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VALUATION OF MINIMUM REVENUE GUARANTEE IN BOT TOLL ROAD PROJECTS

M. Sc. Thesis by

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Faruk Büyükyoran tarafından hazırlanan VALUATION OF MINIMUM REVENUE GUARANTEE IN BOT TOLL ROAD PROJECTS adlı bu tezin YÜKSEK LİSANS tezi olarak uygun olduğunu onaylarım.

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Bu tez, Mimar Sinan Güzel Sanatlar Üniversitesi Fen Bilimleri Enstitüsü tez yazım kurallarına uygundur.

ABSTRACT

Public-private partnerships (PPPs) have been widely used to deliver public infrastructure throughout the world. Although governments benefit from the advantages of the PPP structure, its implementation may be affected negatively by various uncertainties embedded with PPP projects.

These uncertainties mostly appear as demand risk, exchange risk and political risk etc. Especially, in Build-Operate-Transfer (BOT) toll road projects, demand risk may be vital for the project success. Therefore, private investors often prefer the mitigations of these risks through government supports. Minimum revenue guarantee (MRG) is one of the most common form of these government supports against demand risk in BOT toll road projects.

However, inadequate evaluation of these supports can burden heavy contingent liabilities to the public. To deal with that issue, a real option based model using Monte Carlo Simulation is proposed to value MRGs. The model is then applied to a hypothetical toll road project in order to observe financial effects of MRGs from different viewpoints of the private and the public parties.

ÖZET

Kamu-Özel Sektör İşbirlikleri (KÖİ), kamu altyapı ihtiyacının karşılanmasında dünya genelinde yaygın olarak kullanılmaktadır. Hükümetler, KÖİ kurgusunun birçok avantajından faydalanmalarına rağmen, uygulama süreci KÖİ projesinin barındırdığı çeşitli belirsizliklerden olumsuz şekilde etkilenebilir.

Bu belirsizlikler talep riski, kur riski ve politik riskler vb. şekillerde karşımıza çıkmaktadırlar. Özellikle Yap-İşlet-Devret (YİD) tarzı yapılan otoyol projelerinde, talep riski proje başarısı için hayati bir önem taşıyabilir. Bundan dolayı, özel sektör yatırımcısı genellikle bu risklerin hükümet garantileri vasıtasıyla hafifletilmesini talep ederler. Minimum gelir garantisi (MGG), YİD otoyol projelerinde, talep riskine karşı en yaygın kullanılan garanti tiplerinden biridir.

Öte yandan, bu garantilerin uygun olamayan bir şekilde değerlendirilmesi, kamunun sırtına ağır borçlar yükleyebilmektedir. Bu soruna çözüm bulmak adına, Monte Carlo simülasyonunu kullanan reel opsiyon tabanlı bir model önerilmiştir.

Model, MGG'nin finansal etkililerini özel sektör ve kamunun farklı bakış açıları tarafından gözlemlemek üzere bir hipotetik otoyol projesine uygulanmıştır.

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Faruk Büyükyoran

(Civil Engineer)

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LIST OF ABBREVIATIONS

PPP : Public-Private Partnership

MRG : Minimum Revenue Guarantee

DCF : Discounted Cash Flow

JV : Joint Venture

BOT : Build-Operate-Transfer

TOR : Transfer and Operation Rights

SPV : Special Purpose Vehicle

CAPEX : Capital Expenditures

OPEX : Operation Expenditures

PPA : Power Purchase Agreement

EPC : Engineering, Procurement and Construction

OBC : Outline Business Case

NPV : Net Present Value

ROA : Real Option Analysis

IRR : Internal Rate of Return

MTG : Minimum Traffic Guarantee

GBM : Geometric Brownian motion

SDE : Stochastic Differential Equation

WACC : Weighted Average Cost of Capital

CAPM : Capital Asset Pricing Model

AADT : Annual Average Daily Traffic

1. INTRODUCTION

1.1. BACKGROUND

Public-private partnerships (PPPs) have been widely used to finance infrastructure projects which involve high risk and require large amounts of irreversible capital investments. PPP has many forms that are implemented in different countries for specific projects and situations; therefore, it has various definitions. Even though there is no globally accepted definition of PPP, in the most general sense PPP can be defined as the “contractual arrangement between a public sector agency and a for-profit private sector developer, whereby resources and risks are shared for the purpose of delivery of a public service or development of public infrastructure” (Akintoye et al., 2003).

Despite the fact that public and private sectors collaborate to achieve a common objective; namely the successful realization of an infrastructure project, these two partners are motivated by different objectives. From the viewpoint of governments, “private participation to public infrastructure is perceived as a way to overcome budgetary constraints and to foster economic growth, while, at the same time exploiting private sector efficiency and maintaining control of the project” (Walker and Smith, 1995). In other words, public sector is interested in political and socio-economic benefits that a successful project can provide while the private sector is primarily concerned with the financial viability of a project (Chiara et al., 2007). In this decade, PPPs are extensively adopted throughout Turkey for delivering public infrastructure. The Northern Marmara Motorway, Eurasia Tunnel and 3rd Istanbul Airport are just some of the recent projects subject to PPP in Turkey. Figure 1.1 represents the position of Turkey PPP market among European countries.

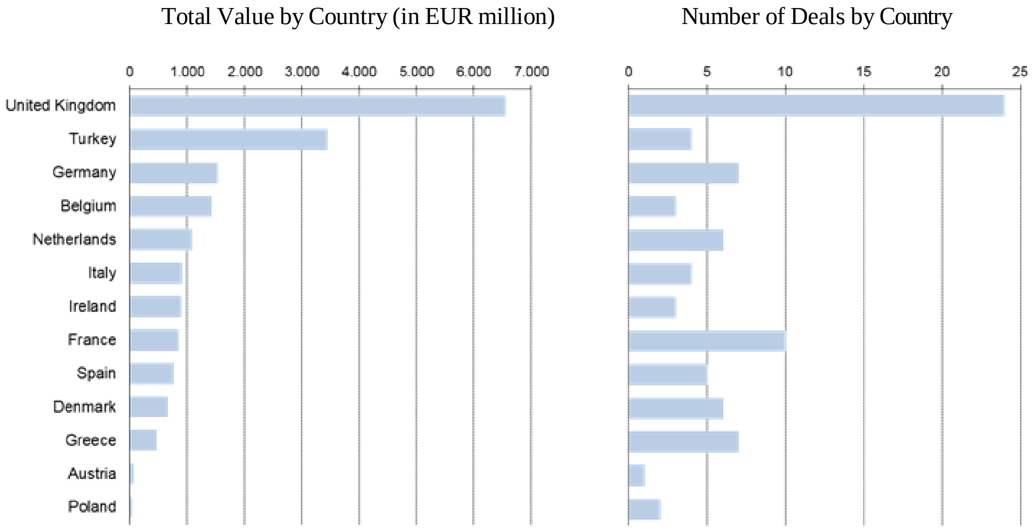


Figure 1.1. Country breakdown by value and number of transactions in 2014 (EPEC, 2014).

According to EPEC (2014) report, in value terms, Turkey was the second largest PPP market in 2014, even though only four projects were signed. The most significant project is the Northern Marmara motorway (EUR 2 billion) which was the second largest transaction reaching financial close in 2014 in Europe. Moreover, The Adana integrated health campus (EUR 542 million) and the Mersin integrated health campus (EUR 363 million) were the first healthcare PPP projects to close in Turkey. The projects are part of a EUR 12 billion government sponsored PPP hospital program involving the construction of 60 facilities.

These type of projects generally attract public attention in local or national level with their high financing needs, macroeconomic effects, socio-economic and environmental outputs. Significant increase in adaptation of PPPs for realization of public infrastructure in Turkey, and collaterally, concentrated public attention toward to these projects are the main motivations of this research.

1.2. PROBLEM DEFINITION

Despite, the attractiveness of the PPP structure, its implementation has not been without trouble due to multiple uncertainties embedded with PPP projects (Carbonara et al., 2014). There is a strong evidence in the literature that inappropriate consideration of these uncertainties and risks contributes to financial failure of PPP projects. To promote successful implementation of PPP projects, a government should to form a comprehensive and transparent PPP framework that addresses issues such as legislation, fiscal and technical constraints, and government support (Kokkaew and Chiara, 2013). Government support is generally provided as a response to market risk, which can cause the withdrawal of private sector from PPP project. However, it has reciprocal effect to both public and private sector. On the one hand, it is one of most effective financial instrument held by government that mitigates risks and makes the investment attractive for the private investor. On the other hand, excessive intervention of government by providing too many subsidies, guarantees and protections to private investor can burden heavy contingent liabilities to public. Hence, valuation of the government support becomes a critical step for PPP framework and accordingly there is significant increase in research papers published in literature (Almassi et al., 2013; Ashuri et al., 2012; Carbonara et al., 2014; Cheah and Liu, 2006; Chiara et al., 2007; Kokkaew and Chiara, 2013). Even though, significant increase in research is observed and models have been proposed, valuation of government guarantees is still a problematic issue in PPP frameworks and no standardized and systematic model have been adopted to overcome these problematic issues in risk allocation.

1.3. RESEARCH SCOPE AND OBJECTIVES

The main objective of the research is to propose a model for identification of the level of minimum revenue guarantees (MRG) that establish a fair risk allocation structure for public and private parties. The other objectives are to observe the financial impacts of the determined MRG to investment decision of the private party and to reveal its fiscal impacts to public budget.

Within the scope of this research to achieve these objectives an intensive literature review is conducted to examine the position of guarantees in PPP framework and to understand methods used to value government guarantees. Since conventional valuation methods such as discounted cash flow (DCF) are limited in valuing guarantees (Ashuri et al., 2012), real option based Monte Carlo simulation model is used to analyze minimum revenue guarantee (MRG) in a hypothetical BOT highway project. Likewise the nature of the provided guarantees such as MRG requires the use of option pricing methods known as real options analysis (Dixit and Pindyck, 1994, Trigeorgis, 1996).

1.4. RESEARCH METHODOLOGY

Research methodology includes three main phases to achieve the goals identified in the previous section. Figure 1.2 illustrates the basic structure of the research. Outputs of the activities are parallel with the objectives of this research.

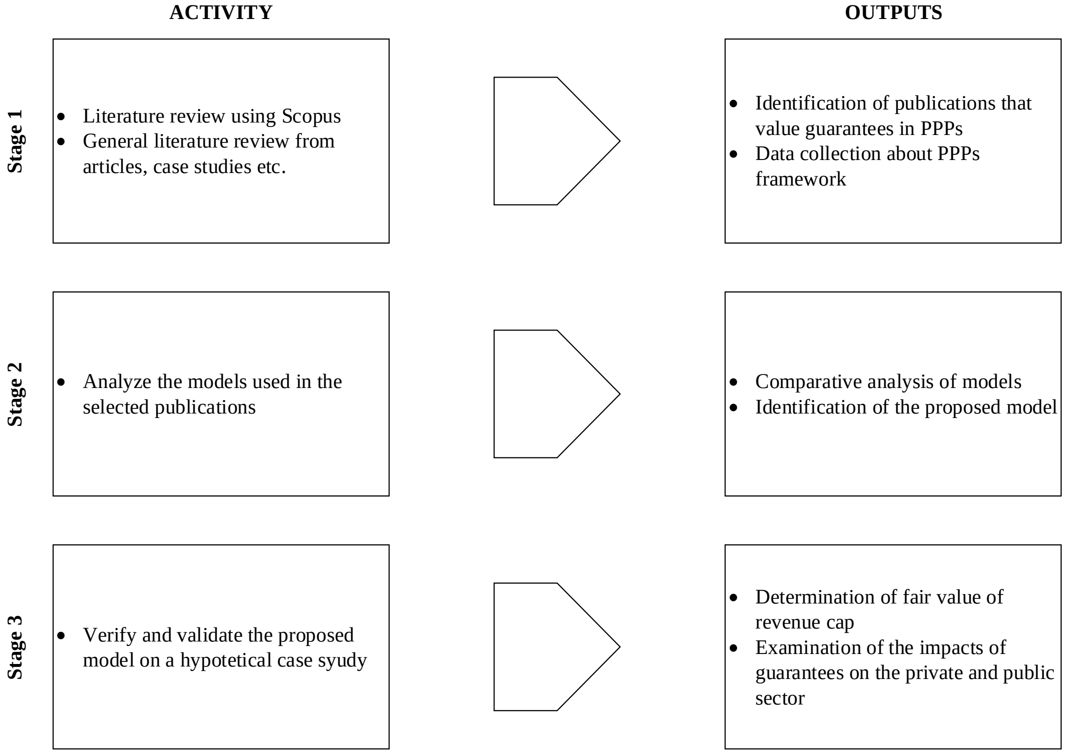


Figure 1.2. The basic structure of the research

Stage one is designed as data collection stage to identify key features of PPP, especially in financing and risk issues, government guarantees and guarantee valuation methods. To deal with that, the search engine ‘‘Scopus’’ was used to conduct the first phase of the research. This stage consists of literature review and determination of the most related articles about guarantees in PPP and their valuation. Keywords selected under the ‘‘title/abstract/keyword’’ field of the search engine included ‘‘public private partnership’’, ‘‘public finance initiative’’, ‘‘build operate transfer’’ and ‘‘guarantee’’. As the search was comprehensive, resulting publications contained several irrelevant items. Thus, the search was further narrowed in order to meet the requirements of the research. Following Ke et al. (2009) the search was further limited in the subject areas such as “business, management, and accounting,” “decision sciences,” “economics, econometrics, and finance,” “energy,” “engineering,” “environmental science,” and “social sciences” with document type ‘‘article or review’’ in source type ‘‘journals’’ and the papers published in ‘‘English’’. The full search code is as follows:

TITLE-ABS-KEY(public private partnership) OR TITLE-ABS-KEY(private finance initiative) OR TITLE-ABS-KEY(build operate transfer) AND TITLE-ABS-KEY(guarantee) AND (LIMIT-TO(SUBJAREA,"ENGI") OR LIMIT-TO(SUBJAREA,"BUSI") OR LIMIT-TO(SUBJAREA,"SOCI") OR LIMIT-TO(SUBJAREA,"DECI") OR LIMIT-TO(SUBJAREA,"ECON") OR LIMIT-TO(SUBJAREA,"ENVI") OR LIMIT-TO(SUBJAREA,"ENER")) AND (LIMIT-TO(DOCTYPE,"ar") OR LIMIT-TO(DOCTYPE,"re")) AND (LIMIT-TO(LANGUAGE,"English")) AND (LIMIT-TO(SRCTYPE,"j")) Search result: 72 (searched on 09 February 2015).

No journal restriction were imposed in terms of their interest since PPPs can be perceived as intersection point of the various disciplines such as engineering, economy, transportation and management etc. It should not be forgotten that, this research is strictly limited to the area of guarantee valuation methods in PPPs. In spite of these search specifications, results may still include unmatched or irrelevant papers. To avoid this situation, first, titles of the resulted papers were reviewed to eliminate those papers which completely belong to another subject and then, abstracts of the papers were reviewed in order to identify articles that matches the topic accurately. After elimination process, 32 papers were identified to be precisely related and match all the requirements of the research. Moreover, literature review sections of these papers were reviewed to catch the papers that are not covered by Scopus. Consequently, a total of 41 papers were reviewed to see different approaches on guarantee valuation methods.

In the second stage of the research a comparative analysis of the proposed models and approaches in selected publications was conducted. Each model was examined critically to identify followed processes when structuring a model. During this activity, three main processes were identified. These are respectively, the establishment of real option based guarantee model, the modelling of a major risk factor and the valuation of these options. Moreover, alternative approaches under each process were reviewed in terms of their advantages and disadvantages in order to identify key features and requirements of the proposed model within the scope of this research.

Finally, in the last stage, the proposed model was verified and validated on a hypothetical case study. During the analysis, the fair value of revenue cap was determined using the model. Moreover, the impacts of guarantees on the financial position of investment were observed and the fiscal impacts of total value of the guarantees to public were revealed.

1.5. ORGANIZATION OF RESEARCH

In the first section, background, problem statement, scope, objective and research methodology is presented. The remainder of the paper is structured as follows: Section 2 provides information about PPPs. In section 3, guarantees and literature review of existing valuation methods is presented. The analysis of a hypothetical BOT highway project took part in Section 4. Finally, next section concludes the paper.

2. PUBLIC-PRIVATE PARTNERSHIPS

This chapter aims to provide basic information about PPPs. It is essential to understand foundations of PPP phenomena since the research aspire to present deep insight about guarantees. With that purpose, this chapter is divided into four sections; definition, types, financing and risk.

2.1. DEFINITION OF PPP

Although different governments, institutions, international organizations and scholars have used several definitions for PPP, all definitions have common features or characteristics. Various definitions of PPP are listed in Table 2.1.

Table 2.1. Differing conceptualizations of public-private partnerships (Roehrich et al., 2014).

Definition	Dimension
An arrangement between two or more entities that enables them to work cooperatively towards shared or compatible objectives and in which there is some degree of shared authority and responsibility, joint investment of resources, shared risk taking, and mutual benefit (Finance, 1998).	• Inter-organizational relationship; • Cooperation; • Shared objectives; • Joint investments; • Risk sharing
Public private partnerships are on-going agreements between government and private sector organizations in which the private organization participates in the decision-making and production of a public good or service that has traditionally been provided by the public sector and in which the private sector shares the risk of that production (Forrer et al., 2010).	• Risk sharing • Inter-organizational relationship
A legally-binding contract between government and business for the provision of assets and the delivery of services that allocates responsibilities and business risks among the various partners (Partnerships British Columbia, 2003).	• Contractual governance; • Risk allocation
The main characteristic of a PPP, compared with the traditional	• Bundling

approach to the provision of infrastructure, is that it bundles investment and service provision in a single long term contract. For the duration of the contract, which can be as long as twenty or thirty years, the concessionaire will manage and control the assets, usually in exchange for user fees, which are its compensation for the investment and other costs (Engel et al., 2013).	• Service provision • Long-term contract
Partnerships which includes contractual arrangements, alliances, cooperative agreements, and collaborative activities used for policy development, program support and delivery of government programs and services (Osborne, 2000).	• Contractual governance; • Inter-organizational relationship
A relationship that consists of shared and/or compatible objectives and an acknowledged distribution of specific roles and responsibilities among the participants which can be formal or informal, contractual or voluntary, between two or more parties. The implication is that there is a cooperative investment of resources and therefore joint risk-taking, sharing of authority, and benefits for all partners (Lewis, 2002).	• Inter-organizational relationship; • Shared objectives; • Mutual investments • Risk sharing • Benefit sharing
A relationship involving the sharing of power, work, support and/or information with others for the achievements of joint goals and/or mutual benefits (Kernaghan, 1993).	• Inter-organizational relationship; • Shared objectives; • Mutual investments • Risk sharing • Benefit sharing

With the illustrated dimensions of different definitions, PPP is defined broadly as "cooperative, contractual arrangement between the public and private sectors that involves the sharing of resources, risks, responsibilities, and rewards with others for the purpose of delivery of a public service or development of public infrastructure". Yescombe (2007) defines key elements of PPP's as:

- A PPP contract is a long-term contractual agreement between a public-sector and a private sector;
- The PPP contract involve the design, construction, financing, and operation of public infrastructure by the private sector;

- The private sector collects the revenues generated by using of the facility or service during the life of PPP contract. The user may be either the public-sector or the general public.
- At the end of the PPP contract, the ownership of the public infrastructure remains with the public sector.

Akintoye et al. (2003) has identified five general defining features of partnerships:

- A partnership involves two or more actors, at least one of which is public and another from the private business sector;
- In a PPP, each participant is principal, i.e. each of the participants is capable of bargaining on its own behalf rather than having to refer back to other sources of authority;
- They establish an enduring and stable relationship among the actors;
- In a PPP, each of the participants brings something to the partnership; and
- A partnership implies that there is some shared responsibility for outcomes or activities.

The mechanism of arrangements can take many forms and may incorporate some or all of the features mentioned above.

2.2. TYPES OF PPPs

PPPs can take many different forms, the most usual being Build-Operate-Transfer/ Build-Operate-Own (BOT/BOO) arrangements, joint ventures (JV), leasing, contracting out or management contracts and various forms of public-private cooperation (Grimsey and Lewis, 2004). In World Bank (2014), PPPs are described in terms of three broad parameters: first, the type of asset involved; second, what functions the private party is responsible for; and third, how the private party is paid. These parameters can depend on the type of asset and service followed and are grouped as follows:

The type of asset

- *New asset* (often called "greenfield"). These type of assets involves private companies in financing, building, and managing new public assets, from schools and hospitals to defense facilities;
- *Existing assets* (often called "brownfield").Where the responsibility for upgrading and managing existing assets is transferred to a private company.

Functions

- *Design* (also called "engineering" work). The design function signifies the development of the project from initial concept and output requirements to construction-ready design specifications;
- *Build or rehabilitate*. When PPPs are used for new infrastructure assets, they typically require the private party to construct the asset and install all equipment. Where PPPs involve existing assets, the private party may be responsible for rehabilitating or extending the asset;
- *Finance*. When a PPP includes building or rehabilitating the asset, the private party is typically also required to finance all or part of the necessary capital expenditure;
- *Maintain*. PPPs assign responsibility to the private party for maintaining an infrastructure asset to a specified standard over the life of the contract. This is typically considered a defining feature of PPP contracts;
- *Operate*. The operating responsibilities of the private party to a PPP can vary widely, depending on the nature of the underlying asset and associated service. For example; technical operation of an asset, and providing a bulk service to a government off-taker, technical operation of an asset, and providing services directly to users or providing support services, with the government agency remaining responsible for delivering the public service to users.

Payment mechanism

- *User pays* (such as toll roads). The private party provides a service to users, and generates revenue by charging users for that service. These fees (or tariffs, or tolls) can be supplemented by subsidies paid by government, which may be performance-based (for example, conditional on the availability of the service at a particular quality), or output-based (for example, payments per user);

- *Government pays*. The government is the sole source of revenue for the private party. Government payments can depend on the asset or service being available at a contractually-defined quality ("availability" payments). They can also be output-based payments for services delivered to users.

Various types of partnerships have been implemented to reflect different project objectives and requirements (Kwak et al., 2009). These PPPs can be classified in terms of the degrees of private involvement (Yescombe, 2007). These types are differ according to the level of public participation in the project. More specifically, there are 5 types of PPP which are widely implemented in the realization of public infrastructure projects. In Table 2.2, definitions of these PPPs are summarized and Table 2.3 represents the variants.

Table 2.2. Descriptions of main types of PPP (Yescombe, 2007)

Operation – Maintenance (OM)	• Private sector is responsible for all aspects of operation and maintenance. • Although private sector may not take the responsibility of financing, it may manage a capital investment fund and determine how the fund should be used together with the public sector.
Design-Build-Operate (DBO)	• Private sector is responsible for the design, construction, operation, and maintenance of a project for a specified period prior to handling it over to the public sector.
Design-Build-Finance-Operate (DBFO)	• Private sector is responsible for the finance, design, construction, operation, and maintenance of a project. • In almost all cases, public sector retains full ownership over the project.
Build-Operate-Transfer (BOT)	• Private sector is responsible for the finance, design, construction, operation, and maintenance of a project for a concession period. • The asset is transferred back to the government at the end of concession period, often at no cost.
Build-Own-Operate (BOO)	• Similar to a BOOT project, but the private sector retains the ownerships of the asset in perpetuity. • The government only agrees to purchase the services produced for a fixed length of time.

Table 2.3. Public and private provision of infrastructure (Yescombe, 2007)

Public project ◄——————► Private project

◄—— Public–Private Partnership ——►

Contract Type	Public-sector procurement	Franchise (*Affermage*)	Design-Build Finance-Operate (DBFO)*	Build-Transfer- Operate (BTO)**	Build-Operate- Transfer (BOT)***	Build-Own- Operate (BOO)
Construction	Public sector(2)	Public sector(2)	Private sector	Private sector	Private sector	Private sector
Operation	Public sector(3)	Private sector	Private sector	Private sector	Private sector	Private sector
Ownership(1)	Public sector(4)	Public sector	Public sector	Private sector during construction, then public sector	Private sector during contract, then public sector	Private sector
Who pays?	Public sector	Users	Public sector or users	Public sector or users	Public sector or users	Private-sector off-taker public sector(5), or users
Who is paid?	n/a	Private sector	Private sector	Private sector	Private sector	Private sector

* Also known as Design-Construct-Manage-Finance (DCMF) or Design-Build-Finance-Maintain (DBFM)

** Also known as Build-Transfer-Lease (BTL), Build-Lease-Operate-Transfer (BLOT) or Build-Lease-Transfer (BLT)

*** Also known as Build-Own-Operate-Transfer (BOOT)

(1) In all cases, ownership may be in the form of a joint venture between the public and private sectors.

(2) Public sector normally designs the Facility and engages private-sector contractors to carry out construction on its behalf (design-bid-build).

(3) Public sector may enter into service (outsourcing) contracts (for operation and maintenance) with private-sector contractors.

(4) Ownership may be through an independent publicly-owned Project Company, *i.e.* a ‘Public-Public Partnership’.

(5) The BOO Contract form applies to PPPs in the minority of cases where ownership of the Facility does not revert to the Public Authority at the end of the PPP Contract

2.3. FINANCING OF PPPs

In PPPs, responsibility is transferred to the private sector for structuring finance of the investment to achieve value for money (World Bank, 2014). This feature of PPPs is one of the main differences between PPPs and traditional procurement systems. In this context, an optimal risk allocation is crucial for the risk-bearing party to best able to control and manage risk (Akintoye et al., 2003). Another argument for private financing is concerned with the private sector’s permanent access to capital markets. Participation of private capital to public infrastructure can provide realization of the project at time when public capital would not be available (Daube et al., 2008). This feature bring more flexibility than traditional procurement systems. “The characteristics of Public Private Partnerships described above show that PPP is not only a financing model, but an alternative, more profitable procurement method that involves a private contractor as well as private capital and know-how in realizing public infrastructure and services to reach value for money" (Daube et al., 2008).

2.3.1. The Mechanism of Financing PPPs

Ordinarily, financial structure of PPP which is developed by the private party consists of equity and third-party debt (Farquharson et al., 2011). In this financial structure, equity is provided by project company’s shareholders and third-party debt is provided by financial institutions either through bonds or other financial instruments. In most PPP contracts, the private party is a “project company” that have been established for realizing a specific project and often called a Special Purpose Vehicle (SPV) (World Bank, 2014). In Figure 2.1 shows a typical finance and contract structure for a PPP toll road project.

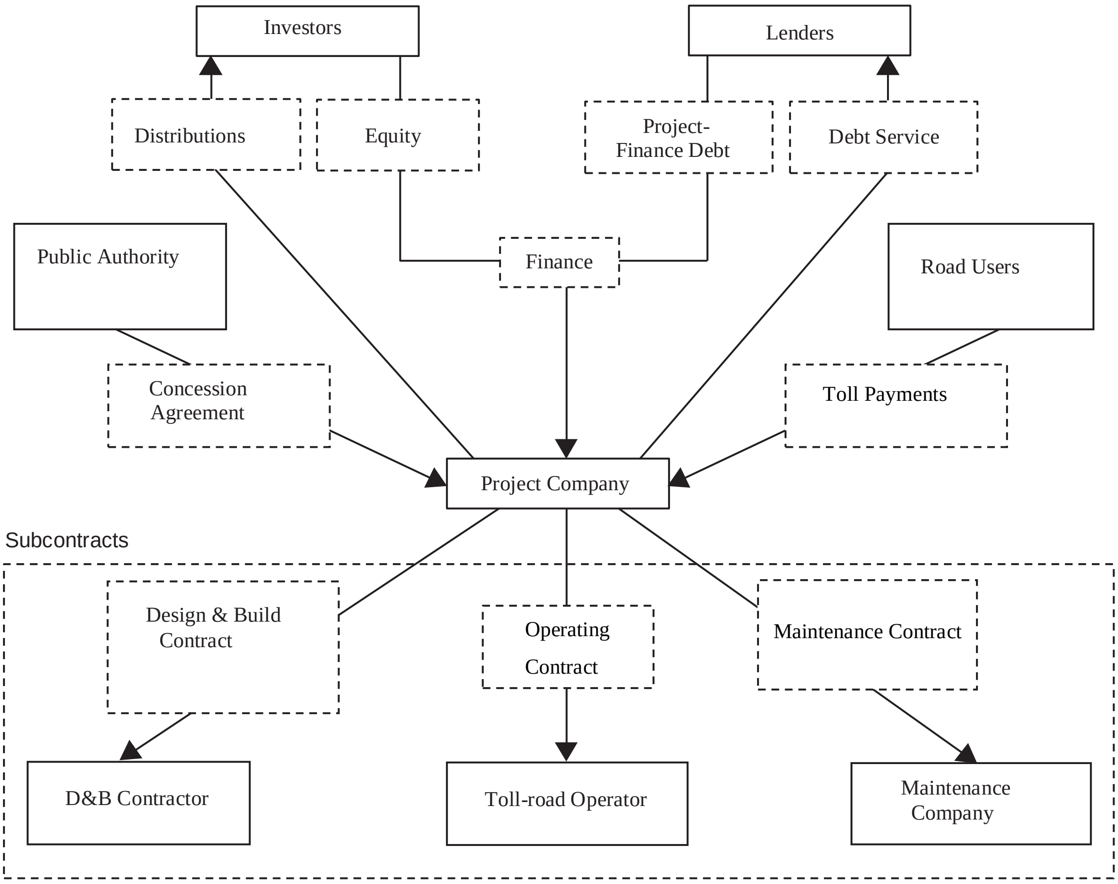


Figure 2.1. Typical PPP project structure of a toll road project (Yescombe, 2007)

Yescombe (2007) has defined key elements of this structure as follows:

- A project company or SPV is established by private party to realize a specific project. The project company may be more than one partner and it may serve more than one project;
- The project's capital costs (capex) is financed by private sector through shareholder equity and project-finance debt;
- The design and construction works are usually subcontracted under a design & build, "D&B" contract. Under D&B contract, the sub-contractor are responsible to design and construct the completed road and related works to the required specification, at a fixed price and schedule. The construction works may be split among more than one sub-contractor, but this depends on the size of construction works;
- Under an operating contract, the operation company is responsible to provide services such as manning the toll booths, minor repairs and accident management etc.;

- Under a maintenance contract, the maintenance Company is responsible to provide all maintenance services about the road during the life of PPP contract.
- A concession agreement which refers to a toll road PPP contract is between the project company and the public authority. This agreement allows the project company to collect tolls from road users.
- Cash flows after operating costs (opex) is the main net income of the project company in a period. These cash flows are used to pay the operating and maintenance contracts and firstly debt services and then distribution to the equity investors.

Another widely implemented contract in PPP framework is Power Purchase Agreement (PPA). In power sector, the main issue is to deliver electricity to public, commercial and residential consumers. It is easy to transfer electricity to long distances but it is hard to store it so it is generated constantly to meet market demand in daily and seasonal periods (Delmon, 2011). Under a PPA, the investors are paid a tariff split between:

- *Availability Charge (Capacity Charge).* This charge includes necessary capital expenditures to realize power station and fixed operating costs which is essential to operate the facility.
- *Usage Charge (Variable Charge).* This charge covers the marginal costs of generating power such as the cost of fuel used to generate power.

The basic structure of a general PPA contract is illustrated in Figure 2.2.

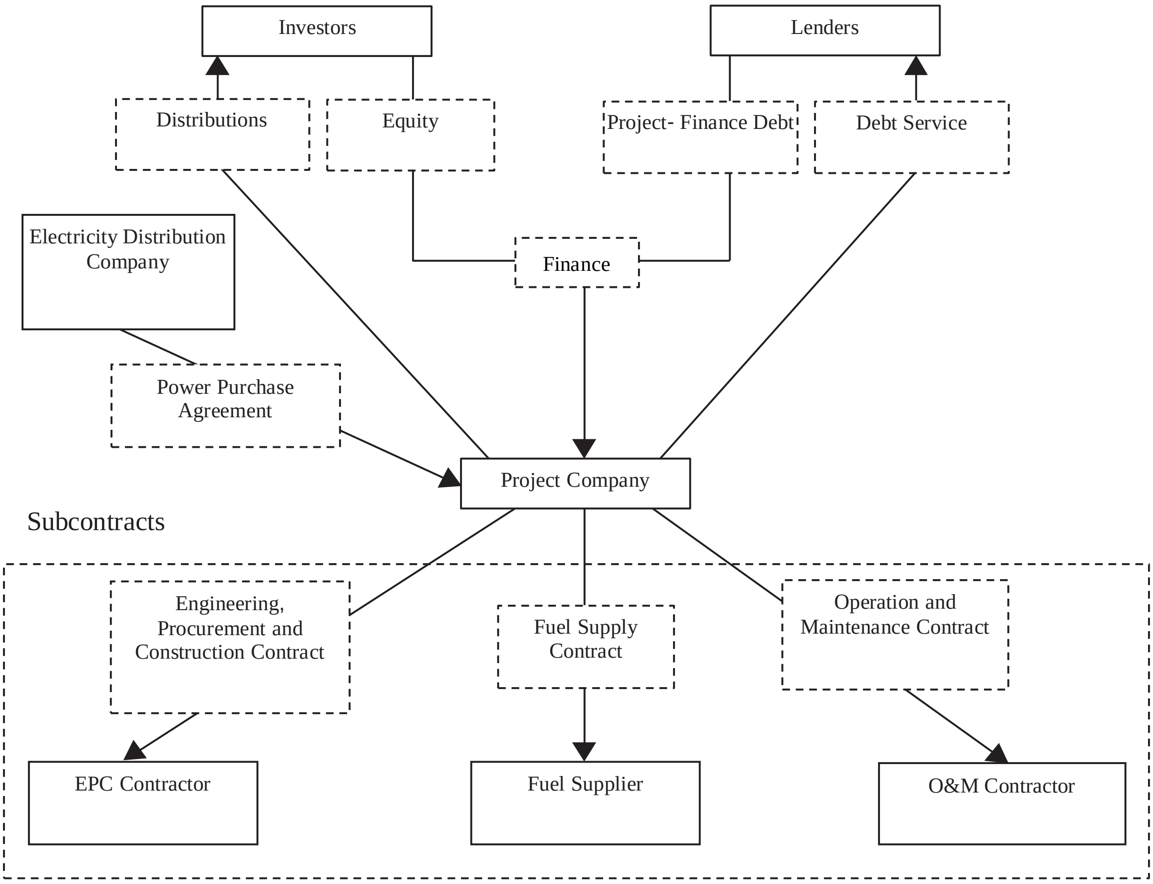


Figure 2.2. The basic structure of a PPA project (Yescombe, 2007)

Similar to the toll road concession structure mentioned before, Yescombe (2007) has defined the key elements as follows:

- Private sector investor is the owner of Project Company which is established for a specific PPA project;
- A project is financing through shareholder equity and project finance debt;
- The contractor delivers a completed and fully-equipped (turnkey) power station to the required specification, at fixed price and schedule under an Engineering, Procurement and Construction (EPC) contract;
- Coal or natural gas to generate electricity is provided by a fuel-supply contract.
- O&M contractor operate and maintain the power plant in the name of project company under an O&M contract;
- A PPA contract is agreement between electric distribution company and project company with payments based on availability and usage charges;

- Cash flows are similar to generated cash flows in toll road concession projects. It is the net income after fuel and operating costs and is used, primarily for payments of loan principal and interest (debt service) to the lenders and then distributed to equity investor (dividends).

Moreover, the equity investment is “first in, last out”. In this principle, the equity investor, primarily, bear any losses that the project face and the lenders meet a loss if the equity investor is lost (Farquharson et al., 2011). In other words, equity investor take a higher risk than debt provider in order to earn a higher return. Since the cost of equity is more expensive than debt, project shareholders tend to use high percent of debt to finance the project in order to reduce financial costs of the project. Using high proportion of debt to finance a project is known as “project finance” (Farquharson et al., 2011) and the strong relationship and interaction between the recent growth of PPPs and relatively recent development of project finance techniques is a non-negligible fact (Yescombe, 2007).

2.3.2. Project Finance

There is a difference between “project finance” and “financing projects”. Projects could be financed by alternative approaches such as public-sector procurement (Yescombe, 2007) or non-recourse forfeiting of instalments (Daube et al., 2008). According Nevitt and Fabozzi (2000), “project finance” is defined as ‘‘financing of a particular economic unit in which a lender is satisfied to look initially to cash flow 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’’. As opposed to corporate finance, the lenders, primarily, consider the revenue stream generated by the project as prerequisite, not the overall financial strength or balance sheet of the sponsor, to lend to a project (Merna and Njiru, 2002). The key features of project finance can be identified as follows:

- *Limited or non-recourse financing.* “In non-recourse project finance, lenders can be paid only from the project company’s revenues, without recourse to the equity investors” (World Bank, 2014). This means the SPV has limited liability with the capital and project assets (Delmon, 2011). However, under certain conditions, the lender recourse to guarantees or securities that are adapted to the risk profile of the specific project (Daube et al., 2008). This is called limited recourse project finance;

- *Off-balance sheet financing.* The debt in project finance is held by the SPV, which is a subsidiary of the parent companies. In this situation, the balance sheet of the parent companies will not be affected from project finance debt (Daube et al., 2008). This approach has some advantages to shareholders since it reduces the impact of the project on shareholder's existing debt and on the shareholder's debt capacity, releasing such debt capacity for additional investments (Delmon, 2011);
- *Bankability*. "The ability of a project to raise finance is often called bankability. "Bankable" really means that a project can attract not only equity finance from its shareholders, but the required amount of debt" (World Bank, 2014). As mentioned before, in project finance approach the lender relies upon project's cash flows to cover interest and debt repayments, operating costs and to yield return on equity (Daube et al., 2008). Thus, project finance approach enhances the realm of authority of the lenders. Consequently, the lenders should bring the technical and commercial expertise to meet the contractual obligations (Daube et al., 2008). This relationship also cause another risk perception between the lender, the SPV and the public authority. The lenders play an important role in this respect. The lenders earn low return when compared to equity investors because they cannot afford to take high risk as much as equity investors (Farquharson et al., 2011). Therefore, if most of the risk is transferred to private parties, the lender will reduce the amount that they are willing to lend to the project so more equity will be used to fill this gap. (World Bank, 2014);
- *Step-in rights*. If SPV cannot overcome the problems that are faced in the project, then the lender would like to bring the situation under control and usually, public authorities prefer that these problems are solved by the lender rather than termination the PPP contract (Yescombe, 2007). Step-in rights can be implemented by both the lender and government. The government usually reserves step-in right for significant health and safety risk, national security problems or legal requirements (World Bank, 2014);

- *Refinancing*. “Refinancing means taking on debt to payoff existing debt”(World Bank, 2014). Once the project is completed, construction risk doesn’t exist anymore. Thus the SPV will seek to ways of refinance project debt at a lower cost and on better terms, given the lower risk premium (Delmon, 2011);
- *Debt to equity ratio*. PPPs are generally financed with the principles of project finance with a high ratio of debt to equity. The underlying reason of this approach is to reach high leverage ratio (World Bank, 2014). The higher leverage %70-%90 helps to the investors to reach higher return on equity easier (Yescombe, 2007). Thus, governments provide more guarantees to debt investor than equity investors in order to support the project’s financial structure to reach a higher leverage ratio. “For example, governments may provide guarantees on demand designed to ensure revenue can cover debt service, or agree to payments in case of early termination that are set equal to the level of debt, such that lenders are repaid even in case of default by the project sponsor on its obligations under the contract”(World Bank, 2014).

The project finance model is not new in the history of economics. The history of project finance dates back to 1299, when the English Crown subsidized a leading Florentine merchant bank to assist in the development of the Devon silver mines (Esty et al., 2014). In particular, in the 19th century, railways were built in many states of Europe. Later, hydro-electrical power and other electrical power plants were realized using this model. In 1930s, facilities in energy sector and in particular, oil drilling in the United States were realized using similar forms of project finance. In the early 1990s, infrastructure projects such as toll roads, power plants and telecommunications systems are financed using project finance. In particular, since 2000, project finance began to be used to finance social infrastructure projects such as schools, hospitals and even prisons. Consequently, from 1994 to 2013, total volume of project financed projects grew from 41.3 $ billion in 1994 to 415.0 $ billion in 2013 (Esty et al., 2014). Main motives to the development of project finance models include:

- privatization;
- globalization;
- increase in infrastructure demand in national economies; and,

- increase in public debt.

2.4. RISK ALLOCATION

One of the main paradox of infrastructure PPPs is dissonance between estimated values and actualized values of key parameters that affect the project. One the one hand, PPPs are mostly framed with contractual arrangements with attached outline business cases (OBC) that include cash-flow projections, macro-economic estimations such as interest rates, inflation rates and economic growth etc. (Cruz and Marques, 2013). On the other hand, despite the significant improvements in econometric models, it is hard to estimate accurately economic performance of regions and countries and their impact on infrastructure projects (Flyvbjerg et al., 2003). This situation is the main resource of renegotiations. Developing more flexible contracts that allow concessionaires to adapt to changing environment during the whole duration of contract is preferable (de Bettignies and Ross, 2009) rather than traditional contracts in which the concessionaire is limited with pre-determined investment plans and the contracted services that must be followed (Cruz and Marques, 2013).

In this section, a brief information about risks and uncertainties in PPPs is provided. These constitute the main arguments behind the development of more flexible contracts due to their significant impacts on forecasting.

2.4.1. The Allocation of Risks and Their Transfer

Uncertain outcomes have different effects on both the provision of the services and the financial viability of the project. However, risk in PPP projects are highly related to these uncertainties. Regardless of the source, any type of risk can cause some losses or costs. Transfer or allocation of these losses or costs among parties, is one of the main elements of a PPP structure (Yescombe, 2007). Iossa et al. (2007) argue that the aim of risk allocation is “to give appropriate incentives for the private partner to perform according to the contract terms, thus achieving value for money”. Other objectives of risk allocation are:

- to create incentives for the parties to manage risk well and thereby improve project benefits or reduce costs.

- to minimize the average cost of project risk by insuring parties against risks they don’t want to bear.

A widely recognized basic principle of effective risk allocation is to trasnfer them to the party that can higly control and manage them. Irwin (2007) provide three main principles for fair risk allocation. There are explained below.

- *Allocate a risk to the party best able to influence that risk factor*. Other things being equal, a risk should be allocated to the party that has the most influence over the corresponding risk factor- if one party can influence the risk factor and bears the corresponding risk, it gets the benefit of improving the risk factor’s outcome and pays the cost of doing so;
- *Allocate a risk to the party best able to anticipate or respond to the risk factor*. Sometimes no one can influence a risk factor. Even when no one can influence the risk factor, one party may be better able to anticipate or respond to it. One party may be able to mitigate downside risk and exploit upside risk. Therefore, this principle is to allocate the risk to the party that can most influence the sensitivity of total project value to the risk factor;
- *Allocate a risk to the party best able to absorb the risk*. The first two principles would only matter if parties are all risk neutral or if financial markets are perfect. However these two situations are only theoretical assumptions. Thus, ability of parties to absorb risk should also be taken into account.

In the structure of PPPs, risks are not shared by parties. Instead, most risks are generally transferred fully to one side or the other. In theory, project risk can be handled only in a limited number of ways. These ways are described by Yescombe (2007);

- Risks can be retained by the public authority;
- Risks can be transferred to, and retained by the project company; and
- Risks can be transferred to the project company, but then reallocated to third parties by:
  - passing them on a “back-to-back” basis to sub-contractors;
  - covering them by insurance;

  - having them guaranteed by sponsors.

- In the case of concessions, risks can be transferred to end-users through the project company having a right to impose higher service fees.

The proposed risk negotiation process in PPP/PFI contract procurement by Bing et al. (2005) which is represented in Figure 2.3, summarize and complete the definition, principles and ways to transfer of risk.

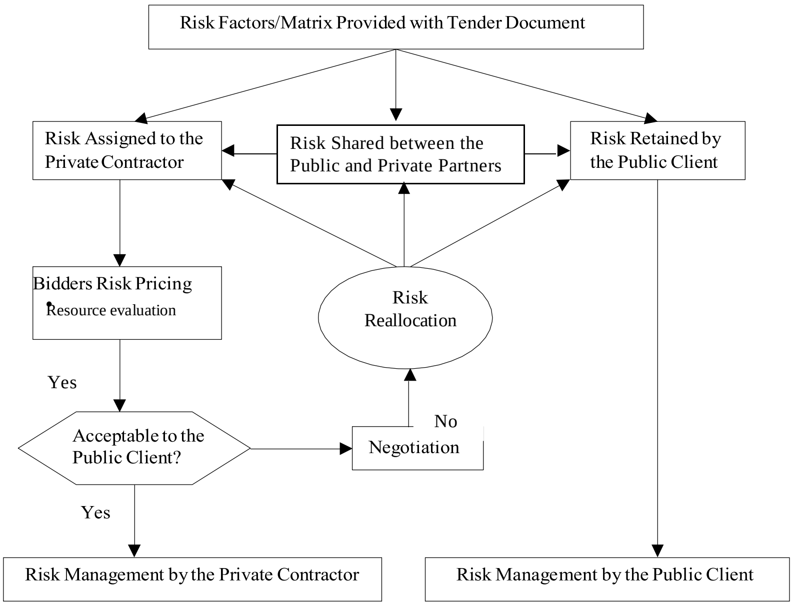


Figure 2.3. Risk allocation process in PPP/PFI contract procurement (Bing et al., 2005)

Bing et al. (2005) explain the proposed framework by stating that “the public authority identifies the risks attaching to the project in a risk register, setting out the risks relevant to each stage of the project, the likelihood of occurrence for each risk event and an estimate of the financial consequences. This analysis helps the public client to establish the type and quantum of risk that it seeks to transfer to the private sector. The private bidders receive tender documents complete with the risk factors, matrix or preliminary allocation framework; and are thus able to carry out their own analysis and assessment of the risks. The bidders can price the risks and look to recover the estimated cost of managing them through the bid-price mechanism. If the bid price is acceptable to the public sector sponsor, and the net present value (NPV) of the payment streams for the project is lower than the equivalent Public Sector Comparator (PSC), a contract can be awarded to the preferred bidder. If the bid price is too high, the public sector client may elect to negotiate with the preferred bidder, and consider whether or not to accept the bid with its higher risk cost, or reschedule risks by sharing or retaining more of them. It is even possible that concern with a higher risk transfer cost will lead to the public sector client to decide to discontinue further development of the project under a PPP/PFI approach."

2.4.2. Identifying Risks in PPPs

The first step when structuring a PPP is to identify all project risks associated with the project and put them together in a comprehensive list which is known as a "risk register" or "risk matrix" (World Bank, 2014). The expected outcomes from that "risk register (or risk matrix)" process are described by Yescombe (2007) as follows.

- The nature of each risk;
- The effect (financial or otherwise) of the risk occurring;
- Allocation of the risk under the PPP Contract;
- Any mitigation of this risk from its being passed down to sub-contractors or covered by insurance;
- The financial impact of any risk which remains with the project company.

The risks which are listed in that matrix can be classified into two main groups; general risks and project risks (Ng and Loosemore, 2007). General risks involve external sourced risks (Bing et al., 2005) and have a significant impact on outputs of PPPs. General risks are not directly linked with a project itself. These risks are often associated with political and economic conditions, legislative regulations and nature. (Ng and Loosemore, 2007). Indeed, these risks arise from the general macro-environment surrounding the project (Bing et al., 2005). In contrast, project risks involve internal sourced risks (Ng and Loosemore, 2007) and risk event and their consequences occur inside the micro-environment of that particular project. These risks include implementation problems, technical problems associated with design, ground conditions, material problems associated with suppliers etc. Table 2.4 represents a sample risk matrix for PPPs.

Table 2.4. Risk matrix for PPPs (Yescombe, 2007)

Risk phase	**Risk category**	**Nature of risk**
General	Political	Political opposition to project Change in law
	Economic	Interest rates Inflation
Construction phase	Site	Site acquisition Ground condition Permits Environmental permits & risks Archaeology and fossils Access, rights of way & easements Connections to the site Protesters Disposal of surplus land
	Construction	Construction Subcontract Construction Subcontractor Price adjustments Changes by the Public Authority Construction Subcontractor's risks Revenue during construction
	Completion	Delay by Construction Subcontract Other causes of delay Design Performance
Operation phase	Operation	Usage/demand risk Network Revenue payment Availability and service Opex Maintenance
	Termination	Project Company default Termination by the Public Authority *Force Majeure* Residual value

There are many factors that affect PPP risks. The country where the project is implemented, the nature of the project and the assets and services involved are just some of these factors (World Bank, 2014). Nevertheless, some types of risks are common for all PPP projects. They are usually grouped into risk categories presented in Table 2.4. Participants of PPP look at risks in different phases of their projects such as conception, inception, design, construction, commissioning, operation and termination (Akintoye et al., 2003). The most important two questions when considering risk issues are: (1) who compensates increase in cost and (2) who compensates time delays in the project? The common risk categories for many PPPs are discussed below.

- *Expropriation.* This can be taught as primary concern of PPP. “Who is responsible for acquiring land?” can be a major question (Akintoye et al., 2003). Expropriation risk is related to the availability of the project site in terms of site acquisition (Yescombe, 2007; World Bank, 2014). Expropriation risks are normally assumed by the public sector as private sector participant do not always have the authority and sanction power to overcome associated problems.
- *Construction.* This is one of the fundamentals of PPP. In PPP scheme, construction works are usually subcontracted with a fixed price rate (Akintoye et al., 2003). In that case, the main risk issue is the possibility of overrun in the planned construction budget (Yescombe, 2007). These risks are potentially the most costly risks (Delmon, 2011). As explained before, the project finance model favors the transfer of construction risks to the private party. However, it has been observed that in practice, public sector participants have partly assumed construction risks such as unforeseen ground conditions (Propersi and Gundes, 2006).
- *Completion.* A delay in the completion has significant impact on project revenues (Yescombe, 2007). The project company’s first aim will be to complete construction as soon as possible to earn more revenues and to improve return on investment (Delmon, 2011). Normally, completion risks are assumed by the private party. However in some cases, there may be exceptions similar to construction risks.
- *Operation.* The project must be operated at predefined performance level in order to pay operating costs, repay debt and make profit needed (Delmon, 2011). Interruption in service availability, failure in service or difference in the expected cost of operation and maintenance are in that risk category. (World Bank, 2014). Operation risks are normally assumed by the private party.
- *Regulatory and political.* Political risks rarely occur but can have a huge impact on the project (Akintoye et al., 2003). Moreover PPP projects need a political support and in the absence of political support the project is likely to face difficulties (Yescombe, 2007). Likewise, changes in the sector regulatory framework may adversely affect the project (World Bank, 2014).

- *Economic or financial.* These risks can be considered as general risks that affect the project exogenously. Changes in interest rates, exchange rates and inflation can have a huge impact on the project (World Bank, 2014). The input supply and offtake agreement play an important role in reducing some of these risks. For example; exchange rate risks can be mitigated by using the same currency in these two agreements. Inflation in input supply costs can also be controlled by placing proper terms on input supply contracts.
- *Demand.* Demand risk can be defined as any decrease or failure of the use of service provided by the facility (Delmon, 2011). This risk has a significant impact on project revenues. This risk concerns three main parties of PPPs; SPV, public authority and lenders. In section 2.3, the main principles of financing PPPs were discussed. In project finance framework, the lenders, primarily, consider the revenues generated from the project to provide debt to the project. Therefore, the accurate forecasting of demand is crucial for SPV to find adequate debt source. Moreover, if the forecasted level of demand is not sufficient, public authority will suffer to find a private partner to invest the project. In the early development of PPP, this risk was usually assumed by private investors, but more recently, public authorities bear that risk by providing revenue guarantees (Bing et al., 2005). The motives behind public sector to assume demand risk are (1) to attract private sector by guaranteeing minimum rate of return and (2) to assist SPV finding proper debt from lenders. Consequently, revenue guarantees are provided against demand risk, by securing project minimum revenues, which is inherent in project financing framework.

3. GOVERNMENT GUARANTEES

In the previous chapter, general framework for PPPs is presented. Financing and risk issues in PPPs are examined in detail as the fundamentals of project finance and risk perception in PPPs are essential to understand government guarantees. In this chapter, the definition and types of guarantees, the underlying reasons for the recourse to government guarantees in BOT projects and widely used and new valuation techniques are explained. A comparative analysis of techniques and a discussion is also provided in order to explain and clarify the basics of model selection.

3.1. WHAT ARE GOVERNMENT GUARANTEES AND WHY GOVERNMENT GUARANTEES ARE NEEDED?

Guarantees can be described as “a contractual arrangement under which a third party (the guarantor) agrees to fulfill the financial or other obligations of the guaranteed party (the principal obligor) to another party (the beneficiary) in the case of default by the principal obligor” (Timothy et al., 1997). Figure 3.1 illustrates a decision making process for governments when providing guarantees.

Governments provide guarantees, subsidies or incentives to bear or share certain project risks, even though PPP is expected to generate extra incomes for private investor such as toll rates and charging users for services (World Bank, 2014). These guarantees are used by governments as an effective tool in the structuring of PPPs against certain risk factors such as demand, exchange rates or certain costs. However, their fiscal effects are not always properly calculated mainly due to a lack of a standardized and systematic process for undertaking these calculations. The BOT approach allow governments to realize infrastructure projects without incurring any upfront costs and at the same time to benefit from the skills of the private investors (Irwin, 2007). However, if the guarantees provided are not adequately evaluated, they may generate larger costs in later stages (Irwin, 2003).

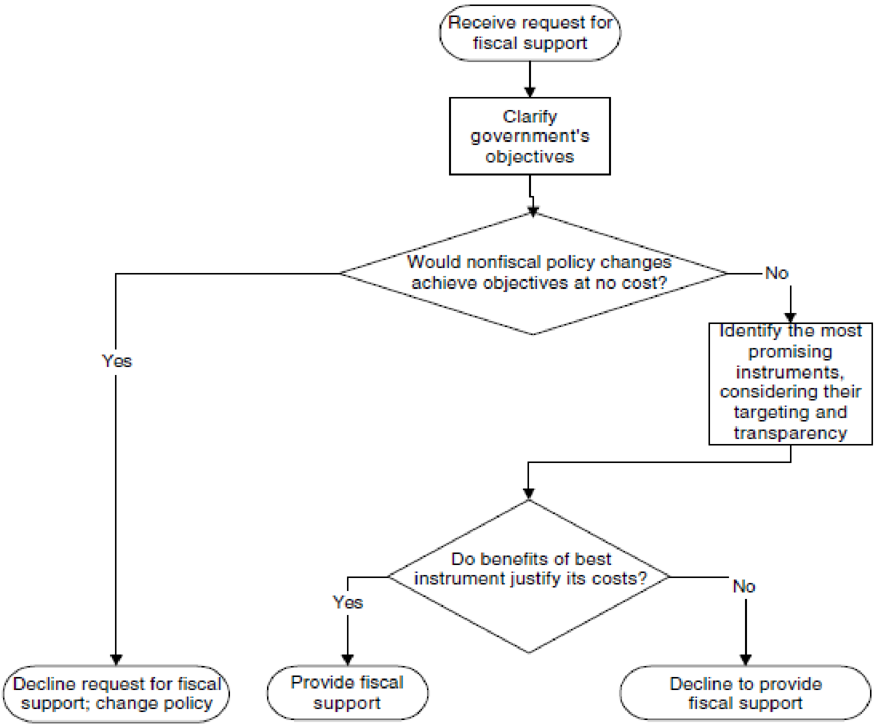


Figure 3.1. Decision-making process for governments (Irwin, 2003)

Governments may aim to reach several objectives when providing guarantees to private investors in a PPP structure. Although governments provide these supports for a mixture of reasons, EPEC (2011) identify three main drivers about why guarantees may be used in PPPs.

Political drivers for public sector

- Supporting the confidence level of a PPP market and demonstrating government commitments;
- Accelerating the realization of investments; and
- Enhancing the credibility of a PPP program.

Financial drivers

- Leveraging additional sources of finance from the private sector;
- Reducing the cost of capital and improving value for money;
- Taking precautions against instability in financial markets;
- Obtaining the asset without any upfront payment; and
- Attracting new sources of funds from the private sector.

Project risk drivers

- Default risks;
- Demand risks;
- Construction risks;
- Technology risks;
- Sub-sovereign risks;
- Policy risk;
- Macroeconomic risk; and
- Residual value risks.

Guarantees are form of government intervention intended to alter the incentives faced by the private sector and other public sector entities (Carbonara et al., 2014). Guarantees are generally used as a response to market failure. However, guarantees are not the only instruments that governments have to deal with. Irwin (2003) lists six different possible instruments of fiscal support:

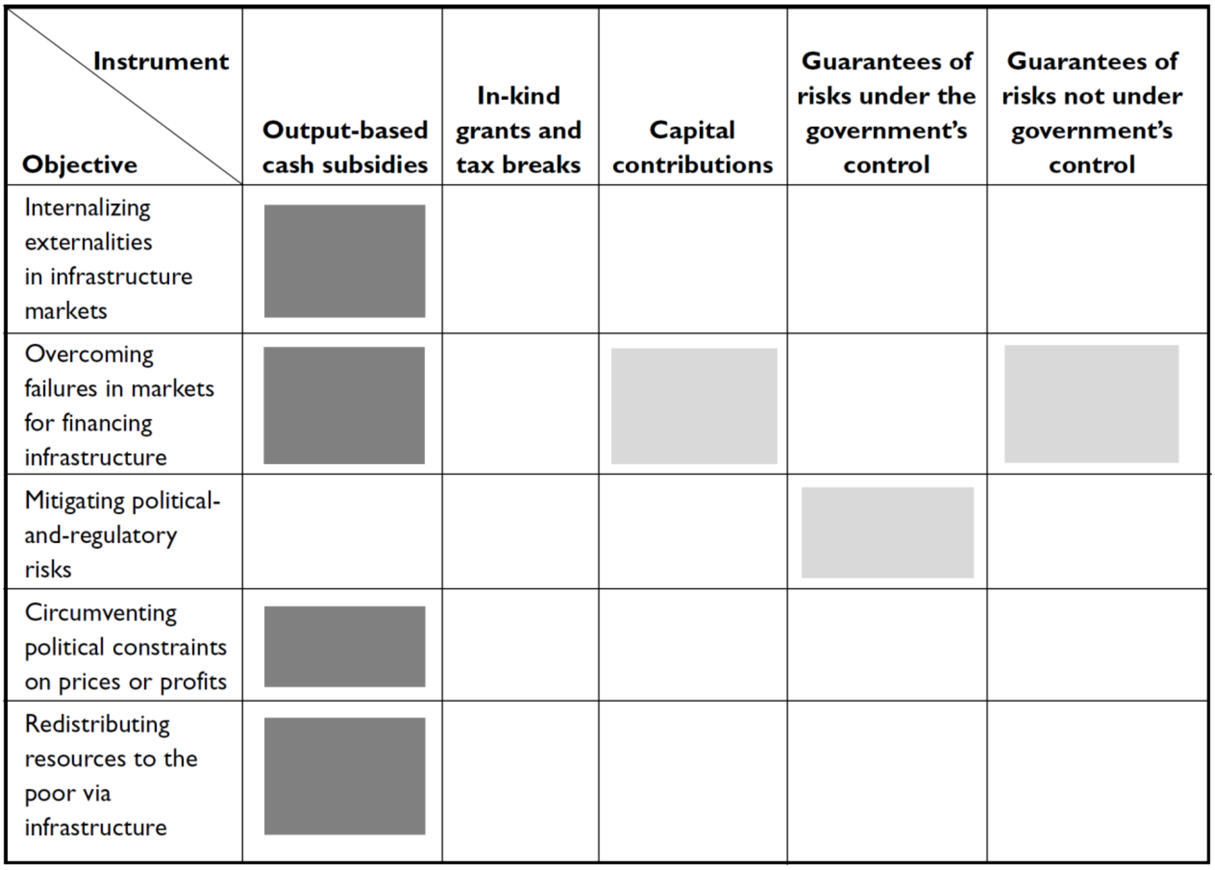
- *Output based cash subsidies*. Out-based cash subsidy is a kind of government intervention to make the projects financially viable by directly subsidizing part of the payment for service delivery (Farquharson et al., 2011). Giving the private sector a cash subsidy may be the easiest way of support (Irwin, 2003). Cash subsidies are usually tied to provision of certain services by the private firm or to customers' purchasing (Brook and Smith 2001).
- *In-kind grants*. A government may also provide real assets such as land and rights-of-way which are available at subsidized price or for free. Toll road projects usually benefit from such grants (Irwin, 2003). "For example, on the Zagreb-Macelj toll road, the government provided in-kind support in the form of land and contingent debt drawn down whenever revenues were insufficient to cover debt service. Thus, lenders were protected, but the risk remained with the equity holders" (Delmon 2011).
- *Tax breaks.* Receiving tax break either in the form of reduced tax rates or a temporary "tax holiday" may be sought by private investors (Irwin, 2003). For

example recently the government of the Turkish Republic changed the VAT law in order to provide %18 tax break to concessionaires.

- *Capital contributions.* The public authority may provide a direct capital contribution to a PPP in the form of loans and upfront grant subsidies (Yescombe 2007). This approach reduces the amount of debt and equity funding required for the realization of the project (Farquharson et al., 2011). However, capital contributions raise several important risk-transfer issues. This is because in principle the public sector money should not to go in first and bear the whole construction project risk (Yescombe 2007).
- *Guarantees of risks under government's control.* The government takes on some of the risks of the project while providing capital to the project (Irwin, 2003).The basic principle of risk mitigation is to transfer the risks to those who can best manage them. This approach is also valid for the governments. It is usually expected that the governments take the risks which they have significant control on, such as political and regulatory risks. A common example regards the expropriation risks where the governments expropriate assets and keep prices below costs (Smith, 1997).
- *Guarantees of risks not under government's control.* The governments often bear important risks that no one has much control in (Irwin 2003). One example is the future demand for the services provided by a project. Moreover, natural disasters and force-majeure are other examples. Future demand is especially important issue for toll road projects. In project finance framework, the cash flows generated by a project is the main source of debt reimbursement. To mitigate that risk and to make the project attractive for the private investor, the governments provide some subsidies such as MRG and MTG.

Irwin (2003) proposes the use of a particular approach when choosing a fiscal support instrument. The approach is explained as "a guidance on the issues governments should consider when choosing which instruments to use to achieve which objectives, rather than to specify which instrument should be used to achieve which objectives." This structure of the proposed model is illustrated in Table 3.1.

Table 3.1. Options most likely to address government objectives (Irwin 2003)



Instrument Objective	Output-based cash subsidies	In-kind grants and tax breaks	Capital contributions	Guarantees of risks under the government's control	Guarantees of risks not under government's control
Internalizing externalities in infrastructure markets	▓				
Overcoming failures in markets for financing infrastructure	▓		░		░
Mitigating political-and-regulatory risks				░	
Circumventing political constraints on prices or profits	▓				
Redistributing resources to the poor via infrastructure	▓				

Likewise, EPEC (2011) classify these instruments into three groups: finance guarantees, PPP contract provisions and sub-sovereign creditworthiness guarantees.

Finance guarantees

- Loan guarantees; and
- Refinancing guarantees.

PPP contract provisions

- Revenue or usage guarantee;
- Guaranteed minimum service charges;
- Change of law/regulation undertakings;
- Termination payments;
- Debt assumption undertakings; and
- Residual value payments.
- *Sub-sovereign creditworthiness guarantees.*

3.2. VALUATION OF PPPs

In the previous section, definition, type and drivers of guarantees are presented. This section aims to examine valuation methods of guarantees and clarify the components of proposed model in Chapter 4.

3.2.1. PPPs and Guarantees

Using government guarantees is widely implemented by governments in PPP projects. However, there is a significant number of projects that financially have been affected negatively form these guarantees. The government guarantees may not have been wrong, but they can cause problems (Irwin, 2007). For example, in the 1990s, the government of Republic of Korea launched a privately financed road linking project between Seoul and a new airport at Incheon and guaranteed 90% percentage of a 20 year forecast of revenue. Moreover, a revenue sharing mechanism framework was adopted which give an option to the government of Republic of Korea to keep any revenue exceeding 110% of the forecast. However, the road opened in 2000 and the traffic revenue fell 50% under the expected forecast revenue. Consequently, the government had to pay tens of million dollars every year. Even though concession period was not over yet, the government had paid over $1.5 billion as a present value (Irwin, 2003). This is a good example in terms of to show how guarantee valuation is vital for the governments. Thus, government guarantees must be evaluated and valued adequately and carefully.

In this paper, revenue guarantees are selected as an area of investigation. The main reason is that traffic volume (and accordingly project revenues) is the main risk factor in toll road projects. Thus, governments provide minimum revenue guarantees MRGs to projects in order to attract private investors and to secure generated revenues which is crucial in the project finance framework. Today, the provision of MRGs is frequently used by governments. However, experience to date shows that in many cases this approach has broken the principles of risk allocation structure set by theory. In theory, BOT project delivery system under PPP scheme should have several promising features for highway development such as no requirement for an upfront payment by governments and thus enabling the governments use resources in more indispensable areas.

According to Ashuri et al. (2012) "there is a considerable amount of evidence indicating that improper consideration of uncertainty about future traffic demands in BOT projects contributes to the financial failure of these projects". For instance, the government of Mexico awarded 52 projects between 1987 and 1995 to realize the largest PPP toll road program in the world. However, the result of this investment attack was heavy. After concession, construction cost overruns averaged 25%, average toll road fees increased from $0.02 to $0.17, average actual revenues were approximately 30% below projected revenues and interest rates rose during Tequila Crisis to 100%. Consequently, the government had to take over 23 projects and paid approximately $5 billion in outstanding debt to Mexican banks and $2.6 billion to construction companies (Hodges, 2006). Queiroz (2007) attribute the failure of many BOT projects during the operation phase to two major issues:

1. Unrealistic assumptions in estimating toll revenues; and
2. Inefficient revenue risk-sharing mechanisms between the public and private sectors.

There are several approaches in the literature to value BOT projects. In broad context, there are two groups: traditional valuation methods and real option analysis. Traditional valuation methods such as the Net Present Value Analysis (NPV) is not an efficient way to value BOT projects due to several reasons. These reasons are examined in detail in the next section. Real Option Analysis (ROA) on the other hand, is frequently used to value BOT projects as an alternative approach and recently a significant amount of research papers have emerged in literature about the valuation of guarantees as options using ROA (i.e. Almassi et al., 2013; Ashuri et al., 2012; Carbonara et al., 2014; Cheah and Liu, 2006; Chiara et al., 2007; Kokkaew and Chiara, 2013).

3.2.2. Traditional Valuation Methods

A large number of research has already been conducted about the evolution and valuation of investment projects. Traditional financial theory proposes the NPV approach to evaluate projects using a cost of capital based on the inherent project risk (De Reyck et al., 2008). In the 1950's, when the discounted cash flow methods (DCF) were first introduced in firms, they were considered to be sophisticated approaches for the valuation of projects due to the need to use present value tables.

Although it has lots of advantages over the payback period, it began to be popular among most practitioners only after the development of portable calculators and computers (Brandao and Dyer, 2005). In DCF methods, the future expected cash flows are discounted by risk-adjusted discount rates which takes the risk of the project in to consideration. The sum of all the future expected present values of the cash flows determine the value of the project. Equation 3.1 represents the total value of the project in NPV approach.

$$NPV = I_0 + \sum_{t=1}^{T} \frac{C_t}{(1+r)^t} \tag{3.1}$$

where

t= year;

$I_{0=}$ initial investment cost;

C_t = expected cash flow in year t; and,

r= discount rate

Among various capital investment appraisal alternatives, the payback method, internal rate of return (IRR) and NPV have been long used by corporate planners. Figure 3.2 represents the results of a survey conducted by Graham and Harvey (2001) about the popularity of capital budgeting methods.

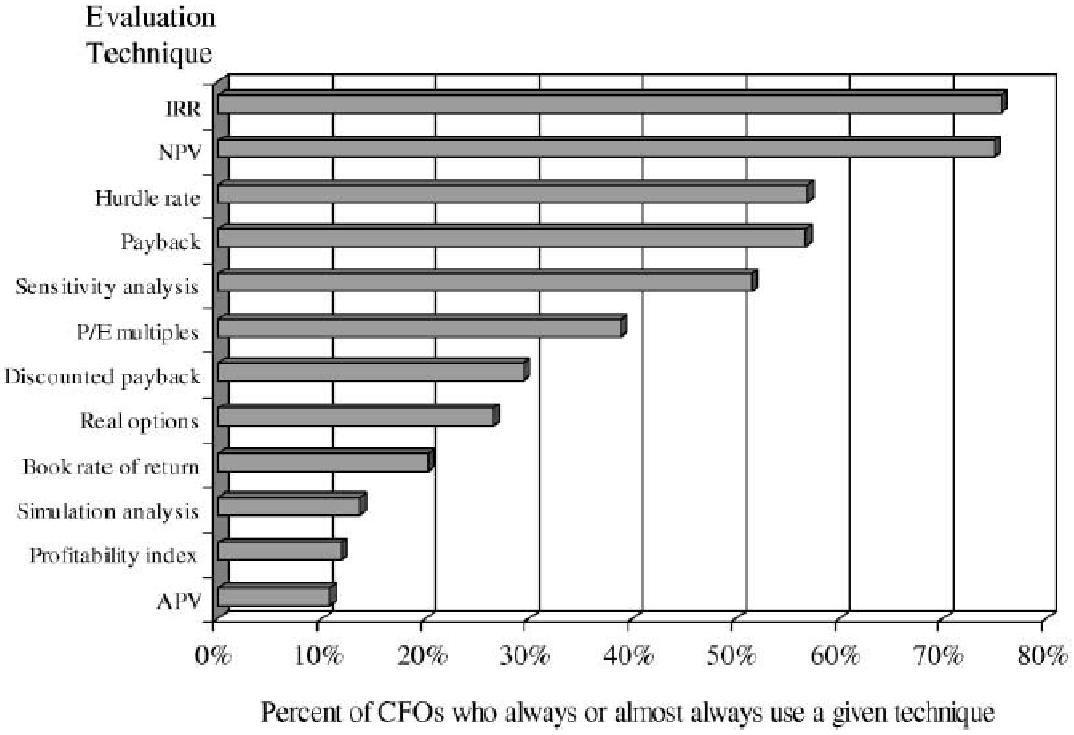


Figure 3.2. The popularity of capital budgeting methods (Graham and Harvey, 2001).

However, through time several drawbacks of these methods have also been revealed. For example, traditional DCF-based methods "require the assumption of perfect certainty of project cash flows", even though this is rarely true for real world projects (Miller and Park, 2002). Moreover, these techniques fail to satisfy needs of strategic investment decisions. Particularly, these DCF-based methods have three main limitations. These are summarized below.

- *Selecting an appropriate discount rate is difficult.* The total value of the project is very sensitive to the discount rate when using DCF methods (Garvin and Cheah, 2004) and the selection of a proper discount rate is difficult (Miller and Park, 2002). The discount rate should both represent the risk of project and the expected return of investor (Brealey and Myers, 2000).
- *Ignore the operational flexibility that can affect the project when new information arrives.* Investments often contain future possibilities such as growth or contingency possibilities in itself (Garvin and Cheah, 2004). From beginning to end, the projects are not static processes. In other words, developments in the project or receiving new information about the uncertainties can change the risk premium of the project cash flows (Garvin and Cheah, 2004). In such cases, DCF

methods are inadequate to value this flexibility (Dixit and Pindyck, 1994; Trigeorgis 1996; Amram and Kulatilaka, 1999).

- *Now or never approach.* Investment decisions are not typically “now or never” decisions. Using DCF methods, if the NPV is positive, the decision simply results in the acceptance of the project immediately (Miller and Park, 2002). However, in practice they can also be delayed.

Although traditional valuation methods have these limitations, they still remain as powerful tools to evaluate the decisions where certain decision environment is established such as cost-reduction problems when future cash flows are relatively certain (Miller and Park, 2002). To deal with these limitations, Real Option models and alternative valuation techniques have been proposed and developed.

3.2.3. Real Option Analysis

The real options approach has been widely suggested as a capital budgeting and strategic decision-making tool due to its outstanding features to value future flexibility (Trigeorgis 1996; Amram and Kulatilaka, 1999). The basic assumption of real option model is that “there is an underlying source of uncertainty and over time, the outcome of the underlying uncertainty is revealed and managers can adjust their strategy accordingly” (Bowman, 2001). This issue addresses one of the main limitations of DCF approaches. The future flexibility or any revealed uncertainty definitely adds value to the project. However, this added value does not come alone, cost components in terms of money, time and complexity accompany them. This value added should prevail against its cost. The DCF approaches do not support such analyses (Garvin and Cheah, 2004). Consequently, the first thing to do is to decide whether it is feasible to purchase the available option or not. Later, if the available option is purchased, the issue is then to decide if or when to exercise this option (Bowman, 2001).

Brealey and Myers (2000) present a simple reason for using real options: “When you use DCF to value a project, you implicitly assume that all assets are held passively. But managers are not paid to be dummies. After they have invested in a new project, they do not simply sit back and watch the future unfold. If things go well, the project may be expanded, if they go badly the project may be cut back or abandoned altogether. Projects that can be modified in these ways are more valuable than those that do not provide such flexibility. The more uncertain the outlook, the more valuable this flexibility becomes…Options to modify projects are known as real options." Consequently, ROA is a promising tool to value strategic investment decisions.

In a single investment project there are a number of outputs. These outputs, inherently, may occur at different times, may have different uncertainty levels and may be in the form of subsequent options (Miller and Park, 2002). ROA enable to aggregate and evaluate all these possible outputs. Miller and Park (2002) state that when using option framework, managers can regard two factors as advantageous in increasing the value of investment projects.

1. The negative financial impacts or losses caused by increased volatility are limited as the option value is incorporated in calculations. In addition, options embedded in projects produce greater gains as they enable decision makers to capture increments.
2. As the uncertainties surrounding the project decrease through time, new information creates new options and these can be revalued using the real options model. In DCF approaches however, a long time horizon increases the project uncertainty and this lowers the value of the project. In short, the real options model offer a more flexible decision making structure.

Real option theory is based on financial options theory. It is an extension of financial options to real assets and projects (Rakic and Radenovic, 2014). The term "real option" is initially proposed by Myers (1977) for the application of option pricing theory and other financial methods for valuation of non-financial, real assets. The pioneer work of Black and Scholes (1973) and Merton (1973) provided a method to properly value financial options. Their work have caused an explosion of research in pricing all derivative products (Miller and Park, 2002). Some pioneering works made the transition from the valuation of financial options to real options. For instance, Tourinho (1979) evaluated a non-renewable natural resources reserves under price uncertainty using the concept of options; Brenann and Schwartz (1985) similarly used the concept of options to analyze the optimal operational policy of a copper mine; and McDonald and Siegel (1986) determined the optimal timing for investing in a project. Finally, Dixit and Pindyck (1994) and Trigeorgis (1996) were the first authors to lay the foundations for the development of a wide range of real options models. The paper by Polio (1998) is one of the earliest studies that introduces the real options approach in project finance. More recent literature on BOT road investments address the issue of valuation of individual real options.

In broad context, a real option is similar to financial options (Rakic and Radenovic, 2014), which gives the holder the right, not the obligation, to take decisions concerning a project at a predetermined price or pre-specified time over the life of the option (Lawrence and Thomas 2008). Table 3.2 represents the comparison of variables used in real and financial options.

Table 3.2. Comparison of real and financial options (Rakic and Radenovic, 2014).

Variable	Financial option	Real option
S	Value of the underlying risky asset	Expected cash flows from the project – value of the project
X	Exercise price	Investment costs
T	Time to maturity	Time to maturity
σ	Volatility of the underlying risky asset	Volatility in the expected cash flows from the project
r	Risk-free interest rate	Risk-free interest rate

The value of option is directly related with the project uncertainty level. In BOT toll road investments, there are two main sources of uncertainty; cost of construction and revenues generated from toll rates. The uncertainty in cost of construction may be dealt with a cost contingency reserve. Likewise, various forms of guarantees are designed to mitigate the shortfall in traffic revenue such as minimum revenue guarantee (MRG), minimum traffic guarantee (MTG). The MRG can be considered as a put option for the concessionaire (Irwin, 2003) which can be exercised during the project life. Moreover, the government and concessionaire can also negotiate other forms of guarantees such as tariff, debt and maximum funding cost guarantees (Wibowo, 2004).

There are two types of options, call and put. If the price of the real asset is above a predetermined level (exercise price) a call option gives the holder the right to buy real asset either on a pre-specified date (American options) or only on the exercise date (European option). Conversely, if its price is below the exercise price, a put option gives the holder the right to sell the asset (Rakic and Radenovic, 2014). Equation 3.2 and 3.3 represent the value of call and put options.

$$C = \max(S - X, 0) \tag{3.2}$$

$$P = \max(X - S, 0) \tag{3.3}$$

Several options can be observed in a project such as option to expand, abandon, defer, contract, switch and compound etc. (Trigeorgis 1996; Hull, 2006) Each kind of option in a project provides a managerial flexibility to alter the project in order to respond to changing market conditions.

3.3. VALUATION OF REAL OPTIONS

There are numerous types of option pricing methodologies that can be applied to valuation of real options such as the Black-Scholes model, Monte Carlo simulation, lattices (binominal, trinomial and multinomial) and more (Mun, 2002). However, in broad context, these methodologies can be classified into two groups; continuous time models and discrete time models (Miller and Park, 2002; Garvin and Cheah, 2004). Regardless of the approach, all valuation techniques aim to determine the value of option precisely. Figure 3.3 represents the advantages and disadvantages of each modelling approach and show the classification of models.

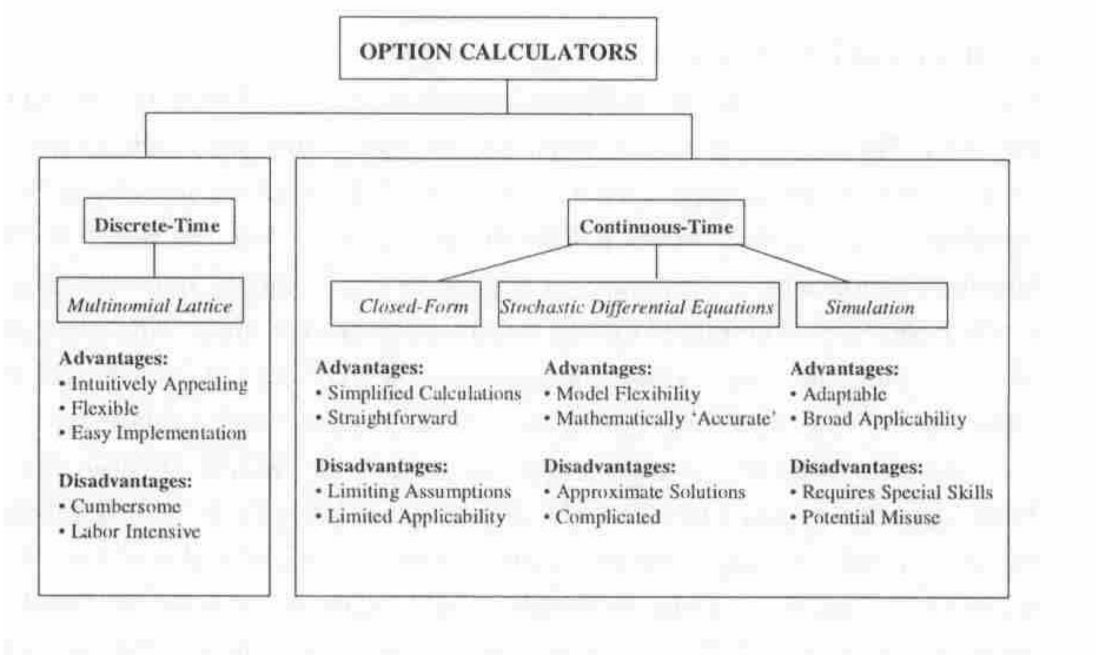


Figure 3.3. Numerous ROA modelling approaches for option calculation (Miller and Park, 2002).

3.3.1. Continuous-Time Models

Common forms of continuous-time models include closed-form equations, stochastic differential equations and simulation. Continuous-time models assume that one or more variables represent a stochastic behavior (Garvin and Cheah, 2004). Both continuous-time and discrete time models are concerned with the movement of underlying asset during the project life.

There are three stochastic process used in literature: Geometric Brownian Motion (GBM), a Poisson jump process and a mean-reverting process. Commonly, GBM is employed to model the movement of underlying asset. The Black and Scholes equation assume GBM process. Poisson jumps are used to model sudden and sharp movements in the underlying asset. A mean reverting process is employed when the underlying asset tend to revert back his long-run average level (Miller and Park, 2002).

Closed-form equations

Several developed closed-form equations exist in the ROA literature. All these equations reach an option value in a continuous-time context for a given set of assumptions (Iyer and Sagheer 2011). “The advantage of using the closed-form equations is the ease with which options can calculated” (Miller and Park, 2002). Black and Scholes 1973 developed the first closed-form equation to value financial options. The majority of option pricing methods used today are derived from the B-S equation and approach (Iyer and Sagheer 2011). Equation 3.4 and 3.5 represent the Black-Scholes formulas for the prices on a non-dividend paying stock for European call and put option at time 0 (Hull, 2006).

$$c = S_0 N(d_1) - Ke^{-rT} N(d_2) \tag{3.4}$$

$$p = Ke^{-rT} N(-d_2) - S_0 N(-d_1) \tag{3.5}$$

where

$$d_1 = \frac{ln\left({}^{S_0}/_K\right) + (r + {}^{\sigma^2}/_2)T}{\sigma\sqrt{T}} \tag{3.6}$$

$$d_2 = \frac{ln\left({}^{S_0}/_K\right) + \left(r - {}^{\sigma^2}/_2\right)T}{\sigma\sqrt{T}} = d_1 - \sigma\sqrt{T} \tag{3.7}$$

N(x) is the cumulative probability distribution

c and p are the European call and put price;

S_0 is the stock price at time 0;

K is the strike price;

R is the risk free rate;

σ is the stock price volatility; and

T is the time to maturity of the option.

Stochastic differential equations

A series of stochastic differential equations (SDE) with boundary conditions must be solved in order to derive the closed-form equations (Miller and Park, 2002). But this is not possible every time because often solutions to the SDE do not exist. In this case, the partial equation must be solved numerically using either finite difference method or Monte Carlo simulation (Iyer and Sagheer 2011). However, from a ROA perspective, deriving SDE to value the option and, then employing a numerical procedure to reach results is still applicable, but it requires some background in stochastic calculus (Miller and Park, 2002).

Simulation

Monte Carlo simulation is valuable and practical numerical procedure to value options (Iyer and Sagheer 2011). Monte Carlo simulation enables to simulate a large number of sample paths in its stochastic environment (Garvin and Cheah, 2004). Monte Carlo simulation is being popular among practitioners due to complex nature of SDE and the labor intensive lattice approach (Miller and Park, 2002).

3.3.2. Discrete-Time Models

Discrete-time models include the binomial model, trinomial model and the lattice model. These models intent to provide an approximation to continuous-time model "in the limit" (Garvin and Cheah, 2004). These approaches assume that "underlying asset flows a discrete, multinomial, multiplicative stochastic process through to time to form some of tree" (Miller and Park, 2002). The most important advantage is "the intuitive valuation procedure and the flexible valuation process" (Iyer and Sagheer

2011). The option values may be observed in the tree and the tree supports nearly valuation of every kind of options such as delay, growth contraction, American-style, compound and exotic options (Miller and Park, 2002).

3.4. GUARANTEE VALUATION MODELS IN LITERATURE

There are various models in the literature that contribute to valuation of guarantees using real options approach. In most general sense, all these models were constructed in three steps. These are:

1. Structuring guarantee model using real option approach;
2. Modelling underlying risk factor; and,
3. Applying valuation technique to the model.

Existing models are different from each other as different approaches are adopted for each step. Using real options theory in BOT project evaluation isn’t a new idea. Ho and Liu (2002) developed a real option pricing model to value government debt guarantees in BOT projects which can’t be assessed using traditional valuation techniques. They showed that that failing to evaluate the guarantee value has a significant negative impact on the decision making of the developer and government.

Charoenpornpattana et al. (2003) model government support instruments as a bundle of independent options from government given to private investors. They design and formulate the options-like government support instruments in BOT projects, e.g., minimum revenue guarantee (MRG) and shadow toll, based on real options theory

Wibowo (2004) modeled guarantees as European put options and applied stochastic simulation method using Latin Hypercube technique on the cash flow model with and without guarantees. Moreover, the author identified several types of guarantees including minimum revenue guarantee, maximum interest rate guarantee, debt guarantee, tariff guarantee and minimum traffic guarantee. He showed that guarantees can reduce risks but are not free of cost. If compared with equivalent subsidies, some guarantees can be more effective in lessening the extent of project risk.

Huang and Chou (2006) used real option approach to value MRG and the option to abandon in BOT infrastructure projects. They modeled MRG as a series of European style call options and formulated the option to abandon under an investment option held by the concessionaire at the stipulation of the contract which expires before construction starts. They rely on rely on Black and Scholes' (1973) model and develop a compound option pricing formula for valuing these options and show that both the government supports and the option to abandon create a value.

Cheah and Liu (2006) used 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. In their model, traffic volume was assumed to follow lognormal distribution and the initial annual traffic growth rate is modeled using normal distribution. It is demonstrated that the guarantee granted, which ultimately resulted in subsidy payments, could indeed be substantial. To match the value that has been conferred, a repayment scheme can be designed to place a cap on the private sector's return.

Chiara et al. (2007) present a new method for quantifying the value of a revenue guarantee in a BOT project. They proposed an elegant guarantee framework for infrastructure projects, known as the Australian guarantee, in which the concession period is only partially covered by the government guarantees. The smaller number of guarantees in this framework compared with the classic full-coverage framework causes fewer financial commitments for the government. The valuation approach extends and modifies existing computational finance methods used to price discrete-exercise financial options, specifically the least-squares Monte Carlo method. The approach is then illustrated in a hypothetical case study. Moreover, they modeled future traffic demand using Variance Model. In this paper, it was shown that this new framework could be worth 99% of the traditional full-coverage guarantee structure with as few as half the number of guarantees.

Brandão and Saraiva (2008) develop a real option model for assessing the value of minimum traffic guarantees in highway projects, which differs from most of the literature in the field by using market data to determine stochastic project parameters. Their model can be used to assess the value of these guarantees, allows the government to analyze the cost–benefit of each level of support, and proposes an alternative to limit the exposure of the government while still maintaining the benefits to the private investor.

Iyer and Sagheer (2011) presented the application of traffic guarantees as a combination of traffic floor and traffic ceiling and demonstrate a comparison between traditional NPV method and real options analysis. The comparison showed that the incorporation of traffic guarantees may enhance the value of the project. Such guarantees should be designed taking into account the benefits and risk exposure and modern financial tools such as real options analysis can be applied to capture the correct valuation of guarantees. The proposed real options methodology can aid decision makers in deciding the appropriate level of traffic floor and ceiling caps, which can ensure a stable revenue stream to the concessionaire while averting windfall gains to the private investors at the expense of highway users.

Ashuri et al. (2012) propose a new real option model to explicitly price MRG options in BOT projects. Their approach builds on a binomial lattice model and the Monte Carlo simulation technique. A market-based option pricing approach called risk-neutral valuation method is used to determine the correct value of MRG options. The authors' approach also describes a procedure for characterizing the concessionaire's economic risk profile under uncertainty about future traffic demands. In addition, it uses real options analysis to price MRG and traffic revenue cap (TRC) options as compound options and determines their effects on the concessionaire's economic risk profile. The proposed model can help public and private sectors better analyze and understand the economic risk of BOT projects under uncertainty about future traffic demands. The private sector can use this proposed model to make better entry decisions to BOT highway projects considering the level of support provided by the government. The government can also use the proposed model to identify the appropriate MRG levels to encourage private investments without comprising future budgetary strength.

Almassi et al. (2013) presented a continuous stochastic process derived from the risk factor forecast, thereby providing a more realistic and flexible model. A new valuation approach was developed by using a finite-difference method based on this continuous stochastic process. In a numerical example with one risk factor, it was shown that this new valuation tool is 100 times faster than the existing simulation-based approach. Its superior speed presents the opportunity to examine different contractual configurations, and as a result, design a more cost effective guarantee contract. Exercise strategies were derived for a multiple-exercise (Australian) guarantee structure. This new approach can be used by a government to reserve budget for the guarantees. Finally, the continuous underlying random process and exercise strategy enable this method to value more complex guarantee structures.

Carbonara et al. (2014) proposed a real option based approach to establish a fair risk allocation between the public and private sector. The authors applied Monte Carlo simulation to take uncertainty into consideration. Although their model has a stochastic nature like most of the real option literature, it isn’t mathematically heavy due to its simulation based approach. Table 3.3, 3.4, 3.5, 3.6, 3.7, 3.8, 3.9, 3.10 and 3.11 represent the critical analysis of some of these models.

Table 3.3. The model proposed by Wibowo (2004)

<table>
<tr><td rowspan="4">Bibliographic Identity</td><td>Title</td><td>Valuing Guarantees in a BOT Infrastructure Project</td></tr>
<tr><td>Author</td><td>Andreas Wibowo</td></tr>
<tr><td>Journal</td><td>Engineering, Construction and Architectural Management</td></tr>
<tr><td>Y/V/I/P</td><td>2004;11(6);395-403</td></tr>
<tr><td rowspan="2">Rationale</td><td>Problem Statement</td><td>Governments often do not know the full extent of contingent liabilities when issuing guarantees, and because they account and record guarantee costs only when guarantees come due.</td></tr>
<tr><td>Scope and Objective</td><td>This paper discusses the guarantees’ financial impact from the perspectives of the government and the project sponsor. Stochastic simulation using Latin Hypercube technique is applied on the cash flow model with and without guarantees. Several types of guarantees including minimum revenue guarantee, maximum interest rate guarantee, debt guarantee, tariff guarantee and minimum traffic guarantee are discussed to understand affects of guarantees to the project financial performace.</td></tr>
<tr><td rowspan="6">Guarantees and Caps</td><td rowspan="2">Type</td><td>Minimum revenue guarantee (MRG)</td></tr>
<tr><td>Traffic, tariff, debt and maximum interest rate guarantees are discussed but disturbations of these guarantess are not shown for reason of brevity.</td></tr>
<tr><td>Option</td><td>European option</td></tr>
<tr><td rowspan="2">Manner</td><td>MRG as a put option</td></tr>
<tr><td>Other guarantees also are treated as a put option.</td></tr>
<tr><td>Coverage</td><td>Full</td></tr>
<tr><td rowspan="8">Risk</td><td rowspan="4">Major Risk Factors</td><td>Interest and interest rate</td></tr>
<tr><td>Traffics and revenues</td></tr>
<tr><td>Delays in tool adjustment</td></tr>
<tr><td>Other variables</td></tr>
<tr><td rowspan="4">Modelling of Risk</td><td>Risky variables whose future values are expected to eqaul current values are assumed to evolve following a Wiener process or Brownian motions with a zero drift - interest and interest rate.</td></tr>
<tr><td>Risky variables that are expected to grow at a constant rate, they are assumed to evolve following the geometric Brownian motion (GBM) - traffics and revenues.</td></tr>
<tr><td>Delays in toll adjusment are assumed to obey a geometric distrubition.</td></tr>
<tr><td>Other risky variables are simply assumed to follow normal distrubition.</td></tr>
<tr><td rowspan="6">Model</td><td>Approach</td><td>Simulation</td></tr>
<tr><td>Valuation Method</td><td>Latin Hypercube Simulation</td></tr>
<tr><td rowspan="4">Process</td><td>The cash flows of the project is modelled.</td></tr>
<tr><td>Simulation is carried out on the project sponsor cash flow model without guarantees to see inherent project risk level.</td></tr>
<tr><td>A Latin hypercube simulation is applied to cash flow model with guarantees.</td></tr>
<tr><td>The financial impacts of guarantees and direct subsidies for equal expected payoff are compared.</td></tr>
<tr><td rowspan="4">Application</td><td>Name</td><td>Indonesian toll road project</td></tr>
<tr><td>Type</td><td>Toll road-BOT</td></tr>
<tr><td>Technical details</td><td>No technical details are avaliable.</td></tr>
<tr><td>Data and Assumptions</td><td>
<table>
<tr><td>Data</td><td colspan="2">Value</td><td>Data</td><td colspan="2">Value</td><td>Data</td><td>Value</td></tr>
<tr><td>Construction duration</td><td colspan="2">3 years</td><td>Max. capacity</td><td colspan="2">180.000</td><td rowspan="2">Jakarta Inter Bank Offered Rates(JIBOR)</td><td rowspan="2">13,50%</td></tr>
<tr><td>Concession duration</td><td colspan="2">22 years</td><td>Initial toll of vehicles small</td><td colspan="2">IDR 400/km</td></tr>
<tr><td>Total cost</td><td colspan="2">IDR 30 Billion/km</td><td>Initial traffic level</td><td colspan="2">18000 veh./day</td><td>Inflation rate</td><td>0,07</td></tr>
<tr><td>Debt/Equity</td><td colspan="2">70/30</td><td>Traffic growth rate</td><td colspan="2">0,08</td><td>Initial operating cost</td><td>IDR 950 million/km</td></tr>
<tr><td>Risk-free interest rate</td><td colspan="2">12,75%</td><td rowspan="3">Toll rate indexes</td><td>Small Veh.</td><td>100,00%</td><td>Land and building tax</td><td>%1,00 of operating revenue</td></tr>
<tr><td rowspan="3">Traffic classification</td><td>Small Veh.</td><td>85,00%</td><td>Med. Veh.</td><td>150,00%</td><td></td><td></td></tr>
<tr><td>Med. Veh.</td><td>10,00%</td><td>Large Veh.</td><td>200,00%</td><td></td><td></td></tr>
<tr><td>Large Veh.</td><td>5,00%</td><td>Income tax rate</td><td colspan="2">30,00%</td><td></td><td></td></tr>
</table>
</td></tr>
<tr><td rowspan="6">Outputs</td><td rowspan="6">Findings</td><td>First simulation results of cash flow model without guarantees show that the project sponsor NPV can be under 0. This fugure reveals two factors. First, there is a possibility that the project sponsor can receive no payment because the obligation service has finished off all the funding. Second, with the loss amounting to the equity contribution, there should be only operating profit; otherwise the project sponsor must suffer a loss greater than equity contribution.</td></tr>
<tr><td>Second simulation results of cash flow model with exhibit that guarantees can reduce cost but they are not cost-free.</td></tr>
<tr><td>The least expected cost is found when the government guarantees the debt repayment. This result does make sense because it is most unlikely that the debt cannot be fully serviced during the concession period.</td></tr>
<tr><td>Entire payment distributions are positively skewed, indicating that they have long tails in the positive direction. A positively skewed asset is perhaps favorable to many investors, but in this case a high degree of skewness implies that the government is exposed to high risk of being confronted with exceptionally high payments.</td></tr>
<tr><td>It has been showed that when subsidy amounts increase, risk decreases. All guarantees except the tariff guarantee lie at or below the line, indicating that at equal expected payoffs guarantees reduce risk more than equivalent direct subsidies do.</td></tr>
<tr><td>The methodology used here is not without difficulties. To define a density function of a risk factor, an extensive set of sample data is required. Some data (e.g. inflation rates and interest rates) are often observable while some others are not, simply because of insufficient number of samples for making appropriate judgment.</td></tr>
</table>

Table 3.4. The model proposed by Huang and Chou (2006)

Bibliographic Identity	Title	Valuation of the Minimum Revenue Guarantee and the Option to Abandon in BOT Infrastructure Projects					
	Author	Yu-Lin Huang, Shih-Pei Chou					
	Journal	Construction Management and Economics					
	Y/V/I/P	2006;24(4);379-389					
Rationale	Problem Statement	For BOT projects, the concessionaire is usually required to undertake project development tasks. The concessionaire faces substantial project development risks. Even if the concessionaire can successfully accomplish these tasks, BOT projects often become financially not viable due to changes in external investment conditions. As a result, BOT projects are more likely to fail in the pre-construction phase than in other project phases. Likewise, BOT infrastructure projects usually face substantial revenue risks during the operation phase.					
	Scope and Objective	To reduce the concessionaire’s investment risks, BOT concession contracts often grant the concessionaire an option to abandon during the pre-construction stage and to avoid the downside risks of revenues, the concessionaire often negotiates with the government to provide a minimum revenue guarantee (MRG). In this paper, the real option based approach is used to value the MRG and the option to abondon in BOT infrasturucture projects. First,both options is formulated individually and then compound option pricing formula is developed.					
Guarantees and Caps	Type	Abandonment option					
		Minimum revenue guarantee (MRG)					
	Option	European option					
	Manner	Abondenment option is formulated under an investment option held by the concessionaire at contract signing and to expire before construction commencement.					
		MRG as a put option					
	Coverage	Full					
Risk	Major Risk Factors	Revenue					
	Modelling of Risk	Revenues is supposed random varibable (stochastic in nature) and follows generalized Wienner process.					
Model	Approach	Analytic					
	Valuation Method	Black Scholes Formula					
	Process	The option to abandon is formulated under an investment option held by the concessionaire at contract signing and to expire before construction commencement.					
		MRG is formulated as a series of European style put options in a single option pricing model.					
		MRG is reconstructed as a series of European style call options to develop a compound option pricing formula when combined with the option to abandon in the pre-construction phase.					
Application	Name	Taiwan High-Speed Rail Project					
	Type	Railway-BOT					
	Technical details	Taiwan High Speed Rail is a high-speed rail line that runs approximately 345 km along the west coast of Taiwan, from the national capital Taipei to the southern city of Kaohsiung.					
	Data and Assumptions	Data	Value	Data	Value	Data	Value
		Pre-construction duration	1 years	Pre-construction cost	NT$3.400.000	Expected growth rate	6,00%
		Construction duration	5 years	Construction cost	NT$242.422.000.000	Growth rate volatility	30,00%
		Operation duration	30 years	Operating cost	NT$101.429.000.000	Discount rate	12,00%
Outputs	Findings	The results indicated that both MRG and the option to abandon could create substantial values.					
		When the MRG and the option to abandon were combined, they counteracted each other and their values were reduced.					
		If the level of the MRG were high enough, the option to abandon would be rendered valueless.					
		MRG involves substantial budgetary commitments, and its benefits and costs should be carefully justified. The option to abandon is a preferable policy choice under budgetary constraints, and its justification ismore straightforward.					
		The presented formulas do not consider the options to abandon during construction and operation. In addition, if the MRG is to be used as a credit enhancement tool, it should also be valued from the lender’s perspective.					

Table 3.5. The model proposed by Cheah and Liu (2006)

<table>
<tr><td rowspan="4">Bibliographic Identity</td><td>Title</td><td colspan="11">Valuing Governmental Support in Infrastructure Projects as Real Options using Monte Carlo simulation</td></tr>
<tr><td>Author</td><td colspan="11">Charles Y. J. Cheah and Jicia Liu</td></tr>
<tr><td>Journal</td><td colspan="11">Construction Management an Econmics</td></tr>
<tr><td>Y/V/I/P</td><td colspan="11">2006</td></tr>
<tr><td rowspan="2">Rationale</td><td>Problem Statement</td><td colspan="11">Although researchers have generally acknowledged the significance of subsidies and guarantees leading toward successful negotiation, there is a lack of attempt to evaluate these concessions quantitatively. Without a deeper understanding of the value of these concessions, risk and reward may not be equitably matched in the proposed terms and arrangements.</td></tr>
<tr><td>Scope and Objective</td><td colspan="11">In this paper, relevant elements of a contractual package are treated as a form of real options. A proposition is put forward to incorporate the value of such options into the negotiation framework. By relying on simplifying assumptions on risk preferences, these options can be evaluated using Monte Carlo simulation of a discounted cash flow (DCF) model.</td></tr>
<tr><td rowspan="6">Guarantees and Caps</td><td rowspan="2">Type</td><td colspan="11">Total Subsidy (SD) (minimum revenue guarantee)</td></tr>
<tr><td colspan="11">Repayment Scheme (RP)</td></tr>
<tr><td>Option</td><td colspan="11">European option</td></tr>
<tr><td rowspan="2">Manner</td><td colspan="11">SD as a put option</td></tr>
<tr><td colspan="11">RP as a call option</td></tr>
<tr><td>Coverage</td><td colspan="11">Full</td></tr>
<tr><td rowspan="2">Risk</td><td>Major Risk Factor</td><td colspan="11">The initial traffic volume and the growth rate of the traffic volume</td></tr>
<tr><td>Modeling of Risk</td><td colspan="11">The traffic volume variable is assumed to follow lognormal distribution. The initial annual growth rate is modelled by a normal distrubition.</td></tr>
<tr><td rowspan="9">Model</td><td>Approach</td><td colspan="11">Simulation</td></tr>
<tr><td>Valuation Method</td><td colspan="11">Monte Carlo simulation of DCF.</td></tr>
<tr><td rowspan="7">Process</td><td colspan="11">Three scenario is constructed in order to capture fuller picture.</td></tr>
<tr><td colspan="11">The DCFs of these scenarios are evaluated from the project equity investors' point of view and discounted using return-on-equity from Capital Asset Pricing Model(CAPM).</td></tr>
<tr><td colspan="11">The growth rate and the initial traffic volume are modelled, respectively using normal and lognormal distribution.</td></tr>
<tr><td colspan="11">The distribution of the of the total subsidy is obtained by simulating (Monte Carlo) DCFs based on the assumed distributions of the initial traffic volume and growth rate as specified earlier.</td></tr>
<tr><td colspan="11">In the view of the fact that the distribution is highly skewed, the authors would not recommend the mean. Rather, median represents the fair value, since there is an equal %50 chance that the total subsidy is overvalued.</td></tr>
<tr><td colspan="11">The distribution of the of the repayment scheme is obtained by simulating DCFs.</td></tr>
<tr><td colspan="11">The sensitivty of SD and RP, subject to changes in the standard deviations of initial traffic volume and growth rate is analysed.</td></tr>
<tr><td rowspan="12">Application</td><td>Name</td><td colspan="11">The Malaysian-Singapore Second Crossing</td></tr>
<tr><td>Type</td><td colspan="11">Bridge-BOT</td></tr>
<tr><td>Details</td><td colspan="11">2 km bridge project with expressways through neighbourhood that connects Malaysia and Singapore.</td></tr>
<tr><td rowspan="9">Data Sets</td><td>Data</td><td colspan="2">Value</td><td>Source</td><td>Data</td><td>Value</td><td>Source</td><td>Data</td><td colspan="2">Value</td><td>Source</td></tr>
<tr><td>Construction duration</td><td colspan="2">3 years</td><td rowspan="6">News articles, prospectus and presentation made by a financial institution</td><td>Corporate tax</td><td>28,00%</td><td rowspan="6">News articles, prospectus and presentation made by a financial institution</td><td rowspan="5">Toll Rates</td><td>Cars</td><td>8/4,80</td><td rowspan="5">News articles, prospectus and presentation made by a financial institution</td></tr>
<tr><td>Concession duration</td><td colspan="2">30 years</td><td rowspan="2">Rf (Risk-free interest rate)</td><td rowspan="2">8,00%</td><td>Buses</td><td>21/6,20</td></tr>
<tr><td>Total Financing Amount</td><td colspan="2">RM1,4 billion</td><td>Vans</td><td>21/11,40</td></tr>
<tr><td>Debt: Equity</td><td colspan="2">70:30</td><td rowspan="3">Operation and Maintain Cost</td><td rowspan="3">4,00%</td><td>Lorries</td><td>53/25,50</td></tr>
<tr><td>Loan term</td><td colspan="2">8,00%</td><td>Taxies</td><td>8/4,10</td></tr>
<tr><td>Interest Rate</td><td colspan="2">10,00%</td><td colspan="4" rowspan="3"></td></tr>
<tr><td rowspan="2">α (Ann. exp. growth rate of AADT)</td><td>1998-07</td><td>18,00%</td><td rowspan="2">Normal distribution</td><td rowspan="2">The initial traffic volume</td><td rowspan="2">11.000.000</td><td rowspan="2">Lognormal distribution</td></tr>
<tr><td>2007-full ca</td><td>9,00%</td></tr>
<tr><td rowspan="3">Outputs</td><td rowspan="3">Findings</td><td colspan="11">The value of SD is more sensitive to the standard deviation of the initial traffic volume assumed. On the other hand, the value of RP seems to be more sensitive to the standard deviation of the growth rate.</td></tr>
<tr><td colspan="11">The standard deviations of these two variables determine the volatility of the project cash flows, which is a key determinant of the value of the two options evaluated. The findings essentially underline the differences in risks that confront the government and the project sponsor, since RP technically ‘belongs’ to the former and SD to the latter.</td></tr>
<tr><td colspan="11">The value of repayment does not always increase with the standard deviation of the initial traffic volume, particularly when the standard deviation of the growth rate is low. This seems counterintuitive to the known feature of a financial option, the value of which increases when volatility of the underlying asset increases. This peculiarity is due to the distribution chosen for the initial traffic volume and the setting of the cash flow model (where factors such as traffic volume, growth rate, maximum capacity and time value of money all interact in a complex manner). It emphasizes that financial and real options sometimes differ in their characteristics.</td></tr>
</table>

Table 3.6. The model proposed by Chiara et al. (2007)

Bibliographic Identity	**Title**	Valuing Simple Multiple-Exercise Real Options
	Author	Nicola Chiara, Michael J. Garvin, Jan Vecer
	Journal	Journal of Infrastructure Systems
	Y/V/I/P	2007
Rationale	**Problem Statement**	If the value of an option (guarantee) is substantial and no effort is made to quantify it, then the government may unknowingly provide the sponsor a tremendous subsidy. Alternatively, the sponsor may unwittingly disregard or attach a conservative value to the option in view of its vagueness.
	Scope and Objective	The intent of this paper is to present a method for quantifying the value of a revenue guarantee in a BOT project. The valuation approach extends existing computational finance methods used to price discrete-exercise financial options, specifically the least-squares Monte Carlo method, and the approach is illustrated in a hypothetical case study.
Guarantees and Caps	**Type**	Third party guarantee(TPG)-revenue guarantee
	Option	Australian options
	Manner	TPG as a put option
	Coverage	Partial
Risk	**Major Risk Factor**	Future traffic volume
	Modelling of Risk	Variance model (VM).
Model	**Approach**	Simulation
	Valuation Method	Multi-least squares Monte Carlo simulation
	Process	Discounted annual equity cash flows is calculated.
		A Monte Carlo simulation risk analysis is the performed where traffic volume is the only risk variable considered. The traffic volume is modelled as a random variable with dynamic variance This representation of the traffic volume uses a variance model.
		Multiple-exercise guarantee is modelled as an Australian option.
		The least-square regression is performed.
Application	**Name**	Hypothetical BOT project
	Type	Toll road-BOT
	Details	Comparison of the guarantee values with different exercise rights (M).
	Data Sets	Generated randomly
Outputs	**Findings**	Modelling guarantees as an Australian options can mitigate the revenue risk significantly without using conventional full coverage guarantee options.
		Credible methods to value revenue guarantees can improve the assessment and allocation of risks in BOT projects.
		Such methods will permit governments, lenders, and sponsors to determine the fair value of this risk mitigation strategy, which can preclude conferring substantial subsidies or undervaluing investment opportunities.

Table 3.7. The model proposed by Brandao and Saravia (2008)

<table>
<tr><td rowspan="4">Bibliographic Identity</td><td>Title</td><td>The Option Value of Government Guarantees in Infrastructure Projects</td></tr>
<tr><td>Author</td><td>Luiz Eduardo T. Brandao, Eduardo Saravia</td></tr>
<tr><td>Journal</td><td>Construction Management and Economics</td></tr>
<tr><td>Y/V/I/P</td><td>2008</td></tr>
<tr><td rowspan="2">Rationale</td><td>Problem Statement</td><td>For some types of projects, this investment may require government participation in the form of project guarantees in order to reduce the risk to the private investor, and as a consequence, the government assumes a contingent liability which may have significant future budgetary impacts. The value of these guarantees is an open issue in the literature.</td></tr>
<tr><td>Scope and Objective</td><td>A real options model is developed for infrastructure projects subject to minimum traffic guarantee (MTG) in order to assess the value of these guarantees, their impact on risk of the project and how the risk premium of the project can be determined indirecetly from the project returns, allowing for a more accurate assessment of the model parametres and the expected value of the government outlays . It has also been showed that how different levels of guarantees affect the project's risk profile and provide suggestions on how the government may use this information to minimize its costs.</td></tr>
<tr><td rowspan="5">Guarantees and Caps</td><td>Type</td><td>Minimum Traffic Guarantee (MTG)</td></tr>
<tr><td>Option</td><td>Europen options</td></tr>
<tr><td rowspan="2">Manner</td><td>Traffic floor as a put option</td></tr>
<tr><td>Traffic ceeling as a call option</td></tr>
<tr><td>Coverage</td><td>Full</td></tr>
<tr><td rowspan="2">Risk</td><td>Major Risk Factor</td><td>Future traffic demand, indirectly revenues since the toll rate is constant.</td></tr>
<tr><td>Modelling of Risk</td><td>The future traffic level and revenues will vary stochastically in time following a geometric Brownian motion (GBM). The volality is estimated under the standart assumption that traffic levels are positively correlated with regional gross domestic product (GDP).</td></tr>
<tr><td rowspan="9">Model</td><td>Approach</td><td>Simulation</td></tr>
<tr><td>Valuation Method</td><td>Monte Carlo simulation of the stochastic traffic level assuming the option will be exercised whenever revenues fall below the established minimum, which is then discounted at the risk free rate.</td></tr>
<tr><td rowspan="7">Process</td><td>Traffic levels are positively correlated with GDP to estimate volatility.</td></tr>
<tr><td>NPV of the project is provided by the discounted cash flow (DCF) analysis using the free cash flow to equity (FCFE).</td></tr>
<tr><td>Then, project volatility is computed from a Monte Carlo simulation run of the stochastic cash flows of the project.</td></tr>
<tr><td>The risk premium of the project cash flows is determined from Capital Asset Pricing Model (CAPM).</td></tr>
<tr><td>The following path of the revenues and traffic level stochastically in time is derived using a GBM.</td></tr>
<tr><td>The value of the guarantee options is determined by a Monte Carlo simulation of the stochastic traffic level assuming the option will be exercised whenever revenues fall below the established minimum, which is then discounted at risk free rate.</td></tr>
<tr><td>The value of the concession with the revenue guarantee is obtained by simply repeating this analysis for each of the years of the concession and adding the present value of all these options to the static value of the project.</td></tr>
<tr><td rowspan="4">Application</td><td>Name</td><td>BR-163 Roadway Project</td></tr>
<tr><td>Type</td><td>Toll Road-Bot</td></tr>
<tr><td>Details</td><td>Expansion of the projected 1000 mile long BR-163 toll road that will link the Brazilian Midwest to the Amazon River.</td></tr>
<tr><td>Data Sets</td><td>
<table>
<tr><td>Data</td><td>Value</td><td>Source</td><td>Data</td><td colspan="2">Value</td><td>Source</td></tr>
<tr><td>Concession duration</td><td>25 years</td><td rowspan="4">Basic info</td><td rowspan="2">Traffic volatility</td><td colspan="2" rowspan="2">7,00%</td><td rowspan="2">GDP</td></tr>
<tr><td>The initial investment</td><td>R$966,7 million</td></tr>
<tr><td>Continuous road</td><td>R$1291,5 million</td><td rowspan="3">Initial level of traffic</td><td>Normal</td><td>96.205</td><td rowspan="3">Assumed</td></tr>
<tr><td>Debt: Equity</td><td>60:40</td><td>Optimistic</td><td>125.066</td></tr>
<tr><td>Equity cost of capital</td><td>16,00%</td><td rowspan="2">(Brandao, 2002)</td><td>Pesimistic</td><td>67.343</td></tr>
<tr><td>The risk free rate</td><td>7,00%</td><td></td><td></td><td></td><td></td></tr>
</table>
</td></tr>
<tr><td rowspan="4">Outputs</td><td rowspan="4">Findings</td><td>When the level of guarantee increases, the project NPV increases too, which shows that the minimum traffic guarantees are an effective form of risk reduction.</td></tr>
<tr><td></td></tr>
<tr><td>Indiscriminate granting of guarantees can create significant future contingent liabilities for the government.</td></tr>
<tr><td>The use of caps on the total outlays associated with a particular level of MTG can help reduce this liability risk, and owing to their asymmetric impact on project value.</td></tr>
</table>

Table 3.8. The model proposed by Ashuri et al. (2012)

<table>
<tr><td rowspan="4">Bibliographic Identity</td><td>Title</td><td colspan="11">Risk-Neutral Pricing Approach for Evaluating BOT Highway Projects with Government Minimum Revenue Guarantee Option</td></tr>
<tr><td>Author</td><td colspan="11">B. Ashuri, H. Kashani, K.R. Molenaar, S.Lee, J. Lu</td></tr>
<tr><td>Journal</td><td colspan="11">Journal of Construction Engineering and Management</td></tr>
<tr><td>Y/V/I/P</td><td colspan="11">2012</td></tr>
<tr><td rowspan="2">Rationale</td><td>Problem Statement</td><td colspan="11">The improper consideration of uncertainties contributes to the financial failure of BOT projects. The inherent limitation of conventional economic analysis methods contributes to this uncertainty; most notably the net present value (NPV) approach that is typically used in the economic valuation of BOT projects. the NPV approach is insufficient to determine the correct market value of minimum revenue guarantee (MRG) options.</td></tr>
<tr><td>Scope and Objective</td><td colspan="11">Application of the real options theory from finance/decision science to explicitly price MRG options in BOT projects to achieve this objective, a real options model that utilizes a market-based pricing approach to determine the correct value of MRG is presented.</td></tr>
<tr><td rowspan="6">Guarantees and Caps</td><td rowspan="2">Type</td><td colspan="11">Minimum revenue guarantee (MRG)</td></tr>
<tr><td colspan="11">Traffic revenue cap (TRC)</td></tr>
<tr><td>Option</td><td colspan="11">Australian option</td></tr>
<tr><td rowspan="2">Manner</td><td colspan="11">MRG as a put option</td></tr>
<tr><td colspan="11">TRC as a call option</td></tr>
<tr><td>Coverage</td><td colspan="11">Partial</td></tr>
<tr><td rowspan="2">Risk</td><td>Major Risk Factor</td><td colspan="11">Future traffic demand</td></tr>
<tr><td>Modelling of Risk</td><td colspan="11">Binomial lattice model is developed and Monte Carlo simulation is used to generate random paths .</td></tr>
<tr><td rowspan="7">Model</td><td>Approach</td><td colspan="11">Simulation</td></tr>
<tr><td>Valuation Method</td><td colspan="11">Risk neutral valuation</td></tr>
<tr><td rowspan="5">Process</td><td colspan="11">Specify required input data (e.g., cost data related to the BOT project, the concessionaire’s capital structure, and future traffic demands).</td></tr>
<tr><td colspan="11">Develop a binomial lattice model to characterize traffic demands.</td></tr>
<tr><td colspan="11">Generate random future paths for future traffic demands using Monte Carlo simulation technique.</td></tr>
<tr><td colspan="11">Conduct life cycle cost and revenue analysis for the BOT project under each random traffic path and characterize the concessionaire’s economic risk profile.</td></tr>
<tr><td colspan="11">Adjust the binomial lattice model of future traffic demands based on the risk-neutral option valuation approach and repeat.</td></tr>
<tr><td rowspan="12">Application</td><td>Name</td><td colspan="11">IIAH Project</td></tr>
<tr><td>Type</td><td colspan="11">Highway- BOT</td></tr>
<tr><td>Details</td><td colspan="11">36.6 km highway connecting Korea's Incheon International Airport to the capital city of Seoul.</td></tr>
<tr><td rowspan="9">Data Sets</td><td>Data</td><td colspan="2">Value</td><td>Source</td><td>Data</td><td>Value</td><td>Source</td><td>Data</td><td colspan="2">Value</td><td>Source</td></tr>
<tr><td>Construction duration</td><td colspan="2">5 years</td><td>Basic info</td><td>AADT$_0$ most likely</td><td>100.720</td><td rowspan="3">Traffic study report</td><td>Duration of MRG option</td><td colspan="2">15 years</td><td>Assumed</td></tr>
<tr><td>Concession duration</td><td colspan="2">30 years</td><td>Basic info</td><td>AADT$_0$ optimistic</td><td>120.864</td><td rowspan="3">The percentage of the revenue shortfall to be paid</td><td>2000-04</td><td>90,00%</td><td rowspan="3">Assumed</td></tr>
<tr><td>Total Financing Amount</td><td colspan="2">$1,7 billion</td><td>Basic info</td><td>AADT$_0$ pessimistic</td><td>80576</td><td>2005-09</td><td>80,00%</td></tr>
<tr><td>Debt: Equity</td><td colspan="2">75:25</td><td>Basic info</td><td rowspan="3">The capacity cap for future traffic demand</td><td rowspan="3">20% above the max. forecasted optimistic AADT</td><td rowspan="3">Assumed</td><td>2010-14</td><td>70,00%</td></tr>
<tr><td>Rf (Risk-free interest rate)</td><td colspan="2">13,06%</td><td>Lee (2007)</td><td>Duration of TRC option</td><td colspan="2">20 years</td><td>Assumed</td></tr>
<tr><td rowspan="3">α (Ann. exp. growth rate of AADT)</td><td>2001-05</td><td>9,80%</td><td rowspan="3">Traffic study report</td><td rowspan="3">The percentage of the revenue excess to be shared</td><td rowspan="3" colspan="2">110,00%</td><td rowspan="3">Assumed</td></tr>
<tr><td>2006-10</td><td>5,30%</td><td rowspan="2">σ (Ann. volatility of AADT)</td><td rowspan="2">10,00%</td><td rowspan="2">Assumed</td></tr>
<tr><td>2011-20</td><td>3,10%</td></tr>
<tr><td rowspan="10">Outputs</td><td rowspan="10">Findings</td><td colspan="11">Forecasted future traffic demands are insufficient to capture uncertainty about the financial performance of BOT projects.</td></tr>
<tr><td colspan="11">When the traffic volatility increases, the risk of underestimating future traffic demands increases and, consequently, uncertainty about the project’s future revenues increases.</td></tr>
<tr><td colspan="11">The risk of underestimating the AADT grows as the BOT project advances.</td></tr>
<tr><td colspan="11">The expected value and standard deviation of the concessionaire’s investment value distribution with MRG and TRC options are lower than the expected value and standard deviation of the concessionaire’s investment value distribution with just MRG options, respectively.</td></tr>
<tr><td colspan="11">Consider the volatility of future traffic demands in the valuation of BOT projects.</td></tr>
<tr><td colspan="11">Characterizes the concessionaire's economic risk profile under future traffic uncertainty.</td></tr>
<tr><td colspan="11">Overcome the inherent limitation of conventional economic analysis methods and most notably the NPV approach.</td></tr>
<tr><td colspan="11">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.</td></tr>
<tr><td colspan="11">The government can also use this model to identify the appropriate MRG levels to encourage private investments without comprising future budgetary strength.</td></tr>
<tr><td colspan="11">The model does not incorporate the other sources of risk such as uncertainty about interest and exchange rates and construction costs in BOT project valuation.</td></tr>
</table>

Table 3.9. The model proposed by Kokaew and Chiara (2013)

Bibliographic Identity	**Title**	A Modelling Government Revenue Guarantees in Privately Built Transportation Projects: A Risk-Adjusted Approach
	Author	Nakhon Kokaew, Nicola Chiara
	Journal	Transport
	Y/V/I/P	2013;28(2);186-192
Rationale	**Problem Statement**	Several additional risks to project risks in PPP can be characterized as inter-temporal because current decisions can affect the future decisions which in turn may change the future risk profile.
	Scope and Objective	A new model of government guarantees that promotes fair risk allocation between the government and the concessionaire.
Guarantees and Caps	**Type**	Minimum revenue guarantee (MRG)
		Maximum revenue cap (MRC)
	Option	Australian option
	Manner	MRG as a put option
		MRC as a call option
	Coverage	Partial
Risk	**Major Risk Factor**	Revenue risk
	Modelling of Risk	A discrete time stochastic process called the Variance model (VM).
Model	**Approach**	Simulation
	Valuation Method	Multi-least squares Monte Carlo simulation
	Process	Modelling of revenue risk using a VM
		Modelling of minimum and maximum guarantee thresholds multiplying with beta which indicates the coverage ratio of
		Modelling of government guarantee mechanism
		Forward projections of underlying risk variables using Monte Carlo simulation
		Determine the optimality of decisions t each time step using dynamic programming techniques and least squares regression to estimate an expected continuing payoff, which is the value of not exercising option at this time step
Application	**Name**	Hypothetical BOT project
	Type	Highway
	Details	Comparison of the new government guarantee model to conventional guarantees
	Data Set	Generated randomly
Outputs	**Findings**	The costs of government revenue guarantee from using the new model are more affordable than using the conventional model.
		If revenue windfalls occur, the new model captures the value of revenue sharing, thereby protecting the public interest by not allowing the private to the profits as a windfall.
		Revenue guarantee thresholds are adjusted over time to reflect the inter-temporal risk profiles of the project.
		The necessary information for the analysis may not be readily available and therefore needs to be estimated. the estimation of relevant parameters should be carefully made, and reference forecasting techniques to avoid cognitive biases are strongly encouraged

Table 3.10. The model proposed by Almassi et al. (2013)

Bibliographic Identity	**Title**	Real Options Based Approach for Valuation of Government Guarantees in Public Private Partnerships
	Author	Ali Almassi, Brenda McCabe, Matthew Thompson
	Journal	Journal of Infrastructure Systems
	Y/V/I/P	2013;19(2);196-204
Rationale	**Problem Statement**	The slowness and the variation in MC results could cause difficulties in designing guarantee contracts as well as in investigating the sensitivity of the guarantee value to forecast parameters.
	Scope and Objective	Presents a novel approach for guarantee valuation that is computationally more efficient than the existing Monte-Carlo based approach.
Guarantees and Caps	**Type**	Minimum revenue guarantee (MRG)
	Option	Australian option
	Manner	MRG as a put option
	Coverage	Partial
Risk	**Major Risk Factor**	Future traffic demand risk
	Modelling of Risk	A continuous-time stochastic differential equation (SDE) is derived from the forecasted risk factor.
Model	**Approach**	Numerical
	Valuation Method	Using the SDE, the partial differential equation (PDE) that governs the value of government guarantee was obtained and then solved with the finite-difference method (FDM).
	Process	Modelling of risk using a continuous-time stochastic process model.
		Derivation of PDE from risk model.
		Solving derivated PDE using a FDM.
		Verifying exercise strategies by simulation.
		Estimation of the probability of a budget shortfall.
Application	**Name**	Hypothetical BOT project
	Type	-
	Details	The proposed model compared with the least-squares Monte Carlo-simulation method (LSM) for the valuation of Australian guarantees.
	Data sets	Generated randomly
Outputs	**Findings**	The values of Australian guarantees obtained from FDM and LSM are consistent with each other.
		The values of Australian guarantees obtained from FDM and exercise strategies on simulated paths (ESR) are consistent with each other.
		The theoretical probability of budget shortfall and the probability obtained from simulation match each other.
		Computationally more efficient that the existing Monte-Carlo based approach.
		Capable of handling complex contracts.
		Greatly enhanced computational speed.
		Easy to analyse sensitivities to the many assumptions and contract features.
		Calculating the probability of a budget shortfall for the government offering the guarantees.
		Benefits of the model diminish when solving higher dimensional problems(four or more risk factor).

Table 3.11. The model proposed by Carbonara et al. (2014)

<table>
<tr><td rowspan="4">Bibliographic Identity</td><td>Title</td><td>Revenue Guarantee in Public-Private Partnerships: A Fair Risk Allocation Model</td></tr>
<tr><td>Author</td><td>Nunzia Carbonara, Nicola Constantino, Roberta Pellegrino</td></tr>
<tr><td>Journal</td><td>Construction Management and Economics</td></tr>
<tr><td>Y/V/I/P</td><td>2014;32(4);403-415</td></tr>
<tr><td rowspan="2">Rationale</td><td>Problem Statement</td><td>The review of the existing studies that value government guarantees by real option theory shows that the literature lacks studies that specifically deal with the issue of setting the level of minimum revenue guaranteed.</td></tr>
<tr><td>Scope and Objective</td><td>To fill the gap mentioned in the problem statement, a real option-based model is developed that uses a new mechanism for setting the revenue guarantee level secured by the government, which balances the private sector’s profitability needs and the public sector’s fiscal management interests and uses the concept of fairness for structuring MRGs.</td></tr>
<tr><td rowspan="4">Guarantees and Caps</td><td>Type</td><td>Minimum revenue guarantee (MRG)</td></tr>
<tr><td>Option</td><td>European options</td></tr>
<tr><td>Manner</td><td>MRG as a put option</td></tr>
<tr><td>Coverage</td><td>Full</td></tr>
<tr><td rowspan="2">Risk</td><td>Major Risk Factor</td><td>Future traffic demand</td></tr>
<tr><td>Modelling of Risk</td><td>The future traffic level will vary stochastically in time following a geometric Brownian motion (GBM).</td></tr>
<tr><td rowspan="9">Model</td><td>Approach</td><td>Simulation</td></tr>
<tr><td>Valuation Method</td><td>Monte Carlo simulation is used to calculate probability distributions of the Net Present Values of maximum (R_{gmax}) and minimum (R_{gmin}) value of the revenue guarantee.</td></tr>
<tr><td rowspan="7">Process</td><td>Conditions of the Rgmin and Rgmax is established, respectively using the NPV method to evaluate the profitability the investment for the private party and Eurostat treatment economic risk and reward criterion that keeps the investment off-balance sheet of the government.</td></tr>
<tr><td>Probability distribution of the NPV generated by the infrastructure to the concessionaire without government support is calculated using Monte Carlo simulation.</td></tr>
<tr><td>Probability distributions of the R_{gmax} and R_{gmin} generated using Monte Carlo simulation.</td></tr>
<tr><td>In order to support the decision-maker in choosing a value which fairly allocates risks between parties, the risks borne by the parties for some given values ranging between the minimum value of the probability distribution of R_{gmin} and the maximum value of the probability distribution of R_{gmax} is calculated.</td></tr>
<tr><td>R_g is selected from the risk profile of the public and private sector which illustrated in previous step.</td></tr>
<tr><td>Probability distribution of the total value of guarantee G and of the NPV calculated for R_g generated using Monte Carlo simulation.</td></tr>
<tr><td>The sensitivity analysis is carried out between R_g and r.</td></tr>
<tr><td rowspan="4">Application</td><td>Name</td><td>Camionale di Bari</td></tr>
<tr><td>Type</td><td>Highway-BOT</td></tr>
<tr><td>Details</td><td>1 km long toll road that link the port of Bari with the existing road network without affecting the urban traffic.</td></tr>
<tr><td>Data Sets</td><td>
<table>
<tr><td colspan="2">Data</td><td colspan="2">Value</td><td>Source</td><td colspan="2">Data</td><td colspan="3">Value</td><td>Source</td><td>Data</td><td>Value</td><td>Source</td></tr>
<tr><td rowspan="7">Traffic data of the first year and Tariffs</td><td>Automobile</td><td>270.000</td><td>€ 1,50</td><td rowspan="7">Historical data, data collected on similar projects and/or provided by public agencies and stakeholders, and experts’ opinions.</td><td colspan="2" rowspan="2">σ (Ann. volatility of the traffic)</td><td colspan="3" rowspan="2">10,00%</td><td rowspan="6">The analysis of studies on the traffic</td><td>Residual value</td><td>€ 20.000.000</td><td rowspan="4">Assumed</td></tr>
<tr><td>Auto bus</td><td>5.500</td><td>€ 1,50</td><td>Payroll costs</td><td>€ 398.000</td></tr>
<tr><td>Truck</td><td>175.000</td><td>€ 2,50</td><td rowspan="4">μ (The traffic growth rate)</td><td></td><td>2010-15</td><td>2015-20</td><td>after</td><td>Maintain costs</td><td>€ 19.000</td></tr>
<tr><td>Container Truck</td><td>250</td><td>€ 2,50</td><td>Auto</td><td>1,60%</td><td>1,60%</td><td>1,60%</td><td>Overheads</td><td>3,5% of the</td></tr>
<tr><td rowspan="2">Auto bus (50 cruise</td><td rowspan="2">10.000</td><td rowspan="2">€ 1,50</td><td>Auto bus</td><td>0,90%</td><td>0,90%</td><td>0,90%</td><td>r (Discount rate)</td><td>5,00%</td><td>Gov. Bond</td></tr>
<tr><td>Truck</td><td>1,10%</td><td>1,2,%</td><td>1,2,%</td><td colspan="3" rowspan="2"></td></tr>
<tr><td>Truck (bulk freight)</td><td>30.000</td><td>€ 2,50</td><td colspan="2">Revenue of service areas</td><td colspan="3">€ 314.111</td><td>Experts opinion</td></tr>
</table>
</td></tr>
<tr><td rowspan="6">Outputs</td><td rowspan="6">Findings</td><td>As the value of Rg increases, the private risk decreases, while the public risk increases.</td></tr>
<tr><td>The sensitivity analysis indicates that Rg increases when r increases in an almost linear way. It is interesting to note, however, that the model keeps its robustness as both parties seem reasonably well protected against movements in the interest rate. In fact, the risk borne by each party increases (even significantly) but the model still maintains the fairness as a mechanism for setting the revenue guarantee level.</td></tr>
<tr><td>The main contribution of our model is then to propose fairness as a mechanism for setting the revenue guarantee level and to model the concept of fairness in practice.</td></tr>
<tr><td>In order to include the perspective of both parties, builds on specific conditions of satisfying the interests of both parties, thus mining the generalizability of the model.</td></tr>
<tr><td>This model, in fact, does not consider that over a certain upper level, the revenues can be shared between the public and private sectors.</td></tr>
<tr><td>The main limitation of the model is inherent in the simulation-based approach, where input data modelling is a critical step that affects the outcome.</td></tr>
</table>

4. THE PROPOSED MODEL AND ANALYSIS

The aim of this research was to propose a fair risk allocation model for toll road projects in terms of guarantees provided by the government and revenue risks assumed by the private party. For this purpose, a real option based model is introduced in the previous section. In this chapter, a hypothetical case study is used in order to clarify the application of the proposed real options model to typical BOT toll road project.

A real option based model is used to determine the ‘revenue cap’ which is provided by government to the concessionaire in order to guarantee a minimum amount of toll revenues and thus render the investment profitable for the private investor. In addition, a Monte Carlo simulation is used to take into account uncertainty. The model is adjusted based on proposed model by Carbonara et al. (2014). Finally, it is applied to hypothetical BOT toll road project and the results are discussed.

The model has three main processes.

1. Modelling Minimum Revenue Guarantee
2. Modelling Revenue Risks
3. Valuation Method

Figure 4.1 represents the flow chart of the proposed model. Further information about these processes are provided respectively in section 4.1, 4.2 and 4.3.

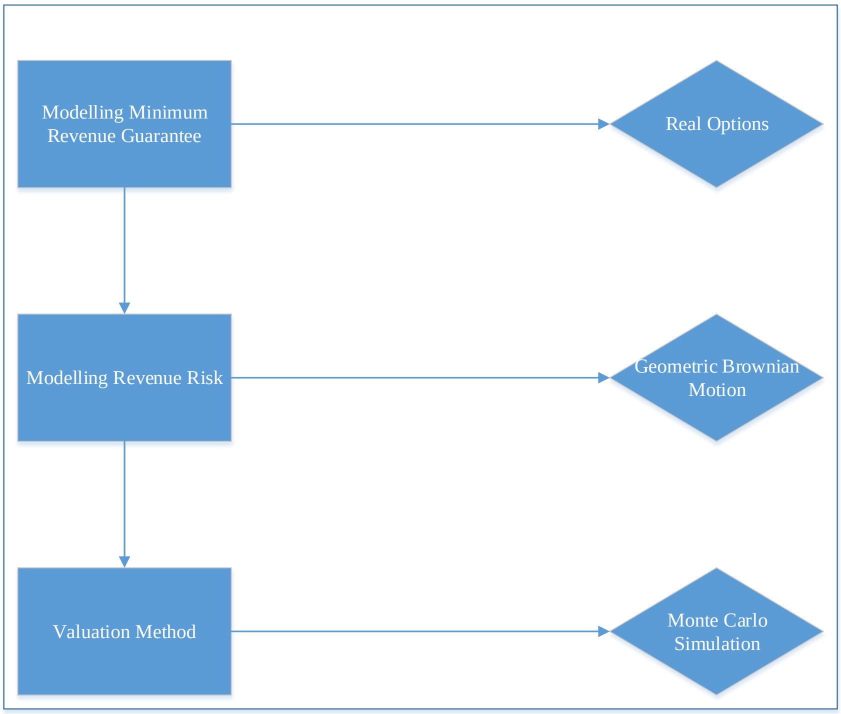


Figure 4.1. The flowchart of the model

4.1. THE MINIMUM REVENUE GUARANTEE (MRG) MODEL

One of the most common forms of government support instruments is the MRG (Ashuri et al., 2012). MRG is a type of financial support where the government agrees to pay the concessionaire the possible revenue shortfall up to a predefined level of revenue cap, thus mitigating risks and making the investment attractive for the private investor (Carbonara et al., 2014). Many subsidies and guarantees, especially MRG represent a form of options and options have values (Mason and Baldwin, 1988). The concept of real options was born in the financial world where two kinds of options exist: call and put options. "They respectively give their owner the right, not the obligation, to sell (put options) or to buy (call options) before and on the pre-specified date (American options) or only on the exercise date (European options) the underlying asset at a fixed predefined price (exercise price)" (Damodaran, 2001).

In particular, MRG is a contract in which the government promises to pay the concessionaire, the private investor, revenue shortfall $(R_c\text{-}R_t)$ which is difference between the revenue cap R_c and the actual revenue R_t relative to a period of time Δt. The option, of course, will be exercised only if the actual revenues drop down below this guaranteed and predefined revenue cap, otherwise the option will be worthless. This feature of MRG is similar to financial put option (Chiara et al., 2007). The MRG model is constructed and valued as an independent series of European style put options in the operation phase of BOT infrastructure project (Wibowo, 2004; Cheah and Liu, 2006; Huang and Chou, 2006; Carbonara et al., 2014).

The effective revenue in year t will be $R_e\ (t) = max\ (R_c, R_t)$. Likewise the value of the government guarantee in that year will be $G\ (t) = max\ (0; R_c\text{- } R_t)$.

$$if\ Rc > Rt\ then\ \ Re(t) = Rc\ and\ G(t) = Rc - Rt \tag{4.1}$$

$$if\ Rt > Rc\ then\ \ Re(t) = Rt\ and\ G(t) = 0 \tag{4.2}$$

The sum of the present value of all these independent European options with maturity one year during the concession period T_c results in the total value of the guarantee.

$$G = \sum_{t=T_0}^{Tc} \frac{G(t)}{(1+r)^t} = \sum_{t=T_0}^{Tc} \frac{max(0; Rc - Rt)}{(1+r)^t} \tag{4.3}$$

T_0 is the starting year of the infrastructure operation phase and r is the discount rate. 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 (Ashuri et al., 2012). In BOT projects, the weighted average cost of capital (WACC) and the capital asset pricing model (CAPM) are the most frequently used techniques to determine discount rate. However, Monte Carlo simulation has the advantage of taking into consideration risks and uncertainties in the probability distribution definition (Carbonara et al., 2014). This feature of Monte Carlo simulation enables decision makeers to use risk-free discount rate and thus double counting of risks may be avoided (Brealey and Myers, 2000). Underlying theoretical concepts of Equations 4.1 and 4.2 are shown in Figure 4.2.

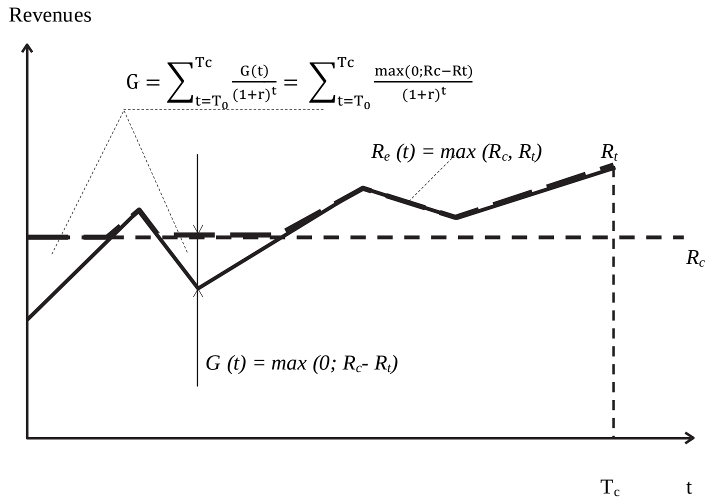


Figure 4.2. The mechanism of real option model (Carbonara et al., 2014)

The main objective of private investor is to make profit when investing in a project. Net present value (NPV) method is the basic principle to evaluate profitability of an investment (Liu and Cheah, 2009; Shan et al., 2010; Carbonara et al., 2014). The level of R_c should be established in such way that the investment satisfies the expectations of the private investor in terms of economic profit. NPV can be described mathematically as follows:

$$NPV = \sum_{t=To}^{Tc} \frac{FCFE_t}{(1+r)^t} + \sum_{t=To}^{Tc} \frac{G(t)}{(1+r)^t} - \sum_{t=1}^{T_0-1} \frac{I_t}{(1+r)^t} \qquad (4.4)$$

where:

I_t is the initial investment cost (capital expenditure) in year t;

$FCFE_t$ is the free cash flow to equity in year t which is presented in Equation 5.

$$FCFE = Gross\ revenues - Operating\ expenses$$
$$-Debt\ service - Income\ tax \qquad (4.5)$$

NPV>0 is the first condition of the private party to invest a project. However, in practice, private investor usually judges the investment attractive if NPV is higher than expected minimum return on investment. In this analysis, following Carbonara et al. (2014), NPV>0 is preferred to determine a level of R_c that defines the minimum profit.

Revenues over a certain upper level can be shared between public and private sector (Cheah and Liu, 2006; Brandao and Saraiva, 2008; Ashuri et al., 2012; Kokkaew and Chiara, 2013). In any case, the model can take into account the private perspective by simply changing the second term of Equation 4.4 (Carbonara et al., 2014).

4.2. MODELLING REVENUE RISKS

As it can be seen from Equation 4.6, since toll rate is constant, traffic volume is the main determinant of toll revenues. Thus, traffic volume is thought as the main risk factor.

$$Rt = AADT_t \times \ Toll\, Rate \tag{4.6}$$

The fundamental measure of traffic volume is the annual average daily traffic (AADT), which is defined as the number of vehicles that pass through the facility during a period of 24 hours, averaged over a period of 365 days (Iyer and Sagheer, 2011). Estimation of future traffic volume is difficult but, in particular for BOT projects it is important for economic valuation. It is assumed that traffic will vary stochastically in time following a Geometric Brownian Motion (GBM). Many researchers used GBM to model uncertainty in future traffic demand (Pichayapan, 2003; Garvin and Cheah, 2004; Wibowo, 2004; Brandao and Saraiva, 2008; Iyer and Sagheer, 2011; Carbonara et al., 2014). The fluctuation in future traffic demand Q that follows a GBM can be described mathematically as follows:

$$\frac{dQ}{Q} = (\mu_Q)dt + \sigma_Q dz_Q \tag{4.7}$$

where:

dQ is the incremental change in traffic demand Q;

μ_Q is the traffic growth rate;

σ_Q is the annual volatility of the traffic;

dt is an increment of time;

$dz_Q \ = \varepsilon\sqrt{dt}$ where $\varepsilon \sim N(0,1)$ is the standard Wiener process.

On the right hand side of the Equation 4.7, the first term is the expected drift or a “slope”. This ‘slope’ parameter sets the average rate of change in long-term value.

Short-term fluctuation in value evolving around the slope, usually referred to as "volatility", is modelled by the second term, $\sigma\, dz$. By itself, dz is stochastic process of the equation and represents the basic Wiener process (Garvin and Cheah, 2004). Equation 4.7 implies that, in an infinitely short time interval, the logarithm of traffic demand is normally distributed with mean $(\mu_Q - \frac{1}{2}\sigma_Q^2\ )dt$, and variance $\sigma_Q^2 dt$. Mathematically, this means that the traffic demand will follow a lognormal distribution and the degree of uncertainty of traffic demand depends upon how far into the future one looks. Applying Ito's lemma to this process with $\mathrm{f}(Q) = \log(Q)$ gives

$$d\,log(Q) = f'(Q)dQ + \frac{1}{2}f''(S)S^2\sigma^2 dt$$

$$= \frac{1}{Q}\left(\sigma_Q Q dz_Q\ + \mu_Q Q dt\right) - \frac{1}{2}\ \sigma_Q^2 dt$$

$$= \sigma_Q dz_Q\ + (\mu_Q - \tfrac{1}{2}\sigma_Q^2\ ) \qquad (4.8)$$

It follows that $\log(Q_t) = \log Q_0 + \sigma z_t + (\mu - \frac{1}{2}\sigma^2)\ t$, and exponentiation gives the expression for Q,

$$\mathrm{Q_{t+1} = \ Q_t\ e^{\left(\mu_Q - \frac{1}{2}\sigma^2\right)\Delta t + \sigma z_t}} \qquad (4.9)$$

Thus the stochastic evolution process can be modeled in yearly periods as a function of the value in previous period as shown in Equation 4.9 (Iyer and Sagheer, 2011).

4.3. VALUATION METHOD

As previously mentioned, MRG is modeled as a series of independent European options. This framework provides full coverage with multiple, regular exercise dates throughout the concession period of the PPP project, and M = N = the number of concession periods. Hence, at each exercise date, one guarantee is redeemed if its payoff is positive (Almassi et al., 2013). A valuation method for revenue guarantee using Monte Carlo simulation is developed by several researchers (Dailami et al., 1999; Carbonara et al., 2014). Monte Carlo simulation is considered to be a superior technique for this framework. Stochastic nature of future traffic demand is the underlying reason of this selection. As it can been seen from Equation 4.9, it follows a different path for each random number which are normally distributed between

(0,1) $dz_Q = \varepsilon\sqrt{dt}$ where $\varepsilon \sim N(0,1)$. This is illustrated in Figure 4.3. Therefore, revenues are, not single values, but probability distributions.

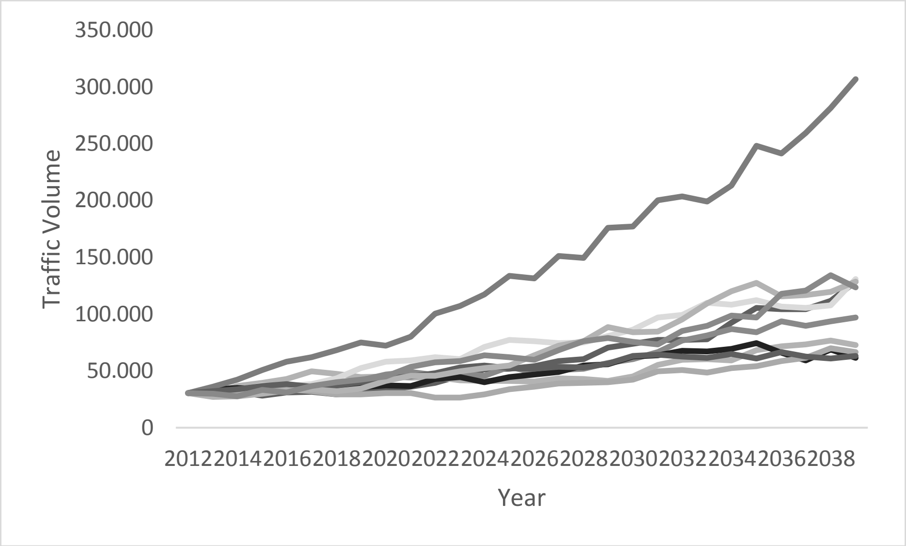


Figure 4.3. Stochastic nature of traffic demand for 10 different paths

Existing methods for pricing options such as Black and Scholes' formula, and the binomial model are borrowed from financial options and rarely used in practice to price real options. Despite their robustness, Lander and Pinches (1998) provide three reasons to explain why there is a little application of these models in practice. First, these models are not well known or understood by managers and practitioners since they are not familiar with the mathematics of these models. Second, these models are borrowed from financial world. Most of these methods assume that only few (one/two) financial inputs are uncertain and mostly a single variable is taken into account. This approach are often too narrow for real options. Third, these models, especially when the number of options embedded in the project increases, are very complex from a mathematical perspective thus causes a series of simplifying assumptions. As a consequence the use of these models and the reliability of the results are limited. From all reasons above, stochastic simulation approach is employed in this research.

4.4. NUMERICAL EXAMPLE

The model is applied to a hypothetical BOT toll road project because, generally a confidentiality agreement is signed between the public party, the private sector and the lenders. Therefore, it is hard to reach original financial data of a real project. To overcome this obstacle, a hypothetical BOT toll road project financial structure is constructed by the author to verify and validate the proposed model. Note that this is standard procedure in the literature (Chiara et al. 2007; Almassi et al. 2013; Kokkaew and Chiara 2013). When constructing this hypothetical BOT project, the traffic data (initial daily traffic volume, annual traffic growth rate, annual traffic volatility and toll rates), the main costs (opex, annual growth rate of opex and capex) and the concession period data are based on Chiara et al. (2007)'s base case to obtain meaningful values during the analysis. The debt and equity ratio is adjusted on the basis of project finance principles. The main characteristic of the hypothetical BOT project are shown in Table 4.1.

Table 4.1. The main characteristics of the hypothetical BOT project

Initial daily traffic volume	30.000
Annual traffic growth rate, μ_Q	5,00%
Annual traffic volatility, σ_Q	7,00%
Toll Rate (year 1-5)	$1,50
(year 6-10)	$2,00
(year 11-25)	$2,25
(year 26-30)	$2,50
OPEX	$7.000.000
Annual growth rate of OPEX	3,00%
Concession period, Tc	30 years
Construction period	2 years
Operation period	28 years
CAPEX, I	$250.000.000
Debt/Equity	75/25
Debt	$187.500.000
Loan interest rate	12,50%
Loan payback period	25
Equity	$62.500.000
Risk free interest rate	8,00%
Tax rate	18,00%

*project prepared by author

In the first step, cash flow model without any guarantees need to be calculated to see financial viability of the project. The followed steps and assumptions when calculating the cash flow model are:

1. $AADT_n$ is calculated using Equation 4.9 which mathematically expresses GBM stochastic process. For example,

$$\mathrm{AADT}_{2013} = \mathrm{AADT}_{2012}\ \mathrm{e}^{\left(\mu_Q - \frac{1}{2}\sigma^2\right)\Delta t + \sigma z_t}$$

$$= 30.000\ \mathrm{e}^{\left(0{,}05 - \frac{1}{2}0{,}07^2\right)1 + 0{,}07 z_t}$$

$$= 33.293$$

In this equaiton z_t takes difference value for each simulation.

2. Toll revenues are calculated by multiplying AADT and toll rates for each operation year.

$$\text{Toll Revenues}_{2013} = \mathrm{AADT}_{2013} \times \text{Toll Rate}$$

$$= 33.293 \times 1.50$$

$$= \$18.227.651$$

3. It is assumed that construction phase takes 2 years and capital expenditures (capex) are respectively \$100.000.000 and \$150.000.000.

4. It is assumed that operation expenditures (opex) start from the beginning of the operation year and growth %2 annually until the end of concession period.

$$\mathrm{OPEX}_{2013} = \mathrm{OPEXs}_{2012} \times \text{Growth Rate}$$

$$= \$7.000.000 \times 1{,}02$$

$$= \$7.210.000$$

5. Earnings before interest and taxes (EBIT) is calculated by subtracting opex from toll revenues.

$$\mathrm{EBIT}_{2013} = \text{Toll Revenues}_{2013} - \mathrm{OPEX}_{2013}$$

$$= \$18.227.651 - \$7.210.000$$

$$= \$11.017.651$$

6. It is assumed that interest payments start after 5 years from the beginning of concession period and are calculated using equal annual payment method and illustrated in Table 4.2.

Table 4.2. Interest calculations

Interest Calculations

Debt	$187.500.000
Loan interest rate	12,50%
Loan period	25
(1+interst)^period	19,00260151

Period	Annualy Payments	Interest Paymnets	Principal Amount	Remaining Amount of Principal
				$187.500.000
2015	$24.739.395	$23.437.500	$1.301.895	$186.198.105
2016	$24.739.395	$23.274.763	$1.464.632	$184.733.473
2017	$24.739.395	$23.091.684	$1.647.711	$183.085.762
2018	$24.739.395	$22.885.720	$1.853.675	$181.232.087
2019	$24.739.395	$22.654.011	$2.085.384	$179.146.702
2020	$24.739.395	$22.393.338	$2.346.057	$176.800.645
2021	$24.739.395	$22.100.081	$2.639.315	$174.161.330
2022	$24.739.395	$21.770.166	$2.969.229	$171.192.102
2023	$24.739.395	$21.399.013	$3.340.382	$167.851.719
2024	$24.739.395	$20.981.465	$3.757.930	$164.093.789
2025	$24.739.395	$20.511.724	$4.227.672	$159.866.117
2026	$24.739.395	$19.983.265	$4.756.131	$155.109.987
2027	$24.739.395	$19.388.748	$5.350.647	$149.759.340
2028	$24.739.395	$18.719.917	$6.019.478	$143.739.862
2029	$24.739.395	$17.967.483	$6.771.912	$136.967.950
2030	$24.739.395	$17.120.994	$7.618.401	$129.349.548
2031	$24.739.395	$16.168.694	$8.570.702	$120.778.847
2032	$24.739.395	$15.097.356	$9.642.039	$111.136.807
2033	$24.739.395	$13.892.101	$10.847.294	$100.289.513
2034	$24.739.395	$12.536.189	$12.203.206	$88.086.307
2035	$24.739.395	$11.010.788	$13.728.607	$74.357.700
2036	$24.739.395	$9.294.713	$15.444.683	$58.913.018
2037	$24.739.395	$7.364.127	$17.375.268	$41.537.750
2038	$24.739.395	$5.192.219	$19.547.176	$21.990.573
2039	$24.739.395	$2.748.822	$21.990.573	$0

7. Taxes are calculated by subtracting interest payments from EBIT and if the result is higher than 0, the result is multiplied with tax rate. If not no tax payment is foreseen because it means no profit is earned.

$$\text{Tax}_{2013} = (\text{EBIT}_{2013} - \text{Interest}_{2013}) \times \text{Tax Rate}$$

$$= (\$11.017.651 - \$0) \times 0.18$$

$$= \$1.983.177$$

8. Finally, net cash flow for each year is calculated by subtracting interest and tax payments from EBIT. Then, these net cash flow values are discounted with risk-free interest rate.

$$\text{Cash Flow}_{2013} = \text{EBIT}_{2013} - \text{Interest}_{2013} - \text{Tax}_{2013} - \text{CAPEX}_{2013}$$

$$= (\$11.017.651 - \$0 - \$1.983.177 - \$0$$

$$= \$9.034.474$$

The sample cash flow of the project without guarantees and is presented in Table 4.3 and illustrated in Figure 4.4.

Table 4.3. Cash flow model of the hypothetical BOT project

Year	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
AADT			30.000	33.293	36.303	41.425
Annual Cumulative Traffic			10.950.000	12.151.767	13.250.584	15.120.231
Toll Rate			$1,50	$1,50	$1,50	$1,50
Toll Revenues			$16.425.000	$18.227.651	$19.875.877	$22.680.346
CAPEX	$100.000.000	$150.000.000				
OPEX			$7.000.000	$7.210.000	$7.426.300	$7.649.089
EBIT			$9.425.000	$11.017.651	$12.449.577	$15.031.257
Interest						$23.437.500
Tax			$1.696.500	$1.983.177	$2.240.924	$0
Net Cash Flow	($100.000.000)	($150.000.000)	$7.728.500	$9.034.474	$10.208.653	($8.406.243)
Discounted Cash Flow	($100.000.000)	($138.888.889)	$6.625.943	$7.171.856	$7.503.665	($5.721.148)
Cumulative Discounted Cash Flow	($100.000.000)	($238.888.889)	($232.262.946)	($225.091.089)	($217.587.425)	($223.308.573)
Year	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
AADT	44.092	48.162	49.812	47.209	48.538	46.371
Annual Cumulative Traffic	16.093.570	17.578.969	18.181.329	17.231.259	17.716.486	16.925.386
Toll Rate	$1,50	$2,00	$2,00	$2,00	$2,00	$2,00
Toll Revenues	$24.140.356	$35.157.939	$36.362.658	$34.462.519	$35.432.972	$33.850.773
CAPEX						
OPEX	$7.878.562	$8.114.919	$8.358.366	$8.609.117	$8.867.391	$9.133.412
EBIT	$16.261.794	$27.043.020	$28.004.292	$25.853.402	$26.565.581	$24.717.360
Interest	$23.274.763	$23.091.684	$22.885.720	$22.654.011	$22.393.338	$22.100.081
Tax	$0	$711.241	$921.343	$575.890	$751.004	$471.110
Net Cash Flow	($7.012.969)	$3.240.096	$4.197.229	$2.623.500	$3.421.239	$2.146.169
Discounted Cash Flow	($4.419.360)	$1.890.565	$2.267.632	$1.312.403	$1.584.696	$920.455
Cumulative Discounted Cash Flow	($227.727.933)	($225.837.368)	($223.569.736)	($222.257.333)	($220.672.637)	($219.752.182)

Year	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**
AADT	54.822	53.973	57.495	55.308	55.187	59.187	66.131	65.215	62.947	66.314	63.228	70.391
Annual Cumulative Traffic	20.010.191	19.700.065	20.985.705	20.187.277	20.143.194	21.603.352	24.137.795	23.803.295	22.975.730	24.204.646	23.078.099	25.692.822
Toll Rate	$2,25	$2,25	$2,25	$2,25	$2,25	$2,25	$2,25	$2,25	$2,25	$2,25	$2,25	$2,25
Toll Revenues	$45.022.929	$44.325.147	$47.217.836	$45.421.372	$45.322.187	$48.607.542	$54.310.040	$53.557.414	$51.695.392	$54.460.454	$51.925.723	$57.808.850
CAPEX												
OPEX	$9.407.415	$9.689.637	$9.980.326	$10.279.736	$10.588.128	$10.905.772	$11.232.945	$11.569.933	$11.917.031	$12.274.542	$12.642.779	$13.022.062
EBIT	$35.615.514	$34.635.510	$37.237.510	$35.141.636	$34.734.059	$37.701.770	$43.077.095	$41.987.481	$39.778.361	$42.185.911	$39.282.945	$44.786.788
Interest	$21.770.166	$21.399.013	$20.981.465	$20.511.724	$19.983.265	$19.388.748	$18.719.917	$17.967.483	$17.120.994	$16.168.694	$15.097.356	$13.892.101
Tax	$2.492.163	$2.382.570	$2.926.088	$2.633.384	$2.655.143	$3.296.344	$4.384.292	$4.323.600	$4.078.326	$4.683.099	$4.353.406	$5.561.044
Net Cash Flow	$11.353.185	$10.853.928	$13.329.957	$11.996.529	$12.095.651	$15.016.678	$19.972.885	$19.696.398	$18.579.041	$21.334.119	$19.832.183	$25.333.644
Discounted Cash Flow	$4.508.506	$3.990.967	$4.538.331	$3.781.806	$3.530.605	$4.058.542	$4.998.195	$4.563.893	$3.986.100	$4.238.145	$3.647.942	$4.314.707
Cumulative Discounted Cash Flow	($215.243.675)	($211.252.709)	($206.714.378)	($202.932.572)	($199.401.966)	($195.343.425)	($190.345.229)	($185.781.336)	($181.795.236)	($177.557.091)	($173.909.149)	($169.594.443)

Year	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**
AADT	65.957	71.955	77.887	78.180	84.218	97.397
Annual Cumulative Traffic	24.074.157	26.263.690	28.428.873	28.535.522	30.739.686	35.549.899
Toll Rate	$2,25	$2,25	$2,25	$2,50	$2,50	$2,50
Toll Revenues	$54.166.854	$59.093.302	$63.964.964	$71.338.805	$76.849.215	$88.874.747
CAPEX						
OPEX	$13.412.724	$13.815.106	$14.229.559	$14.656.446	$15.096.139	$15.549.023
EBIT	$40.754.130	$45.278.197	$49.735.406	$56.682.360	$61.753.076	$73.325.724
Interest	$12.536.189	$11.010.788	$9.294.713	$7.364.127	$5.192.219	$2.748.822
Tax	$5.079.229	$6.168.133	$7.279.325	$8.877.282	$10.180.954	$12.703.842
Net Cash Flow	$23.138.711	$28.099.275	$33.161.368	$40.440.951	$46.379.903	$57.873.060
Discounted Cash Flow	$3.648.959	$4.102.997	$4.483.475	$5.062.674	$5.376.067	$6.211.372
Cumulative Discounted Cash Flow	($165.945.483)	($161.842.486)	($157.359.010)	($152.296.337)	($146.920.269)	($140.708.897)

*cash flows prepared by author

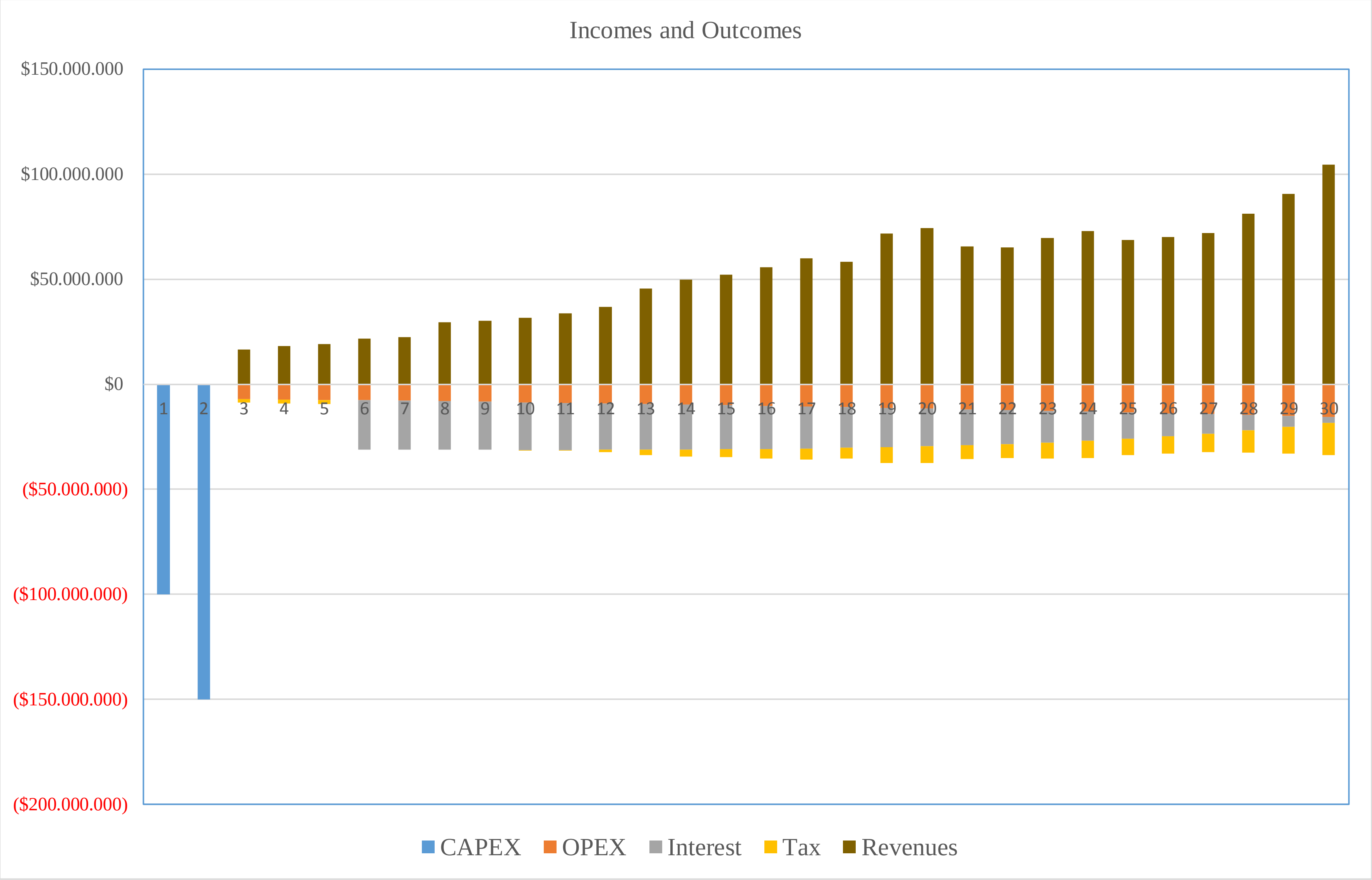


Figure 4.4. Cash flow diagram of the hypothetical BOT project

Then, Monte Carlo simulation with 1000 trials was ran to find probability distribution of the NPV without guarantees. It was observed that after 1000 trials the simulation results showed nominal changes. Since there are uncertainties in future traffic volume, the value of the NPV and accordingly R_c is not deterministic but instead follows a certain distribution. The probability distribution and several key statistics of NPV are shown, respectively in Figure 4.5 and Table 4.4 The simulation results reveal that there is 96,40% possibility that NPV of the project is negative. This means that government support is needed to make the project attractive for private investors.

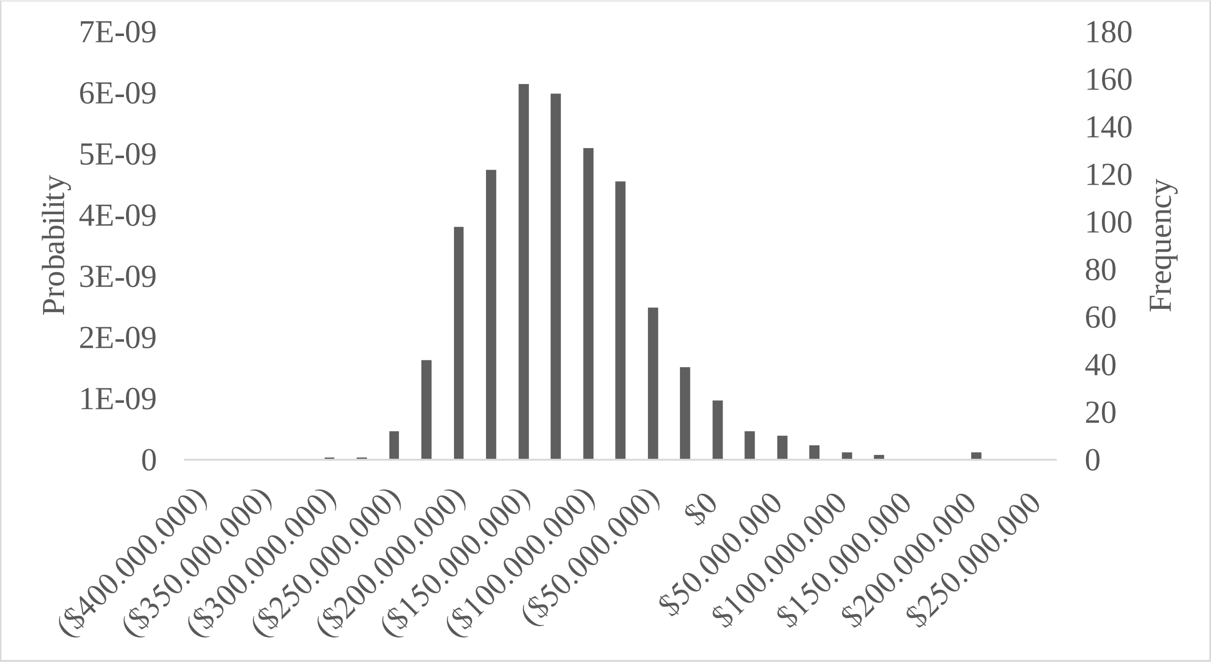


Figure 4.5. Probability distribution of NPV without guarantees

Table 4.4. Simulation results of NPV

Key statistic of NPV	Values
Mean	($132.953.864)
Median	($138.882.790)
Maximum	$192.228.667
Minimum	($300.273.212)
Maximum when NPV<0	($910.241)
Standard deviation	67.336.445
Variance	4.534.196.891.300.790
Skewness	0,82
Kurtosis	1,65

In the established MRG framework, NPV>0 is defined as the first condition of private participation. Thus, the total value of guarantee is the value which equalizes the value of NPV to zero as presented before in Equation 4.4.

R_c is calculated by trial and error for mean, median, maximum when NPV<0, and minimum statistics values of the NPV distribution. Table 4.5 represents the calculated values of R_c. At this stage, the main issue is to decide which of statistics would present a fair value of the guarantee. For example, Cheah and Liu (2006) proposed the use of the median value due to high skewness of distribution.

Table 4.5. Values of R_c for different statistics values

Key statistics	R_c
Minimum	$48.422.750
Median	$46.298.323
Mean	$42.955.961
Maximum when NPV<0	$17.437.443

Carbonara et al. (2014) have developed another approach to find a fair value for R_c, based on the Eurostat rules for off-balance investment. In this concept, if the total value of guarantee less than half of the total capital investment, guarantee is treated as off-balance sheet. Therefore, intersection value of the R_{cmin} and R_{cmax} is selected as the fair value of R_c.

Following the Cheah and Liu (2006), median value of the revenue cap R_c=$46.298.323 is selected as the fair value. Figure 4.6 shows the probability distributions of the NPV calculated for R_c = $46.298.323 and Table 4.6 shows several key statistics of the NPV distribution.

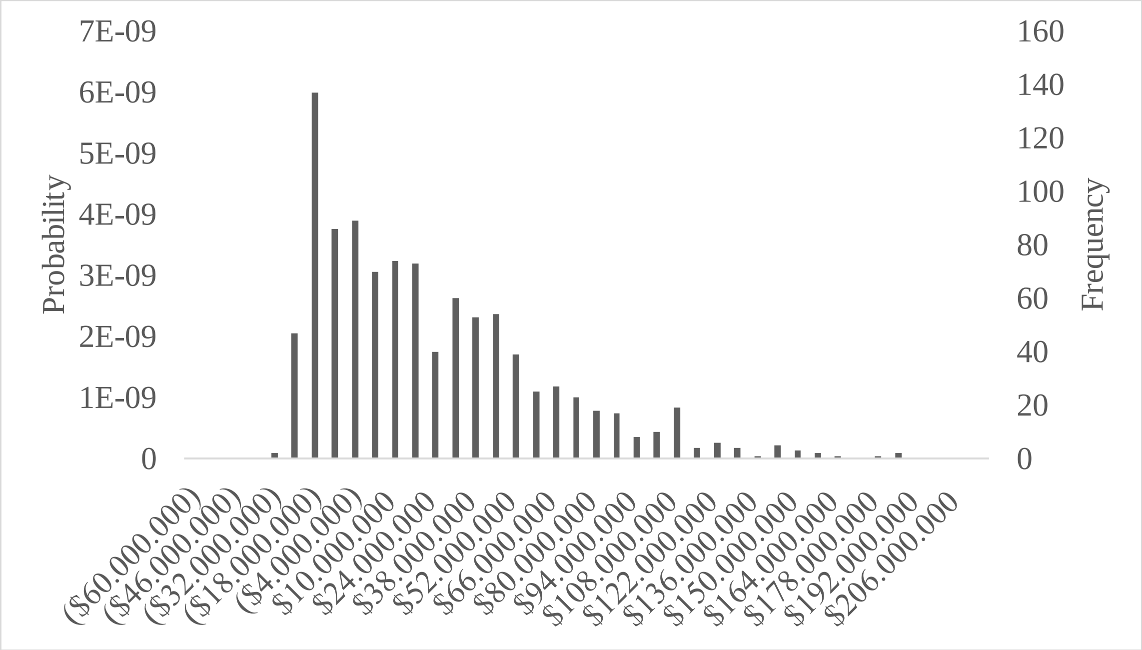


Figure 4.6. Probability distribution of NPV with R_c = \$46.298.323

Table 4.6. Simulation results of NPV with R_c = \$46.298.323

Key statistic	Values
Mean	$18.634.878
Median	$9.244.182
Maximum	$184.658.473
Minimum	($33.758.673)
Maximum when NPV<0	($51.084)
Standard deviation	39.204.493
Variance	1.536.992.279.949.670
Skewness	1,13
Kurtosis	1,13

Simulation results show that there is 36,10 % possibility that NPV is still negative but there is significant progress relative to first result of simulation 92,10% which was ran without any guarantee. This supports that option value of the guarantees can totally change the decision to invest in a project.

In Table 4.6, maximum value of NPV is approximately $184.000.000. To avoid these high NPV probabilities for private investor, a revenue sharing mechanism may be developed. If the traffic volume somehow surpasses the initial projection by some pre-specified level, the government should rightfully demand a reduction in toll rates to benefit the users, increase taxes, or even directly participate in the upside of the project. All these represent a form of ‘repayment’ from the concessionaire to the government (Cheah and Liu, 2006). This mechanism is often referred to as toll revenue cap (TRC) (Ashuri et al., 2012). In banded revenue guarantees, the government will share extra revenues exceeding the maximum revenue threshold. Such revenues can be modeled as call options. A call option is defined as the right, but not the obligation, to buy a designated asset at an exercise price (Kokkaew and Chiara, 2013).

Until this phase of the analysis, financial viability of the hypothetical BOT project with MRG option is evaluated from the private perspective. However, these guarantees have also fiscal impacts to public sector. In Figure 4.7, probability distribution of the total guarantee is presented with R_c=\$46.298.323, to illustrate fiscal impacts of guarantee to public sector and Table 4.7 shows key statistics.

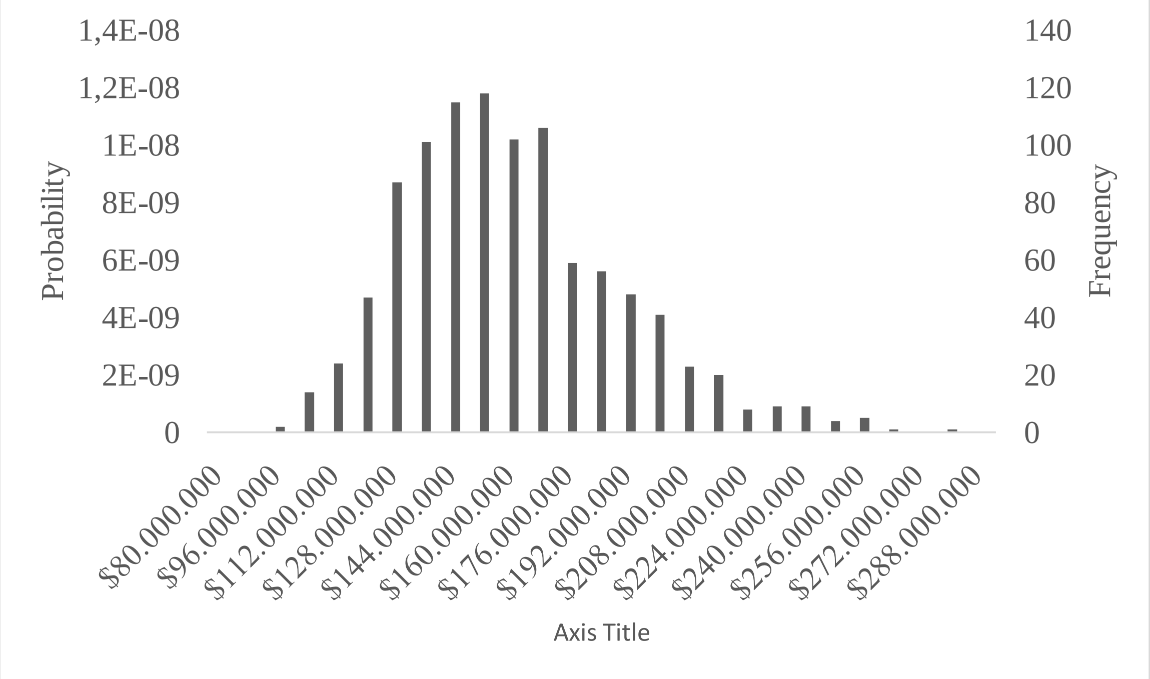


Figure 4.7. Probability distribution of the total value of guarantee.

Table 4.7. Simulation results of G with R_c = $46.298.323

Key statistic	Values
Mean	$155.539.888
Median	$151.485.038
Maximum	$275.692.420
Minimum	$94.181.910
Standard Deviation	29.849.082
Variance	890.967.723.973.479
Skewness	0,73
Kurtosis	0,58
G>$250.000.000(I)	0,70%
G>$125.000.000(0,5*I)	91,30%

According to “economic risk and reward” criterion proposed within the Eurostat treatment of PPPs, if a government finances the majority of the capital costs associated with a PPP asset, Eurostat considers that the government implicitly bears the majority of the construction risk. For asset classification purposes, an assessment needs to be made as to whether the total percentage of financing provided by the government exceeds fifty percent of the capital cost associated with the asset. When a government bears the majority of the financing risk (whether through debt, equity or direct or indirect guarantees), the PPP assets should be reported on its balance sheet (EPEC, 2010). In Table 4.6, possibility of guarantees to cost more than fifty percentage of initial investment cost is 91,30%; thus investment should be considered on-balance sheet. This result is challenging in terms of fiscal impacts of guarantees to the government. Some strategies can be developed to reduce the level R_c. These strategies should be focus on either retrenching costs or increasing revenues of private investor. However, increasing revenues mostly is possible with changing toll rates thereby it burdens extra costs to users. Another approach can be adjusting concession period to increase revenues. Moreover, tax reduction can be considered as a strategy that could retrench costs of private investor.

4.5. DISCUSSION OF RESULTS

The importance of government guarantees when taking an investment decision is shown by using real option approach with Monte Carlo simulation method. Minimum revenues of private investor for each concession year is guaranteed with revenue lower limit or revenue cap R_c. Traditional valuation techniques such as NPV are not adequate to take guarantees into consideration.

The first step of the analysis is to determine future traffic volumes as a main risk factor. It is assumed that traffic will vary stochastically in time following a GBM. Equation 4.9 is used to model future traffic demand. Then, NPV value of the project without guarantees is calculated using Equation 4.4 and Equation 4.5 to see financial viability of the project form the private perspective. Since the future traffic volume has a stochastic nature, NPV is not deterministic. Thus Monte Carlo simulation is run 1000 times to find values of NPV for each different path of future traffic volume. Probability distribution of results is presented and there is 96,40% possibility that NPV of the project is negative. This means that the project need to be supported with government guarantees to make it attractive for private investor.

Public and private sectors have different approaches in terms of investment decisions. The first objective of private party when investing a project is to make profit. On the other hand, from the perspective of public sector, socio-economic and political benefits are the main motivations behind the investment decision. Consequently, public sector can be decisive in investing to a financially non-viable project. In such a case, public party would not hesitate to provide some guarantees to the project. But inadequate evaluation of these supports can put a heavy burden of contingent liabilities to the public sector.

The second step of this analysis is to determine the level of R_c which mitigates the financial risks of the project and satisfies the commercial expectations of private investor. NPV>0 is identified as primer condition for private party to invest the project. R_c is calculated by trial and error using Equation 4.1 and 2 for mean, median, maximum and minimum values of NPV distribution. Although, there are different approaches for determining the fair value of R_c, the value of R_c=\$46.298.323 is selected as the 'median' value. First simulation is run again but with R_c to observe effects of guarantee to the project's financial position. The results show that teher is 36,10% that probability NPV of the project is negative. This result prove that guarantees are effective financial tools that have the power to totally change a project's financial viability and thus the investment decision.

The last step of the analysis is to observe fiscal impacts of guarantees to public budget. The total value of guarantees, when R_c=$46.298.323, is simulated using Equation 3. Eurostat rule established a framework to evaluate guarantees. If total value of guarantees is more than fifty percent of total capital expenditure, guarantees should be considered on-balance sheet. The results show that there is 91.30 % possibility that the total value of guarantees is higher than fifty percent of the total capital expenditures. In this case, some precautions should be taken to hold the total value of guarantee in requested limits.

5. CONCLUSION

Since today, private sector has increasingly played a vital role in the delivery of public infrastructure by contributing to the financing, constructing and operating of these infrastructure projects (Ashuri et al., 2012). In this concept, BOT project delivery system under PPP scheme has been widely used throughout the world for the realization of infrastructure systems as an interface between the construction industry, finance and insurance markets.

In order to address one of the most problematic issues in PPP context; the MRG provided by governments to concessionaires against demand risk in toll road projects is modelled as real options within the scope of this thesis. The model used Monte Carlo simulation to find a fair value for the MRG for both public and private sectors and to observe the effects of the MRG on the financial viability of the hypothetical BOT toll road project.

In the beginning of this research, three main goals identified for this thesis were;

1. To propose a model for the identification of MRG level that establishes a fair risk allocation structure for both public and private parties;
2. To observe the financial impacts of the determined MRG level to the private party and its decision to invest; and
3. To reveal MRG's fiscal impacts to public budget.

The proposed real-options based model with Monte Carlo simulation has been successful in achieving these goals. The model enables decision makers to determine a fair value of MRG under defined constraints which represents the different motivations of public and private parties. In the sample case study provided in section 4, $NPV > 0$ is defined as constraint for private party according to the basic rule of evaluation of projects and $G < 0,5 \times I_0$ is defined as constraint for public party according to Eurostat "economic risk and reward" criteria. However, it has been observed that the model could be easily adjusted for different situations and constraints such as the IRR of the private party.

The level of the revenue cap identified using the model does not aim to fully satisfy both parties; instead, it establishes a fair bargaining environment between them. Using this model, decision makers can value the flexibility for different scenarios which is not possible to do using traditional DCF methods. This bargaining environment is essential to structure a fair risk allocation between parties.

In addition to the possibility of determining a fair value for MRG, this model further enables decision makers to analyze the impact of guarantees provided on the project’s financial viability and the public budget. This is another important advantage of the model as such an analysis informs public decision makers on the possible return profile of the private party and thus any excessive profits could be prevented. On the other hand, as experience to date shows that inadequate levels of guarantees may pose difficulties in the realization of facilities using the BOT toll road model (i.e. if the level of the MRG is insufficient, the government would not attract any private investor to the project), the proposed real options approach is also useful for overcoming project failures.

This model can be used by both public and private parties which have different motivations when investing in a project. The real options approach enables decision makers to evaluate priorities and risks in a variety of large scale infrastructure projects. Moreover, it can also be used by lenders who assume a significant amount of risks as financial institutions provide a high proportion of project expenditures (approximately 70%-90% of the total investment cost) in the BOT approach. In this way, lenders can observe the variation in the cash flows of the project for different scenarios.

Although at first sight the mathematical base of the proposed model may seem sophisticated, progress in software programming and increased learning with experience could inevitably pave the way for a wider use of such flexible models. Furthermore, the simulation based valuation process of the proposed model is easier to apply compared to other real options valuation methods such as SDE or various analytic formulas introduced in Chapter 3. The constraints expressed in mathematical language could also be easily incorporated into the model whether they are unique for a specific project or defined by government regulations as applied in the sample case study.

Finally, it should be stated that the application of the proposed model is not limited to MRGs in toll road projects. Future studies may focus on valuing a wide range of guarantees such as debt, equity guarantees or exchange rate etc. Furthermore, the development of this model by incorporating several other risk factors such as construction cost risk or interest rate risk etc. beside the level of the future traffic demand risk could be of great value for public, private parties and the research community.

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Faruk Büyükyoran was born in Antalya on the 29th of January, 1983. He completed primary and high school education in Antalya. He graduated from Yildiz Technical University in 2011 with a Bachelor’s degree in Civil Engineering.

After graduating, he worked in various construction projects in different positions for four years. During this period he completed my first Master’s degree in “Construction Management Program” (non-thesis) at the same university in 2013,he got a success scholarship from Renaissance Holding whilst completing my degree.

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