highway asset to the government; CC_i $i = 1, 2, ..., n$ are the annual construction costs from the beginning of the project until the end of construction period; OC_j $j = n+1, n+2, ..., N$ are the annual operations, maintenance, and rehabilitation costs from the first year after the project is

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completed until the end of concession period; $OR_j\, j = n+1,\ n+2,\ ...,\ N$ are the randomly

generated traffic revenues from the first year after the project is completed until the end

of concession period; and ρ is the discount rate. The concessionaire's cost of capital is

used as the discount rate (ρ) in this equation.

A sufficiently large number of simulation runs should be conducted to calculate

all possible NPVs, in addition to their respective likelihoods. Using the simulation results,

the Cumulative Distribution Function (CDF) can be identified for the concessionaire's

NPV. Therefore, the proposed model expands the conventional NPV analysis approach

by the systematic treatment of uncertainty about future traffic demand.

The CDF of the concessionaire's NPV can be used to calculate the probability of

the event that the NPV of investing in the BOT project is negative. Investors can use this

probability and decide whether investing in the BOT concession stays within the

appropriate confidence level in their portfolio. Moreover, a sensitivity analysis can be

conducted to evaluate the effect of traffic demand volatility on the distribution of the

concessionaire's NPV. The sensitivity analysis starts from that analysis of a reference

scenario, where usually the most likely estimate of the traffic demand volatility will be

utilized to develop the reference NPV distribution. Then, while keeping all other

variables equal to their value in the reference case, traffic demand volatility will be

modified around the reference value. The results of this analysis provide an insight into

how the distribution of NPV changes in response to the variations of traffic demand

volatility.

Price Minimum Revenue Guarantee and Traffic Revenue Cap Options

Due to the uncertainty about future traffic demand, the private sector often request

government support instruments such as Minimum Revenue Guarantee, which transfer a portion of the revenue risk to the government.

Minimum Revenue Guarantee is a contract that allows the concessionaire to redeem the revenue shortfalls up to a certain level at discrete points over the operation phase of the BOT project. Thus, Minimum Revenue Guarantee can be modeled as a discrete-exercise option, which can be exercised at discrete points over a pre-determined time period. As the Minimum Revenue Guarantee holder, the concessionaire has the right but not the obligation to exercise this option and receive payments from the government at specific points of time over the concession lifetime. The additional revenue is the concessionaire's option pay-off that changes the concessionaire's financial risk profile in the BOT project and makes up the value of Minimum Revenue option.

Similarly, Traffic Revenue Cap is a revenue-sharing mechanism through which the concessionaire shares a percentage of the excess traffic revenue with the government if the traffic revenue exceeds the pre-specified ceiling level. Traffic Revenue Cap can also be modeled as a discrete-exercise option, which is exercised at discrete points over a pre-determined time period. While Minimum Revenue Guarantee options are intended to provide the concessionaire with government supports against downside traffic revenue risk, Traffic Revenue Cap options provide the right for the government to claim a portion of excess revenues when the traffic revenue is higher than the pre-specified traffic revenue ceiling. The payments to the government are option pay-off that changes the concessionaire's revenue, as well as financial risk profile, and make up the value of Traffic Revenue Cap options.

It is necessary for both the concessionaire and the government to determine the

market value of Minimum Revenue Guarantee options. The concessionaire needs to determine the impact of Minimum Revenue Guarantee options on its financial risk profile while the government needs to evaluate the cost of Minimum Revenue Guarantee options to the public. The conventional NPV analysis approach is not the correct method to evaluate investment opportunities with embedded real options, such as BOT projects with Minimum Revenue Guarantee options.

Real options analysis can be used as an alternative approach to valuation of investments in transportation projects under uncertainties. However, the appropriate application of real options analysis to valuation of investments in transportation projects is conditioned upon overcoming specific theoretical challenges. Current real options models do not provide a systematic method for estimating the project volatility, which measures the variability of investment value. Existing models do not provide a method for calculating the market value of Minimum Revenue Guarantee and Traffic Revenue Cap options. In this research a novel method for estimating the project volatility for real options analysis is presented. In addition, a market-based option pricing approach is devised that utilizes the estimated project volatility and determines the market value of Minimum Revenue Guarantee and Traffic Revenue Cap options.

Estimate Project Volatility for Real Options Analysis

Uncertainty is the key driver of the value of a real option. Project volatility, which measures the uncertainty about project value over time, is one of the most critical inputs to any real options valuation model. The current literature on the application of real options in transportation infrastructure management does not provide a systematic

method for estimating the project volatility and often prescribes the use of assumptions. Due to this limitation, the application of the current real options models to the valuation of investments in BOT projects can lead to an erroneous pricing of real options such as Minimum Revenue Guarantee and Traffic Revenue Cap. Researchers in other domains have proposed the use of specific proxies for estimating the project volatility. These proxies are described below.

1. *Historical volatility of underlying asset:* It has been proposed that, when the future cash flow of the project is determined by the price of an exchange-traded natural resource, the natural resource can be considered as the underlying asset and its historical volatility can be used as the volatility of the project. For instance, gold price returns has been used to analyze the optimal time to invest in (Kelly 1998; Luenberger 1998) or to close a mine (Moel and Tufano 2002).

2. *Historical volatility of a related asset:* It has been proposed that, when the underlying asset is not traded in the market, the volatility of a related asset can be used as the project volatility. For instance, the volatility of retail price of lumber has been used to evaluate the real options on timber harvesting (Insley and Rollins 2005).

3. *Historical volatility of stock prices of a company:* In some applications, the project volatility is assumed to be perfectly correlated with the movement of company stock prices. For instance, the value of a new research project in an R&D company has been assumed to be perfectly correlated with it stock prices (Herath and Park 2002; Miller and Park 2005).

4. *Historical volatility of an industrial index:* In some applications, the historical volatility of a corresponding industrial group index has been used as the volatility of a

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particular project value. For instance, the volatility of pharmaceutical industry's index

has been used as the volatility of an R&D project focused on new drug applications

(Cassimon et al. 2004).

It is evident that, due to their underlying assumptions, these approaches that rely

on using proxies for estimating the project volatility are only applicable to a few specific

domains. These approaches cannot be used in order to estimate the project volatility in

BOT transportation projects. Transportation project are unique and there is no exchange-

traded underlying asset or corresponding index that can be utilized as a proxy for the

value of investments in these projects.

In situations like this, the future cash flows of a project can be used in order to

compute the project volatility of a project (Cobb and Charnes 2004; Copeland and

Antikarov 2003). In this approach the project without options is considered as the

underlying asset and, thus, its volatility is used as the project volatility in the valuation.

The volatility of project without option is the uncertainty over expected investment

returns from one period to the next.

Accordingly, for BOT transportation projects, the value of project without

Minimum Revenue Guarantee and Traffic Revenue Cap option is as an unbiased

indicator of the market value of project. Therefore, the return on the project value can be

used to compute the project volatility. Some key variables have to be defined first.

Suppose there is a project that generates a series of uncertain cash flows occurring in

future CF_t $t = 1, 2, \ldots, T$, and a continuously compounded discount rate ρ. The market

value of project at time n i.e., (PV_n) is defined as the value of the cash flows that will

occur after time n, discounted to time n

$$PV_n = \sum_{t=n+1}^{T} CF_t e^{-\rho(t-n)} \qquad (3.11)$$

The present worth of the project at time n (PW_n) is defined as the market value at time n plus the current cash flow

$$PW_n = PV_n + CF_n = \sum_{t=n}^{T} CF_t e^{-\rho(t-n)} \qquad (3.12)$$

Both PV_n and PW_n are the expected future cash flows, discounted back to time n. At time 0, the present worth (PW_0) is the project present value of investment. Also, for $n = 0$, $PW_0 = PV_0$. Suppose R_n is a random variable that represents the continuously compounded rate of return on the project between time $n-1$ and time n. Then

$$PW_n = PV_{n-1} e^{R_n} \qquad (3.13)$$

The equation above can be also written as

$$R_n = \ln\left(\frac{PW_n}{PV_{n-1}}\right) \qquad (3.14)$$

The project volatility is defined as the uncertainty over expected project returns

from one period to the next period. In other words, the project volatility is the standard

deviation of R_n, which is the rate of return of the project between two consecutive time

periods (i.e., $n-1$ and n). A Monte Carlo simulation can be utilized in order to build the

probability distribution of R_n. The standard deviation of this simulated distribution will

considered as the volatility of the project (σ_p) in the nth period. Assuming that the

project volatility will remain constant over time, the standard deviation of R_1 can be used

as the project volatility. If the volatility changes over time, instead of only using R_1 as the

constant project volatility, the standard deviation of R_n for different values of n has to be

calculated and a term structure of volatility should be created.

There are two slightly different procedures for developing the probability

distribution of R_1. Copeland and Antikarov (2003) argue that PV_0 should be estimated

once and then held constant. Therefore, the only PW_1 will be simulated. Cobb and

Charnes (2004) have argued that PV_0 and PW_1 should both be considered as random

variables and, thus, be simulated independently using different sets of random variables.

Nevertheless, from a statistical point of view, the application of these Monte Carlo

simulation methods for estimating volatility is problematic. These methods have a

tendency to overestimate the project's volatility (Godinho 2006). This problem stems

from their approach to generation of future cash flows. These methods incorrectly

incorporate additional sources of variations when simulating PV_0 and PW_1. They include

sources of variation in project value that are subsequent to the first year cash flows and,

therefore, artificially increase the annualized project volatility. If used, these approaches

to creating the probability distribution of R lead to an upwardly biased estimate of project

volatility and hence inaccurate valuation of real options.

In order to avoid this problem of overestimating the investment volatility shared by the current methods, a different Monte Carlo simulation procedure is used in this research. In this approach, PV_0 is calculated using the expected value of the future cash flows. By simulating the cash flows from the start to the end of the project life, the expected value of future cash flows (i.e., market value of project) can be obtained. PW_1 is calculated using a two level Monte Carlo simulation procedure. The first round of this Monte Carlo simulation generates random cash flows for the first period (CF_1). Each iteration of the first level is followed by a complete simulation of the second level. The second level of this simulation uses the first period cash flows generated during the previous round of simulation as the starting point and, for each randomly generated cash flow, generates a series of future project cash flows. In other words the second level, estimates the expected future cash flows based on the first year outcome. Every iteration of the second step simulation creates a random path of future cash flows from first year until the end of project life. At the end of second level simulation, the expected cash flows for each year and hence the expected value of the future cash flows PW_1 are estimated. Once the second level simulation is over, the PV_0 and PW_1 are used to calculate R_1. By continuing this two level simulation, a distribution of R_1 can be created. The project volatility is the standard deviation of this distribution. The estimated project volatility will be a critical input to the real options pricing model introduced in the next segment.

Find the Market Value of Real Options in BOT Transportation Projects

In order to determine the price of an option, the benefits resulted from exercising the option should be discounted at an appropriate risk-adjusted rate. When it comes to the valuation of real options in transportation projects, it is impossible to estimate the correct and exact risk-adjusted discount rate that reflects the market risks, project risks that are unique to these projects and asymmetric benefit patterns created by the options. Under the condition of the absence of arbitrage opportunity in the market, there is an alternative equivalent method to do this calculation. Instead of first taking the expectation and then discounting for the risk, one can first adjust the probabilities of future asset values to incorporate the risk effects, calculate the expectation under these risk-adjusted probabilities, and then, discount the expected future option pay-offs at the risk-free rate. These revised probabilities are just mathematical artifacts and do not exist in the real world. These probabilities are called risk-neural probabilities and this option pricing method is referred to as risk-neutral valuation approach. The option value using the risk-neutral valuation approach is equivalent to the option value using the former direct approach. The major benefit of risk-neutral valuation approach is that once the risk-neutral probabilities of the underlying asset are found, the expected option pay-offs will be discounted at the risk-free rate. The risk-neutral valuation approach was developed in mathematical finance to price options and derivatives by revising the probability measures of underlying assets (Luenberger 1998; Hull 2008). It is the underlying logic for dominant pricing models such as Black-Scholes model and is frequently used in the pricing of financial derivatives.

In order to determine the market value of a Minimum Revenue Guarantee option,

it should be evaluated as a derivative for which the underlying asset is the future traffic

demand. Therefore, in order to use the risk-neutral valuation and find the value of

Minimum Revenue Guarantee option, the probabilities of future traffic demand have to

be revised and risk-neutral probabilities should be calculated. In this study, a method

introduced by Hull (2008) is modified so that it can be used for adjusting the probabilities

of AADT movements in the binomial lattice. The modification of the AADT binomial

lattice for applying the risk-neutral valuation approach is described below.

In order to derive the risk-neutral probabilities, first the actual expected growth

rate of AADT (α) in Equation 3.3 has to be substituted with the risk-neutral expected

growth rate of AADT, which is denoted by $\alpha - \lambda \sigma$. Then, the risk-neutral probabilities of

upward and downward movements will be calculated using this revised expected growth

rate. In this adjustment, σ is the volatility of AADT and λ is the market price of traffic

revenue risk, which is also called the Sharpe ratio or reward-to-variability ratio. It is a

measure of the excess return or risk premium per unit of risk of the underlying asset.

Using the Sharpe's definition (1994), the risk premium of future traffic demand is

described as follows:

$$\lambda = \frac{R - r_f}{\sigma} \tag{3.15}$$

Where R is the asset return, r_f is the risk-free rate of return, and σ is the volatility of

future traffic demand. The future traffic demand is not a traded asset in the financial

markets and, therefore, it is impossible to observe and find the excess return $R - r_f$ that

investors require to bear the traffic revenue risk. Since the traffic revenue risk in the operations phase of the project stems from uncertainty about future traffic demand, the market price of risk of investment in the BOT project , which is denoted by λ_p , must be identical to the market price of future traffic revenue risk, i.e., $\lambda = \lambda_p$. The concessionaire's risk premium in the project λ_p , on the other hand, can be computed.

The concessionaire's excess return, which is denoted by $R_p - r_f$, is the excess return that the concessionaire demands to invest in this project. The concessionaire's return is its cost of capital (ρ) that been has used as the discount rate in the calculation of investment value. Thus, the concessionaire's excess return in the project is $\rho - r_f$. The project volatility σ_p is estimated using the Monte Carlo estimation procedure described in the previous segment. Thus, the market price of future traffic demand λ or the market price of risk of investment in the BOT project λ_p can be calculated as follows:

$$\lambda = \lambda_p = \frac{R_p - r_f}{\sigma_p} = \frac{\rho - r_f}{\sigma_p} \qquad (3.16)$$

The valuation of the BOT project with Minimum Revenue Guarantee and Traffic Revenue Cap options will be conducted using the risk-neutral binomial lattice of AADT. Monte Carlo technique will be used to generate random AADT paths along the risk-neutral binomial lattice. In this study it is assumed that the concessionaire is offered with Minimum Revenue Guarantee option on an annual basis after the project completion, i.e., year j where $j = n+1, n+2, ..., N$. It is also assumed that these Minimum Revenue

Guarantee options are provided free-of-charge to the concessionaire as an incentive to promote the private investments in public transportation infrastructure development.

Suppose PR_j is the guaranteed projected traffic revenue generated from the operation of the project during year $j = n+1, n+2, ..., N$. PR_j is computed based on the most likely value of future traffic demand – which are specified in the traffic study – as follows:

$$PR_j = \textit{Most Likely Estimated AADT}_j \times 365 \times \textit{Scheduled Toll Rate}_j \quad j = n+1, n+2, ..., N \quad (3.9)$$

In any year, the government compensates the concessionaire based on Minimum Revenue Guarantee if the traffic revenue generated from the operation of the project, i.e., $OR_j \ j = n+1, n+2, ..., N$, falls below the respective, pre-specified and guaranteed traffic revenue, i.e., $PR_j \ j = n+1, n+2, ..., N$. The Minimum Revenue Guarantee is offered as a $X_j \ j = n+1, n+2, ..., N$ guaranteed percentage of projected revenue in any year as follows:

$$MRG_j = Max\{0, X_j \times (PR_j) - OR_j)\} \quad j = n+1, n+2, ..., N \quad (3.10)$$

Here $MRG_j \ j = n+1, n+2, ..., N$ is the additional revenue in year j if the traffic revenue falls shorter than the pre-specified revenue in year j. These additional revenues will be added to respective annual traffic revenues on each random AADT path. The entire project cash flows can then be discounted at risk-free rate (r_f) in order to compute

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the concessionaire's present value for each random AADT path. Therefore, the CDF will be created for the concessionaire's investment value in the BOT project considering (possible) additional Minimum Revenue Guarantee options. The concessionaire can apply the described risk-neutral option pricing approach to update his financial risk profile in the BOT investment with Minimum Revenue Guarantee options. The market value (or option premium) of Minimum Revenue Guarantee is the difference between the concessionaire's investment value with Minimum Revenue Guarantee options and the concessionaire's investment value without any Minimum Revenue Guarantee option. This difference will be computed for each random AADT path to create the CDF of Minimum Revenue Guarantee option value. The expected value of this distribution is the expected value or the expected premium of Minimum Revenue Guarantee options.

The described risk-neutral pricing approach can also be used to evaluate BOT projects that include Traffic Revenue Cap (TRC) options in addition to the Minimum Revenue Guarantee options. Suppose both Minimum Revenue Guarantee and Traffic Revenue Cap options are available in a BOT project. The combined impact of these options will be considered through appropriate adjustments in the concessionaire's revenue streams. The revised concessionaire's revenue in realm of Traffic Revenue Cap options in year j, i.e., ROR_j $j = n+1, n+2, \ldots, N$, can be written as:

$$ROR_j = Min\left\{(OR_j + MRG_j), \left(\left(\left(1 + K_j\right) \times PR_j\right) + AR_j\right)\right\} \qquad (3.17)$$

In this equation K_j $j = n+1, n+2, \ldots, N$ is the maximum portion of revenue

that the concessionaire can entirely claim above the projected revenue

PR_j $j = n+1, n+2, \ldots, N$ in year j. The BOT agreement between the government

and the concessionaire will specify the values of K_j. ARj $j = n+1, n+2, \ldots, N$, is the

additional revenue the concessionaire can claim above $\left(1+K_j\right) \times PR_j$ $j = n+1, \ldots, N$ in

year j as identified below:

$$AR_j = Max\left\{0, \left(\left(OR_j - \left(\left(1+K_j\right) \times PR_j\right) \times T_j\right)\right)\right\}$$ (3.18)

In this equation T_j $j = n+1, n+2, \ldots, N$ is the portion of revenue that the

concessionaire can claim above $\left(1+K_j\right) \times PR_j$ $j = n+1, n+2, \ldots, N$ in year j. The

BOT agreement between the government and the concessionaire will specify the values

of T_j.

Together, Minimum Revenue Guarantee and Traffic Revenue Cap form a specific

case of compound options on the BOT project. The valuation of the BOT project with the

combined will be conducted using the risk-neutral binomial lattice of AADT. The

concessionaire's financial risk profile with combined Minimum Revenue Guarantee and

Traffic Revenue Cap can be characterized using a probabilistic analysis approach on the

project life cycle costs and revenues. Monte Carlo technique will be used to generate

random AADT paths along the risk-neutral binomial lattice. For each random AADT

path, the resulting annual revenues will be adjusted considering the Minimum Revenue

Guarantee and Traffic Revenue Cap payments at the end of each year when the actual

traffic demand falls below the forecasted traffic demand or exceeds the specified ceiling. The entire project cash flows will then be discounted at risk-free rate (r_f) to compute the concessionaire's present value for each random AADT path. Therefore, a CDF will be created for the concessionaire's investment value in the BOT project considering the Minimum Revenue Guarantee and Traffic Revenue Cap risk and revenue sharing mechanism. The concessionaire can apply the described risk-neutral option pricing approach to update its investment risk profile investment with the combined Minimum Revenue Guarantee and Traffic Revenue Cap options. The market value (or option premium) of this risk and revenue sharing mechanism is the difference between the concessionaire's investment value with Minimum Revenue Guarantee and Traffic Revenue Cap mechanisms and the concessionaire's investment value without them. This difference will be computed for each random AADT path to create the CDF of combined Minimum Revenue Guarantee and Traffic Revenue Cap option value. The expected value of this distribution is the expected value or the expected premium of combined Minimum Revenue Guarantee and Traffic Revenue Cap options. A scenario analysis can also be conducted in order to answer a series of what-if questions concerning the impact of various Minimum Revenue Guarantee and Traffic Revenue Cap threshold levels on the concessionaire's risk profile.

In the next chapter, the proposed real options model is applied to the Incheon international Airport Highway (IIAH) project in the Republic of Korea in order to illustrate the proposed valuation process.

CHAPTER 4   ILLUSTRATIVE EXAMPLE

In the previous chapter, an investment valuation model for pricing

Minimum Revenue Guarantee and Traffic Revenue Cap in BOT projects was

created. This model presents a novel method for estimating the project volatility

for real options analysis. This model devises a market-based risk-neutral option

pricing approach to determine the market value of Minimum Revenue Guarantee

and Traffic Revenue Cap options. An appropriate procedure is also created for

characterizing the impact of Minimum Revenue Guarantee and Traffic Revenue

Cap options on the investors' financial risk profile.

In this chapter, the proposed real options model is applied to a BOT project

in order to illustrate the valuation process. The data used in this illustrative

example are obtained from the Incheon international Airport Highway (IIAH)

project in the Republic of Korea.

Incheon International Airport Highway (IIAH)

Background

The International Airport Highway (IIAH) project is Korea's first privately

financed project based on the Private Participation in Infrastructure program. The

IIAH project is a 36.6 km highway connecting Korea's Incheon International

Airport to the capital city of Seoul. The construction began in 1995 and the

highway was open to traffic by 2000.

The New Airport Highway Corporation (NAHC), a consortium of eleven

construction companies that took part in this project and invested their equity in the

project, was responsible for building, operating and maintaining the IIAH. The

NAHC has the operating rights on this BOT project for 30 years from the date the

construction was finished (Lee 2007).

Traffic Demand Projections

Initially, the IIAH project was intended to be government-funded but later

it was decided that project be delivered using the public-private partnership model.

As a result, the traffic and review study was conducted by the Korean ministry of

construction and transportation. The concessionaire did not conduct an

independent traffic and revenue study (Lee 2007).

The traffic study report specifies that the value of annual expected growth

rate of AADT or parameter α is 9.8% from 2001-2005, 5.3% from 2006-2010, and

3.1% from 2011-2020. The traffic study forecasts the most-likely initial AADT to

be 100,720. In addition, the traffic study identifies 80,576 and 120,864 as

pessimistic and optimistic forecasts for the initial AADT respectively. Further, the

capacity cap for future traffic demand is assumed to be 20% above the maximum

projected AADT.

In addition, it was assumed that the annual volatility of AADT is $\sigma=10\%$ to

characterize uncertainty about future traffic demand over the project lifetime. A

sensitivity analysis was conducted in order to determine how the changes in

volatility impact the investment value. The expected growth rates and volatilities

are then used to compute the AADT binomial lattice parameters – u, d, and p – as described in Chapter 3.

Project Financing

The total financing amount needed for the construction of this project was $1.7 billion, which was raised between 1995 and 2000. The concessionaire's capital is $434 million in private equity (25% of the total financing amount) and $1.3 billion in syndicated loans (75% of the total financing amount). Eighteen banks, insurance companies, and merchant banking corporations were involved as lenders in this project. The details of the financing plan by year were as Table 4.1.

Table 4.1 Financing plan for IIAH (Source: Ministry of Construction and Transportation in Korea 1996)

							($ Million)
Year	Total	1995	1996	1997	1998	1999	2000
Equity	434.2	40.0	244.7	149.5	-	-	-
Private Placement	224.9	25.6	117.7	81.6	-	-	-
Corporate Bond	126.7	4.3	76.9	45.5	-	-	-
Loan	82.6	10.1	50.1	22.4	-	-	-
Others	-	-	-	-	-	-	-
Debt	1,300.0	-	-	306.3	408.7	271.1	313.9
Total	1,734.2	40.0	244.7	455.8	408.7	271.1	313.9

Table 4.2 partially summarizes the concessionaire's cash flow in the IIAH project. The concessionaire's annual cash outflows consist of construction costs,

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operations, maintenance, capital improvement costs, and debt payments. The

concessionaire's cash inflows are anticipated annual traffic revenues based on the

most-likely forecasts of future traffic demand.

Table 4.2 Concessionaire's cash flow in the IIAH project

									($ Million)
Year	1995	1996	1997	1998	1999	2000	2001	....	2030
Financing Activities Inflows	34.9	209.7	385.4	351.7	240.1	279.8		....	
Equity	34.9	209.7	131.9					....	
Debt			253.6	351.7	240.1	279.8		....	
Financing Activities Outflows							-1.9		
Construction Cost	-34.9	-209.7	-385.4	-351.7	-240.1	-277.8		....	
Operations Revenue						45.3	208.3	....	882.5
Operations & Maintenance						-47.2	-185.7	....	-373.7
Investor's Net Cash Flow	-34.9	-209.7	-131.9	0.0	0.0	0.1	20.6	....	508.8

The risk-free rate of return and the concessionaire's cost of capital are

specified in the project agreement between the concessionaire and the government.

According to Lee (2007), "through negotiation between the parties in the

consortium, it was decided that the concessionaire's cost of capital was the sum of

risk-free interest r_f=12.56% and a 0.5% spread." Hence, the concessionaire's

discount rate is ρ=12.56+0.5=13.06% per year.

Minimum Revenue Guarantee and Traffic Revenue Cap

The use of government guarantees to help persuade private investors to finance new infrastructure is appealing because it can allow the government to get the infrastructure built without paying anything immediately and to benefit from the skill and enterprise of private firms. The Republic of Korea, typically offers to guarantee infrastructure firms specified fractions of their forecast revenue. In case of the IIAH, the government guaranteed the 20-year projected revenues (Irwin 2007). Based on this Minimum Revenue Guarantee (MRG) agreement, the government had to pay the concessionaire a percent of the difference between the actual and forecasted revenue if the actual traffic revenue falls shorter than the forecasted revenue. These Minimum Revenue Guarantee options are available in any year after the project is completed until 15 years after the project completion date, i.e., from 2000-2014. This percent is 90% from 2000-2004, 80% from 2005-2009, and 70% from 2010-2014. Minimum Revenue Guarantee options are completely terminated after 2014.The government did not have to pay anything up front and would get to keep a share of any revenue exceeding 110 percent of the forecast (Irwin 2007) through a Traffic Revenue Cap (TRC) mechanism. These Traffic Revenue Cap options are available in any year after the project is completed until 15 years after the project is built, i.e., from 2000-2015. The proposed real options model will be applied to this example in to price the Minimum Revenue Guarantee and Traffic Revenue Cap and characterize the concessionaire's financial risk profile in this BOT project. The summary of results

is presented in the next section.

Summary of Results

First, a conventional NPV analysis for the IIAH project is conducted. The

formula for calculating NPV is as follows

$$NPV = -\sum_{i=0}^{n} \frac{CC_i}{(1+\rho)^i} + \sum_{j=n+1}^{N} \frac{(PR_j - OC_j)}{(1+\rho)^j} \qquad (4.1)$$

Where n is the length of construction period in years; N is the total

concession length in years from the initial construction to the return of the highway

asset to the government; CC_i $i = 1, 2, ..., n$ are the annual construction costs from

the beginning of the project until the end of construction period; OC_j $j = n+1,$

$n+2, ..., N$ are the annual operations, maintenance, and rehabilitation costs from

the first year after the project is completed until the end of concession period; PR_j

$j = n+1, n+2, ..., N$ are the forecasted annual traffic revenues from the first year

after the project is completed until the end of concession period; and ρ is the

discount rate. The deterministic NPV calculated according to Equation 4.1 is

$35.37 million. This indicates that the concessionaire should invest in this BOT

project. However, as previously discussed, the conventional NPV does not capture

the concessionaire's financial risk under traffic demand uncertainty. The model

created in this research can be used to characterize the concessionaire's financial

risk profile under uncertainty about future traffic demand. The dynamic traffic

demand uncertainty is characterized in an approximate discrete fashion using binomial lattice model. Monte Carlo simulation is applied to generate a large number of random AADT paths across the binomial lattice. Next, randomly generated AADT paths and scheduled toll rates are used for developing revenue streams over the concession life. For each revenue path, the present value of investment can be calculated. Using the investment value for randomly generated revenue paths are calculated, the Probability Density Function (PDF) and Cumulative Distribution Function (CDF) of the investment value of project can be created. Figure 4.1 shows the probability distribution of the concessionaire's investment value in this project. This distribution shows all possible investment values and the probability of their occurrences.
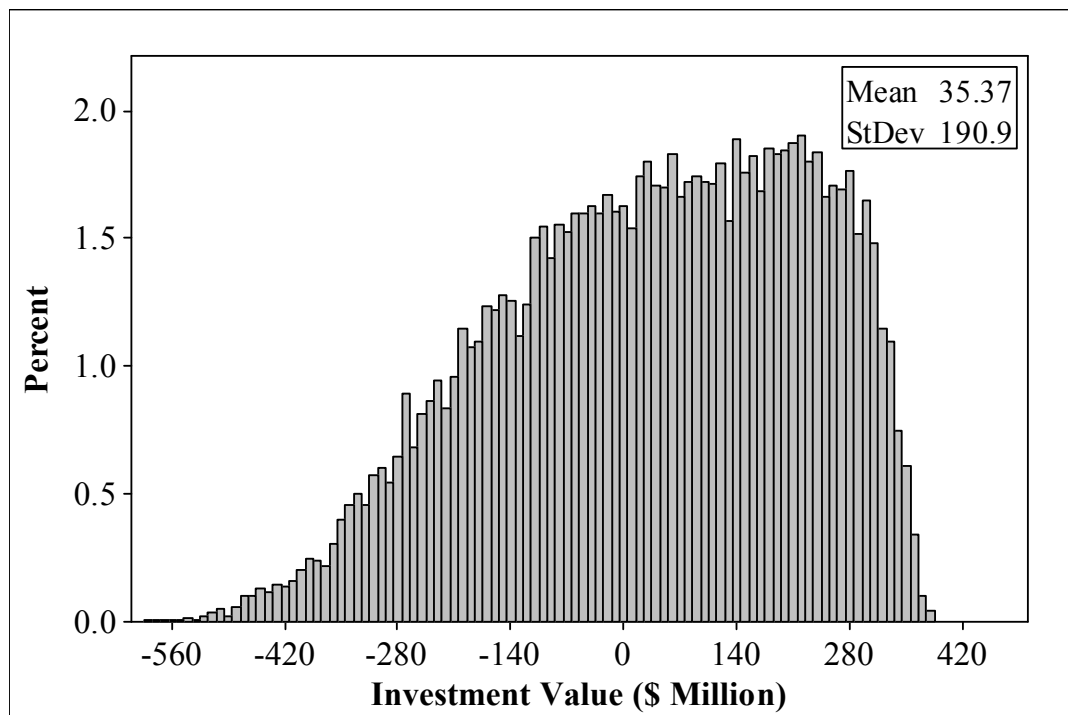

Figure 4.1 Probability distribution of the concessionaire's investment value in the IIAH project

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Figure 4.2 (a) shows the Cumulative Distribution Function (CDF) of concessionaire's investment value and highlights the riskiness of in the IIAH project. There is approximately 42.5% chance that the concessionaire's investment value becomes negative. Although the concessionaire's expected NPV is much greater than zero ($35.37 million), there is a considerable amount of uncertainty about the investment value. The standard deviation of the concessionaire's investment value distribution is $189.8 million due to the uncertainty about future traffic demand, which makes the investment in this project volatile.

The value of BOT investments can be influenced by changes in several factors. Thus, the investors are encouraged to consider variety scenarios in their valuation and conduct a comprehensive sensitivity analysis in order to determine the extent to which the viability of a project is influenced by variations in major quantifiable variables. The model proposed in this research offers a flexible interface that can capture the information required for conducting the sensitivity analysis. The proposed valuation procedures that are at the core of this model are capable of incorporating this information, calculate the investment value under different scenarios and characterize the impact of variations in different input variables on concessionaire's investment value.

Figure 4.2 (a) shows how the CDF of concessionaire's investment value changes as the annual traffic demand volatility changes from 5% to 10%, 20%, and 30%. It can be concluded that as the traffic volatility increases, the risk of underestimating future traffic demand increases and, consequently, uncertainty

about the project's future revenues increases. Thus, it becomes more likely that the project underperforms and the concessionaire's investment value becomes negative. This great exposure to the risk of underestimating future traffic demand is the primary motivation for the private investors to request government supports such as Minimum Revenue Guarantee mechanisms.

A primary obstacle in the utilization of BOT model is the lengthy delays in contract negotiation phase due to a variety of issues such as the lack of experience and appropriate skills among key decision makers, lengthy political debate and public opposition (AECOM Consult 2007; Chan et al. 2010). A prolonged contract negotiation phase can result in a significant deviation of the concessionaire's investment value from the projected levels. This deviation is resulted from changes in the key variables such as construction costs and traffic revenues. Figure 4.2 (b) shows the change to CDF of concessionaire's investment value under the scenario that due to a two-year delay in contract negotiation process, the construction cost has increased by a magnitude of 6%, while all other variables have remained equal to their value in the reference case. This increase in the construction cost shifts the concessionaire's risk profile and reduces the expected investment value.
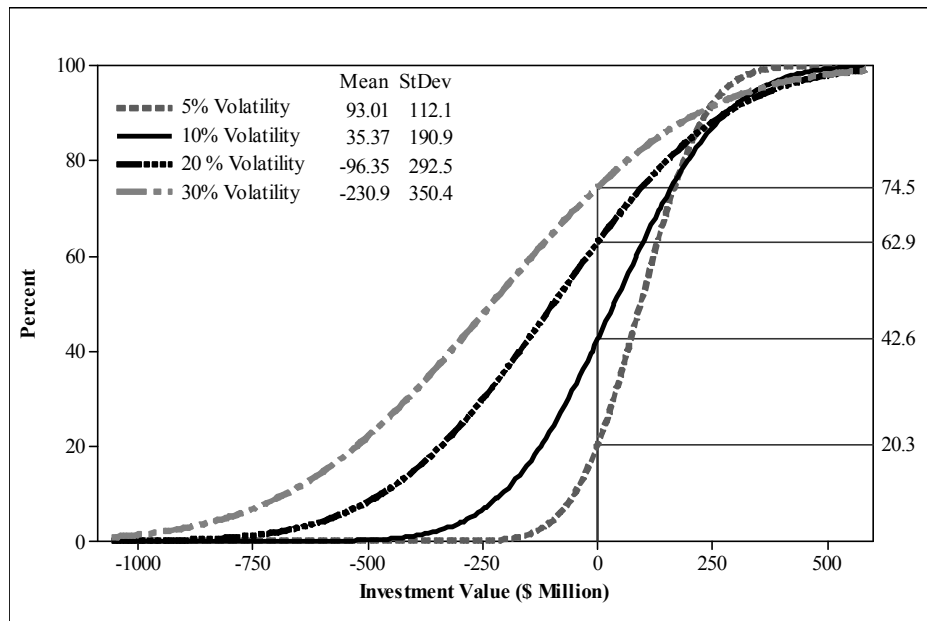
(a)
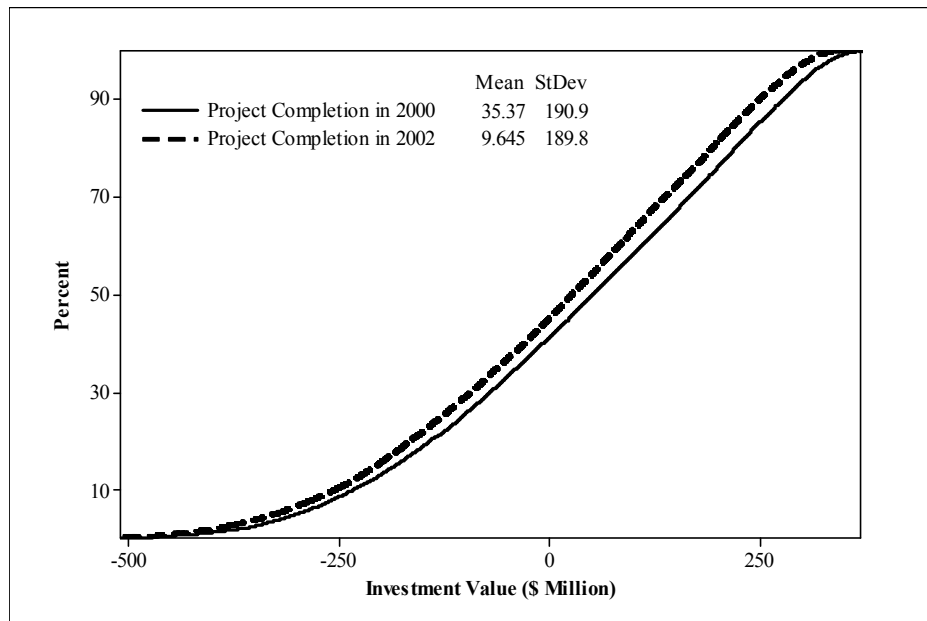
(b)

Figure 4.2 (a) The impact of changes in the annual traffic demand volatility on the concessionaire's CDF; (b) The change in concessionaire's CDF due to delays in contract negotiation phase

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Figure 4.3 depicts the probability distribution of the concessionaire's log-return present value, i.e., the probability distribution of ln (PW$_1$/PV$_0$). The standard deviation of this log-return present value distribution is 78.64% per year. This is the project volatility, i.e., σ_P=78.64% per year.
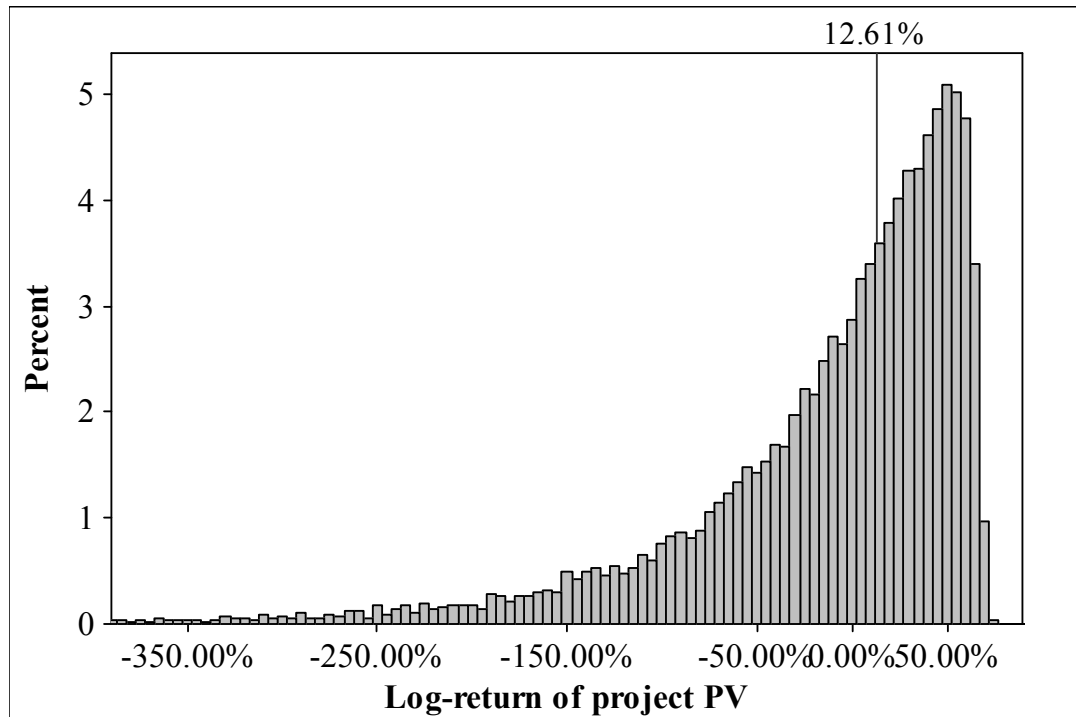
Figure 4.3 Probability distribution of the present value (PV) of concessionaire's log-return

The details of Minimum Revenue Guarantee options offered by the government are specified above. The proposed real options model is applied in order to characterize the concessionaire's financial risk profile with Minimum Revenue Guarantee options. The expected growth rate of AADT was revised in order to create the risk-neutral binomial lattice. According to Equation 4.2, the risk

premium of the concessionaire's investment in this project λ_p, which is equal to

the risk premium of future traffic demand λ, is 0.5% per year. Therefore, $\sigma\lambda$ that

will be subtracted from expected annual growth of AADT (α) in order to create the

risk-neutral binomial lattice is equal to 0.1272% per year.

$$\lambda = \lambda_p = \frac{R_p - r_f}{\sigma_p} = \frac{\rho - r_f}{\sigma_p} \qquad (4.2)$$

Figure 4.4 shows the CDF of the concessionaire's investment value in this

project with Minimum Revenue Guarantee options and compares it with the CDF

of the concessionaire's investment value in this project without Minimum Revenue

Guarantee options. The (possible) additional revenues of Minimum Revenue

Guarantee options increase the concessionaire's expected investment value from

$35.81 million to $70.87 million. Also the chance that the concessionaire's

investment value becomes negative reduces from 42.52% to 35.39%. Hence, the

concessionaire's financial risk profile shifts to the right when Minimum Revenue

Guarantee options are added to the agreement.
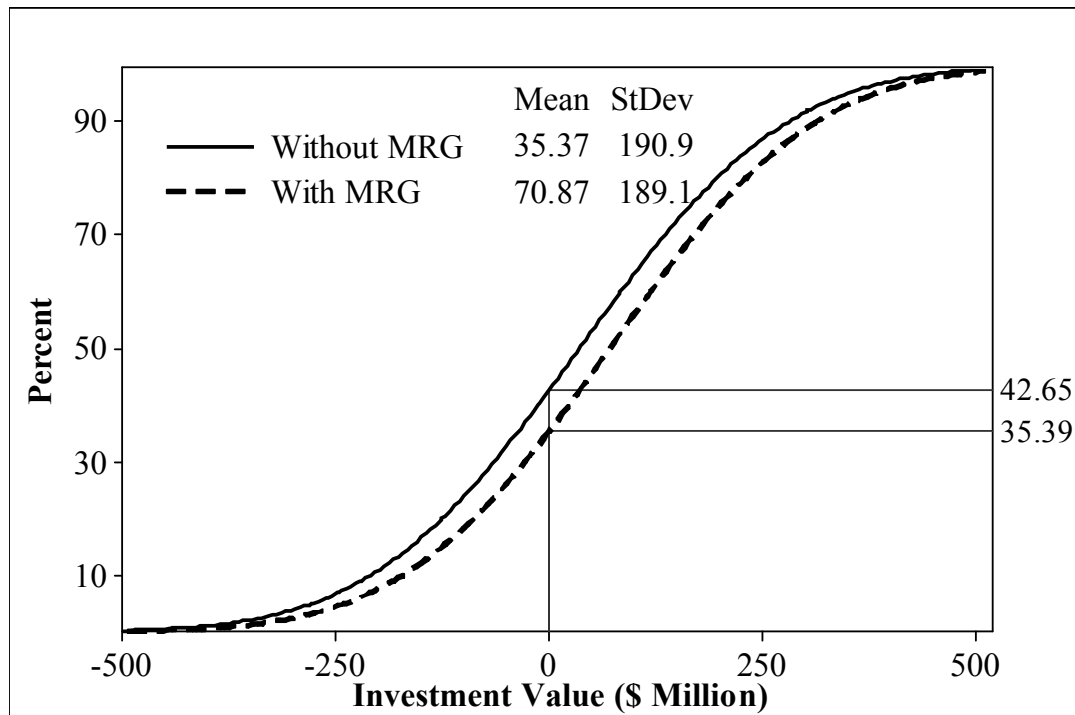
Figure 4.4 CDF of the concessionaire's investment value in the IIAH project with
and without MRG options

In addition, Figure 4.5 shows the probability distribution of the value of

Minimum Revenue Guarantee options in this project. This value is computed as the

difference between the concessionaire's investment values with and without

Minimum Revenue Guarantee option. The expected value of this distribution is the

expected premium of Minimum Revenue Guarantee options, i.e., $14.42 Million.

This is the market-based premium, which the government implicitly offers to the

concessionaire in this BOT project through considering Minimum Revenue
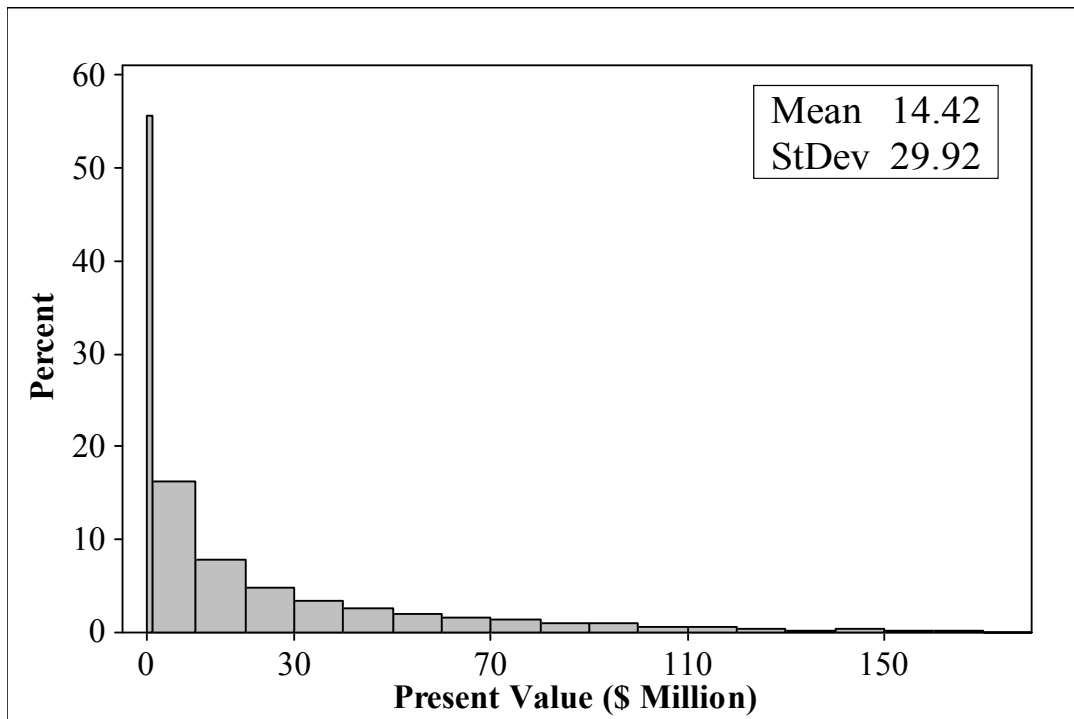
Guarantee options.

Figure 4.5 Probability distribution of the value of MRG options

It is important to study the significance of Minimum Revenue Guarantee options from the government standpoint. Figure 4.5 can also be considered as the probability distribution of the present value of Minimum Revenue Guarantee options paid by the government over the concession lifetime. It can be noticed that there is approximately 56% chance that the present value of Minimum Revenue Guarantee options become zero. This occurs when actual traffic demand is higher than forecasted traffic demand and therefore, the concessionaire never requests Minimum Revenue Guarantee options. The distribution of the Minimum Revenue Guarantee present value depends on the number of times that the concessionaire actually requests support.

Figure 4.6 shows the probability distribution of the number of times that the concessionaire may request Minimum Revenue Guarantee options in the first 15 years of the concession lifetime. The number of times that the concessionaire may request Minimum Revenue Guarantee from the government is variable and can take any values from 0 to 15. It can be seen that there is approximately 56% chance that the concessionaire never requests Minimum Revenue Guarantee options and, therefore, the present value of Minimum Revenue Guarantee options becomes zero. This probability drops sharply to approximately 10% for one Minimum Revenue Guarantee exercise and continues to decrease until 15 possible Minimum Revenue Guarantee option exercises.
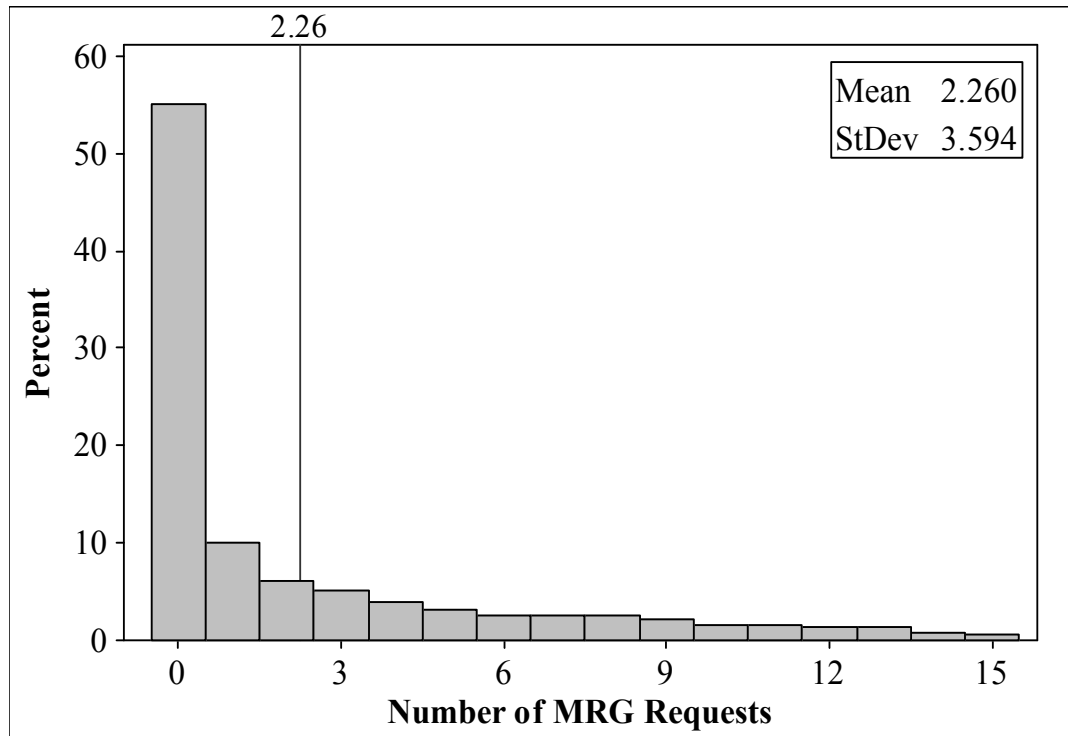

Figure 4.6 Probability distribution of the number of times that the concessioner may request MRG options

The government also needs information about how likely it is that the concessionaire requests Minimum Revenue Guarantee in any year after the project is completed. Figure 4.7 shows how likely it is that the concessionaire requests Minimum Revenue Guarantee in 2000, 2001, …, 2014. This likelihood drops twice in 2005 and 2010 due to the structural changes in the percentage of revenue shortfalls for calculating Minimum Revenue Guarantee options, i.e., the initial 90% Minimum Revenue Guarantee coverage rate will be reduced to 80% and 70% in 2005 and 2010, respectively. On the other hand, the probability that the concessionaire requests Minimum Revenue Guarantee increases from 2000-2004, 2005-2009, and 2010-2014. In any of these three distinct periods, forecasted future traffic demand increase rapidly based on the traffic study report. However, this report does not address the volatility of future AADTs. The rising AADT forecasts combined with the volatility of future traffic demand increase the probability that actual AADTs become smaller than forecasted AADTs. Figure 4.7 shows how the risk of underestimating the AADT grows as the BOT project advances. It can be seen that relying on just forecasted future traffic demand can be problematic for the government. As the project advances, the government is more likely to pay Minimum Revenue Guarantee options to the concessionaire if it does not consider the volatility of future traffic demand in the project valuation.
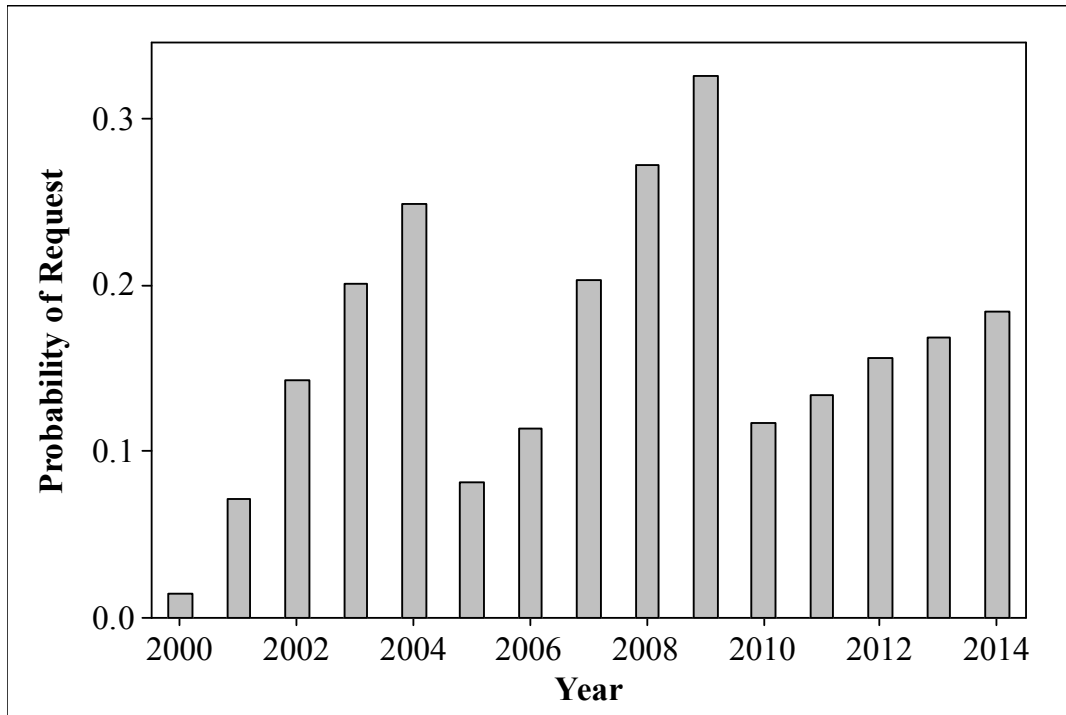
Figure 4.7 Probability distribution that the concessioner requests MRG option from 2000 to 2014

The amount of Minimum Revenue Guarantee, which is requested by the concessionaire in any year, is also variable. For instance, Figure 4.8 illustrates the probability distribution of Minimum Revenue Guarantee, which is requested from the government in 2004. It is shown that there is a great chance (approximately 76%) that the concessionaire does not request Minimum Revenue Guarantee in 2004. The expected value and standard deviation of Minimum Revenue Guarantee distribution in 2004 are $6.52 million and $15.19 million, respectively. This distribution shows the inherent uncertainty about the amount of requested Minimum Revenue Guarantee in any year. This is a great challenge for the government in terms of financial resource allocation and annual budget preparation

when related to the BOT project.
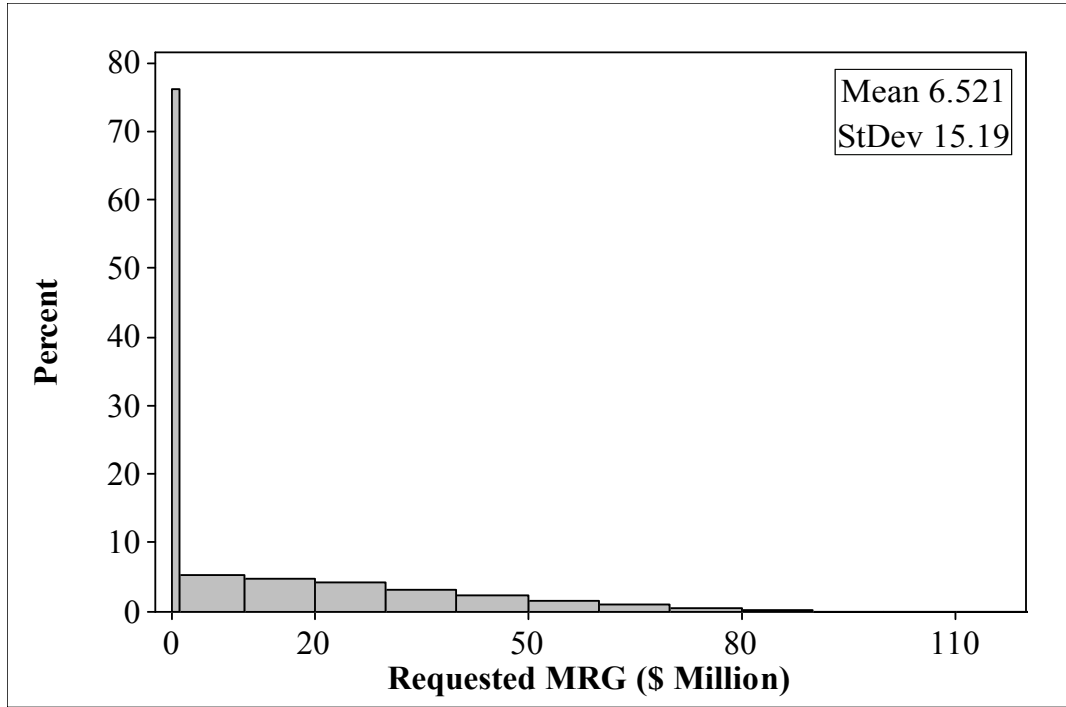
Figure 4.8 Probability distribution of MRG requested by the concessionaire in
2004

Figure 4.9 summarizes the expected values of Minimum Revenue Guarantee

distributions in every year between 2000 and 2014. This graph shows the expected

value of Minimum Revenue Guarantee payments to the concessionaire by the

government during the guarantee period (i.e., 2000 to 2014).
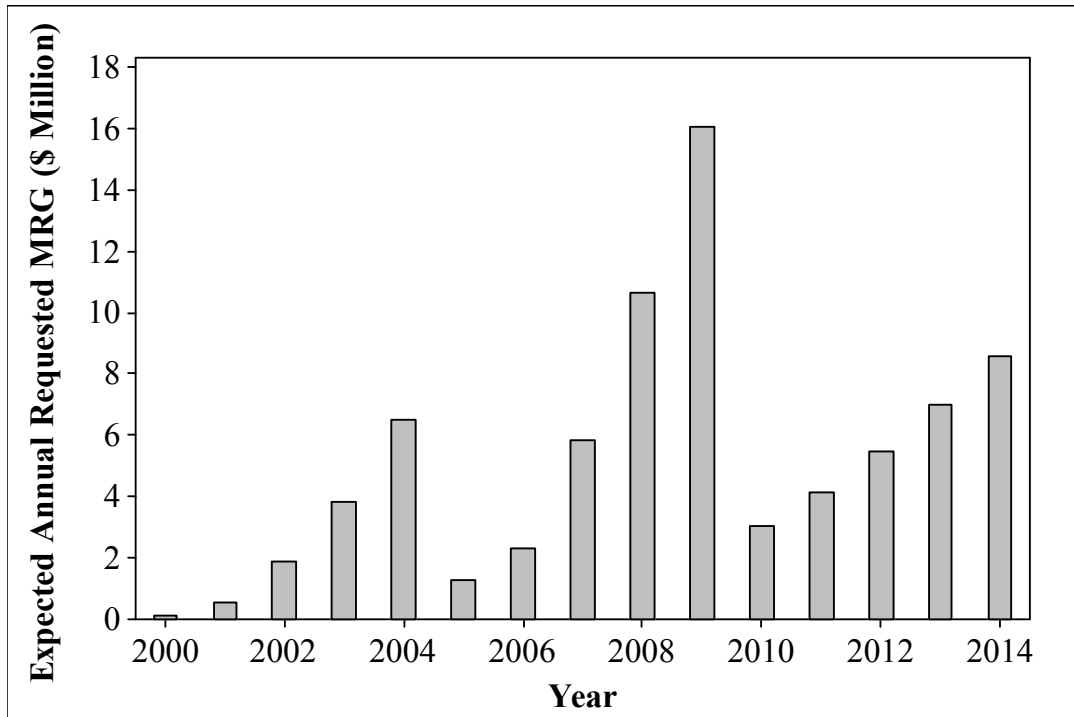
Figure 4.9 Expected value of MRG payments by the government between 2000 and 2014

The Korean government shares the risk of overestimating future traffic demand with the concessionaire through offering Minimum Revenue Guarantee options. The concessionaire also shares the excess revenues with the Korean government through offering Traffic Revenue Cap options. The details of Traffic Revenue Cap options requested by the government are specified above. The proposed real options model is applied in order to characterize the concessionaire's financial risk profile with Minimum Revenue Guarantee and Traffic Revenue Cap options. Figure 4.10 shows the CDF of the concessionaire's investment value with both Minimum Revenue Guarantee and Traffic Revenue Cap options and compares it with the CDF of the concessionaire's investment value with just

Minimum Revenue Guarantee options and without any options in the IIAH project. The concessionaire's access to extremely high revenues will be limited through offering of Traffic Revenue Cap options to the government. Hence, it can be seen that the expected value and standard deviation of the concessionaire's investment value distribution with Minimum Revenue Guarantee and Traffic Revenue Cap options are lower than the expected value and standard deviation of the concessionaire's investment value distribution with just Minimum Revenue Guarantee options, respectively. However, the expected value of the concessionaire's investment value distribution with Minimum Revenue Guarantee and Traffic Revenue Cap options is greater than the expected value of the concessionaire's investment value distribution with just Minimum Revenue Guarantee options. Also, the probability of the event that the concessionaire's investment value becomes negative is lower when the concessionaire considers both Minimum Revenue Guarantee and Traffic Revenue Cap options compared to the case without any options.

Figure 4.10 CDF of the concessionaire's investment value under 3 circumstances:
(1) with both MRG and TRC; (2) with just MRG options; and (3) without any
options

Further, Figure 4.11 characterizes the probability distribution of the present

value of Traffic Revenue Cap options. This probability distribution specifies all

possible present values of total excess revenues that the Korean government

receives under Traffic Revenue Cap options. The expected value and standard

deviation of this distribution are $16.38 million and $21.79 million, respectively.

There is approximately 36% chance that the Korean government does not receive

any additional revenues through Traffic Revenue Cap options. This probability is

lower than the 56% chance that the concessionaire never requests Minimum

Revenue Guarantee. Thus, Traffic Revenue Cap options are attractive to the

government. Excess revenues, if they occur, can be collected and used to pay the

concessionaire as Minimum Revenue Guarantee options if requested.
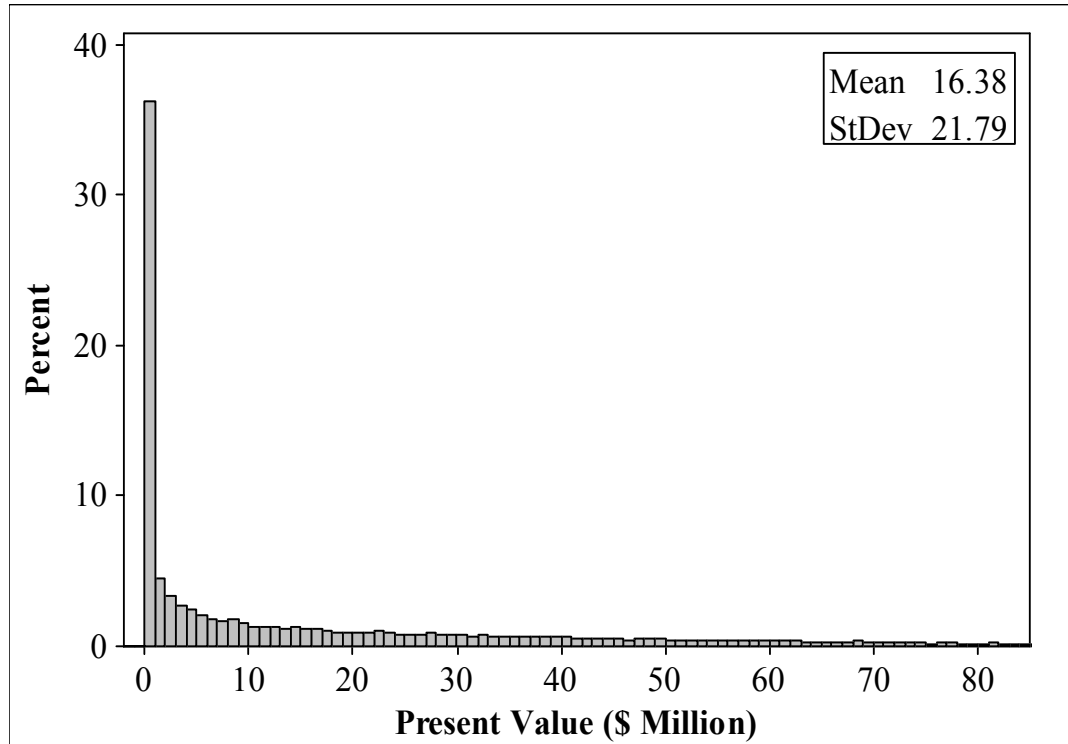
Figure 4.11 Probability distribution of the present value of TRC options

Figure 4.12 characterizes the probability distribution of the government's

net present value of Traffic Revenue Cap and Minimum Revenue Guarantee

options. This probability distribution specifies all possible net present values of

total excess revenues – which the Korean government receives under Traffic

Revenue Cap options – subtracting all Minimum Revenue Guarantees that it pays

to the concessionaire over the project lifetime. The expected value and standard

deviation of this probability distribution are $1.96 million and $42.66 million,

respectively. The asymmetry in the shape of this probability distribution indicates

that the above Minimum Revenue Guarantee and Traffic Revenue Cap options will

possibly be in the favor of the Korean government. It can be seen that the

probability that the government realizes a gain (i.e., the probability of the event

that the government's present value of Traffic Revenue Cap and Minimum

Revenue Guarantee options is positive) is approximately 58.1%.
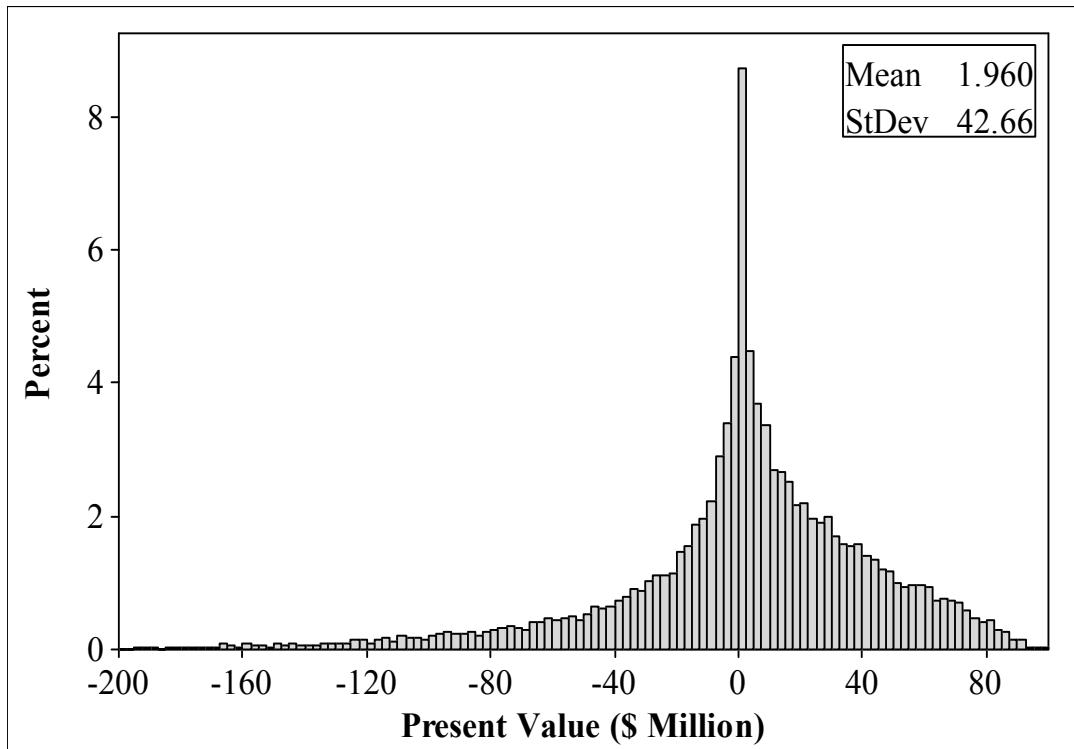
Figure 4.12 Probability distribution of the government's present value of TRC and
MRG options

CHAPTER 5   LIMITATIONS OF THE PROPOSED REAL OPTIONS MODEL, IMPLEMENTATION BARRIERS AND RECOMMENDATIONS FOR FURTHER RESEARCH

After three decades of development, real options analysis is gradually becoming a mainstream valuation tool and a strategic decision-making method for investment in real assets. Unlike traditional investment valuation tools such as NPV, the real options analysis recognizes the impact of uncertainty on the value of investment and is able to evaluate the impact of the mechanisms that are designed to deal with uncertainty on the investor's risk profile. This is the important feature that makes the real options analysis approach applicable to BOT transportation projects. The BOT project are subject to high levels of traffic demand uncertainty and, in many cases, have risk and revenue sharing mechanisms designed to deal with the revenue risk stemmed from the uncertainty about future traffic demand.

In this research, a new real options model that utilizes the market-based risk-neutral valuation method for assessing the Minimum Revenue Guarantee and Traffic Revenue Cap mechanisms risk and revenue sharing mechanism and determining their market value. Nevertheless, similar to other investment valuation models, this model is not perfect and is subject to limitations.

Limitations of the Proposed Real Options Model

The proposed real options model is subject to specific limitations. These limitations are discussed in this section.

Single Source of Uncertainty

The first limitation is concerned with the scope of the research. In order to create an investment valuation model applicable to the BOT transportation projects, the research should capture all the essential factors that can impact the value of a project. Among these factors are commercial, macro-economic and political risks that in reality govern the value of investment in a BOT project. For instance, stated preference surveys are typically conducted in order to obtain detailed information on the probable effects of changes to the transport infrastructure systems (e.g., changes in toll rates) and the sensitivity and response of travelers to these changes (Kriger et al. 2006). These surveys ask current users of the freeway to determine the implied values of time based on tradeoffs within specific questions. These time-cost, tradeoff questions offer the respondents choices based on travel alternatives. Nevertheless, it has been known that the conclusions from stated preference surveys are subject to biases, errors and uncertainties due to many factors including the complex behavior of individual travelers (Lu et al. 2006). Therefore, stated preference surveys cannot accurately characterize the changes in long-term behavior of travelers as a result of changes in regulated prices of services (scheduled toll rates), economic conditions, fuel prices

and service quality levels (Koonc 1998; Research and Innovative Technology Administration 2012).

Similarly, the uncertain variation of factors such as the exchange rate and the interest rate and the can affect the value of investment a BOT transportation project. These uncertainties and their interrelations should be among the fundamental inputs for the real options valuation of a BOT project. Nevertheless, the scope of this research is limited to capturing and modeling traffic demand uncertainty, which the literature identify as one of the most important uncertainties that can affect the value of BOT projects.

Estimation of Input Parameters for Uncertainty Modeling

Another limitation of this research is related to the method used for modeling the traffic demand uncertainty and some of the underlying assumptions about the long-term behavior of traffic demand that may be distant from the reality.

In this research, a binomial lattice model, which is a form of the random walk model, was used to capture the dynamic uncertainty about the long-term traffic demand in an approximate and discrete fashion. This modeling choice is consistent with the general body of knowledge in real options analysis (Hull 2008; Luenberger 1998). Nevertheless, there are some challenges in implementing this modeling approach. For instance, the construction of proposed binomial model requires the estimating of two fundamental inputs: the expected annual growth rate of AAD (α) and the annual volatility of AADT (σ). It is very difficult to get

accurate estimates of these inputs especially in case of a greenfield transportation project since there is no relevant historical traffic demand data that can be used for as the basis for estimation.

In spite of significant improvements of the transport demand models over the past few decades, the current traffic demand models are still incapable of characterizing the uncertainty of long-term traffic demand systematically (Matas et al. 2012). Transport demand models, which are commonly used around the world, project the traffic demand volumes and traffic flows on specific network links based on a single scenario or, at most, a limited number of scenarios. These models attempt to predict the likely impacts of transport infrastructure projects (e.g. new roads, wider roads, new railway lines) and transport policies (e.g. road pricing). Nevertheless, all these predictions are point estimates, and, even when produced for several scenarios, do not give insight into the uncertainty margin that exists around the projections (Jong et al. 2007; Matas et al. 2012). The literature on the appropriate methods for quantifying uncertainty in traffic forecasts is limited and the research efforts focused on characterizing the input uncertainty (e.g. on the future incomes and car ownership levels) and model uncertainty (e.g., specification error and error due to using parameter estimates instead of the true values) are still evolving (Jong et al. 2007).

The value of annual expected growth rate of AADT or parameter α can be retrieved from the traffic study report. However, due to the limitations of current traffic models, the estimation of annual expected growth rate of AADT

may be subject to errors. The annual volatility of AADT (σ), which is not typically provided by the traffic and revenue study can be estimated using the historical AADT data of similar existing highway projects (Irwin 2003), or the forecasted annual volatility of Gross Domestic Product (GDP) of the region (Banister 2005) or the subject matter experts' opinions (Brandão and Saraiva 2008). This approach to estimating the annual volatility of AADT is also subject to errors. Thus, a sensitivity analysis is proposed in order to evaluate how the changes in traffic demand volatility impact the investors' financial risk profiles and also check the rationality of the assumption about the traffic demand volatility.

In addition, the proposed approach assumes that the traffic demand volatility is constant over time. The use of binomial model also implies that large movements in the traffic demand do not occur, and the changes in the traffic demand levels are independent over time. These assumptions may not hold in reality.

Adoption and Implementation Barriers

Although the capacity of real options to add value to projects has been adequately demonstrated by academic literature, evidence indicates that the attempts to disseminate real options widely in practice have been largely failed (Krychowski and Quelin 2010; Sandahl and Sjogren 2003; Waldron 2000). In fact closing the gap between real options theory and the derived pricing models and real options use among the practitioners has often been recognized as the

formidable challenge faced by academics involved in real options research (Garvin and Ford 2012; Wan 2007).

Ford and Garvin (2010), Triantis (2005) and (Krychowski and Quelin 2010) provide an insight into the most common barriers to real options adoption and use by the practitioners in general. In the infrastructure development and construction project management, the gap between real options theory and infrastructure project practices seems to be wide due to the nature of industry and the characteristics of infrastructure projects. Thus, similar to existing real options models, the model created in this research faces a variety of barriers that have been known to limit the adoption and use of real options in infrastructure development. An overview of these barriers is presented below.

Exposure-Based Perspective

It should be understood that options do not necessarily increase the project value even if they are accurately priced and their price is justified from the financial point of view. The impact of an option on a project value depends on the way the underlying uncertainty evolves throughout the project life. If the uncertainty resolves such that the option should not be exercised, then the development and integration of the option in the contract does not lead to any enhancement of value for the option holder. This in fact may decrease the project value if there are costs associated with the development and incorporation of options in the project contract. The pricing and recommendation of these options is based on the expected value of many possible outcomes i.e., the option holder will

capture the average of all the benefits and losses.

The current practices in the infrastructure development and management discipline often contradict this assumption. In this discipline, practitioners often face the circumstances in which they have to make decisions with many long-term implications and consequences at once early in the project. This encourages an exposure-based perspective of risk. From this perspective, the uncertainties associated with the project are often perceived as the origins of risk that can threaten the success of a project. When practitioners adopt the exposure-based perspective, they likely to act conservatively and only take on low-risk projects. The exposure-based perspective also assumes that the worst-case scenario will be the mostly likely event and, thus, the practitioners should give the highest priority to improving their value in worst-case scenario instead of maximizing their expected value by using appropriate mechanisms such as real options. As a result, the options that can increase the expected value of a project (e.g., risk and revenue sharing mechanisms) may be overlooked in favor of the strategies that are designed to work only in the worst-case scenario.

Practitioners' Hope-for-the-best Attitude

Often, firms cannot afford to request the loss-limiting options (e.g., the minimum revenue guarantee) in their proposals and survive in today's highly competitive market. The reason is that, typically, there are competitors that assume no loss-limiting mechanism is required since the uncertainty will resolve in their desired way and losses will not occur or, if they occur, there is potential to shift

costs to others (e.g., through contract renegotiations or buyback arrangement). This "hope-for-the-best" practice of not including adequate protection for uncertain conditions is fatal to overly optimistic firms in the long run. However, in short term, it motivates these firms to reduce their price proposals. This put these firms in advantage compared to firms that are more concerned with the uncertainties in the project and request loss-limiting options (e.g., minimum revenue guarantees) in their proposals. In the BOT context, the proposers that request government guarantees in order to manage the downside risk will be in competitive disadvantage compared to those firms that are optimistic about the way the demand uncertainty will evolve in future and do not request for government support.

Risk Aversion in Valuing Real Options

Similar to many other disciplines, practitioners in the infrastructure development and management discipline have tendency to be risk-averse; they are willing to sacrifice some benefits in order to reduce uncertainty. Practitioners demonstrate their risk aversion regularly when choosing among alternative projects and strategies with different amounts of uncertainty and reward. For instance, given two otherwise equal strategies, practitioners in general prefer the strategy for which the success and value is less dependent on the resolution of uncertainty. They may also tacitly implement risk aversion by adding a cost in their valuation of real options that reflects their level of risk aversion. This would decrease the attractiveness of real options relative to more certain alternatives and thereby decreases the use of real options. Current real options pricing models do not

capture the risk aversion costs included in the valuation due to practitioners'
perspectives. These managerial risk aversion costs reduce the perceived value and
attractiveness of real options.

Industry Practices and Assumptions of Real Options Pricing Models

Some of the common practices in the infrastructure development and
management discipline vary from the fundamental assumptions of most real
options pricing models. These differences lead to incorrect valuation of real
options, which contributes to limited adoption of real options.

There are many possible actions that practitioners can take in order to
increase the project value. Some of these can be structured as options while many
others cannot be constructed as options. In cases where practitioners have access to
a variety of alternative to manipulate the project uncertainties and increase project
values, the potential benefits of integrating real options in projects is limited
(Trigeorgis 1996).

Moreover, most real option models assume that the option holder does
not have influence on the value of underlying asset. The foundations of this
assumption originate from option pricing models for financial assets (e.g. stocks in
a market that can reasonably be assumed to be perfect) in which the option holder
is independent of the asset except through the market. Nevertheless, the
practitioners in the infrastructure development and management discipline
typically have the capability and means to make adjustments that change the level
of project uncertainties. This contradicts the central assumption of real options

valuation concerning the independence of the option holder and uncertainty independence. Therefore, the current real options pricing models that assume independence of option holders and uncertainties do not price strategies accurately and cannot be used to guide practitioners. They price real options incorrectly by reducing their value. This in turn reduces the possibility of justifying and using real options in infrastructure development projects.

Resource Inadequacy

Real options theory assumes that when an option adds value, the potential holder of the option will create and maintain this option for the project. Nevertheless, creating and maintaining options often requires the commitment of resources that may be scarce. Limitations on various types of resources required for structuring or maintaining real options in an infrastructure project restrict the utilization of real options. Among the required resources for structuring real options in an infrastructure project are the cognitive abilities, tools, and methods required to understand, design, evaluate, and implement options. Moreover, time and team efforts are required to recognize and use options and other value-adding alternatives in an infrastructure. In the infrastructure development and management projects, many choices and decisions are often made based on a benefit– cost ratio analysis that aims at maximizing the total project value derived from a given set of limited resources. Therefore, alternatives with the largest perceived benefit-cost ratio are often chosen first. Along with other challenges, substantial resources requirements will bring the benefit-cost ration of real options down and limit their

applicability.

Agency Problem

The classic agency problem may arise if some of the participants in an infrastructure project are not seeking to merely increase the financial value of an asset. This is in direct contrast with the fundamentals of option theory. In some cases, real options are valued and assessed in dimensions that cannot be measured with money, or at least with project money. For instance, options can be to increase competition among the potential bidders in the project as well as to reduce costs. The presence of factors other than economic product value changes the environment for real options analysis substantially. This can lead to an increase in the perceived value of certain options that may not necessarily enhance the value of the project. This also suggests that practitioners may have various motivations as well as means to manipulate or influence asset values, hence changing the value of real options in an infrastructure project. This may reduce the perceived value of options that merely focus on the enhancement of expected value for the project including the risk sharing mechanisms.

Bounded Rationality

Similar to other disciplines, there is an upper limit to the cognitive capacity of practitioners in the infrastructure development and management discipline. Although, a variety of management tools can expand the practitioners' cognitive capacity, the upper limit will always remain. The complexity inherent in

the infrastructure development projects often approaches or exceeds the cognitive capacity of project managers and project management teams. The integration of real options in a project can only increase the project complexity. Typically, practitioners prefer the strategies that are simpler to those that are more complex ones. An infrastructure project with many complex contractual mechanisms such as various kinds of real options is generally less attractive to the practitioners. This can decrease the attractiveness and utilization of real options since, from the perspective of practitioners, they increase the management complexity.

Overcoming the Limitations of the Current Model

There are three fundamental areas of improvement that are central to improving the real options model presented in this research and enhancing its applicability:

1. *Assumptions,* which is concerned with the critical assumptions that underlie the modeling approach and the evidence regarding the validity of these assumptions;

2. *Mechanics,* which is concerned with steps involved in applying the approach, and the associated challenges; and

3. *Applicability,* which is concerned with the practitioners' understanding of the value that options thinking and real options analysis offer, and providing practitioners with the opportunities to use them.

While making improvements in the first two areas (assumptions and mechanics) is mostly about enhancing in the existing real options models to better

reflect current real world practice, the last (applicability) is more concerned with improving the options thinking skills of practitioners and enhancing their understanding about the value of real options. Each of these approaches is discussed in more details below.

Relax Assumptions Concerning the BOT Uncertainties

The current model considers the traffic demand uncertainty as the only risk factor that can impact the value of a BOT project. However, the assumption that the project value is affected by one risk factor can only be correct for very simple types of projects. Infrastructure projects are typically very complex and it is impossible to assume that their value is only affected by one risk factor (i.e., traffic demand uncertainty). The real options valuation of complex infrastructure projects requires the consideration of several interdependent variables representing various risk factors that impact the value of a project. Therefore, the model should be expanded in order to include not only the revenue risk stemmed from the traffic demand uncertainty but also other commercial, macro-economic and political risk that in reality govern the financial value of investments in BOT projects.

This requires a comprehensive study of the nature of different uncertainties as well as the potential interrelationships among them. These should be characterized and incorporated in the valuation of BOT projects. Uncertainty is the key driver of option value. Therefore, studying and characterizing the trends and volatilities of uncertain factors and the relationships among them can provide

valuable insight on how appropriate mechanisms can be developed and utilized for managing these uncertainties. Various kinds of real options can be designed for mitigating the risks in BOT projects. Therefore, the proposed real options valuation model should be expanded to incorporate different options designed to manage various uncertainties in the BOT projects. If many options are considered at the same time or sequentially, there will also be a need for the expansion of current model so that it can treat a combination of options when evaluating the investments in BOT projects.

Improve Modeling Procedure

In this research a novel approach for estimation of the project volatility, which is one of the critical parameters in valuation of real options, was presented. Nevertheless, research on more accurate models that can characterize the critical inputs to the real options valuation model is still needed.

In this research, a binomial lattice model was used to capture the dynamic uncertainty about the future traffic demand. This modeling choice is consistent with the general body of knowledge in real options analysis. However, its application implies that the traffic demand volatility is constant, large movements in the traffic demand do not occur, and the changes in the traffic demand level are independent over time. Moreover, estimating the expected annual growth rate of AADT (α) and the annual volatility of AADT (σ), which are the critical inputs to the real options valuation model, is challenging. The current

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traffic models do not provide accurate projections of future demand. Also, they are generally unable to provide an insight into the uncertainty margin that exists around these projections. These issues underline the need for suitable traffic models that incorporate a variety of relevant socio-economic factors and present the possible range of future traffic demand and the probabilities attached to these possible outcomes in an appropriate fashion. These traffic models enhance the understanding about how the traffic demand evolves over time and, also, facilitate a more appropriate estimation of parameters such as expected annual growth rate and annual volatility of traffic demand.

Overcome Barriers to Real Options Application

Real options can be used as an analytical tool, a mode of thinking, and an organizational process. In its essence, real options analysis allows practitioners to value strategic decisions using appropriate analytical criteria and, thus, establishes a tie between the strategic decisions of an organization and their financial value. It helps the practitioners decide what measures should be considered so that investment in a project can move successfully into the next stage.

However, some organizations have faced difficulties with the integration of real options analysis into their business strategy. The key to successful implementation of real options analysis is to give priority to options thinking and gathering various management tools, processes and techniques under the real options umbrella rather than just focusing on the options mathematics.

The efforts should also focus on enhancing the options thinking skills of practitioners. These options thinking skills can be improved by building upon basic project management concepts, tools, and methods (Ford and Garvin 2010). Educating practitioners and providing them with appropriate practical heuristics that reflect both real options theory and practice can help them effectively implement options thinking and real options analysis in various aspects of their projects.

A widespread misunderstanding of real options analysis is that it encourages risk-taking while, in fact, real options in concerned with approaching uncertainty as a source of opportunity. This approach to responding to uncertainty distinguishes option-thinking from the traditional management practices. The practitioners should appreciate that when it comes to dealing with uncertainties, real options analysis is more opportunity-focused rather than risk-focused. This shift in perspective - from minimizing investment due to the fear of uncertainty to seeking gains from uncertainty by maximizing learning - can be achieved by educating the practitioners and improving their understanding of real options. Using options thinking and real options analysis provides the practitioners with a wider range of possible actions that can be taken in order to deal with uncertain circumstances. For instance, the governments can lower initial irreversible investments cost and mitigate the financial risk of overinvestment in transportation infrastructure by expanding existing transportation systems. Real options analysis can be used in order to determine the optimal traffic level, and hence the optimal time, at which it is possible to expand a transportation infrastructure (Ashuri et al.

2011).

In addition, it is important to highlight the usefulness of real options analysis as a strategic tool rather than a valuation model. A successful strategy emerges from decision processes that take into account different viewpoints. Real options has the capability of integrating the concerns of various stakeholders (Eisenhardt 1999; Krychowski and Quelin 2010). Thus, options thinking and real options analysis can become integrated in the business strategies of an organization rather than being treated as independent from other business strategies. The practitioners should understand that there can be a close tie between competitive strategy and option-thinking. They should be educated and trained in order to realize that not only competition can give rise to a variety of real options, but option-thinking can also be widely applied on strategic level in order to shape an organization's future competitive strategies. The key is to educate the practitioners so they could identify the latent "shadow options" in their projects and incorporate appropriate options in their firms' strategies and define to what extent aligning their business strategies with real option logic may affect competitive advantage (Bowman and Hurry 1993).

Moreover, real options techniques cannot be treated as independent from other features of the organization (Gordon and Stark 2000). The practitioners should realize that options thinking can become an effective tool for addressing the internal challenges of an organization. On this level, considering the management structure, resources, organization culture, organization's competitive advantages and it overall strategy, a variety of real options can be structured and used in order

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to improve performance or address organization's challenges and limitations. There are tools and systems that can help organizations integrate options thinking and real options analysis in their internal decision-making. Among these tools is an information system that is capable of providing the necessary data for the identification and development of appropriate options as well as an incentive system capable of motivating managers to identify and utilize options in order to enhance that value for the organization. Detailed processes models can be designed in order provide practitioners with additional guidance and a framework for utilizing their options thinking skills.

Practitioners in the transportation infrastructure development and management tend to focus on the delivery of physical asset rather than focusing on strategic and systematic processes for operating, maintaining, upgrading and expanding transportation assets throughout their lifecycle. There should be a paradigm change in the management of transportation infrastructure. Enhancing the option thinking skills of practitioners and decisions makers in transportation agencies can facilitate this paradigm shift. Through the use of real options analysis, transportation agencies and practitioners can evaluate opportunities for improving the lifecycle of transportation infrastructure and decide how scarce resources should be deployed in order to deliver safe and adequate transportation infrastructure, and maximize economic competitiveness and public welfare.

CHAPTER 6   CONCLUSION

Public-Private Partnerships (PPPs) are the interface between the construction industry and the financial markets. PPPs have been growingly adopted by governments in order to confront the shortage of public funds required for ambitious, yet necessary, transportation infrastructure programs (Angelides and Xenidis 2009).

A common form of implementing PPP in transportation projects is the Build-Operate-Transfer (BOT) method. The introduction of the BOT model changes the traditional roles of public and private sector participants in the development, operations, and management of transportation infrastructure systems. In a typical BOT project, a private partner, which is known as the concessionaire, has the responsibility to finance, design, build and operate a facility for a specific period of time under a concession agreement. The concessionaire typically raises return on its investment through the user charges (Ye 2009). The BOT model has many benefits in improving project delivery, efficiency, and risk management. Moreover, using the BOT model can bring reductions in the implementation time as well as greater opportunities in obtaining innovation (United Nations 2000).

The BOT model is different from the traditional models for delivering transportation infrastructure systems in many aspects. The BOT agreements typically expand over several decades. A longer duration results in many complications in projecting the traffic demand, the revenue stream as well as quantifying many other risks such as the regulatory change, currency exchange or

interest rate risks (Smith, 2009). Therefore, for BOT projects there is a broader spectrum of risks that can impact the project outcomes. A relevant BOT project risk that may seriously undermine the profitability of a project is the revenue risk. Revenue risk is stemmed from the uncertainty about the future traffic demand and is concerned with the possibility that the project may not generate sufficient revenue to cover its operating costs, service the debt and leave an adequate return for investors.

Revenue risk mitigation has strategic relevance for BOT private participants since revenue risk can adversely impact the profitability of a BOT project and prevent its successful implementation. In fact, the private participation in many BOT transportation projects is conditioned upon the existence of proper mechanisms for mitigating the revenue risk. In order to encourage private investment in BOT transportation projects, governments usually assume a portion of the revenue risk by offering Minimum Revenue Guarantee options to the concessionaire. By offering the Minimum Revenue Guarantee options, the government compensates the concessionaire if the revenue falls below a specified threshold. A similar mechanism can be applied to share the surplus revenue when the traffic demand grows significantly beyond the projected levels. This mechanism is often referred to as Traffic Revenue Cap. Combined together, Minimum Revenue Guarantee and Traffic Revenue Cap options create a risk and revenue sharing mechanism.

The conventional valuation methods including NPV analysis are incapable of properly evaluating BOT projects since they do not explicitly capture and treat

uncertainty about future traffic demand. The conventional valuation methods are also unable to address the impact of risk and revenue sharing mechanism on the financial value of BOT projects and determine their market value.

Evidence indicate that the improper financial valuation of BOT projects and the risk-sharing mechanisms between the private and public sectors can contribute to the failure of these projects and consequently, reduce the participation of the private sector in development of transportation infrastructure systems. To address this challenge, in this research a novel financial model is created to evaluate BOT projects under uncertainty about future traffic demand.

It is necessary to price Minimum Revenue Guarantee and Traffic Revenue Cap risk and revenue sharing mechanisms so that its market value and its effects on the concessionaire's financial risk profile can be determined. Moreover, pricing this mechanism establishes the extent of financial compensation that government receives by assuming a portion of the revenue risk. The valuation model created in this research utilizes the real options theory from finance/decision science in order to explicitly price Minimum Revenue Guarantee and Traffic Revenue Cap options in BOT projects.

This model captures the future traffic demand uncertainty in BOT projects in a stochastic manner and integrates it in the valuation of BOT projects. Thus, the concessionaire's financial risk profile can be characterized under the traffic demand uncertainty. It is shown that as the traffic volatility increases, the uncertainty about the project's future revenues increases and it becomes more likely that the project underperforms and the concessionaire's investment value

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becomes negative. It is also concluded that the risk of underestimating future traffic demand grows as the BOT project advances.

The proposed model is able to overcome the inherent limitation of conventional financial analysis methods and most notably the NPV approach. The NPV approach is insufficient to determine the market value of Minimum Revenue Guarantee and Traffic Revenue Cap options. Determining the optimal threshold of these mechanisms cannot also be done through conventional investment valuation methods and requires the use of option pricing techniques. The proposed model devises a market-based option pricing approach to determine the correct value of Minimum Revenue Guarantee and Traffic Revenue Cap options. It is shown how this model can be used to determine how different Minimum Revenue Guarantee and Traffic Revenue Cap thresholds affect the project value. It is concluded that the Minimum Revenue Guarantee mechanism can be a viable financial incentive in cases where the high levels of traffic demand uncertainty reduce the potential of the private sector investment in infrastructure projects. Moreover, it is shown that the Traffic Revenue Cap can be an effective mechanism for sharing the "upside" potential between the concessionaires and the government by splitting the surplus revenue resulted from excessive growth of the traffic demand beyond the anticipated levels. It is shown that as the project advances, the government is more likely to pay Minimum Revenue Guarantee options to the concessionaire if it does not consider the volatility of future traffic demand in the project valuation.

It is concluded that the expected value and standard deviation of the concessionaire's investment value distribution with Minimum Revenue Guarantee

and Traffic Revenue Cap options are lower than the expected value and standard deviation of the concessionaire's investment value distribution with just Minimum Revenue Guarantee options, respectively. However, the expected value of the concessionaire's investment value distribution with Minimum Revenue Guarantee and Traffic Revenue Cap options is greater than the expected value of the concessionaire's investment value distribution without Minimum Revenue Guarantee options. Also, the probability of the event that the concessionaire's investment value becomes negative is lower when the concessionaire considers both Minimum Revenue Guarantee and Traffic Revenue Cap options compared to the case without any options. It is also demonstrated that since Minimum Revenue Guarantee and Traffic Revenue Cap mechanisms have an asymmetric impact on the value of the project, they may be an acceptable solution to all stakeholders involved. This would allow governments leverage their investment capabilities by redirecting scarce resources away from financing public infrastructure investment to providing a limited level of guarantees, as long as precautions are taken in selecting government project portfolio.

The proposed model can help public and private sectors better analyze and understand the financial risk of BOT projects. The private sector can use this innovative model to make better entry decisions to BOT highway projects considering the level of support provided by the government. The government can also use this model in order to calibrate the level of revenue guarantee required for a specified degree of risk reduction and set the appropriate Minimum Revenue Guarantee levels that encourages private sector investments without comprising

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future budgetary strength. The proper levels of Traffic Revenue Cap can also be identified as a reward-sharing strategy to enhance the government's spending flexibility in highway projects without hurting the financial success of the concessionaire. It is shown that an appropriate combination of Minimum Revenue Guarantee and Traffic Revenue Cap options is an effective risk-and–reward sharing strategy between the government and the concessionaire in the BOT project. This limits the exposures of both parties to the risk of underestimating or overestimating future traffic demand.

Contributions to State of Knowledge

The real options model created in this research contributes to the body of knowledge on the application of real options in transportation infrastructure management. These contributions are summarized below.

A Method for Estimating the BOT Project Volatility for Real Options Analysis

One of the critical inputs to real options valuation models is the project volatility that measures the uncertainty about project value over time. In case of investments in transportation projects, it is very difficult to estimate the project volatility directly or using proxies since transportation projects are unique and there is no relevant data on historical or current market prices of the transportation projects that can be used as the basis for volatility estimation (Cobb and Charnes

2004; Copeland and Antikarov 2003). The current literature on the application of real options in transportation infrastructure management does not provide a systematic method for estimating the project volatility and often prescribes the use of assumptions. Therefore, the application of the current real options models to the valuation of investments in BOT projects under the uncertainty about future traffic demand can lead to an erroneous valuation. In this research a volatility estimation approach that combines Monte Carlo simulation and the stochastic processes is presented. In this approach, the investment without options is considered as underlying asset of the real options investment and, its volatility is used as the volatility in the real options valuation. The volatility of investment without option is considered to be the uncertainty over expected investment returns from one period to the next. This method, which is comprised of two Monte Carlo simulation rounds, can be applied in order to estimate the volatility for real options that is the most critical input to the valuation of investments in BOT projects.

Risk-neutral Valuation of Real Options in BOT Projects

In order to determine the price of an option, the benefits resulted from exercising the option should be discounted at an appropriate risk-adjusted rate. When it comes to the valuation of real options in transportation projects, it is typically impossible to estimate the correct and exact risk-adjusted discount rate that reflects the market risks, project risks that are unique to these projects and asymmetric benefit patterns of options (Brigham and Ehrhardt 2011; Ford et al.

2002). The existing literature on the application of real options in transportation infrastructure management does not address this problem and often suggest the utilization of approximate discount rates for real options valuation. Therefore, the application of the current real options models to the valuation BOT investments under traffic demand uncertainty does not lead to the determination of correct market value of real options. In this research, a novel method was presented so that the estimated project volatility can be used for determining the market value of Minimum Revenue Guarantee and Traffic Revenue Cap options. In this approach, instead of first taking the expectation and then discounting for the risk, one can first adjust the probabilities of AADT movements in order to incorporate the risk effects, calculate the expectation under these risk-adjusted probabilities, and then, discount the expected future option pay-offs at the risk-free rate. These probabilities are called risk-neural probabilities and this option pricing method is referred to as risk-neutral valuation approach. The valuation model presented in this research utilizes this market-based risk-neutral option pricing approach in order to determine the fair value of Minimum Revenue Guarantee and Traffic Revenue Cap mechanisms in BOT projects.

The proposed real options model also contributes to the growing body of knowledge in the application of real options in built environment. Most notable application areas real options in built environment are building technology (Ashuri et al. 2011; Greden et al. 2006; Kolahdoozan and Ashuri 2010), and corporate real estate (Ashuri 2010; Cunningham 2006; Guma et al. 2009). The proposed real options model contributes to this body of knowledge by providing a flexible

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valuation procedure that can be adopted in the valuation of real options in built environment.

Contributions to State of Practice: A Novel Class of Assessment Tools for Decision Makers

The current real options models for transportation infrastructure projects do not address several critical questions when it comes to the valuation of investments BOT project under traffic demand uncertainty. These models do not provide an insight into the impact of traffic demand uncertainty as well as risk and revenue sharing mechanisms on the concessionaire's financial risk profile. They are also unable to characterize the financial implications of Minimum Revenue Guarantee and Traffic Revenue Cap mechanisms for the government.

The model presented in this dissertation provides a novel class of assessment tools that address these concerns. It helps the public and private sector participants in making decision about the entering into a BOT contract. By evaluating the concessionaire's financial risk profile under uncertainty about future traffic demand, the model presented in this research evaluates the impact of Minimum Revenue Guarantee and Traffic Revenue Cap options on the concessionaire's financial risk profile. In addition, the proposed model is capable of determining the probability of Minimum Revenue Guarantee payment request by the Concessionaire as well as the probability that the public sector receives a share of surplus revenue as part of Traffic Revenue Cap agreement. Further, the proposed model characterizes the distribution of the number of times that the

concessionaire requests the Minimum Revenue Guarantee option, and the number of times that the public sector receives additional revenue. Finally, this model identifies the distribution of the present value of Minimum Revenue Guarantee options, and the present value of total additional revenues recalled by the public sector.

In the course of evaluating the opportunity to invest in a BOT project, the concessionaire can use this valuation model to determine the market value and the financial risk profile of the investment opportunity with more confidence in the valuation results. The proposed real options approach can complement the traditional assessment methods such cost- benefit analysis as well as the more recent methods such as value for Money (VfM), which are typically used to evaluate the public sector's opportunities to invest in transportation infrastructure. Value for money (VfM) assessment has been recently used by various public agencies worldwide as a tool to compare the viability of pursuing a project as a Public–Private Partnership with traditional procurement (Morallos et al. 2009). The proposed real options model is capable of enhancing these assessment models. Governments can use the proposed real options model to identify the appropriate Minimum Revenue Guarantee and Traffic Revenue Cap thresholds, and avoid conferring substantial subsidies or undervaluing investment opportunities in BOT projects.

Recommendations for Further Research

Based on the identified limitation of the proposed model, three main

research threads are recommended for further studies:

1. The model created in this research considers the traffic demand uncertainty as factor that can impact the revenue and hence value of a BOT project. However, infrastructure projects are very complex and their value is affected by many risk factors. Therefore, the current model should be expanded in order to include not only the revenue risk but also other commercial, macro-economic and political risk that in reality govern the financial value of investments in BOT projects. This requires a study of the nature of different uncertainties as well as their potential interrelationships. Studying and understanding the uncertain factors in BOT projects can provide valuable insight on how appropriate real options can be structured and utilized for managing these uncertainties. The proposed real options valuation model should be expanded in order to incorporate various other options designed to manage various uncertainties in the BOT projects.

2. In this research a novel approach for estimation of the project volatility, which is one of the critical parameters in valuation of real options, was devised. Nevertheless, research on more accurate models that can characterize the annual growth rate of AADT and the annual volatility of AADT is still needed. The current traffic models do not provide accurate projections of future demand. Also, they are generally unable to provide an insight into the uncertainty margin that exists around these projections. Therefore, research should focus on appropriate traffic models that incorporate relevant socio-economic factors and present the possible range of future traffic demand and

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the probabilities attached to these possible outcomes in an appropriate fashion. The real options model created in this research can benefit from these traffic models since they can facilitate more accurate estimation of critical input values including the annual growth rate of AADT and the annual volatility of AADT.

3. In Chapter 5, the barriers to the adoption and use of real options in the transportation infrastructure systems development and management were identifies. These barriers have limited real options in the transportation development and management discipline and thus, hindered the realization of benefits of real options such as improvements in project performance and value. The barriers can be overcome by focusing the further research on improving current real options pricing models so that they could better reflect the characteristics of infrastructure development projects and the current managerial practices in the infrastructure development discipline. Moreover, research should focus on developing tool and methods that help improving the options thinking skills of practitioners. If successful, this thread of research will promote the adoption of real options as an analytical tool, a mode of thinking, a strategic tool and an organizational process.

4. The application of the real options model can be expanded to the valuation of Public-Private Partnership transportation projects in which the government grants a private entity the exclusive rights to operate and maintain an existing facility over a long period in accordance with performance requirements set out in the concession or lease agreement. In these cases, typically adequate

information is available concerning the historical demand levels. Nevertheless, the value of investment is still subject to uncertainty due to the uncertain performance and deterioration of the facility. The body of knowledge in the modeling of the uncertain behavior of transportation infrastructure is growing (Durango-Cohen and Madanat 2002; Durango-Cohen and Madanat 2007; Guillaumot et al. 2003). There is a unique opportunity to expand the real options model presented in this research in order to incorporate the uncertainty about the behavior of transportation infrastructure as well as the statistical models for transportation infrastructure maintenance and management. This thread of research can lead to the development of appropriate models for the valuation and identification of optimal operation and maintenance strategies for Maintain-Operate-Transfer (MOT) and Rehabilitate-Operate-Transfer (ROT) transportation projects.

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