Option-based quantification and generic optimization of debt refinancing in public-private partnership infrastructure projects

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**NANYANG
TECHNOLOGICAL
UNIVERSITY**

**OPTION-BASED QUANTIFICATION AND GENERIC
OPTIMIZATION OF DEBT REFINANCING IN
PUBLIC-PRIVATE PARTNERSHIP
INFRASTRUCTURE PROJECTS**

**ZHENG SHA
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING
2013**

**OPTION-BASED QUANTIFICATION AND GENERIC
OPTIMIZATION OF DEBT REFINANCING IN
PUBLIC-PRIVATE PARTNERSHIP
INFRASTRUCTURE PROJECTS**

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School of Civil and Environmental Engineering

A thesis submitted to the Nanyang Technological University
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SUMMARY

The concept of Public-Private Partnerships (PPPs) and its application in procurement and development of infrastructure projects have been promoted worldwide due to the introduction of additional financing sources and value for money by this means. A large portion of debt or high leverage is usually structured in PPP infrastructure projects. It is very common for infrastructure PPP projects to undertake debt refinancing for improving project sponsors' returns at a later stage. It is considered particularly suitable for long-term infrastructure projects where the construction has been completed and the successful operation has been demonstrated. The project profile has become less risky and can obtain better terms in refinancing.

The aim of this research is to quantify the financing flexibility created by the future debt-refinancing opportunities and optimize refinancing plans in PPP infrastructure projects in the perspective of project sponsors. The scope of the research is to study the debt refinancing with the potential of return enhancement or generating refinancing gains in PPP infrastructure projects.

This research contributes to the knowledge set on understanding the role of debt refinancing in PPP infrastructure projects by delivering the “option to refinance” valuation (ORV) framework and the debt-refinancing optimization (DRO) model.

The financing flexibility created by the future debt refinancing opportunities that the project sponsors can refinance the existing debt for better financial terms at a future date, i.e. the “option to refinance”, is first recognized and structured as a real option in this research. It is the first attempt to quantify the value of such flexibility in an option-based methodology of the ORV framework. No existing literature on the area of PPP infrastructure and real options has studied this. It is new

contribution to the existing literature by capturing and quantifying this financing flexibility and the modified Black model theory is first used in valuing real options.

The research further delivers the DRO model to optimize debt-refinancing plans in PPP infrastructure projects, and analyze the impact of debt-refinancing plans on project equity cash flows. Taking into consideration of project conditions and refinancing parameters, the DRO model provides a generic algorithm that can apply to PPP infrastructure projects. It is a new analytical model to maximize the equity investors' value and can also be served as an analytical tool for project sponsors to negotiate with lenders.

Three Build-Operate-Transfer (BOT) projects from the road transport, power and water sectors were used as case studies to demonstrate the valuation of “option to refinance” and the analysis and optimization of debt-refinancing plans in PPP infrastructure projects.

It is demonstrated that the “option to refinance” can enhance project value. A high-risk profile can have a negative impact on the expected value of the option because lenders are reluctant to make refinancing deals if significant risks are still prevailing. That is why the debt refinancing for PPP projects is normally carried out after the construction phase or early operation phase. Additional financial support from the project sponsors, banks and public agencies can help to lower the risk. On the other hand, if the refinancing is done at a late stage of the project, the time value of money has gone, and the option value can be decreased.

In terms of different variables in refinancing optimization, generally speaking, refinancing can normally increase the cash flow sharply at the year of refinancing. Decrease in the interest rate can increase the equity cash flows by lowering the interest cost. The extension of the debt maturity may increase the equity cash flows in the early years of a project followed by decrease in the equity cash flows after the year of the original debt maturity.

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LIST OF ABBREVIATIONS

ADB	Asian Development Bank
AfDB	African Development Bank
BGM	Brace, Gatarek and Musiel
BLOT	Build-Lease-Operate-Transfer
BOO	Build-Operate-Own
BOT	Build-Operate-Transfer
CDC	Commonwealth Development Corporation
DCF	Discounted cash flow
DRO	Debt refinancing optimization
DSCR	Debt service cover ratio
ECA	Export credit agency
EDF	Electricite de France
EDFI	Electricite de France International
EFIC	Export Finance & Insurance Corporation
EIB	European Investment Bank
EMV	Expected monetary value
FPSL	Fazakerley Prison Service Limited
FRA	Forward rate agreement
GCFC	Guangxi Construction & Fuel Company Ltd
GDIC	Guangxi Development and Investment Co. Ltd
GPIB	Guangxi Power Industry Bureau
HJM	Heath, Jarrow and Morton
IDB	Inter-American Development Bank
IFC	International Finance Corporation
IRR	Internal rate of return
JBIC	Japan Bank for International Cooperation

KEXIM	Korea Export and Import Bank
LIBOR	London inter-bank overnight rate
LLCR	Loan life cover ratio
LWS	Labuan Water Supply Sdn Bhd
M&A	Merge and acquisition
NAO	The National Audit Office
NPV	Net present value
OGC	The Office of Government Commerce
ORV	"Option to refinance" valuation
PEFCO	Private Export Funding Corporation
PF	Project finance
PFI	Private finance initiative
PFP	Privately-financed projects
PLCR	Project life cover ratio
PPI	Private participation in Infrastructure
PPP	Public-private partnership
PSP	Private-sector participation
R&D	Research and development
S&P	Standard & Poor's
SPE	Special purpose entity
SPV	Special purpose vehicle
UN/ECE	United Nations Economic Commission for Europe
UNIDO	United Nations Industrial Development Organization
VfM	Value for money
WHO	World health Organization

LIST OF SYMBOLS

A	Base local construction cost expressed in constant value
a	Fraction factor of projected revenue
$ATOCF$	After-tax operating cash flow in the base case
CC	Construction cost in the base case
CF	Cash flow
CF^d	Net debt cash flow
DD	Debt drawdown in the base case
DEP	Depreciation expense in the base case
DIN	Debt interest payment in the base case
DPR	Debt principal repayment in the base case
DS	Debt service payment in the base case
$DSCR_{\min}$	Minimum deb service cover ratio required by the lender in the refinanced case
D_T	Outstanding principal balance of the original debt at time T
ED	Equity drawdown in the base case
$E^{\hat{Q}}$	Denotation of expected value under forward risk-neutral measure
F	Base foreign construction cost expressed in constant value
$F(0, T)$	Time-zero forward market value of the original debt obligation at time T
$FCFE$	Free cash flow to equity in the base case
IDC	Interest during construction in the base case
$IRRET$	Threshold equity internal rate of return
L	Monetary value of uncertainty of completion time
$LLCR_{\min}$	Minimum loan life cover ratio required by the lender in the refinanced case

M	Maturity of the original debt
$M_{\max}$	Maximum maturity by taking account of minimum tail periods in the refinanced case
N	Concession period
N_C	Construction period
$NPV_0(E)$	Time-zero net present value of equity cash flows in the base case
$NPV_0(P)$	Time-zero net present value of the project base case
$NPV_T(E)$	Time-T net present value of equity cash flows in the base case
$NPV_T(ReE)$	Time-T net present value of equity cash flows in the refinanced case
OM	Operation and maintenance cost in the base case
$P(0, T)$	Time-zero price of T-maturity zero coupon bond with a par value of one unit of currency
$PLCR_{\min}$	Minimum project life cover ratio required by the lender in the refinanced case
PV	Present value
$\hat{Q}$	Forward risk-neutral measure
$ReATOCF$	After-tax operating cash flow in the refinanced case
ReD	New debt amount in refinancing
$ReDD$	Debt drawdown in the refinanced case
$ReDEP$	Depreciation expense in the refinanced case
$ReDIIN$	Debt interest payment in the refinanced case
$ReDPR$	Debt principal payment in the refinanced case
$ReDS$	Debt service payment in the refinanced case
$ReDSCR$	Debt service cover ratio in the refinanced case
$ReFCFE$	Free cash flow to equity in the refinanced case
ReG_0	Time-zero net present value of equity gains arising from debt refinancing
ReG_T	Time-T net present value of equity gains arising from debt refinancing
$ReINR$	New interest rate in refinancing

$ReINR_{\min}$	Minimum interest rate in the refinanced case
$ReLLCR$	Loan life cover ratio in the refinanced case
ReM	New maturity in refinancing
$ReOM$	Operation and maintenance cost in the refinanced case
$RePLCR$	Project life cover ratio in the refinanced case
$ReREV$	Revenue in the refinanced case
$ReTAX$	Tax payment in the refinanced case
$ReTC$	Total project cost in the refinanced case
REV	Revenue in the base case
R_p	Required rate of return of the project
S	Monetary value of mitigation support
TAX	Tax payment in the base case
$TAXR$	Tax rate
TC	Total project cost in the base case
TCC	Total construction cost
TCC_0	Budgeted total construction cost in the base case
TD	Total debt amount in the base case
TE	Total equity amount in the base case
$TNPV(P)$	Total project net present value
V_0	Conditional expected value of the "option to refinance"
V_{OR}	Expected value of "option to refinance"
$V_T(D)$	Time-T market value of the original debt obligation
$V_T(ReD)$	Market value of the new debt used to refinance the original debt at time T
X	Demand
XD	Increase in debt amount due to refinancing
XM	Extension in maturity due to refinancing
XR	Reduction in interest rate due to refinancing
Z_i	Zero coupon discount factor of i-period
α	Incremental change of debt amount
θ^A	Local inflation rate

θ^F	Foreign inflation rate
λ	Fraction of revenue to be converted to another currency against the currency in which revenue was collected
σ_F	Forward volatility
φ	Foreign exchange rate (local currency/foreign currency)
Φ	Cumulative probability of success in both conditions 1 and 2
Ψ	New debt repayment structure
Ω_1	Cumulative probability of success in condition 1
Ω_2	Cumulative probability of success in condition 2
$\sim$	Denotation of stochastic variables

CHAPTER 1

INTRODUCTION

This chapter provides a brief introduction to the research background, the research questions, the objectives, the novelty of the research and the significance and the contribution of the research. It briefly explains the need for a study on quantification of the financing flexibility created by the future debt-refinancing opportunities and optimization of refinancing plans in PPP infrastructure projects in the perspective of project sponsors.

1.1 Research Problem

Public-Private Partnerships (PPPs) have been promoted worldwide to develop infrastructure projects. For instance, the total investment commitments to infrastructure projects with private participation in developing countries during the period from 2001 to 2008 was US\$ 843.3 billion (The World Bank and PPIAF 2008).

In PPP infrastructure projects, debt financing is the majority of the funding. The ratio can be up to 70% to 90% of the total project cost in some cases, while the rest of the funding comes from equity investors. PPP infrastructure projects normally have long-term lifecycle. As the project develops, the project and market conditions change, project sponsors can undertake debt refinancing to change or replace the existing debt profile at a future date. Debt refinancing takes place in many PPP infrastructure projects for different purposes such as increase in project or equity value, interest rate risk hedge, currency risk hedge or rescuing project distress.

In particular, it is very common for infrastructure PPP projects to undertake debt refinancing for improving project sponsors' returns. It is considered particularly suitable for long-term infrastructure projects where the construction has been completed and the successful operation has been demonstrated. The project profile has become less risky and can obtain better terms in refinancing. This has been popular in the UK, where a total refinancing gain of £ 247.2 million was secured from 2002 to February 2006 (National Audit Office 2006).

The future debt refinancing opportunities embedded in PPP infrastructure projects create the financing flexibility to project sponsors with the possibility of improving the returns of project sponsors at a future date. The flexibility whether the project sponsors will refinance the existing debt or not for better financial terms at a future date is contingent to the future project and market conditions with project sponsors' managerial discretion. This flexibility as "option to refinance" increases project value, but is not captured in the traditional capital investment valuation. The project value could be underestimated at the project planning stage. It is similar to real options to

create value by managerial response to future market and project conditions, but the “option to refinance” is not recognized by the existing literature or research on the areas of either project valuation or real options in infrastructure projects.

Furthermore, it is important to know how the debt refinancing package to be structured that can provide the maximum value to project sponsors when information on market and project conditions become available at a later time. It is more economical for project sponsors to utilize this opportunity fully to negotiate an optimized debt refinancing plan with lenders which is the most beneficial to their project. Therefore, the financial resources can be efficiently reallocated. An analytical tool incorporating different project conditions and refinancing parameters is needed.

Therefore, the research attempts to answer the following questions:

- (a) How can the value of the financing flexibility created by the future debt refinancing opportunities, i.e. “option to refinance” in PPP infrastructure projects, be captured and quantified?
- (b) How does the value of such financing flexibility impact on the total net project value?
- (c) What could be the optimal debt-refinancing plan if the project company considers the possibility of undertaking a plan for a specific PPP infrastructure project?
- (d) How do debt-refinancing plans influence the equity cash flow of PPP infrastructure projects?

1.2 Objectives of Research

The aim of this research is to quantify the financing flexibility created by the future debt-refinancing opportunities and optimize refinancing plans in PPP infrastructure

projects in the perspective of project sponsors. The scope of the research is to study the debt refinancing with the potential of return enhancement or generating refinancing gains to answer the research questions identified in previous section, thus the specific objectives of the study are designed as below:

- (1) To capture and quantify the value of the financing flexibility created by the future debt-refinancing opportunities that project sponsors can refinance the existing debt for better financial terms at a future date, i.e. the “option to refinance” embedded in PPP infrastructure projects.
- (2) To incorporate the value of such flexibility into the initial project valuation.
- (3) To optimize debt-refinancing plans to generate maximum gains for the project sponsors in PPP infrastructure projects.
- (4) To provide analysis for the impact of debt-refinancing plans on project equity cash flows.

Objectives (1) and (2) are designed to answer research questions (a) and (b). Objectives (3) and (4) are designed to answer research questions (c) and (d).

1.3 Significance and Contribution of the Research

This research contributes to the knowledge set on understanding the role of debt refinancing in PPP infrastructure projects by delivering the “option to refinance” valuation (ORV) framework and the debt-refinancing optimization (DRO) model.

The research delivers the ORV framework that can capture and quantify the value of financing flexibility created by the future debt refinancing opportunities that project sponsors can refinance the existing debt for better financial terms at a future date, i.e. “option to refinance” embedded in PPP infrastructure projects. It leads to more accurate project valuation compared with the traditional project valuation techniques.

This financing flexibility shares similarities with real options. The novelty of this is the first attempt to structure such flexibility as the “option to refinance” fitting into the context of PPP infrastructure projects. The valuation of the conditional “option to refinance” can be viewed as a valuation of interest rate derivatives, which could end up being extremely complicated mathematically. The research adjusted and justified the Black model to be built into the framework. This provides a simplified procedure to calculate the value of the “option to refinance” so that the framework becomes easier for project sponsors to understand.

The research further delivers the DRO model to optimize debt-refinancing plans in PPP infrastructure projects, and analyze the impact of debt-refinancing plans on project equity cash flows. The DRO model is useful to facilitate investors’ decision making, and also can be served as an analytical tool for project sponsors to negotiate with lenders.

In conclusion, the research can help project sponsors to capture the flexibility value created by the future debt refinancing opportunities, the impact of such flexibility on the project value, the solution of optimal debt-refinancing plan, and the impact of the debt-refinancing plan on the project’s cash flow. It gives the project sponsors valuable implications for their decision making.

1.4 Novelty of the Research

The flexibility that the project sponsors can refinance the existing debt for better financial terms at a future date with the possibility of increasing project’s return is first recognized and structured as a real option in this research. This flexibility that provides intangible value to the project is first quantified in the option-based valuation methodology of the ORV framework. Existing literature on the area of PPP infrastructure and real options have no study on it.

This research also provides a new analytical methodology of the DRO model to optimize debt-refinancing plan that can maximize the equity investors’ value. Taking

into consideration of project conditions and refinancing parameters, the DRO model provide a generic algorithm that can apply to PPP infrastructure projects.

1.5 Structure of the Thesis

This research is presented in seven chapters as illustrated in Figure 1.1.

Chapter 1 provides a brief introduction to the background of the study, the research questions and objectives, the significance and contribution of the research and the novelty of the research.

Chapter 2 reviews the literature that is essential for working on the problem set. It comprises the basics and relevant literature from the area of PPP, debt financing and refinancing practice, risk management and real option theories in PPP infrastructure projects.

Chapter 3 outlines the research methodology employed in the research. The development of the ORV framework for the financing flexibility created by the future debt refinancing opportunities, i.e. “option to refinance”, integrated cashflow modeling, risk analysis with Monte Carlo simulation in @RISK software, and the bond option pricing theory of the Black model. The development of the DRO model is conducted by cashflow simulation via Visual Basic programming and scenario analysis. The validation of the ORV framework and the DRO model is conducted by case studies.

Figure 1.1 Structure of thesis

Chapter 4 is the development of the ORV framework for the value of the financing flexibility created by the future debt refinancing opportunities that project sponsors can refinance the existing debt for better financial terms at a future date, i.e. the “option to refinance” embedded in PPP infrastructure projects. The framework consists of several elements including: discounted cash flow analysis of the project base case, risk analysis of conditions for “option to refinance”, conditional option valuation and output of the value of “option to refinance”, and the total project NPV with the value of such flexibility incorporated.

Chapter 5 is the development of the DRO model designed to optimize a debt-refinancing plan and analyze its impact on the equity cashflows. It develops three sub-models of base case financial model, pre-refinancing financial model and post-refinancing financial model, and an objective function of equity gains. The financial models developed are intended to segregate different components affecting the equity gains. The optimization algorithm is designed to maximize the objective function with certain constraints.

Chapter 6 provides descriptions of the case studies used to validate the ORV framework and the DRO model developed in Chapter 4 and Chapter 5 respectively. The three Build-Operate-Transfer (BOT) cases are: the Toll Road BOT Project A, Indonesia; the Laibin B Power BOT Project, China; and the Labuan Water Supply BOT Project, Malaysia. The Indonesian project remains anonymous due to confidentiality issues. Key observations drawn from case studies are presented as well.

Chapter 7 presents the conclusions and recommendation for the future work. It concludes on the main contribution and results of the research, as well as the limitations of the research. It also provides recommendations on areas for future research work.

CHAPTER 2

LITERATURE REVIEW

This chapter reviews literature from the area of PPP, debt financing and refinancing, risk management, and real option theories. It forms the theoretical basis in developing the “option to refinance” valuation (ORV) framework and the debt-refinancing optimization (DRO) model in PPP infrastructure projects. Various ways of debt financing, the comparison of debt refinancing with alternative financial solutions, and the UK’s development of debt refinancing in FPI projects are studied as well.

2.1 Previous Studies on PPP Infrastructure Projects

2.1.1 Introduction to PPP concept

PPP has been used to promote the development of infrastructure projects. There is no single agreed definition for PPP worldwide. Various definitions are available in different sources and different countries (The Canadian Council for Public-Private Partnerships , The National Council for Public-Private Partnerships , HM Treasury 2000, Ministry of Finance 2004, Partnerships Victoria 2005, Renda and Schrefler 2006). A general definition is that PPP is a contractual arrangement between private sector and public sector, in which, the private sector will deliver the public services traditionally provided by the public sector. There are some variant names for PPPs which could lead to confusion. They may be used interchangeably or subject to different interpretations. The terminologies of PPP are summarized in Table 2.1. In this research, PPP and those terms such as PFI are used interchangeably.

Table 2.1 Variants of PPP

Variants	Description
Private Participation in Infrastructure (PPI)	used by the World Bank
Private-Sector Participation (PSP)	used in the development-banking sector
P3	used in North America
Privately-Financed Projects (PFP)	used in Australia
P-P Partnership	to distinguish from “Purchasing Power Parity” (PPP)
Private Finance Initiative (PFI)	a term originating in Britain, and now also used in Japan and Malaysia

Source: Yescombe (2007)

The key features of PPP projects are summarized as below (Grimsey and Lewis 2004, Grimsey and Lewis 2005):

- Type: PPP projects primarily involve long-term service provision contracts related to social and economic infrastructure.
- Collaboration: the public and private sectors share both responsibilities and risks in a collaborative framework.
- Focus on service: the public sector purchases a service instead of an asset, and the

service is provided and delivered by the private party.

- Length: the service provision is a long-term contract between government and the private project company.
- Whole-of-life costing: The cost can be integrated from design, construction, maintenance, operation and refurbishment under one party, who is in a good position to optimize lifecycle cost.
- Innovation: the private sector can introduce innovative solutions to deliver the service, as a PPP approach only specifies the output.
- Risk allocation: the government retains substantial risks in conventional procurement by owning and operating infrastructure, and the PPP approach transfers some of the risks to a private party, which can manage it more effectively, and can substantially lower the overall cost to the government.

There are many PPP models, ranging from the least private sector involvement to the most private sector involvement, as shown in Figure 2.1. Ranked in order from the least private sector involvement to the most, they can take the form of: service contract, management contract, lease contract, concession, Build-Lease-Operate-Transfer (BLOT), BOT and Build-Operate-Own (BOO). The higher the degree of the private sector involvement, the higher the degree of risk transferred to the private sector.

Figure 2.1 PPP models

Source: Modified from the Canadian Council for Public-Private Partnerships, Yescombe (2002), Ministry of Finance (2004), Renda and Schrefler (2006), and Yescombe (2007)

The general structure of a BOT project is shown in Figure 2.2, which includes various parties such as lenders, equity investors, EPC contractors, O&M contractors, service end users, and suppliers if apply.

Figure 2.2 Contractual structure of a BOT project

Source: Tiong (1992)

The PPP approach can bring benefits to the public sector, the private sector and the public members. It has been promoted to develop infrastructure projects. The benefits include the introduction of the private sector's financial sources, technical and managerial expertise and innovation, reduced lifecycle cost, proper risk allocation, improved quality of service and performance, and enhanced public management (The World Bank 1997, European Commission 2003, Ministry of Finance 2004).

2.1.2 Main research areas of PPP infrastructure

Research on PPP infrastructure embraces many areas that are interlinked among them. Kwak et al. (2009) summarized five main research areas of PPP infrastructure by conducting a comprehensive literature review on PPP-related research in the last 20 years. The five PPP research areas they identified were: government's roles and responsibilities, the concession selection, PPP risks, PPP finance, and the critical success factors and/or barriers for PPP projects. Ke et al. (2009) did a similar study on research trends in PPP from selected construction journals, and concluded that the major research interests in PPP from 1998 to 2008 were risk management, integration research, governance issue, investment environment, procurement, economic viability and financial package. Some selected references on PPP research are summarized in Table 2.2 by author's analysis.

Table 2.2 Selected references on PPP research

Main Research Area	Selected References	Key Findings	Comments/Remarks
Financing/financial viability	Ho and Liu (2002)	Authors developed an option pricing based model to evaluate financial viability of privatized infrastructure projects.	It is an alternative to traditional valuation method such as net present value analysis. It can account for the impact of the risks and project characteristics.
	Zhange (2005)	Author developed a methodology to optimize capital structure and assess financial viability of privatized public infrastructure project.	It is comprehensive framework that can incorporate analytical analysis, stochastic variables (risk factors), and other constraint factors.
	Laishram and Kalidindi (2009)	Authors developed a Desirability Rating Analytical Tool (DRAT) to assess the desirability of debt financing in PPP projects. Six dimensions of criteria were identified for PPP road projects including technology, construction and operational aspects; financial strength; demand risk; political and economic environment; contractual foundation; and counterparty exposure.	DRAT method uses Choquet fuzzy integral to aggregate the information, but it is subject to the quality of information.
Risk management	Grimsey and Lewis (2002)	Authors summarized nine general risks (technical risks, construction risks, operating risks, revenue risks, financial risks, regulatory/political risks, environmental risks, project default and force majeure risk) in any infrastructure project and examined various risks in different entities' perspective (procurer, sponsor, and lender).	It is important to assess risks in different entities' perspective, as objective of different entities in investing infrastructure are different.

	Sachs and Tiong (2009)	Authors developed a methodology for quantifying qualitative information on risks. Fuzzy set theory is applied in the QQIR method to transform the expert qualitative opinions on uncertain information to quantitative distribution.	The QQIR method can bridge the gap between qualitative and quantitative risk assessment methods.
	Demirag, Khadaroo et al. (2012)	Authors examined the risk diffusion process through PPP project network from financiers and the SPV to other contracting parties using various means such as insurance, performance support guarantees, interest rate swaps and inflation hedges, and challenged the economic value of risk transfer.	The paper presents empirical evidence to raise questions whether proper allocation of risks is achieved for value for money in PPP projects under implementation.
Government/public sector issues	Kumaraswamy and Zhang (2001)	Authors discussed the government role in creating favorable investment environments, project quality control, public satisfaction and national development for BOT projects.	It is comprehensive discussion on the government role in BOT infrastructure development.
	Tserng, Russell et al. (2012)	Authors analyzed the national PPP unit as an institution by defining it as an endogenous equilibrium outcome of the game by applying new institutional economics with game theory, and the model indicated that the common role of a national PPP unit is a trust-creator between the public and private sectors.	It is a pilot study by using new institutional economics with game theory to analyze the role of national PPP units.
	Boardman and Vining (2012)	Authors proposed some rules for governments to design and manage PPP projects for improved social welfare including: establishing a jurisdictional PPP transparency constitution; separating the analysis, evaluation, contract administration and oversight agencies; competitive bidding; partial government financing; using cost-benefit analysis to evaluate projects and selecting providers; standard and efficient dispute resolution; avoiding stand-	This paper presents a novel application of a theory of PPP participants' behavior and a social welfare benchmark.

		alone subsidiary and consortia's shells; prohibiting early exit of private sector; and no indemnifying bond holders.	
Procurement/tendering/ concessionaire selection	Tiong (1995a, 1995b, and 1996)	Authors conducted extensive research on tendering and negotiations of BOT projects including competitive advantage of equity, impact of financial package and technical solution, risks and guarantees in the BOT tender, and identified that the financial and technical strengths of the consortium are the most important critical success factors in a BOT tender.	The series of papers are the first milestone of academic research into PPP tendering.
	Akintoye, Hardcastle et al. (2003)	Authors concluded the factors to achieve best value for PFI projects which include detailed risk analysis and appropriate risk allocation, drive for faster project completion, curtailment in project cost escalation, encouragement of innovation in project development, and maintenance cost being adequately accounted for. Authors also summarized the challenges including high cost of the procurement process, lengthy and complex negotiations, difficulty in service quality specification, pricing of facility management services, potential conflicts of interests among various parties, and the public sector clients' inability to manage consultants.	It is comprehensive summary on factors and challenges to achieve best value in PPP projects.
	Kumaraswamy and Anvuur (2008)	Authors developed an integrated framework that unified technical, relational, and sustainability criteria for selecting sustainable PPP teams.	This paper presents an integrated decision-making framework beyond project-specific selection methodologies that have been previously developed.
Critical success factors/barriers	Zhang (2005)	Author identified economic viability, appropriate risk allocation via reliable contractual arrangements, sound financial package, reliable concessionaire consortium	The critical success factors are based on a public-private win-win principle and a systematic research

		with strong technical strength, and favorable investment environment as the most critical successful factors for PPP infrastructure projects.	approach. They are in general and not in any specific country context.
	Aziz (2007)	Author presented principles to characterize the PPP implementation at the program level and guidelines for successful implementation in aspects of legal framework and Institutional integration.	The guidelines for successful implementation of PPPs are in the context of the United States.
	Babatunde and Opawole (2012)	Authors identified the most critical success factors to the private investors including well-organized and committed public agency; social support; project technical feasibility and multi-benefits objectives; and also the most critical success factors to the public sector including transparency in the procurement process; shared authority between public and private sector; thorough and realistic assessment of the cost and benefits; commitment and responsibility of public and private sector; and strong and good private consortium	The critical success factors are in the context of Nigeria.

The following three sections will explore the areas of debt financing and refinancing in PPP infrastructure projects, risk management and real options theory that are relevant to this research in developing the “option to refinance” valuation (ORV) framework and the debt-refinancing optimization (DRO) model in PPP infrastructure projects.

2.2 Debt Financing and Refinancing in PPP Infrastructure Projects

2.2.1 Debt financing in PPP infrastructure projects

Debt financing usually takes a large portion of total financing (i.e. 70%) for PPP infrastructure projects. It can be in the form of bank loan or project bonds. Yescombe (2007) concluded three key factors of financing size, cost and term that affect the financial decision between bank loan and bond financing for PPP projects. A comprehensive comparison between bank loans and bonds is summarized in Table 2.3.

Table 2.3 Comparison between bank loans and bonds

Factors	Bank loans	Bonds
Size	<i>Smaller size</i>	<i>Larger size</i>
Cost	<i>Higher cost</i>	<i>Lower cost</i>
Term	<i>Shorter term</i>	<i>Longer term</i>
Amendment to terms	<i>Flexible</i>	<i>Rigid</i>
Investor involvement	<i>Early stage of the project</i>	<i>Late stage of the project</i>
Investor base	<i>A small number of banks in a loan syndication</i>	<i>The public can be the investor base in public issues</i>
Investors' control over project	<i>Banks have direct control over project</i>	<i>Investors have little control over project</i>
Confidentiality of project contract	<i>Confidential to the public</i>	<i>Information can be published in a public rating report or bond prospectus</i>
Interest rate	<i>Floating rate can be hedged</i>	<i>Normally fixed interest rate</i>
Funds drawdown	<i>Timely drawdown when needed</i>	<i>Full drawdown at once and redeposited</i>
Repayment	<i>Flexible loan repayment schedules</i>	<i>Fixed loan repayment schedules</i>

Prepayment	<i>Low or no penalties for prepayment</i>	<i>High penalties for prepayment</i>
Renegotiation with investors	<i>It is easier to negotiate with banks if the project gets into difficulty, and the content of negotiation remains private</i>	<i>It is difficult to negotiate with bond investors if the project gets into trouble, and the content of negotiations may be publicized</i>

Source: adapted from Yescombe (2007)

In general, bond financing is more favorable in terms of larger financing size, lower cost, fixed interest rate and longer maturity for infrastructure projects; however, the bond markets are not available or not efficient for some countries, especially developing countries. Bank loans are more flexible in terms of financing, repayment and negotiation, especially with banks that have direct control over the project, and the public exposure of project information is not required.

A typical debt profile in a PPP infrastructure project includes interest rate, maturity period, repayment schedule, prepayment clauses (if apply) and covenants etc.

Interest rate

A project finance loan normally has a floating interest rate, consisting of a base rate and a fixed credit margin. The base rate is short term, and adjusted periodically. A common base rate is the London inter-bank overnight rate (LIBOR). The floating rate can be hedged by interest rate swap. The bond issue can be based on a credit margin over government bonds of a comparable maturity. The fixed rate bond is charged at a pre-set fixed coupon rate.

Debt maturity

The maturity is normally long term, and can be for 10 to 30 years. Project-finance bonds could have an even longer term. In order to avoid confusion, the maturity of debt in this research refers to the period from the start of debt drawdown to the end of repayment period.

Repayment schedule

The repayment of the principal starts after a grace period in which only the interest is paid. The common repayment schedules are annuity repayment, equal principal repayment, bullet repayment and flexible repayment.

The structure of annuity repayment is illustrated in Figure 2.3. The periodic debt service payment remains the same over the maturity period of the loan after the grace period.

Figure 2.3 The structure of annuity repayment of debt facility

The structure of equal principal repayment is illustrated in Figure 2.4. The periodic debt service payment decreases over the maturity period after the grace period, because the periodic principal repayment remains the same but the interest payment is decreasing due to the decreasing outstanding balance.

Figure 2.4 The structure of equal principal repayment

The structure of bullet repayment is illustrated in Figure 2.5. The entire principal is repaid at the end of the maturity period. Many public issued bonds use this repayment structure.

Figure 2.5 The structure of bullet repayment of debt facility

There are some other structures of repayment that are more flexible, and can be known as flexible repayment. For instance, the repayment schedule could be proportionate to the operating cash flow linking to a constant cover ratio, or could be a preset percentage of the loan principal.

Prepayment clauses

Loan agreements can allow prepayment in part or full with or without penalties. Some loan agreements impose a no-call period, where the prepayment is only allowed after that period. In the case of project default or other preset conditions, the mandatory prepayment may be required by lenders so that the entire loan must be repaid.

Covenants

The project debt could include positive, negative and financial covenants that require the project company to fulfill or restrict certain conditions to reduce lenders' risk. The typical covenants are that the lenders impose a minimum limit to debt cover ratios. The common debt cover ratios used are debt service cover ratio (DSCR), loan life cover ratio (LLCR) and project life cover ratio (PLCR).

2.2.2 Debt refinancing in PPP infrastructure projects

2.2.2.1 Introduction

The UK Standardisation of PFI Contracts defines refinancing as following (HM Treasury 2007):

During the life of the Project, the Contractor may wish to replace, augment or change the structure, nature or terms of the financing solution that it put in place at Financial Close for the purposes of financing the Project.

In its broadest sense, refinancing can be any change to a project's original financing arrangements (National Audit Office 2002). Refinancing with the intention of improving the financing terms in a successful project can significantly improve the

private sponsors' returns and profit from the refinancing gains. The different ways such debt refinancing may operate are summarized in Table 2.4.

Table 2.4 Ways of debt refinancing

References	Ways of debt refinancing
(HM Treasury (2007))	<ul style="list-style-type: none"> • <i>Reduction in interest margins</i> • <i>Reduction or release of reserve accounts</i> • <i>Release of contingent junior capital</i> • <i>Extension in the maturity of debt</i> • <i>Increase in the amount of debt</i> • <i>Refinancings undertaken without the direct involvement of the contractor, but which rely upon rights being granted in respect of the cash flow, assets, or contracts of the contractor</i>
National Audit Office (2002)	<ul style="list-style-type: none"> • <i>Increase in the number of years over which the consortium will repay its financing</i> • <i>A change in the consortium's finance provider</i> • <i>A reduction in the margin used to determine the amount of interest payable on the financing</i> • <i>A reduction to the consortium's borrowing costs as a result of fixing interest rates lower for the balance of the contract term than had been expected at contract letting</i> • <i>A repayment to the consortium's shareholders of some or all of their equity or subordinated debt (usually facilitated by introducing into the project new finance from other sources)</i> • <i>Constraints on dividend payments have been removed or eased</i> • <i>A change in the financing arrangements that allows the reserve accounts to be reduced or released</i>
Yescombe (2008)	<ul style="list-style-type: none"> • <i>Reducing the interest cost</i> • <i>Increasing the debt amount</i> • <i>Extending the debt repayment term (reducing the tail)</i> • <i>Improving loan terms (e.g. reducing reserve-account requirements)</i>
Gatti (2008)	<p><i>Soft refinancing (waiver)</i></p> <ul style="list-style-type: none"> • <i>To free up cash from the debt service reserve account</i> • <i>To reduce spreads paid on the loan</i> • <i>The reduce restrictions imposed by covenants</i> <p><i>Hard refinancing</i></p> <ul style="list-style-type: none"> • <i>Change in the level of leverage</i> • <i>Change in the tenor of the loan</i>
Merna and Njiru (2006)	<ul style="list-style-type: none"> • <i>Loan refinancing</i> • <i>Bond refinancing</i>

There are few detailed studies on the role of debt refinancing in PPP projects from the perspective of project sponsors. This might be largely because the benefits of debt refinancing for project sponsors are obvious. In addition, there are many criticisms of the private sector gaining massive profits from debt refinancing in PPP

projects, thus the majority of the research on debt refinancing has focused on discussing possibilities and mechanisms of sharing refinancing gains between project sponsors and the public sector in the regulatory and government perspective for protecting public interests. The UK government takes the lead in this area, and has conducted extensive studies on debt refinancing in PFI projects (National Audit Office 2000, National Audit Office 2002, Committee of Public Accounts 2003, HM Treasury 2003, National Audit Office 2004, HM Treasury 2005, Committee of Public Accounts 2006, National Audit Office 2006, Committee of Public Accounts 2007, HM Treasury 2007).

2.2.2.2 Comparison of debt refinancing with alternative financial solutions

The purpose of undertaking debt refinancing can be classified into 4 categories: increase in project/equity value, hedging interest rate risk, hedging currency risk and rescuing distressed project.

Enhancing project and equity value

The strong incentive for undertaking debt refinancing is to improve project and equity returns. PPP infrastructure projects are normally financed by substantial amounts of debt to cover the capital costs. The project company normally can find new finance with better terms when the construction has been completed and stable revenue streams have been demonstrated. This is because much of the project risks have been reduced, and the existing debt can be renegotiated or refinanced on better terms. The project investors can make huge gains generated by this debt refinancing strategy, which can be conducted in various ways.

- **Debt refinancing: reduction in interest cost**

The project company can refinance the original debt at a lower interest rate if the market interest rate has gone down. Sometimes, debts are hedged by interest rate swaps that have a breakage cost for prepayment, or senior debts have prepayment penalties. In this case, refinancing may not bring significant gains because the breakage costs or penalties need to be paid off. More often the debt refinancing to enhance project profitability is to reduce credit margins in

floating debts. It can improve project cash flows to earn refinancing gains. The typical pattern of changes in equity cashflow is a series of increased equity cash flow streams after debt refinancing because the debt interest payment is reduced if the total debt amount remains the same (HM Treasury 2003).

- **Debt refinancing: increase in the amount of debt**

Debt refinancing can be undertaken by raising a larger amount for the new debt than that of the original debt in the project. An increase in the amount of debt will change the leverage level of the project. The increased amount of new debts essentially replaces a certain amount of equity, and the project sponsors benefit from immediate equity payback. The debt service payments will increase over the remaining term of the debt due to the increased debt amount. The problem of this way of refinancing is that if project sponsors hold very small shares of equity in the project, there is little incentive for them to perform well continuously, especially if they have been rewarded well by the early equity payback, and their expected return from the project has been earned. In addition, the termination liability will be increased for public authorities in the case of default. The typical pattern of changes in equity cashflow is a single increased cash flow immediately after the refinancing, and decrease in subsequent cash flow streams due to increased debt service payments (HM Treasury 2003). There is a tradeoff between early equity gains and delayed debt payment. The early payback effect of equity normally has higher time value in NPV than the delayed payment in later years, thereby, the total equity NPV is normally increased.

- **Debt refinancing: extension in the maturity of debt**

Debt refinancing can be undertaken by extending the original debt's maturity, or refinancing a new debt with a longer maturity. The principal repayment is decreased in the early years after refinancing, because it can spread into a longer term. The typical equity cashflow pattern is a series of increased cashflow streams in the early years after the refinancing and decreased cashflow streams in the later years as the delayed debt payment will be paid then (HM Treasury

2003). Over the life of the project, the total accumulated interest payment is increased as the repayment period is lengthened. The total accumulated equity payback after the refinancing is decreased as more cashflows are required to pay interest payments. However, the investors' equity IRR might still be improved because the equity payback is increased in early years after refinancing given the higher time value of money. One concern on the maturity extension is that a project normally has a tail period after maturity of the debt to provide some safety margin for debt repayment. When the maturity is extended, the tail period will be shortened. If the project has a sufficient tail period after maturity of the debt then the lenders would be still comfortable to extend the maturity. Sometimes, the maturity of debts is extended together with the extension of the concession period.

- **Debt refinancing: improvement in other debt terms**

If the success of the project is demonstrated, the original loan terms can be improved in many aspects. This includes reduction or release of reserve accounts, release of contingent junior capital, reduced restrictions imposed by covenants and so on. Those transactions can be considered as debt refinancing in the broader sense of changing the original financing terms and conditions. The equity cash flow positions can be improved as less cash is held by the project, and the balance eventually goes to equity investors.

The refinancing of the Fazakerly PFI prison in UK is one example to enhance equity value and gain to investors. The project was originally financed in 1995 by bank loans of £92.5 million, which was refinanced after construction in 1999 via a decreased lending margin, extended maturity period from 19 years to 22 years and improved terms of the early repayment of the subordinated debt by shareholders. As a result of refinancing, the expected equity returns have been increased by £10.7 million compared to the original projected £17.5 million at the time of the contracted awarded in 1995 (National Audit Office 2000, Asenova, Beck et al. 2007).

Another example is the refinancing of the Norfolk and Norwich PFI hospital in UK in 2003. The refinancing increased the original borrowing amount by 53% from £200 million to £306 million and extended the maturity due date from 2018 to 2035 by replacing the senior bank debt repayable in 2018 with bond issues repayable by 2035. As a result, the total refinancing gain was £116 million and the investor's rate of return was trebled from 19% to 60% (Asenova, Beck et al. 2007, Committee of Public Accounts 2007).

- **Alternative financial solutions**

There are a few alternatives to compete with debt refinancing for return enhancement. They are illustrated in Figure 2.6.

Figure 2.6 Debt refinancing and alternative financial solution for enhancing project and equity return

Short-term construction loans can be used to finance capital projects during the construction phase, with the expectation of being refinanced after the completion of construction. The repayment of a construction loan is structured as a balloon or bullet repayment whereby the principal will be repaid at the end of the loan term. A construction loan may be cheaper than a long-term project loan, given the short-term nature of such loan. In addition, lenders may be more

willing to provide short-term lending than the project finance loans that have the long-term uncertainty of the credit risk of a project. With optimistic expectations, the short-term construction loan, followed by undertaking a long term debt after construction completion such as project bonds, would be cheaper than a long-term project finance loan which covers both construction and operation phases. The lower capital cost can enhance the project and equity value. Actually the structure is almost the same as the structure of debt refinancing. The difference is that in this type of debt refinancing, the initial debt in a PPP project is on a long-term basis, and thereby the project has the flexibility to decide whether to refinance or not upon market and project conditions at a future date. However, the construction loan with bullet repayment is on a short-term basis and has to be refinanced before or at the maturity date. Therefore, the construction loan has significant refinancing risk, and it might be difficult to find a new debt to repay the construction loan when it is due. It is also subject to the market conditions at the time of maturity of the construction loan. The refinancing risk is the primary concern of borrowing such loans. The financial crisis that started in 2007 dried up the market liquidity, and banks were reluctant to provide funding. The credit margin and base rate were increased significantly, and all the capital markets were in a downturn. Construction loans that matured in that period faced significant refinancing risks. It was difficult to find additional sources of finance to repay the loan, or it was refinanced at much higher cost. “Mini-perm” is one type of construction loan commonly used in project finance, and is popular in United States. The UK has very few PPP projects using mini-perm structure for financing, basically because it increases the risk exposure for private sector investors and causes the affordability issues for the public sector (KPMG 2009). In addition, UK markets are still willing to provide long-term funding for PPP projects. That is why mini-perm is not common in UK PPP projects.

Equity sale involves selling equity shares of a project to secondary investors. It normally takes place after completion of construction. The secondary investors come in with a lower expected return. The original project investor can earn

great gains because of immediate equity payback compared with the projected long-term equity cashflows. It has a similar structure to debt refinancing of increasing the debt amount in the way of early equity payback to investors. The advantage of equity sale is that it is less regulated by the government and it may not be necessary to share the gains from the equity sale with the public authorities. In contrast, the gains arising from debt refinancing must be shared with the public authorities in some countries, such as the UK and Korea. However, if the project sponsor decides to sell its equity, the control of the project will be lost. Its role in management and investment decisions will be replaced by the secondary investors. The future cash flow is no longer relevant to the original project sponsors.

Hedging interest rate risk

Interest rate risk arises from adverse movements of interest rates. For borrowing/lending at floating interest rates, the interest rate risk comes from the increased interest payment or decreased interest income due to the change in interest rates. For investors in fixed-rate debt securities, such as fixed coupon bonds, the risk comes from the decreased value of the security due to increase in the interest rate, and this is also called as price risk. For PPP infrastructure projects, the project finance lending is normally on a long-term basis at a floating interest rate with a credit margin, therefore, the interest rate risk will result in higher interest costs, and reduce the profitability of the project.

- **Refinancing with a new fixed-rate debt instrument**

The interest rate movements are two-way, either increasing or lowering the interest costs. PPP infrastructure projects are heavily leveraged, and the size of the debt amount is significant and can be up to 90% of the total capital cost. In this case, the exposure to interest rate risk is huge. Debt refinancing can hedge the interest rate risk by refinancing the existing floating-rate debt with a new fixed-rate debt instrument. Normally, an issuance of fixed coupon bonds is undertaken to replace the existing floating rate loan, usually after the completion of construction.

The example could be the Fazakerley PFI prison as well. Its refinancing also included the arrangement of a fixed rate of interest covering the full period of the refinanced loan (National Audit Office 2000).

- **Alternative financial solutions**

Besides debt refinancing, there are a few financial instruments that are commonly used in industry to hedge the interest rate risk. These are shown in Figure 2.7. The alternative instruments are forward rate agreement (FRA), interest rate future, interest rate option and interest rate swap.

Figure 2.7 Debt refinancing and alternative financial solutions for hedging interest rate risk

FRA can be used to lock in interest rates by entering a series of FRA transactions matching each interest payment period. The borrowing cost of the project company is different in each period, but is fixed in advance by FRA. One of FRA's advantages is that each FRA is customized so that it can match specific features of project loans.

The interest rate future is a similar instrument to FRA, and can be used in a similar way to hedge interest rate risks. The difference is that the interest rate

future is a standardized contract so that it may be not able to match the terms of project loans exactly; therefore re-adjustment is needed to hedge interest rate risk. For instance, the Eurodollar future is based on 90-day LIBOR, while the interest rate of a project loan can be based on 180-day LIBOR. However, interest rate futures have less default risk and more liquidity than FRA. Both FRAs and interest rate futures have no upfront cost to enter.

In contrast, interest rate options incur premium costs upfront. The different instrument of interest rate options can be used to hedge interest rate risks in different ways. An interest rate call can be used to hedge increase in the interest rate of a short-term loan with bullet payment. An interest rate cap can be used to limit the upside of interest payments for multiple periods. An interest rate collar can lock in a certain range of interest rates. The major advantage of options is that the interest rate risk is hedged without limiting the potential to gain from favorable interest rate movements.

Another alternative is interest rate swap which is the most commonly used instrument to hedge interest rate risks. An interest rate swap can be entered to pay a fixed rate and receive a floating rate. It is easier to implement than forwards, futures and options, because the interest rate swap is basically long one rate and short another rate so that it does not need to respond to market movement when making claims. It has considerably less credit risk because of netting the payment and not exchanging the notional principal.

The debt refinancing of replacing the existing floating rate loan with a fixed-rate debt instrument such as a bond can provide a long-term hedge of interest rate risk, however, it is complicated in arranging the refinancing deal. The alternative instruments used to hedge interest rate risks are comparably easier to implement. For instance, interest rate swaps, as the most common interest rate hedge instruments, are often provided by banks and dealers. The debt refinancing to hedge interest rate risk can be coupled with other means of return enhancement. It is usually undertaken after the completion of construction when the risk profile of a

project is reduced and more favorable terms for a new debt can be obtained. It often takes advantages of a bond issue which provides fixed rates, larger debt amount and longer maturities. A decent tradeoff analysis for each solution for hedging interest rate risks need to be conducted for decision making. The main factors in the analysis include the size of interest rate exposures on a specific project, the risk tolerance of the project company, the costs and resources that need to be used for implementing a specific solution, and the potential benefits of the strategy.

Hedging currency risk

Currency risk arises from the adverse movement of exchange rates. For assets or liabilities denominated in a foreign currency, the adverse movement of exchange rates can lead to depreciation in asset values or appreciation in liability values. For contracts with foreign currency payments or receipts, the adverse movement of exchange rates can lead to increased payments or reduced income. The foreign exchange rate risk can be categorized as economic exposure, translation exposure and transaction exposure (Bartram, Dufey et al. 2005). Economic exposure is the impact on the company value in response to movements of foreign exchange rates. It relates to the future potential transactions and is on a long-term basis. Transaction exposure is the impact of exchange rate movements on current contracted or planned transactions. The transaction could be international trades and financing deals in foreign currency. Translation exposure is the impact of currency risks on the accounting measures of a company. For instance, the asset value of a foreign subsidiary under a multinational corporation needs to be reported in a consolidated balance sheet denominated in the domestic currency. The domestic value of the foreign assets may decline due to depreciation of the foreign currency. In Asia, PPP infrastructure projects often raise capital in the developed bond and banking markets, which can offer competitive terms not available in domestic debt markets. A common case in Asia is that the debt raised for PPP projects is denominated in hard currency, while infrastructure revenues are denominated in local currencies. The mismatch leaves PPP infrastructure projects expose to currency risks.

- **Refinancing with a new debt instrument denominated in a matched currency**

Similar to interest rates, the exchange rate movement is two-way. If the exchange rate exposure is not fully hedged, possible gains can be speculated in expecting the favorable movement of exchange rates. The debt refinancing to hedge currency risks can be conducted by refinancing the original debt with another debt denominated in a currency in which revenues are collected. It realigns the currency mismatch of debt capital and revenues.

- **Alternative financial solutions**

Some alternatives to hedge currency risks are illustrated in Figure 2.8. Currency forwards, futures, options and swaps are financial derivatives available in the market. The conversion of currencies for a single cash flow stream can be done by currency forwards, while the conversion of a series of cash flow streams can be managed by currency swaps. Currency futures are primarily used by dealers to manage foreign exchange portfolios. Tariff adjustment is a currency risk mitigation measure applying to a specific project upon negotiation among investors, the service offtakers and the government. It is specified in the concession or purchase agreement. Those alternative financial solutions compete with debt refinancing in achieving currency risk hedging.

Figure 2.8 Debt refinancing and alternative financial solutions for hedging currency risk

Both currency forwards and futures can hedge currency risks by entering a contract to short one currency and long another to lock in the exchange rate of a particular currency against another one in a future date. Currency forwards are customized contracts that can be tailored to meet the specific requirements of a project, while currency futures are standardized contracts which are difficult to be used in PPP infrastructure projects, as each project is unique and different. However, currency futures have less default risk than currency forwards, because the standardized contracts are traded in clearinghouse and guaranteed against default. Both currency forwards and futures have deep liquidity, therefore the cost of hedging is comparably less than using currency options. If the exchange rate movement is expected to be unfavorable, forwards and futures could be used rather than currency options.

Currency options can be used in amounts equal to the currency to be hedged. They have the advantage of asymmetric hedge, but higher costs. The asymmetric hedge preserves the opportunities of gains from favorable exchange rate movements, and also provides insurance against adverse currency movements. It is less liquid than forwards and futures, and the

payment of premium is made upfront. Another hedging technique is a full currency-option hedge whereby the total value of foreign assets covered will not change despite of the movement of exchange rates. It takes consideration of the relationship between the option premium and the exchange rate movements. The hedge is dynamic and requires sophisticated skills to rebalance. If the exchange rate movement is expected to be volatile without indication of direction, currency options could be used rather than futures to preserve the potentials for gains from favorable movement of exchange rates.

A currency swap is equivalent to borrowing in one currency and lending in another currency. It can effectively convert a loan denominated in a foreign currency to a loan denominated in the local currency. There are some common types of currency swaps: fixed-to-fixed swaps pay a fixed rate in one currency and receive another fixed rate in another currency; fixed-to-floating swaps pay a fixed rate in one currency and receive a floating rate in another currency; floating-to-fixed swaps pay a floating rate in one currency for a fixed rate in another currency; and floating-to-floating swaps pay a floating rate in one currency for another floating rate in another currency. The swap contracts can be customized, and can match loans with longer maturity. The payment in a currency swap is not netted. The principals in two currencies have to be exchanged on the effective date and returned at the maturity date. The interest payments by the two parties also have to be exchanged each period. Therefore, currency swaps have a much higher credit risk than forwards, futures and options. However, they are still a very popular hedge instrument to manage currency risks.

Tariff adjustment is a payment mechanism that passes a certain level of currency risks to the end users. The tariff component can be adjusted periodically by certain foreign exchange indices. It transfers the risk away from project sponsors. However, sometimes the foreign exchange is too volatile, the adjusted tariff might fall in an unacceptable range that

jeopardizes the interests of the public, and the public authority will generally not allow this situation to happen. It is important for the government and the project company to negotiate and set up a reasonable tariff adjustment mechanism. It is an effective mitigation measure in hedging currency risks.

The debt refinancing of issuing project debt in another currency to match with currency of revenues or costs may be not advantageous, given the variety of measures available to hedge currency risks, as discussed above. The debt refinancing is a complex and time-consuming process, and further it might involve another debt market of which the project sponsors may have limited knowledge. For hard currencies, it might be easier to find relevant sources for lending. For currencies in developing countries, the local bond markets and lending systems are still developing, and it may be difficult to raise the huge amount of debt finance that is normally in PPP infrastructure projects. Further, international lenders may be not able to lend in local currencies. The cost of using debt refinancing as a currency hedge strategy is high. Without other hedge measures, it is possible to carry out debt refinancing in this way under the condition of significant currency exposures and highly volatile exchange rate movements. The debt refinancing of borrowing in another currency is most likely undertaken along with other means to increase project and equity returns. It normally takes advantage of bond issues that can raise larger amounts of capital, and have longer maturities.

Rescuing a distressed project

Financial distress occurs when a company has difficulties in making debt payments as scheduled. Sometimes financial distress can lead to bankruptcy. If the financial difficulty is perceived to be temporary, informal reorganization is preferred rather than formal bankruptcy in most cases to avoid the expensive costs, strict legal procedures and substantial time spent for formal bankruptcy. The lenders may postpone the debt payment to a later date or reduce their claims or raise additional debt to help the company to recover from the financial distress. The reason that lenders could do this is that they may lose more if the company goes into

bankruptcy which sometimes takes years in formal proceedings with expensive overall costs.

- **Rescue refinancing**

The debt refinancing carried out to mitigate the financial difficulty of a project is also called debt restructuring or rescue refinancing. Lenders would be careful and reluctant to lend a distressed company with additional debts unless they have strong faith on the company's ability for financial recovery. New bonds can be issued for restructuring. The distressed bonds are likely to be below investment grade. Some institutional investors and pension funds are not allowed to invest in below-investment-grade securities, by regulation or investment policy.

- **Alternative financial solutions**

There are some alternative financial solutions that can be used to rescue a company from financial distress. Some of them are shown in Figure 2.9. Standby credit is a credit facility that will be provided during a given period if the company requires it. It is normally a fixed amount agreed ahead between lenders and the company. When severe financial distress occurs, it usually cannot provide additional financing above the amount agreed ahead. Another alternative is equity injection whereby equity investors make additional equity commitments in order to solve the financial problem. Naturally, equity investors will bear more risks. The company can issue new equity securities, and they may be undervalued due to current financial distress. This would increase the capital cost of the company.

Figure 2.9 Debt refinancing and alternative financial solutions for rescuing a distressed project

Decision-Making framework of undertaking debt refinancing

Undertaking debt refinancing is a complex and time-consuming process. A thorough decision-making process is needed, as shown in Figure 2.10. Whether to respond to a specific problem or target depends on the severity of the problem or incentive of the target, and the attitude of the project company towards the problem or target. If the problem does not significantly affect the operation and profitability of the project, or the project company can tolerate the problem to certain extent, there would be no action taken in response to the problem. For instance, some project companies will not hedge currency risks if their risk exposure is limited.

If there is a need for management to conduct further assessment, a corresponding way of debt refinancing is proposed to solve the problem, or achieve the target. Alternative financial solutions are also proposed, competing with the debt refinancing for the best solution for the project. Cost benefit analysis is conducted to assess the advantages, disadvantages and relevant costs of implementing debt refinancing and each proposed financial solution. Together with understanding the severity of the problem and the attitude and willingness of the project company, the project company can make decision on whether it is worth implementing a specific

solution. If the implementation incurs significant costs and resources which offset the benefits of the solution, the project company will conduct no further action. The costs of undertaking debt refinancing are normally not cheap. If the overall assessment shows that the debt refinancing can effectively solve the problem or achieve the target, outperform other solutions and match the expectations of the project company, it can be implemented. Sometimes, other financial instruments that are available in the market can provide better solutions. In that case, it is not necessary to undertake debt refinancing.

Figure 2.10 Decision-making process of undertaking debt refinancing

2.2.2.3 UK's development of debt refinancing for PFI projects

The PFI model is used to deliver PPP infrastructure projects in the UK. Up to the end of 2005, 780 PFI projects in the UK had been signed with a capital value of over £ 53 billion (International Financial Services 2006). Two main factors associated with negative publicity for PFI refinancing deals in the UK are massive private sector profits in past refinancing deals, and no refinancing gain being shared with the public sector (Asenova, Beck et al. 2007).

In 1997, the Treasury PFI panel guidance on further contractual issues suggested that the public sector should try to capture some of the benefits from debt refinancing. In 1999, the HM Treasury Standardisation of PFI Contracts recommended that it may be appropriate to share refinancing gains between private and public sectors in limited circumstances (National Audit Office 2002).

In June 2000, the National Audit Office (NAO) produced a report on the refinancing of the Fazakerley prison project (National Audit Office 2000). The refinancing improved the expected return of the Fazakerley Prison Service Limited (FPSL) by £10.7 million, 61% of the originally projected level of £17.5 million at the time the contract was awarded. The Prisons Service received £1 million from FPSL as compensation for increased termination liabilities. In July 2002, the UK Office of Government Commerce (OGC) published revised guidance for government departments to share refinancing gains 50/50 in new PFI contracts from private sponsors. In October 2002, the OGC launched a voluntary code of conduct ("the Code") for early PFI deals. Under the Code, government departments will generally seek to receive 30% of any future refinancing gains on early PFI deals where the contract does not explicitly contain an arrangement to share the gains. The early PFI deals, from before July 2002, are likely to have the greatest potential for debt refinancing gains. In 2003, the OGC expected the public sector to receive £175 to £200 million of debt refinancing gains from the introduction of the Code (Committee of Public Accounts 2007).

A summary of refinancing deals in the UK before February 2006 is shown in Table 2.5. Twenty refinancing deals occurred before October 2002 when the code was launched, the total refinancing gains obtained by private sectors was £23 million, but the government did not receive a share of the gains. Another twenty refinancing deals occurred after the Code, thereby, the government was entitled to share £72 million out of total gains of £247 million. Among about 500 early PFI contracts, there were around 150 deals that could have possible refinancing under the Code in the future. Only one refinancing deal was undertaken after October 2002, the London Underground project, for which the refinancing gain-sharing was the subject of a contractual arrangement. There were approximately 150 PFI projects that had a similar contractual sharing mechanism.

Table 2.5 Refinancing deals in the UK up to February 2006

	No. of deals	Value of total refinancing gains	Government share of refinancing gains
Refinancings before the Code	20	£23 million	0
Refinancings as part of the voluntary sharing arrangement under the Code	20	£247 million	£72 million
Refinancings since the Code with a contractual sharing mechanism	1	£70 million	£42 million

Source: National Audit Office (2006)

Refinancing gain and the sharing

HM Treasury (2003) published a guidance note about the calculation of debt refinancing gains. HM Treasury (2007) used the original base case equity internal rate of return as the discount rate for project cash flow, and it also discussed the inappropriate use of the equity IRR excepted by investors at the time of refinancing, the project IRR and senior debt interest rate as the discount rate. NAO (2006) summarized five sources of refinancing gains: the maturing PFI market that becomes more available for financing and less risky in PPP investments, reduced risk after the construction phase, better underlying rates of interest, increased borrowing and contract extension (National Audit Office 2006). Although the refinancing could generate gains, it can increase the termination liabilities and may jeopardize the VfM. It also could leave scant incentives for private sponsors to continue operating the

project successfully if the private sponsors have obtained sufficient gains from refinancing. The government needs to scrutinize refinancing deals to ensure VfM of PPP projects. The party that bears the risks should benefit from the refinancing gains. Therefore, it is appropriate for the government to share the gains when it shares the risks from refinancing.

The public sector can take its share of the refinancing gain in either a lump-sum payment or unitary charge reduction over time (HM Treasury 2003, HM Treasury 2007). Most public sector departments chose to take the gain as a lump sum, partly because the public sector could immediately benefit from the refinancing.

The introduction of the refinancing gain sharing mechanism makes the private sector even more cautious to make decision on refinancing, as a portion of the gains will be taken by the public sector. Further, undertaking debt refinancing is a time-consuming and complex process. Therefore, a detailed study on debt refinancing for private sponsors is needed for them to be more confident in planning and making decisions on debt refinancing, and the financing resources can be more efficiently allocated.

2.3 Risk Management in PPP Infrastructure Projects

2.3.1 Introduction to Risk management

In the UK, the Orange Book compiled by HM Treasury defines risk as the uncertainty of outcome, whether positive opportunity or negative threat, of actions and events (HM Treasury 2004). Tinsley (2000) defines risk as any factor which will change the expected/projected project cash flow. Grimsey and Lewis (2002) summarized nine general risks (technical risks, construction risks, operating risks, revenue risks, financial risks, regulatory/political risks, environmental risks, project default and force majeure risk) in any infrastructure project and examined various risks in different entities' perspective (procurer, sponsor, and lender). It is important to assess risks in different entities' perspective, as objectives of different entities in investing infrastructure are different. Tiong et al. (1999) identified various risks in the power, transport, processing plant and telecommunication sectors. The guidelines provided

by the UN/ECE list eleven risk factors: development risk, construction risk, technology risk, performance/operation risk, market risk, political risk/change in law/change in tax, interface risk, macro-economic risks, revenues risk, *force majeure* risk, and documentation risk (United Nations and Economic Commission for Europe 2000). Wang et al. (2004) categorized risks into country, market and project levels respectively. Despite of different classifications of risk factors in various literatures, the nature of risks remains the same as the uncertainty to project cash flow and project outcomes.

Risk management is a process to identify, prevent, contain, and mitigate risks in the interests of the project. Partnership Victoria (2005) concludes the risk management cycle includes risk identification, risk assessment, risk allocation, risk mitigation and monitoring and review. Ye (2001) proposed a risk management framework for PPP infrastructure projects illustrated in Figure 2.11. Proper risk allocation is key to ensure value for money outcomes in PPP infrastructure projects. The underlying principle of allocation is that the risks need to be allocated to the party who is able to manage the risks efficiently.

Figure 2.11 Risk management framework

Source: Ye (2001)

2.3.2 The cycle of risks in PPP infrastructure projects

The nature of the risk alters in different project phases (Grimsey and Lewis 2002). The life cycle of a project can be broadly divided into the five phases of planning, design and engineering, construction or procurement, commissioning, operation and decommissioning (Pretorius, Lejot et al. 2008). The project's risk profile changes during the life cycle, as illustrated in Figure 2.12. Tiong (1992) viewed any PPP infrastructure project as having two distinct phases: a relatively high-risk construction phase and a relatively low-risk utility phase. As there is a trade-off between risk and

reward, it is reasonable to assume a higher expected return in the pre-completion phase and a lower expected return in the post-completion phase.

Figure 2.12 Risk profile during project lifecycle

Source: Pretorius et al. (2008)

Yescombe (2007) also estimated required equity return on different project phase as listed in Table 2.6

Table 2.6 Equity return on different project phase

Phase	Risk-free rate	Project risk	Phase Risk	Equity IRR
Construction	6%	2–4%	4%	12–14%
Ram-up period	6%	2–4%	2%	10–12%
Long-term operation	6%	2–4%	-	8–10%

Source: Yescombe (2007)

Chan and Woodward (1992) defined risk profiles broadly over the term of a PPP projects, and those rudimentary models make it difficult to ensure that all risks are

appropriately managed and priced during all stages of a project. Other researchers, such as Merna and Owen (1998) and Schell (1995), also recognized that the risk profile is not a static process, and it adapts as the project progresses. Ng and Loosemore (2007) commented that the understanding of how risks change over the duration of a project is less well known.

2.3.3 Quantitative risk analysis

Quantitative risk analysis can be used to assess the range of possible project outcome. The four commonly used techniques in quantitative risk analysis are: expected monetary value, sensitivity analysis, decision tree, and modeling and simulation (Project Management Institute 2004).

Expected monetary value (EMV)

EMV is a statistical concept that calculates the average outcome under uncertainty. It is calculated as the product of the probability of occurrence and the potential severity of the impact of risk in monetary value. To assess the EMV of a project, the EMVs of its subparts are aggregated to give an overall EMV of the project (Akintoye, Beck et al. 2001). However, it lacks the distribution of the monetary value of the project to give investors a confidence level.

Sensitivity analysis

Sensitivity analysis helps to determine which risks have the most potential impact on the project. It evaluates the effect of a change in a single variable by analyzing its effect on the overall target (Martinez 2001). The main weakness of this technique is that the variables are treated individually, which makes it difficult to assess the effect of combinations among these variables, and also there is no indication of the probability of occurrence of the risks (Li 2003).

Decision tree

Decision tree is a diagram that depicts interactions between decisions and chance events. It represents all the logical possibilities of a sequence of events, where each event can occur in a finite number of ways. Each possible outcome is allotted a value, and these values multiplied by their probabilities are rolled back to the start of the

tree. The decision maker is directed to the final EMV. The decision tree approach can logically structure risk management process by identifying alternative action of risk mitigation measures (Dey 2012). However, with the number of possible outcomes and actions increases, it can be overly complex.

Modeling and simulation

The Monte Carlo simulation is one of the most common simulation techniques for risk analysis. It overcomes the limitations of static analysis by examining the outcomes of all possible combinations of variables (Clark, Reed et al. 2010). Monte Carlo is a sampling technique and normally serves as the basis for simulation. The uncertain variables are introduced with a range or distribution of possible values. The Monte Carlo procedure picks a random value from each of the uncertain variables and calculates the target value of the model repeatedly to generate a probability distribution of the target value (Martinez 2001). @RISK is a popular software application that adopts Monte Carlo simulation. In this study, @RISK will be used for risk analysis, in which, a following steps will be carried out:

- Identification of risk factors
- Assignment of probability distribution to each risk factor
- Simulation of the risk factors in model
- Output of the risk profile

2.4 Real Options

2.4.1 Introduction to option basics

2.4.1.1 Definitions

Traditionally, an option is a financial derivative contract that gives a party the right to buy or sell an underlying at a fixed price by a certain time in the future (Chance 2009). The fixed price is called the exercise price or strike price. Options have two types of a call and a put. A call option gives the holder the right to buy the underlying at a specific price; a put option gives the holder the right to sell the underlying at a specific price. In terms of exercise styles, options can be American or European style. American options can be exercised at any time before or at the expiration date.

European options can only be exercised at the expiration date. An American option has more flexibility than a European option in otherwise identical terms, so it is normally worth more.

2.4.1.2 Option payoff

There are four types of option positions:

- A long position in a call option: has the right to buy the underlying at a specific price on a future date.
- A short position in a call option: has the obligation to sell the underlying to the buyer of the call option if the long exercises the call option.
- A long position in a put option: has the right to sell the underlying at a specific price on a future date.
- A short in a put option: has the obligation to buy the underlying from the buyer of the put option if the long exercises the put option.

The payoffs of the four positions in European options are shown in Figure 2.13, where X is strike price, and S_T is the price of the underlying asset at maturity.

Figure 2.13 Payoffs of four positions in European options: (a) long call, (b) short call, (c) long put, and (d) short put

Source: Hull (2003)

The mathematical expressions of the four payoffs are summarized in Table 2.7.

Table 2.7 Payoff of options at maturity

Option position	Payoff
Long call	$\text{Max} (S_T - X, 0)$
Short call	$\text{Min} (X - S_T, 0)$
Long put	$\text{Max} (X - S_T, 0)$
Short put	$\text{Min} (S_T - X, 0)$

2.4.2 Real options in infrastructure projects

2.4.2.1 Introduction to real options

Real options are evolved from financial options theory, which was originated by the French mathematician Louis Bachelier in 1900. Bachelier characterized security price as a random walk and discussed the valuation of stock options (Smithson 1992). In 1973, Black and Scholes (1973) published the first general equilibrium solution for the valuation of options by recognizing that shares and calls could be combined to construct a riskless portfolio (Black and Scholes 1973). In the same year, Merton (1973) extended the Black – Scholes model by relaxing assumptions on dividend and interest rate (Merton 1973). The series of works by Merton, Black and Sholes were recognized by Nobel Prize, and provide foundation for analytic option valuation. In addition to Black- Scholes continues-time model, in 1979, Cox, Ross et al. (1979) initiated a binominal model which is a discrete-time model for numerical option valuation. The two works provided the foundation for future study of both financial and real options.

The origin of the term “real options” was attributed to Stewart Myers, who first identified the fact that many corporate real assets can be viewed as call options (Myers 1977). Consequently, the applications of real options in many sectors appeared in the literature. Lander and Pinches (1998) grouped the literature on real option applications into: natural resources, competition and corporate strategies, manufacturing, real estate, international, research and development (R&D), regulated firms and utilities, merge and acquisition (M&A) and corporate governance, interest rates, inventory, labor force, venture capital, advertising, law, firm behavior, and

environmental compliance and conservation. Trigeorgis (1993,1995) and Lander and Pinches (1998) broadly classified real options into different types including options to defer; options to abandon; options to switch inputs, outputs or risky assets; options to alter the operating scale; growth options; and options of staged investment. Given the complexity of infrastructure projects, the classification of real options is not limited to those categories in infrastructure projects. A general comparison between financial options and real options is summarized in Table 2.8.

Table 2.8 Comparison between financial options and real options

Factor	Financial options	Real options
Maturity	<i>shorter</i>	<i>longer</i>
Underlying assets	<i>equity or other financial asset</i>	<i>free cash flows of a project</i>
Influence of managerial actions	<i>no influence on option valuation</i>	<i>increase in strategic option value by flexible managerial action</i>
Value	<i>usually small</i>	<i>large</i>
Influence of competition and market	<i>irrelevant to option value</i>	<i>driver for the value of a strategic option</i>
History	<i>more than three decades</i>	<i>a recent development in corporate finance within the last decade</i>
Valuation methods	<i>usually solved using closed-form partial differential equations and simulation/variance reduction</i>	<i>usually solved using closed-form equations and binomial lattices with simulation of the underlying variables, not on the option analysis</i>
Information availability	<i>marketable and traded security with comparables and pricing information</i>	<i>not traded and proprietary in nature, with no market comparables</i>
Contract	<i>formal contracts with explicitly specified terms</i>	<i>often no formal contracts, or even not contractual at all</i>
Transaction cost	<i>likely lower transaction costs or taxes</i>	<i>likely higher transaction costs or taxes</i>
Focus of analysis	<i>option valuation</i>	<i>best management/investment decision alternative</i>
Realization of potential benefits from the exercise of options	<i>Financial option holders can always realize potential gains when they choose to do so due to specifications in the formal contracts</i>	<i>Real option holders sometimes cannot realize potential benefits from exercising real options due to the lack of formal contracts</i>
Option exercising rules	<i>clear-cut exercising rules</i>	<i>sometimes no clearly-set exercising rules</i>
Valuation accuracy	<i>important</i>	<i>less important than having a general idea of the correct decision</i>

Source: Li (2007), Mun (2003), and Rees (2008)

The study of real options was developed partly because of dissatisfaction with traditional capital budgeting techniques. The net present value rule and other similar capital budgeting techniques were found to be inadequate because they cannot properly capture the flexibility of management that can adapt and revise investment decisions over time in response to unexpected market conditions or when the uncertainty of a project becomes known (Trigeorgis 1993).

The problems of the traditional net present value analysis have been addressed by many researchers (Lai and Trigeorgis 1995, Teisberg 1995, Schwartz and Trigeorgis 2001, Mun 2002, Rees 2008). The traditional approach to valuing investment projects is discounted cash flow (DCF) analysis which is based on NPV. The risk-adjusted discount rate reflects the risk of the project cash flows, and the future cash flows are projected to be deterministic and fixed. It may underestimate the true value of a project as the analysis does not account for any explicit response to risk. In addition, Mum (2002) summarized some other potential problems of the DCF analysis, including undervaluing an asset that currently produces little or no cash flow, the nonconstant nature of the weighted average cost of capital discount rate through time, the inaccurate estimation of an asset's economic life, forecasting errors in creating the future cash flows, and insufficient tests for plausibility of the final results. On the other hand, real option analysis can mitigate some of these problematic areas. Particularly, real option analysis takes into account managerial and strategic flexibility to respond to future uncertainty.

2.4.2.2 Application of real options in infrastructure projects

The previous studies on application of real options in infrastructure projects have been summarized in Table 2.9.

Table 2.9 Selected references on application of real options in infrastructure projects

Reference	Key findings	Real options valued	Valuation method/model developed
Ho and Liu (2002)	Authors developed an option pricing based model to evaluate financial viability of privatized infrastructure projects.	<ul style="list-style-type: none"> • Government debt guarantee • Negotiation for rescue 	Black- Scholes formula is the basis to develop this option pricing based model.
Yiu and Tam (2006)	Authors proposed a real options model to explain the under - pricing phenomenon in construction tenders.	<ul style="list-style-type: none"> • Uncertainties of cost items and choices to defer and switch modes of construction in tender 	Binomial method is used.
Cheah and Liu (2006)	Authors valued government supports in infrastructure projects as real options using Monte Carlo simulation of a discounted cash flow model.	<ul style="list-style-type: none"> • Revenue guarantee • “Repayment” from the concessionaire to the government (a cap for the private sector’s return) 	Monte Carlo simulation of a cash flow model is used.
Ashuri, Kashani et al. (2012)	Authors developed a market-based option pricing approach to value minimum revenue guarantee and traffic revenue cap options.	<ul style="list-style-type: none"> • Minimum revenue guarantee • Compound options of minimum revenue guarantee and traffic revenue cap 	Binomial lattice with Monte Carlo simulation is used.
Smit (2003)	Author combined real option theory and game theory to capture the value of growth opportunities in airport expansion.	<ul style="list-style-type: none"> • Expansion option 	The discrete time binomial method from real option theory is selected and a combination of real option theory and game theory is applied.
Bowe and Lee (2003)	Authors valued multiple embedded real options in the Taiwan High-Speed Rail project.	<ul style="list-style-type: none"> • Option to defer • Option to abandon • Option to contract • Option to expand • Option to switch use 	The log-transformed binomial algorithm is used.

Chiara, Garvin et al. (2007)	Authors developed a methodology to value a revenue guarantee as a simple multiple exercise option in a BOT project.	<ul style="list-style-type: none"> • A revenue guarantee as a simple multiple exercise option where an option can be exercised M times on specified N dates during its life 	Least-squares Monte Carlo method is used to generate N simulated paths for backward dynamic programming.
Tseng, Zhao et al. (2009)	Authors developed a real option based methodology to estimate contingency in a construction project.	<ul style="list-style-type: none"> • Contingency to cope with uncertainties of schedule and cost overruns 	A trinomial lattice with a backward stochastic dynamic programming is used.
Menassa, Mora et al. (2010)	Authors developed a real option based methodology to value project-specific dispute resolution ladder investments in construction projects	<ul style="list-style-type: none"> • Dispute resolution ladder to deal with claims and change orders in construction phase 	Black- Scholes formula is the basis to develop this option pricing based model
Ho and Liao (2011)	Authors developed a fuzzy binomial valuation methodology to evaluate investment projects with embedded real options.	<ul style="list-style-type: none"> • Option to defer • Option to abandon • Sequential multiple options 	Fuzzy binomial approach is used.
Park, Kim et al. (2013)	Authors developed a real option-based contract model to value real options in revenue and expense agreement in water and sewer systems projects to ensure appropriate risk sharing between private and public sectors.	<ul style="list-style-type: none"> • Maximum expense limit • Maximum revenue limit 	Binomial model with Monte Carlo simulation is used.
Galera and Solino (2010)	Authors developed an option-based methodology to value clauses of highway concessions that have operational flexibility.	<ul style="list-style-type: none"> • Minimum traffic guarantee 	Black- Scholes formula is the basis to develop this option pricing based methodology
Grino, Ranieri et al. (2011)	Authors developed an option-based methodology to value price cap mechanism which provides fair incentive between the regulator, the community and the firm for fair risk allocation among parties.	<ul style="list-style-type: none"> • Price cap mechanism 	Monte Carlo simulation is used.

The previous studies on real options in infrastructure have analyzed various options such as government guarantee, project contingency, expansion options and price cap. There is no literature to recognize the intangible value of the flexibility created by the future debt refinancing opportunities that project sponsors can refinance the existing debt for better financial terms at a future date, and also such flexibility is not identified and structured as a real option in the existing literature. In terms of valuation methods, the Black-Sholes model and binomial model are the main basis for the real-option based methodology with the development of other modeling methods such as Monte Carlo simulation and Fuzzy logic. However, in order to quantify the flexibility created by the future debt refinancing opportunities, i.e. the “option to refinance”, which is similar to an embedded bond option, the Black-Sholes model is not suitable as the use of the Black-Scholes model to price bond options directly by treating the spot bond price as the underlying is subject to the criticism that it cannot address the issue of the pull-to-par phenomenon of the bond. Thus the Black model is introduced in the next section to overcome the difficulty of pricing bond options by assuming the forward bond price as the underlying (Black 1976). The valuation is justified as no pull-to-par effect to a forward bond price (Rebonato 2002).

2.4.3 The Black model

2.4.3.1 Suitability of Black model for valuing bond options

In this research, the “option to refinance” is structured as a European call option on the original debt facility. The Black model is adjusted to develop the option-based valuation framework to quantify the value of “option to refinance” in infrastructure projects which will be discussed in Chapter 4 in detail. The Black model is suitable as a basis for the valuation due to its advantages, and taking consideration of the tradeoff between economic efficiency and additional mathematical precision that it can bring to the valuation.

The Black model was originally developed from the Black-Scholes model to price options on futures, and assumes that the underlying asset is lognormally distributed (Black 1976). The Black model is extended to value European bond options, interest rate caps/floors, swaptions and some other interest rate derivatives (Hull 2003). There are a few advantages of using the Black model. Because of its wide applicability, accuracy in matching market prices, and relative mathematical simplicity, the Black model is widely used in industry and provides a benchmark against the more complicated models (Kolb 2003). Further, the Black model directly incorporates the price of the underlying security or the debt price into the model. It provides a straightforward view of the valuation as most bond options are contingent claims in terms of bond prices, not the level of the short-term rates or forward rates (Athanasakos 1996). Equilibrium models or non-arbitrage models attempt to develop term structures of short rates (Vasicek 1977, Rendleman and Bartter 1980, Cox, Ingersoll et al. 1985, Ho and Lee 1986, Jamshidian 1989, Black, Derman et al. 1990, Hull and White 1990), and the HJM models (Heath, Jarrow et al. 1992, Wu 2009) and the LIBOR market models (Brace, Gatarek et al. 1997) target forward rates. Bond prices are sensitive to short-term rates or forward rates; as a result the prices of bond options are sensitive to those rates too. A small inaccuracy in modeling short-term rates or forward rates can lead to huge imprecision in the pricing of interest rate derivatives. Contrarily, the interest rates used in the Black model are deterministic and can be observed in the market instead of its stochastic process. In the Black model, the payoffs on the option depend largely on stochastic terms that no longer contain the interest rate. The deterministic interest rate is only used to discount the option payoff at the expiration. It is unlikely to affect the valuation of the option to any significant degree by assuming deterministic interest rates. The Black model takes a simple and direct approach to address the underlying bond price which is practically attractive without sacrificing the soundness of the valuation.

The main drawback of the Black model is that it is inconsistent when it comes to price bond options, caps and swaptions altogether, though valuating each type of them is internally consistent and can be justified independently. For instance, the

Black model assumes lognormal forward bond prices for valuating bond options, while assuming the lognormal distribution of the forward interest rate for caps. However, the lognormal forward bond prices cannot correspond to the lognormal forward interest rates. In view of the model's economic efficiency, this problem is economically insignificant (Haug 2007). For valuing European bond options, Haug also (2007) pointed out that the Black model is more suitable to value bond options whose life is short relative to the time to maturity of the underlying bond.

2.4.3.2 Black model originated to value futures options

Black model was originally developed to value futures options. The assumptions of the Black model to value futures options are as following:

- The forward or future price follows the lognormal process
- The short selling of securities with full use of proceeds is permitted
- There are no transaction costs or taxes. All securities are perfectly divisible.
- There are no riskless arbitrage opportunities
- Security trading is continuous
- The risk-free rate of interest is constant
- The options are European

Black model is derived based on the extension of Black-Scholes Model for options on stocks paying known dividend yields.

The extension of Black-Scholes Model for a call option on a stock paying a known dividend yield is shown in equation (2.1).

$$C(S, t_0) = S_0 e^{-q(t-t_0)} N(d_1) - K e^{-r(t-t_0)} N(d_2) \quad (2.1)$$

$$d_1 = \frac{\ln(S_0/K) + (r - q + \sigma^2/2)(t - t_0)}{\sigma \sqrt{t - t_0}}$$

$$d_2 = \frac{\ln(S_0/K) + (r - q - \sigma^2/2)(t - t_0)}{\sigma \sqrt{t - t_0}}$$

where C is the call price, S is the stock price, S_0 is the current stock price, q is the dividend yield, t_0 is the current time, and t is the maturity time of option, K is the strike price, r is the risk-free rate, $N(.)$ is the cumulative distribution function for a standardized normal distribution, and σ is the volatility.

In a risk-neutral world, the stock paying a dividend yield of q follows geometric Brownian motion as shown in equation (2.2). A risk-neutral world is where the expected return on all assets is the risk-free rate of interest. The investors are completely neutral toward risk, and do not require risk premium for their investments. The present value of any cash flow in a risk-neutral world can be obtained by discounting its expected value at the risk-free rate.

$$dS = (r - q)Sdt + \sigma Sdz \quad (2.2)$$

Where z is the standard normal variate.

In a risk-neutral world, a future price behaves in the same way as a stock paying a dividend yield at the domestic risk-free interest rate r . Therefore, the future price F follows the following process in the risk- neutral world:

$$dF = \sigma Fdz \quad (2.3)$$

Therefore, the European call price for a futures option can be derived by replacing S_0 with the current future price F_0 and $q = r$:

$$C(F, t_0) = F_0 e^{-r(t-t_0)} N(d_1) - K e^{-r(t-t_0)} N(d_2) \quad (2.4)$$

$$d_1 = \frac{\ln(F_0/K) + \sigma^2(t-t_0)/2}{\sigma\sqrt{t-t_0}}$$

$$d_2 = \frac{\ln(F_0/K) + (r - q - \sigma^2/2)(t-t_0)}{\sigma\sqrt{t-t_0}}$$

2.4.3.3 Justification for valuing bond options

Hull (2003) used martingale theory to justify the Black model to price bond options theoretically. In a forward risk-neutral world with respect to a zero-coupon bond maturing at time t , the current value of a bond option is its expected payoff at time t multiplied by the price of a zero-coupon bond maturing at time t . Therefore,

$$C_0 = P(0, T)E^{\hat{P}(0, T)}(\max(B_T - K, 0)) \quad (2.5)$$

where T is the time to maturity of option, K is the strike price, $P(0, T)$ is the price at time 0 of a zero-coupon bond paying 1 unit currency at time T , B_T is the bond price at time T , and $E^{\hat{P}(0, T)}$ denotes expectation in a world that is forward risk neutral with respect to a zero-coupon bond maturing at time T .

The expected value of the bond at time T equals its forward price in the forward risk-neutral world.

$$E^{\hat{P}(0, T)}(B_T) = F \quad (2.6)$$

where F is the forward price at time 0 of the bond at the expiration of the option.

Assuming the forward bond price is lognormal at time T with the standard deviation of the logarithm of the bond price equal to $\sigma_F\sqrt{T}$, where σ_F is the volatility of forward price; hence,

$$\begin{aligned} C_0 &= P(0, T)E^{\hat{P}(0, T)}(\max(B_T - K, 0)) \\ &= P(0, T)\int_K^{+\infty} (B_T - K)g(B)dB \\ &= P(0, T)(E^{\hat{P}(0, T)}(B_T)N(d_1) - KN(d_2)) \\ &= P(0, T)(FN(d_1) - KN(d_2)) \end{aligned} \quad (2.7)$$

where

$$d_1 = \frac{\ln(F / K) + \sigma_F^2 T / 2}{\sigma_F \sqrt{T}} \quad (2.8)$$

$$d_2 = \frac{\ln(F / K) - \sigma_F^2 T / 2}{\sigma_F \sqrt{T}} = d_1 - \sigma_F \sqrt{T}$$

2.5 Key Findings of Literature Review

The practice of debt refinancing is common in the construction industry; however, it has received little academic attention. Debt financing plays an important role in the financial viability of PPP infrastructure projects. The focus of debt refinancing in the existing literature is on the sharing of the refinancing gains between the public and private sectors, and how the government can safeguard the public interest and ensure the value for money of the project. Few studies have been found on how the project company can efficiently utilize the debt refinancing opportunities, and achieve optimal allocation of financing resources. However, the parameters and ways of debt refinancing are identified in the review and served as a knowledge base to develop the ORV framework and the DRO model.

In the aspect of risk management, it is agreed that the risk profile changes during the project life cycle for PPP infrastructure projects. The change of risk profile provides the justification to debt refinancing as the risk level can be significantly reduced after construction phase. The original debt financing based on the initial risk profile may not be the most beneficial to the project at a later stage, and a new financing may have better terms subject to project and market conditions. Debt refinancing normally takes place after the construction phase due to the elimination of construction risks. The quantitative technique of modeling and the Monte Carlo simulation is reviewed and will be used in risk analysis in this research.

In the aspect of real option theories, many real options in infrastructure projects have been identified and studied such as government guarantee, traffic guarantee and cap, and options to expand, abandon, contract and deter; however, no literature

identified the flexibility created by the future refinancing opportunities, i.e. the “option to refinance” in infrastructure, as a real option. The “option to refinance” can capture managerial and financial flexibility into the capital project valuation, therefore enhance the project value. It is a new research area of real option application in infrastructure. In the aspect of real option valuation method, the Black-Sholes model and binomial model are still the main streams with the development of other theories such as game theory, and other modeling methods such as Monte Carlo method and Fuzzy logic. However, the Black-Scholes model is not suitable to value bond options due to the pull-to-par phenomenon of the bond. For valuing the “option to refinance” which is similar to bond options, the Black model is introduced as a theoretical basis instead of the Black-Scholes model given its suitability, which has been discussed in detail in section 2.4.3.1.

In summary, the literature review on debt refinancing, risk management and real options forms the theoretical basis for the development of the ORV framework and the DRO model for PPP infrastructure projects.

CHAPTER 3

RESEARCH DESIGN AND METHODOLOGY

This chapter outlines the research design that is used to carry out this research. The four research objectives can be achieved by the development of the “option to refinance” valuation (ORV) framework and the development of the debt refinancing optimization (DRO) model respectively, which are two quantitative methodologies developed in this research. The literature review was conducted to review the relevant research areas that provide knowledge base to support the development of the ORV framework and the DRO model. Case studies were conducted to validate the ORV framework and the DRO model respectively.

3.1 Overview of Research Design

The research is designed as shown in Figure 3.1. Starting with problem formulation to develop research objectives, literature review is conducted in relevant research areas to support the development of the “option to refinance” valuation (ORV) framework and the development of the debt refinancing optimization (DRO) model in order to response to the research objective 1&2 and 3&4 respectively. Three case studies are then used to validate the ORV framework and DRO model.

Figure 3.1 Research design

3.2 Problem Formulation

The research problems were formulated at beginning of the research to clearly define research scope and objectives. The scope of the research is to study the debt refinancing with the potential of return enhancement or generating refinancing gains in PPP infrastructure projects. There is a need to obtain a better understanding of debt refinancing undertaken in PPP infrastructure projects, which can help investors use financial resources more efficiently, and facilitate their managerial decision. Four research objectives are identified and developed in response to the problem studied. Objective 1 is to capture and quantify the financing flexibility created by the future debt refinancing opportunities in PPP projects that project sponsors can refinance the existing debt for better financial terms at a future date, i.e. “option to refinance”. The value of such flexibility is not incorporated in the traditional project valuation model, thus the objective 2 is to incorporate this value into the initial project valuation. Objective 3 is to optimize the debt-refinancing plan and objective 4 is to analyze its impact on the project equity cash flow.

3.3 Literature Review

The literature review was conducted to review the relevant research areas that provide knowledge base to support the development of the ORV framework and the DRO model. The review, as shown in Figure 3.2, includes the introduction of PPP, debt financing and refinancing and risk management in PPP infrastructure projects, and real options.

Figure 3.2 Areas of literature review

The concepts of PPP were introduced, and the main research areas of PPP were also briefly discussed. Among them, risk management and debt financing and refinancing in PPP projects are relevant to this research.

The review on debt financing and refinancing is mainly on typical debt profiles in PPP projects, the ways of debt refinancing, the comparison of debt refinancing with alternative financial solutions and the development of debt refinancing in the UK, which is the leading economy in PPP debt refinancing. The existing research on debt refinancing primarily focuses on the how the government can safeguard the public interest from the debt refinancing taken up by the private sponsors in PPP projects in terms of the sharing of the refinancing gains between the public and private sectors. Few studies have been found on how the project company can efficiently utilize the debt refinancing opportunities to optimize its financing structure. However, the parameters and ways of debt refinancing are identified in the review and served as a knowledge base to develop the ORV framework and the DRO model.

The review on risk management focuses on the change of risk profile in PPP project life cycle and different quantitative risk analysis techniques. The change of risk profile provides the justification to debt refinancing as the risk level can be

significantly reduced after construction phase, and the original debt package may not be in the best interest of the project. Four commonly used quantitative risk techniques including expected monetary value, sensitivity analysis, decision tree, and modeling and simulation are reviewed. The Monte Carlo simulation will be used to conduct risk analysis in developing the ORV framework.

The area of real option theory intersects the area of PPP study, which is the application of real options in PPP infrastructure projects. Many real options in PPP infrastructure have been studied and identified in literature such as government guarantee, project contingency, price cap and options to expand, abandon, contract and deter. However, no literature identified and captured the value of “option to refinance” in PPP infrastructure projects. The review on real option valuation method shows that the Black-Scholes model and binomial model are the main basis for real option valuation. However, the Black-Scholes model is not suitable to value bond option due to the pull-to-par phenomenon of the bond. Instead, the Black model can address this issue to price bond options by assuming the forward bond price as the underlying. The “option to refinance” is structured as a European call option on the original debt facility, which is similar to a bond option, thus the Black model is used as a basis to develop the ORV framework.

3.4 Summary on Development of ORV Framework and DRO Model

The development of the ORV framework and the DRO model is intended to respond to the four research objectives respectively. The different features of the ORV framework and the DRO model in terms of their usage in different project timeline, their impact on targeted cash flow position, and the variable factors to be studied are illustrated in Figure 3.3.

Figure 3.3 Features of ORV framework and DRO model

The ORV framework is an option-based valuation framework to quantify the value of the financing flexibility created by the future debt-refinancing opportunities, i.e. the “option to refinance”, and incorporate it into the project valuation. It is used at planning and feasibility stage of the project to reflect the total project value accurately. The total net present value (*NPV*) of the project can be increased by the value of the financing flexibility. The project conditions and fluctuation of market value of debt due to market movement are taken into consideration in the ORV framework.

The debt-refinancing optimization (DRO) model can deliver the optimal debt-refinancing plan that generates the maximum allowable equity gain and provide equity cash flow analysis on the impact of the plan. It is used at the time when the project company is assessing whether to undertake a debt-refinancing plan, and it is normally at the early operation stage. Information on the conditions of the markets and the project becomes available at that time, and the final terms of the refinancing deal are subject to negotiation between the project company, lenders and the government based upon the market and project conditions. The DRO model is focused on the impact of the debt-refinancing plan on equity gain as the improvement of equity is the key profitability factor for equity investors. The

factors of debt interest rate, maturity, amount and repayment structures are taken into consideration in the model for optimization.

The development of the ORV framework and the DRO model are summarized in Figure 3.4 and Figure 3.5 respectively and the details of their development are presented in Chapters 4 and 5 respectively.

In order to quantify the “option to refinance” in PPP projects and incorporate its value into project valuation, the ORV framework was developed. A cash flow model and net present value analysis was first built for project valuation. The framework further incorporated risk and probability analysis implemented by Monte Carlo simulation to monitor project conditions, and the Black model was adjusted to value the conditional “option to refinance”. The Monte Carlo simulation is run in the software application of @RISK. The theoretical basis of risk analysis, the Monte Carlo simulation and the Black model has been reviewed in the Chapter 2 of “Literature review”.

In order to optimize a debt-refinancing plan and provide analysis of its impact on the project equity cash flow, the quantitative DRO model was built based on cash flow modeling. Three sub-models of cashflows were constructed. An optimization algorithm based on cash flow modeling was developed and coded by Visual Basic programming in Marco and run in the Excel environment. Scenario analysis is incorporated to generate optimal debt-refinancing plans under different scenarios of repayment structure and interest rate.

Figure 3.4 Development of “option to refinance” valuation (ORV) framework

Figure 3.5 Development of debt refinancing optimization (DRO) model

3.5 Case Study

Case study is one of the research methods that can capture unique variables of each project. Case studies were conducted to validate the ORV framework and the DRO model respectively. Based on the availability of the project data, three PPP infrastructure projects are selected and they are (1) a toll road BOT project in Indonesia, (2) a power BOT project in China, and (3) a water supply BOT project in Malaysia. The transport, power and water sectors are three important sectors in infrastructure projects and Indonesia, China and Malaysia are important players in PPP infrastructure projects.

The selection of cases is also intended to test the generalizability of the valuation framework and the optimization model cross different sectors and countries. The working process and outcomes generated from the ORV framework and the DRO model under different project context with unique sector and country features can be demonstrated. The case study also gives specific implication to each project.

The data sources for the three projects came from project documents such as feasibility studies, information memoranda, business plans, annual reports, as well as scholarly theses, articles and papers. Some information is kept confidential. In addition, the historical term structures of interest rates in different countries were sourced from Bloomberg. A brief description of each PPP project is as follows.

Toll Road BOT Project A, Indonesia

The Indonesian government has been facilitated in the development of road infrastructures in recent years. The BOT scheme is considered for such development. The toll road BOT project A is one of the recent series of such toll road projects in Indonesia. Due to confidentiality issues, the project will remain anonymous. The project information was mainly from the project's business plan and feasibility study from the primary source. The project company is responsible for building and operating a 25-kilometer toll road, and will transfer it back to the

government at end of the concession. The concession period is 35 years, starting from the commencement of the construction.

Laibin B Power BOT Project, China

The Laibin B Power BOT Project is a pilot BOT project with strong support from the central government of China. The project company, Guangxi Laibin Electric Power, was permitted to have full foreign ownership, which had been not allowed in China before then. The project company was established and owned by two foreign companies, Electricite de France International and GEC Alsthom Power Plants Ltd. In 1997, the Guangxi Laibin Electric Power and the local government authority of the Guangxi Autonomous Region signed the project contract. The concession period was 18 years, and started at the commencement of the construction.

The Laibin B Plant is located on Laibin County in Guangxi Autonomous Region, which is in the south of China. It is the second phase of the Laibin Power Plant. The Guangxi Laibin Electric Power was responsible for financing, constructing and operating a 2×360 MW coal-fired power plant with an annual capacity of 6,300 million kWh, and transferring it back at the end of the concession. The information on Laibin B Power BOT project was mainly collected from (Wang and Tiong 2000, Ye and Tiong 2000, Ye 2001).

Labuan Water Supply BOT Project, Malaysia

The Labuan Water Supply BOT Project is the first BOT water project in Malaysia. Ipco proposed the project to the Malaysian government, and established the project company in 1987. The project company was Labuan Water Supply Sdn Bhd, which was responsible for building and operating a water supply plant with the ultimate capacity of 38 ML/day, and will transfer it back to the Malaysian government at the end of concession. The BOT contract was signed in 1987, and the concession was for thirteen years including the construction and operation period. The project abstracted and treated the water from Sungei Padas in Sabah, and transported the treated water to storage tanks at Ranca Ranca in Labuan. The project information

was mainly collected from (J. Henry Schroder Wagg & Co. Limited 1987, Cheng 2003, Cheng and Tiong 2005).

CHAPTER 4

DEVELOPMENT OF “OPTION TO REFINANCE” VALUATION (ORV) FRAMEWORK

This chapter develops the “option to refinance” valuation (ORV) framework to quantify the value of the financing flexibility created by the future debt refinancing opportunities that the project sponsors can refinance the existing debt for better financial terms at a future date. This financing flexibility is structured as an “option to refinance” that follows two conditional paths. The framework consists of DCF analysis of the project base case, risk analysis of conditions for “option to refinance”, and conditional option valuation. The output of the framework is the expected value of the “option to refinance”, and the total project value with the value of this financial flexibility incorporated.

4.1 Financing Flexibility Created By Future Debt Refinancing

Opportunities

The financing flexibility created by the future debt financing is defined as the flexibility that the project sponsors can refinance the existing debt in a PPP infrastructure project for better financial terms at a future date. It is contingent to future market and project conditions. This concept is elaborated in the following paragraphs.

The financing of PPP infrastructure projects comes primarily from debt instruments such as bank loans or project bonds. The terms of the loan or bond contract is negotiated and set before the financial close of a project. The pricing of the debt instrument is based on the project forecast and the debt market at the inception stage of the project. The term of debt financing in PPP projects is long, and can be from 10 to 20 years, or even longer for project bonds. The concession of a PPP projects can be 10 to 35 years, and the construction period is normally 2 to 5 years, which is a relatively short time in the life of a PPP project, but the risk involved in the construction phase could be significant. The project conditions and debt market can change during the time when the project is in progress, but the original debt facility cannot reflect the changes in the project and debt market. Normally, after the construction phase, the existing debt can be refinanced on better terms if the market is going well. Such future debt refinancing opportunities create the financing flexibility to project sponsors with the possibility of improving the investors' return at a future date. The flexibility whether the project sponsors will refinance the existing debt or not at a future date is contingent to the future project and market conditions with project sponsors' managerial discretion. This financing flexibility thus creates value for the project at its inception. However, the traditional DCF approach cannot incorporate the value of this flexibility into the project valuation for capital investment. Various real options have been studied to capture management/operating flexibilities, and the values of those real options are added back to the project value for the investment decision. In this research, the

quantification of the financing flexibility created by the future debt refinancing opportunities in PPP infrastructure projects was inspired by the concept of real options. It shares similarities with real options in contributing to the capital project valuation.

Therefore, such financing flexibility created by the future debt refinancing opportunities can be viewed as an “option to refinance”. It is like the prepayment privileges in mortgages, but it is inherent in PPP project finance and adds values to the project. The “option to refinance” can be decomposed into two components. The first component is to prepay the original debt before its maturity date. The original debt might have no restriction on its prepayment, or the lender can price this component with a prepayment clause, penalty or higher interest margin. In fact, some of the repayment structure with increasing credit margin tries to encourage debt refinancing. The incentive of prepayment is the better terms that can be obtained in refinancing. In order to prepay the original debt facility, the second component of “option to refinance” is the ability to find a proper new debt under the new market and project conditions. It requires that the project must be in good condition in order to receive new debt financing; otherwise, lenders will be reluctant to provide lending to a project in trouble, or improve the terms of the refinancing. This structure is slightly more than a bond option, whose assumption does not require the investor must hold cash to buy the underlying bond if the option is exercised. Because bonds are tradable and liquid, the expected payoff at the maturity of the option can be hypothetically realized by simultaneous trades of long underlying bond at strike price and short it at the market price. The debt facilities in PPP infrastructure projects are normally bank loans, which are not publicly tradable. The project company must be sure that the lender is willing to provide a new debt, or reduce the interest cost of the original loan.

The ORV framework is developed to quantify the value of the “option to refinance” in PPP infrastructure projects, and incorporate it into the initial project valuation. The financing flexibility captured in this framework can be viewed as the option to refinance at a lower interest rate, which is hypothetically transformed to an increase

in the market value of the original debt obligation in a PPP project. The reduction in interest rate in refinancing can result from two sources: improvement in the general debt market or the reduced risk profile of a project at the time of refinancing. The ORV framework directly addressed the fluctuation of the market value of debt that leads to the value of “option to refinance”. The value of this financing flexibility will be incorporated into the project valuation to reflect better the profitability of the project.

4.2 Development of ORV Framework

An overview of the ORV framework is illustrated in Figure 4.1. The framework structures the “option to refinance” to follow two conditional paths that an option can be granted if certain conditions are met and no option will be given in the event of failure in the conditions. The conditions used in the framework are completion of construction and demonstration of stable revenue streams. It is assumed that the project company has the right to refinance its project for better terms upon successfully meeting the two conditions. This analytic framework consists of a few elements. The first element is DCF analysis of the project base case. The second element is risk analysis of conditions for “option to refinance” to estimate the probability of the conditions being achieved. It captured the impact of the uncertainty of the project on the option value. The third element is valuation of the option given success in the two conditions. It captured the impact of market uncertainty of the market value of the debt facilities on the option valuation. The output is the expected value of “option to refinance” and the total project NPV by incorporating the value of such financing flexibility. The value of the flexibility was added to the total project NPV as it was the value inflow to the project, and did not break down the cashflow to equity investors and lenders respectively.

Figure 4.1 Flowchart of ORV framework

4.2.1 DCF analysis of project base case

The project base case is valued by the DCF technique. It is a static process, and all the inputs and variables are assumed to be deterministic. The DCF analysis is modeled in excel, and the *NPV* of project base case will be generated. The cash flow components are expressed in current value, unless otherwise specified.

Capital expenditures

Ranasinghe (1996) developed a simplified model of the total project cost which consists of the base construction cost, the escalation during construction and the interest during construction. This framework defines the total project cost as below:

$$TC = \sum CC_i + \sum IDC_i + \sum OTFC_i \quad (4.1)$$

where TC is the total project cost in the base case, CC_i is the base construction cost in the i th year in the base case, IDC_i is the interest during construction in the i th year in the base case, and $OTFC_i$ is the other financing costs in the i th year in the base case.

The construction cost could cover development fees, EPC payment, start-up costs, and other relevant costs. It can be further decomposed into foreign component and local component, and the formula is shown as below:

$$CC_i = A_i \prod_{k=1}^i (1 + \theta_k^A) + \varphi_i F_i \prod_{k=1}^i (1 + \theta_k^F) \quad (4.2)$$

Where A_i is the base local construction cost in the i th year expressed in constant value, θ_k^A is the local inflation rate in the k th year, φ is the foreign exchange rate in the i th year expressed in the unit of local currency/foreign currency, F_i is the base foreign construction cost in the i th year expressed in constant value, and θ_k^F is the foreign inflation rate in the k th year.

Capital expenditures are mainly funded by initial equity and debt injection. However, some projects, especially those with multi-staged construction, can be partially funded by operating cash flow as operation will commence after the first phase of construction and the subsequent phase of construction thereby can be funded by part of its operating cash flow.

Capital structure

For PPP projects, debt is the main source of funds, and it is typically around 65–85% of the total project cost. The leverage or equity-to-debt ratio is defined as:

$$\frac{TE}{TD} = \frac{\sum ED_i}{\sum DD_i} \quad (4.3)$$

where TE is the total equity amount in the base case, TD is the total debt amount in the base case, ED_i is the equity drawdown in the i th year in the base case, and DD_i is the debt drawdown in the i th year in the base case.

Concession period

The concession period starts from the commencement of the construction of the project and ends with termination of the concession contract. The concession period is N year, and the construction period is N_C year.

After-tax operating cash flow

The after-tax operating cash flow is the operating cash flow available before any debt services, including debt principal repayment and interest. It can be called the cash flow available for debt service.

$$ATOCF_i = REV_i - OM_i - TAX_i \quad (4.4)$$

where $ATOCF_i$ is the after-tax operating cash flow in the i th year in the base case, REV_i is the project revenue in the i th year in the base case, OM_i is the operation and maintenance cost in the i th year in the base case, and TAX_i is the tax payment in the i th year in the base case.

Tax payment

The tax payment can be calculated as:

$$TAX_i = (REV_i - OM_i - DEP_i - DIN_i) \times TAXR_i \quad (4.5)$$

where DEP_i is the depreciation expense in the i th year in the base case, DIN_i is the debt interest payment in the i th year in the base case, and $TAXR_i$ is the tax rate in the i th year.

Net present value analysis of the project

The net present value (NPV) of the project is calculated as:

$$NPV_0(P) = \sum_{i=1}^N \frac{ATOCF_i}{(1 + R_p)^i} - \sum_{i=1}^N \frac{CC_i + IDC_i + OTFC_i}{(1 + R_p)^i} \quad (4.6)$$

where $NPV_0(P)$ is the time- zero NPV of the project base case, and R_p is the required rate of return of the project.

4.2.2 Risk analysis of conditions for “option to refinance”

Refinancing normally takes place after the construction phase. If the project is not delivered as well as expected, the lender will be reluctant to refinance the original loan with improved terms. As the future refinancing opportunity is considered as an option to provide financing flexibility to the project company, it is supposed to be a right for the project company to refinance the original loan. If the lender is not comfortable with the progress of the project, the lender can refuse to provide refinancing. In this case, the project company no longer has a right to refinance.

Therefore, the lender must be satisfied first. This framework defines two conditions that need to be achieved before the project company can have an option to refinance the original debt. The two conditions are completion of construction and demonstration of stable revenue streams. The major risks governing the two conditions are construction risks and revenue risks. The construction risks can further break down into construction cost overrun risk and completion risk. Some economic risks, such as inflation risks and foreign exchange risks, are incorporated into the modeling of construction risk and revenue risks as influencing factors. The overview of the risk analysis of conditions for “option to refinance” is illustrated in Figure 4.2. It generates probability distributions of the conditions. Along the probability path, the option valuation will be conducted.

Figure 4.2 Risk analysis of conditions for “option to refinance”

4.2.2.1 Condition 1: completion of construction

Construction risk is the major risk that affects the success of construction completion. It is related to the ability to deliver the physical assets with certain specifications, at a certain cost and within a certain timeframe (Ratings 2009).

Sometimes, it covers construction related risks in the construction, commissioning and ramp-up phases, at the end of which the project will enter a steady operational phase (Ratings 2009).

Construction cost overrun risk is an overrun in construction costs against the budget on which the funding structure has been based. It can be caused by inefficient construction management, change in the macroeconomy (i.e. fluctuation of inflation or foreign exchange rates), change in laws, delays and other events which can directly or indirectly impact on the cost component of construction. Some mitigation measures can be used to mitigate the construction risks and absorb loss if the total cost during construction exceeds the budgeted construction contractual cost. Moody's (2007) categorized those mitigation measures into different support packages including contractor support, performance/insurance-based support, liquid/financial support or equity. The contractor normally allocates the risk through fixed-price turnkey contract in PPP projects. Liquidated damage provision in the contract is used to protect project default. Insurance can be used to transfer the risk to insurers if available. Sometimes, the banks or project sponsors can provide additional financing in terms of standby credit, bank guarantees or equity when the funds are needed.

A delay in completion of the project may cause increase in financing costs, defer revenues and incur liquidated damages (Yescombe 2007). It can be caused by inefficient communication and coordination, poor schedule management, political and legal actions, and so on. The completion risk can also be mitigated by liquidated damage provision and insurance. In addition, a bonus is usually provided as an incentive for early completion of construction. The early revenue collection also encourages project to be completed earlier.

4.2.2.2 Condition 2: demonstration of stable revenue streams

Revenue risk is related to uncertainty of revenue streams in the operation phase. This is critical to the viability of a project, as they are the main sources of project income. Lenders will review the revenue projection when making lending

decisions. In PPP projects, the project revenues are main collaterals backed for project financing. Therefore, the demonstration of stable revenue streams in the early operation period can make lenders comfortable to refinance the existing debt facilities.

The major factor influencing revenue risk is uncertainty of demand. Social infrastructure PPP projects such as schools, hospitals and prisons normally adopt availability payment or unitary payment structure, whereby the government will make payment to the project company when the facility is available and ready to provide services. This type of payment structure eliminates much of the revenue risk, as the revenue will be provided once the facility is built and available. Water treatment PPP projects and non-merchant power PPP projects normally structure the payment with two components of availability and output payment. In addition to the availability payment, the output payment is based on the water or power output generated. The government normally guarantees a minimum output amount and directly purchases the guaranteed output from the PPP water or non-merchant power plants. The output amount to be purchased by the government is specified in the PPP project contract or purchase agreement. In this case, the demand risk is transferred to the government, and the project company no longer bears such risk. If the payment is based on the usage of the service, the demand and revenue risks increase significantly. Especially in transportation PPP projects, the uncertainty in traffic volume is a critical concern. In PPP toll road projects, payment can be charged directly to road users or to the government based on the traffic level. The later payment structure is called “shadow tolls”. The level of demand risk among different PPP sectors is illustrated in Figure 4.3.

Figure 4.3 Revenue risk in different sectors of PPP projects

The revenue is also exposed to foreign exchange risk if it needs to be converted to a denominated foreign currency in which the investors raise capital. This is often the case in developing countries, where international project promoters usually provide financing in hard currency, and the revenue collected locally has to be converted to hard currency to pay off the international investors. The project can specify the indexation formula in the purchase agreement to adjust the tariff against inflation and foreign exchange exposures.

For some PPP projects, such as water/wastewater treatment projects, the construction risk is critical. After the construction completion, the overall project risk profile is reduced significantly. The revenue risks in the operation phase are much mitigated by the availability payment and/or guaranteed purchase amount. In this case, the successful completion of construction is the determinant condition for granting “option to refinance”. For some PPP projects such as toll road projects, even though the construction risk has been eliminated after construction phase, the risks in operation phase are still significant because of the uncertainty of the revenue stream. Thus it is important to demonstrate that the project has sufficient traffic volumes, leading to stable revenues in the early operations. Both condition 1 and 2 should be taken into consideration for granting the “option to refinance”.

4.2.2.3 Risk simulation

The factors modeled in the construction cost overrun risk are fluctuations in base construction cost and inflation and foreign exchange rates if there is any foreign component of the construction cost.

The construction completion risk is modeled and converted to a monetary consequence subject to the completion time being either earlier or later than the contracted time. If the construction is delayed, the penalty needs to be added to the construction cost. If the construction is completed earlier, the bonus needs to be subtracted from the construction cost as a buffer to absorb loss.

Mitigation support is modeled to absorb the cost above the budgeted construction cost due to the construction cost overrun or delay in completion time.

The overall cost with risk factors and mitigation measures during construction is simulated against the projected construction budget. Success in condition 1 is expressed in equations (4.7) and (4.9).

$$\tilde{TCC} \leq TCC_0 + S \quad (4.7)$$

Because

$$\begin{aligned} \tilde{TCC} &= \sum_{i=1}^{N_C} \tilde{C}C_i + \tilde{L} \\ &= \sum_{i=1}^{N_C} \tilde{A}_i \prod_{k=1}^i (1 + \tilde{\theta}_k^A) + \sum_{i=1}^{N_C} \tilde{\varphi}_i \tilde{F}_i \prod_{k=1}^i (1 + \tilde{\theta}_k^F) + \tilde{L} \end{aligned} \quad (4.8)$$

$$\text{Thus } \sum_{i=1}^{N_C} \tilde{A}_i \prod_{k=1}^i (1 + \tilde{\theta}_k^A) + \sum_{i=1}^{N_C} \tilde{\varphi}_i \tilde{F}_i \prod_{k=1}^i (1 + \tilde{\theta}_k^F) + \tilde{L} \leq TCC_0 + S \quad (4.9)$$

where $\tilde{TCC}$ is the risk-simulated total construction cost, TCC_0 is the budgeted total construction cost in the base case, $\tilde{L}$ is the risk-simulated monetary value of uncertainty of completion time, S is the monetary value of mitigation support, and $\sim$ above denotes that the variable is risk-simulated and stochastic rather than deterministic in base case.

The revenue incorporated by risk factors is simulated against the projected revenue in the base case. Success in condition 2 is expressed as below:

$$\tilde{REV}_T \geq aREV_T \quad (4.10)$$

$$\text{Because } \tilde{REV}_T = \tilde{X}_T \times \text{Tariff} \times \lambda \times \tilde{\varphi}_T \quad (4.11)$$

$$\text{Thus, } \tilde{X}_T \times \text{Tariff} \times \lambda \times \tilde{\varphi}_T \geq aREV_T \quad (4.12)$$

where $\tilde{REV}_T$ is the risk-simulated revenue at time T , a is the fraction factor of projected revenue that will satisfy the lender, $\tilde{X}_T$ is the risk-simulated demand at time T , λ is the fraction of revenue to be converted to another currency against the currency in which revenue was collected, and $\tilde{\varphi}_T$ is the risk-simulated foreign exchange rate at time T .

For risk analysis, some common assumptions such as lognormal distribution or normal distribution for construction cost, inflation rate, foreign exchange rate and demand have been demonstrated in different studies (Ye and Tiong 2000, Cheng and Tiong 2005). Some typical assumptions can be used in this framework for risk simulation, shown in Table 4.1.

Table 4.1 Risk assumptions in simulation

Risk factors	Distribution function
Base construction cost	Lognormal distribution (μ, σ^2)
Inflation rate	Normal distribution (μ, σ^2)
Foreign exchange rate	Normal distribution (μ, σ^2)
Completion time	Lognormal distribution (μ, σ^2)
Demand/traffic	Lognormal distribution (μ, σ^2)

The lognormal distribution for base construction cost and completion time are based on the cost saving and time saving being limited, whereas the extent of cost overrun and time overrun is infinite (Ye and Tiong 2000). The mean and the standard deviation of the relevant distribution function can be determined subject to the specific project contract and the condition of the economy where the project is located. The risk simulation can also use other distribution functions customized by expert opinions or historical data sets for a specific project.

The risk simulation will generate a probability tree of the conditions. Figure 4.4 illustrates the probabilistic process.

Figure 4.4 The probability analysis of conditions for “option to refinance”

The cumulative probability of success in two conditions is expressed in equation (4.13). If the project does not have revenue risk, Ω_2 becomes 1.

$$\Phi = \Omega_1 \times \Omega_2 \quad (4.13)$$

where Ω_1 is the cumulative probability of success in condition 1, Ω_2 is the cumulative probability of success in condition 2, and Φ is the cumulative probability of success in both conditions 1 and 2.

4.2.3 Conditional option valuation

The conditional “option to refinance” given success in construction completion and demonstration of stable revenues represents a call option on the original debt facility. Ideally, the refinancing can take place any time before the maturity of the original debt given success in the two conditions. However, the project company usually prefers to undertake debt refinancing as early as the market in favorable movement, because at the time of refinancing, the project company can not only reduce the interest cost subject to the liquidity and project finance market, but also increase debt amount or extend the debt maturity subject to negotiations with lenders. The increase of the debt amount or extension in debt maturity leads to early payback of equity to investors and thereby improves the equity return. It encourages early exercise of the conditional “option to refinance”. Therefore, this valuation framework can approximate the conditional “option to refinance” as a European call option with the expiration date on the early stage of operation for simplification. It is written on the original debt instrument to the project company.

Suitability of the modified Black model for “option to refinance”

The Black model is modified to fit in the context of the PPP infrastructure projects to quantify the “option to refinance”. The modified Black model is suitable for the following reasons. First of all, the option is structured to be contingent to the debt value, not to the level of interest or forward rate. The modified Black model directly assumes the market value of debt obligation to follow lognormal distribution to derive the closed-form analytic equation rather than other equilibrium models trying to construct an intermediate stochastic process of term structure. Second, it has a

much more simplified computation process compared with the mathematical complication in other models. This simplification does not sacrifice the soundness of the valuation. Third, the Black model uses the deterministic term structure of interest rates that can be observed in the market to discount the option payoffs from expiration to the present. It does not affect the valuation much, as the terms of interest rates have been dropped from the stochastic terms of the equation. But it can avoid re-aligning the interest rates in project valuation and the stochastic interest rate behavior modeled for option pricing in other models. Fourth, the use of the Black model in this framework can be justified for its limitation of the inconsistency for pricing bond options, caps and swaptions. The conditional “option to refinance”, which is similar to the bond option, is the only interest rate derivative to be valued; no other interest rate derivatives are present in the framework. The Black model is internally consistent for pricing bond options. Further, this limitation is economically insignificant. Overall, the modified Black model is easier to understand, accept and apply by construction practitioners as a valuation tool for capital projects due to its mathematical simplicity, use of observable market data and being theoretically justified.

Assumptions of the conditional “option to refinance”

The assumptions of the conditional “option to refinance” are summarized as following:

- The option type is an European call option
- Project company owns this option
- Underlying asset is original debt facility
- Strike price is the market value of new debt facility
- Expiration of option is at the end of construction period with a necessary ramp-up period

For PPP projects using bond financing, the debt obligation for the project company is future bond coupon payments and principal repayments. The market value of debt obligation is shown in the market price of the bonds as they can be traded. For PPP projects using bank loans, the debt obligation for the project company is future

periodic debt service payments including interest payments and principal repayments, which are specified in the original loan contract. The market value of the debt obligation is the present value of future loan cash flow streams as there is no market price to reflect its value in the market. If taking the perspective of future cash flows for security valuation, bond coupon payments and principal repayments are essentially the same as the bank loan's interest payments and principal repayments, where both are debt cash outflows from the project company. The modified Black model used this cash flow perspective for forward market value and debt value, thus, the debt facility in this model can refer to either bank loan or bond even though most infrastructure PPP projects are initially financed by bank loans, and can be refinanced by bank loans or bonds at a later stage.

Derivation of solution for the modified Black model

The following paragraphs modify the Black model to value the conditional “option to refinance” in the context of PPP infrastructure projects, and elaborates how a solution can be found for the modified Black equation. The inputs for the modified Black model solution in the conditional option valuation are summarized in Table 4.2.

Table 4.2 Inputs for modified Black model solution in conditional “option to refinance” valuation

Inputs	Variable symbol
Expiration of option	T
Strike Price	$V_T(ReD)$
The time-zero forward market value of the original debt obligation at time T	$F(0, T)$
Forward volatility	σ_F
The time-zero price of T-Maturity zero-coupon bond with a par value of one unit of currency	$P(0, T)$

Expected option payoff

The option to refinance at a lower interest rate is hypothetically transformed to an increase in the market value of the original debt obligation in a PPP project. When the general debt market or the risk profile of a PPP project changes, the market

value of the original debt obligation can be larger than the outstanding value of the original debt, and thereby the original debt obligation can become more expensive compared to the new debts available in the updated market.

When the market value of the original debt obligation is greater than the market value of the new debt raised to refinance the original debt at the time of option expiration, the option will be excised and the debt refinancing will be undertaken. The difference of the market values of the original debt obligation and new debt at the time of refinancing is the value added to the project. When the market value of the original debt obligation is less than the market value of new debt, the option will be expired and no debt refinancing is undertaken.

The expected option payoff at the time of refinancing (T) is

$$V_T = \text{Max}\left(V_T(\tilde{D}) - V_T(\text{Re}D), 0\right) \quad (4.14)$$

where $V_T(\tilde{D})$ is the time- T market value of the original debt obligation, $\sim$ denotes the variable is a stochastic term, and $V_T(\text{Re}D)$ is the market value of the new debt used to refinance the original debt at time T .

The time- T market value of the original debt obligation is assumed to follow lognormal distribution, thus its probability density function is

$$f\left(V_T(\tilde{D})\right) = \frac{1}{V_T(\tilde{D})m\sqrt{2\pi}} \exp\left(-\frac{\left(\ln\left(V_T(\tilde{D})\right) - m\right)^2}{2s^2}\right) \quad (4.15)$$

where m is the mean of $\ln\left(V_T(\tilde{D})\right)$, and s is the standard deviation of $\ln\left(V_T(\tilde{D})\right)$.

Under forward risk-neutral measure $\hat{Q}$, which corresponds to a world that is forward risk neutral with respect to a zero-coupon bond maturing at time T , the value of the option is

$$V_0 = P(0, T)E^{\hat{Q}}(Max(V_T(D) - V_T(ReD), 0)) \quad (4.16)$$

where V_0 is the conditional expected value of the “option to refinance” given success in project conditions, and $E^{\hat{Q}}$ denotes the expected value under forward risk-neutral measure $\hat{Q}$, and $P(0, T)$ is the time-zero price of T -maturity zero-coupon bond with a par value of one unit of currency.

The expected value of the time- T market value of the original debt obligation in the forward risk-neutral world is

$$E^{\hat{Q}}[V_T(D)] = F(0, T) \quad (4.17)$$

where $F(0, T)$ is the time-zero forward market value of the original debt obligation at time T .

Derivation of $F(0, T)$

The cash flow due to debt facility results from debt drawings, interest payments and principal repayments. The original debt may be drawn down a few times during the construction period. Before the refinancing time T , it may have been repaid by debt service repayment a few times. The total debt amount outstanding at time T could be different from the initial amount.

The time-zero forward market value of the original debt obligation at time T thereby is the time- T present value of the future debt obligations from time $T+1$ to the maturity of the debt.

$$F(0, T) = \sum_{i=T+1}^{i=M} \frac{DS_i}{Z_i} Z_T \quad (4.18)$$

Alternatively, it can be calculated as the time- T present value of the original debt subtracting the debt cash outflow during the life of option.

$$F(0, T) = \sum_{i=1}^{i=T} \left(\frac{DD_i}{Z_i} - \frac{DS_i}{Z_i} \right) Z_T \quad (4.19)$$

where DS_i is the debt service payment in the i th year in the base case, and Z_i is the zero-coupon discount factor of i -period.

The debt facility in PPP projects normally has long maturity, but the annual yield of government bonds with maturity longer than 10 years in some markets cannot be observed directly. Therefore, equation (4.19) will be used to calculate the forward market value of the original debt obligation in the three cases in Chapter 6.

Derivation of $V_T(ReD)$

The deterministic market value of an asset can be calculated as the present value of future cash flow streams. If the value is discretely compounded, the market value of an asset at time t is

$$V_t = \sum_{i=t+1}^i PV_t(CF_i) = \sum_{i=t+1}^i \frac{CF_i}{1 + R_i} \quad (4.20)$$

If the value is continuously compounded, the market value of an asset at time t is

$$V_t = \sum_{i=t+1}^i PV_t(CF_i) = \sum_{i=t+1}^i e^{-(r_i - r_t)} CF_i \quad (4.21)$$

where PV_t is the present value at time t , CF_t is the cash flow at time t , R_t is the discrete discount factor, and r_t is the continuous discount factor.

Therefore, the market value of a new debt at time T can be calculated by discounting the future cashflows of the new debt from time T onwards.

$$\begin{aligned}
 V_T(ReD) &= \sum_{i=T+1}^i PV_T(ReDS_i) \\
 &= \sum_{i=T+1}^i \frac{ReDS_i}{1 + ReINR_i} \\
 &= \sum_{i=T+1}^i \frac{ReDPR_i + ReDIN_i}{1 + ReINR_i}
 \end{aligned} \tag{4.22}$$

where $ReDS_i$ is the debt service payment of the new debt at time i for $i > T$, $ReDIN_i$ is the debt interest payment of the new debt at time i for $i > T$, $ReDPR_i$ is the principal payment of the new debt at time i for $i > T$, and $ReINR_i$ is the interest rate of the new debt at time i .

However, in fact, the market value at refinancing time T of the new debt that is used to refinance the original debt ($V_T(ReD)$) can be determined in a much simpler way. It is equal to the amount of the new debt raised at time T regardless of the terms of the new debt. This can be justified by the fact that the new debt can be repaid at time T by the same amount of cash. In an arbitrage-free market, the new debt and the cash must have the same market value. The present value at time T of the future cash flow streams from the new debt must equate to the cash value at time T . So the financing terms and repayment structure of the new debt must be structured at time T to equate the present value of future cash flows to the market value. Thus,

$$V_T(ReD) = \sum_{i=T+1}^i PV_T(ReDS_i) = ReD \tag{4.23}$$

where ReD is the amount of new debt raised to refinance the original debt.

The conditional “option to refinance” assumes the refinancing will only pay off the amount of the original debt outstanding and not increase the additional debt amount. Thereby, the amount of the new debt is assumed to be equal to the original debt outstanding at time T , thus,

$$ReD = D_T \quad (4.24)$$

$$\text{Thus, } V_T(ReD) = D_T \quad (4.25)$$

where D_T is the outstanding principal balance of the original debt at time T .

Substitution and solution

Substitute equation (4.17), (4.22), and (4.23) into (4.16) to derive the expected value under forward risk neutral measure $\hat{Q}$, the conditional expected value of “option to refinance” given success in project conditions is

$$\begin{aligned} V_0 &= P(0, T) E^{\hat{Q}} [Max(V_T(\tilde{D}) - D_T, 0)] \\ &= P(0, T) \int_{D_T}^{+\infty} (V_T(\tilde{D}) - D_T) g(V_T(\tilde{D})) d(V_T(\tilde{D})) \\ &= P(0, T) \left(E^{\hat{Q}} (V_T(\tilde{D})) N(d_1) - D_T N(d_2) \right) \\ &= P(0, T) (F(0, T) N(d_1) - D_T N(d_2)) \end{aligned} \quad (4.26)$$

$$\begin{aligned} d_1 &= \frac{\ln(F(0, T) / D_T) + \sigma_F^2 T / 2}{\sigma_F \sqrt{T}} \\ \text{and} \\ d_2 &= \frac{\ln(F(0, T) / D_T) - \sigma_F^2 T / 2}{\sigma_F \sqrt{T}} = d_1 - \sigma_F \sqrt{T} \end{aligned} \quad (4.27)$$

where σ_F is the volatility of the forward market value.

On the other hand, the expected value of conditional “option to refinance” given no success in project conditions is 0, as no option can be granted to the project company.

4.2.4 Output of ORV framework

The output of the ORV framework is the expected value of financing flexibility created by the future debt refinancing opportunities in PPP infrastructure projects or “option to refinance”, and the total project *NPV* by incorporating the value of such financing flexibility. The logical flow is illustrated in Figure 4.5.

Figure 4.5 Output of ORV framework

The expected value of “option to refinance” can be calculated by the decision tree:

$$V_{OR} = \Phi V_0 + (1 - \Phi)0 = \Phi V_0 \quad (4.28)$$

The total project *NPV* is the sum of the base case *NPV* and the value added by the financing flexibility, or “option to refinance”:

$$TNPV(P) = NPV_0(P) + V_a \quad (4.29)$$

where $TNPV(P)$ is the total project NPV , and V_{OR} is the expected value of “option to refinance”.

CHAPTER 5

DEVELOPMENT OF DEBT-REFINANCING OPTIMIZATION (DRO) MODEL

This chapter develops the debt refinancing optimization (DRO) model that can optimize the debt-refinancing plan and analyze its impact on the equity cashflows for PPP infrastructure projects. It develops a generic financial model consisting of base case financial model, pre-refinancing financial model, post-refinancing financial model, and objective function of equity gains arising from debt refinancing. The model can assess the impact of different cashflow components on equity. The cashflow components that affect the equity gains from debt refinancing are clearly modeled. The optimization algorithm is developed, and run in the financial model to maximize the objective function with certain constraints.

5.1 Introduction

The previous chapter captured the value of financing flexibility created by the future debt refinancing opportunities, and the value-added to the project is recognized at the project planning stage. However, it does not show how a proper debt-refinancing plan should be undertaken at the time of refinancing, which is normally after construction or at the early stage of operation. The impact of the optimal plan on the equity cash flow could be different in projects with different features, base case cashflow patterns, original debt profiles, and refinancing constraints. There is a need to study how a debt-refinancing plan can be structured and how it can impact on the equity cash flow. Therefore, this chapter develops a generic optimization model to optimize the debt-refinancing plan, and analyze its impact on the equity cashflows. The factors in the model are debt interest rate, maturity, amount, repayment structure and other necessary constraints. The optimal refinancing plan is the one that can generate maximum equity gains under allowable project and market conditions. When the information on the market and project conditions becomes available, the terms of refinancing are also subject to the negotiation among lenders, project sponsors, and/or the government. It can, however, serve as a basis for negotiation for the project sponsors.

The overview of the debt-refinancing optimization model is illustrated in Figure 5.1. The details of the development are described in the following sections.

Figure 5.1 Flowchart of DRO framework

5.2 Development of Generic Financial Model of Debt Refinancing and Objective Function

A generic financial model is developed to model the impact of the debt refinancing on the equity cash flow. This model with the optimization algorithm can serve as a useful analytic tool for PPP project investors to optimize the refinancing plan and maximize the benefits from refinancing. It consists of three sub-models: base case financial model, pre-refinancing financial model and post-refinancing financing model. The equity gain arising from the debt refinancing is ultimately derived, and it is the objective function for optimization. The cash flow components are expressed in current value, unless otherwise specified.

Figure 5.2 summarizes the derivation process of the objective function from three sub-models and shows that the objective function is a function of refinancing variables. The details on the construction of the sub-models and the objective function are described in the following sections.

Figure 5.2 Derivation of objective function

5.2.1 Sub-model 1: base case financial model

The base case sub-model is fundamental to analyze debt refinancing. The equity cash flows are projected from the inception of the project to the end of the concession. This sub-model is developed by adopting various previous works (Ranasinghe 1996, Ranasinghe 1999, Bakatjan, Arikan et al. 2003, Cheng and Tiong 2005, Zhang 2005).

Free cash flow to equity

The free cash flow to equity is the cash flow available to equity investors after funding capital requirements, working capital needs, and debt financing requirements. It is used to evaluate equity investors' returns. It can be calculated from cash flow from operation by subtracting capital expenditures and adding back net borrowings. The model assumed that all surplus cash flow is paid out to equity investors after the construction phase. Any surplus cash flow accumulated in the construction phase is carried forward until the equity dividend is paid.

$$FCFE_i = ATOCF_i + DD_i - TC_i - DS_i \quad (5.1)$$

where $FCFE_i$ is the free cash flow to equity in the i th year in the base case.

Base case output

The threshold equity IRR is the original base case equity internal rate of return. It can be calculated from the equation below by setting NPV to 0. It is the discount rate used to calculate equity gains in subsequent sub-models.

$$\begin{aligned}
NPV_0(E) &= y(IRRET) \\
&= \sum_{i=0}^N \frac{FCFE_i}{(1 + IRRET)^i} \\
&= \sum_{i=0}^N \frac{ATOCF_i}{(1 + IRRET)^i} \\
&\quad + \sum_{i=0}^M \frac{DD_i}{(1 + IRRET)^i} - \sum_{i=0}^N \frac{TC_i}{(1 + IRRET)^i} - \sum_{i=0}^M \frac{DS_i}{(1 + IRRET)^i} \\
&= 0
\end{aligned} \tag{5.2}$$

$$\text{Thus } IRRET = y^{-1}(NPV_0(E) = 0) \tag{5.3}$$

where $NPV_0(E)$ is the time-zero NPV of equity cash flows in the base case, $IRRET$ is the threshold equity IRR derived from the base case, and M is the maturity of the original debt.

A project is financially viable from the perspective of equity investors when the threshold equity IRR is equal to or larger than the required equity rate of return of the project.

5.2.2 Sub-model 2: pre-refinancing financial model

The pre-refinancing sub-model is to present the equity cash flow before taking the refinancing into account. The projections in the model are the original estimations from the refinancing date to the end of the concession. The purpose of constructing such a pre-refinancing sub-model is to compare it with the cash flows in the refinanced case in order to derive the equity gains arising from refinancing. The discount rate used in the pre-refinancing model is threshold equity IRR obtained from the base case model.

$$\begin{aligned}
NPV_T(E) &= \sum_{i=T}^N \frac{FCFE_i}{(1 + IRRET)^{i-T}} \\
&= \sum_{i=T}^N \frac{ATOCF_i}{(1 + IRRET)^{i-T}} + \sum_{i=T}^M \frac{DD_i}{(1 + IRRET)^{i-T}} \\
&\quad - \sum_{i=T}^N \frac{TC_i}{(1 + IRRET)^{i-T}} - \sum_{i=T}^M \frac{DS_i}{(1 + IRRET)^{i-T}}
\end{aligned} \tag{5.4}$$

where $NPV_T(E)$ is the time- T NPV of equity cash flows in the base case, and T is the time of debt refinancing.

$ATOCF_i$

Substituting equation (4.5) into equation (4.4), the $ATOCF_i$ can be further broken down as shown in equation (5.5):

$$\begin{aligned}
ATOCF_i &= REV_i - OM_i - TAX_i \\
&= REV_i - OM_i - (REV_i - OM_i - DEP_i - DIN_i) \times TAXR_i \\
&= (REV_i - OM_i) \times TAXR_i - DEP_i \times TAXR_i - DIN_i \times TAXR_i
\end{aligned} \tag{5.5}$$

DS_i

The DS_i can be broken down as shown in equation (5.6):

$$DS_i = DIN_i + DPR_i \tag{5.6}$$

where DPR_i is the debt principal repayment at time i in the base case.

After substituting equations (5.5) and (5.6) into equation (5.4), the NPV of equity becomes

$NPV_T(E)$

$$\begin{aligned} NPV_T(E) &= \sum_{i=T}^N \frac{(REV_i - OM_i) \times TAXR_i + DEP_i \times TAXR_i + DIN_i \times TAXR_i}{(1 + IRRET)^{i-T}} \\ &\quad + \sum_{i=T}^M \frac{DD_i}{(1 + IRRET)^{i-T}} - \sum_{i=T}^N \frac{TC_i}{(1 + IRRET)^{i-T}} - \sum_{i=T}^M \frac{DIN_i + DPR_i}{(1 + IRRET)^{i-T}} \\ &= \sum_{i=T}^N \frac{(REV_i - OM_i) \times TAXR_i + DEP_i \times TAXR_i}{(1 + IRRET)^{i-T}} \\ &\quad - \sum_{i=T}^M \frac{DIN_i \times (1 - TAXR_i) + DPR_i}{(1 + IRRET)^{i-T}} \\ &\quad + \sum_{i=T}^M \frac{DD_i}{(1 + IRRET)^{i-T}} - \sum_{i=T}^N \frac{TC_i}{(1 + IRRET)^{i-T}} \end{aligned} \quad (5.7)$$

Equation (5.7) segregates the debt component from the after-tax operating cash flow, and it clearly shows the impact of the debt cash components on the equity cash flows. In addition, the tax impact in operating cash flow and the tax shield of interest payments are clearly presented.

5.2.3 Sub-model 3: post-refinancing financial model

The post-refinancing model projects the equity cash flow from the refinancing date to the end of the concession by taking the refinancing into account. The discount rate used in the model is also the threshold equity IRR obtained from the base case sub-model. The timelines projected in pre- and post-refinancing sub-models are the same, and the difference is that the cash flows in pre-refinancing sub-model are from the base case, while the cash flows in the post-refinancing sub-model incorporate the timing and cashflow of debt refinancing.

A new debt is constructed theoretically to refinance the original debt at refinancing time (T). The refinancing variables are listed in Table 5.1.

Table 5.1 Variables of debt refinancing

Refinancing Variables	Change in debt refinancing	Relation between refinancing variables and original debt
New interest rate in refinancing ($ReINR_i$)	Reduction in interest cost (XR)	$ReINR_i = INR_i - XR$
New debt amount in refinancing (ReD)	Increase in debt amount (XD)	$ReD = D_T + XD$
New maturity in refinancing (ReM)	Extension in maturity (XM)	$ReM = M + XM$
New debt repayment structure (Ψ)	N/A	N/A
Where INR_i is the interest rate of original debt D_T is the outstanding balance of original debt at time T M is the maturity of original debt		

The main assumptions on the refinancing are listed:

- 1) A new debt facility is structured to refinance the original debt facility at time T
- 2) The new debt facility will fully repay the outstanding principal of the original debt at time T
- 3) The interest rate of the new debt facility is $ReINR$, the debt amount of the new debt is ReD , where $ReD \geq D_T$, and the new maturity in the refinancing is ReM .
- 4) The debt service payment of the new debt facility starts from the time $T+1$ onwards

The time- T NPV of equity cash flow, after taking refinancing into account, is a function of debt refinancing variables.

$$\begin{aligned}
 NPV_T(ReE) &= g(ReINR, ReD, ReM, \Psi) \\
 &= \sum_{i=T}^N \frac{ReFCFE_i}{(1 + IRRET)^{i-T}}
 \end{aligned}
 \tag{5.8}$$

where $NPV_T(ReE)$ is the time- T net present value of equity cash flows in the refinanced case, and $ReFCFE_i$ is free cash flow to equity in i th year in the refinanced case.

ReFCFE_i

Similar to free cash flow to equity in base case, the cash flow components to derive free cash flow to equity in the refinanced case is shown in equation (5.9).

$$ReFCFE_i = ReATOCF_i - ReDD_i - ReTC_i - ReDS_i \quad (5.9)$$

where $ReATOCF_i$ is the after-tax operating cash flow in the i th year in the refinanced case, $ReDD_i$ is the debt drawdown in the i th year in the refinanced case, $ReTC_i$ is the total project cost in the i th year in the refinanced case, and $ReDS_i$ is the debt service payment in the i th year in the refinanced case.

ReATOCF_i

The after-tax operating cash flow in the refinanced case has the same revenue, O&M cost and depreciation components as the base case. The taxable income in the refinanced case takes account of impact of interest payments, which is different in the base case and refinanced case, so the tax payment is also different in the base case and refinanced case. Thereby,

$$ReATOCF_i = ReREV_i - ReOM_i - ReTAX_i \quad (5.10)$$

$$\begin{aligned} &= ReREV_i - ReOM_i \\ &\quad - (ReREV_i - ReOM_i - ReDEP_i - ReDIN_i) \times TAXR_i \\ &= (REV_i - OM_i) \times TAXR_i - DEP_i \times TAXR_i - ReDIN_i \times TAXR_i \end{aligned}$$

where $ReREV_i$ is the revenue in the i th year in the refinanced case, $ReOM_i$ is the operation and maintenance cost in the i th year in the refinanced case, $ReTAX_i$ is the tax payment in the i th year in the refinanced case, $ReDEP_i$ is the depreciation in the

i th year in the refinanced case, and $ReDIN_i$ is the debt interest payment in the i th year in the refinanced case.

ReDD_{*i*}

The debt drawings in the refinanced case from T onwards only occur once at T , thereby

$$ReDD_i = \begin{cases} ReD & i = T \\ 0 & i \neq T \end{cases} \quad (5.11)$$

ReTC_{*i*}

The total project cost at current value in the base case and refinanced case is unchanged, thereby

$$ReTC_i = TC_i \quad (5.12)$$

ReDS_{*i*}

The debt service payment in the refinanced case can also be broken down to two components, as shown in equation (5.13).

$$ReDS_i = ReDIN_i + ReDPR_i \quad (5.13)$$

where $ReDPR_i$ is the debt principal repayment at time i in the refinanced case.

The refinancing is taking place at the end of time T , so the interest payment at time T is still based on the outstanding balance of the original debt. After time T , the interest payment will be based on the new debt, which is a function of refinancing variables $ReINR$, ReD , ReM and Ψ . Thus,

$$ReDIN_i = \begin{cases} D_{T-1} \times INR_T = DIN_T, & i = T \\ h(ReINR, ReD, ReM, \Psi), & T < i \leq ReM \end{cases} \quad (5.14)$$

In the refinanced case, the principal repayment at the time of refinancing (T) has two elements. One element is the original scheduled one-period debt principal repayment based on the original debt due at time T . The second element of the debt principal repayment is the outstanding amount of the original debt at time T that is repaid by a new debt. After time T , the debt principal repayment will be based on the new debt facility, which is a function of refinancing variables $ReINR$, ReD , ReM and Ψ . Thus,

$$ReDPR_i = \begin{cases} D_T + DPR_T = D_{T-1}, & i = T \\ q(ReINR, ReD, ReM, \Psi), & T < i \leq ReM \end{cases} \quad (5.15)$$

$NPV_T(ReE)$

After substituting equations (5.9) to (5.15) into equation (5.8), the NPV of equity in the refinanced case becomes

$$NPV_T(ReE) = g(ReINR, ReD, ReM, \Psi) \quad (5.16)$$

$$\begin{aligned}
&= \sum_{i=T}^N \frac{ReATOCF_i}{(1 + IRRET)^{i-T}} + \sum_{i=T}^{ReM} \frac{ReDD_i}{(1 + IRRET)^{i-T}} - \sum_{i=T}^N \frac{ReTC_i}{(1 + IRRET)^{i-T}} \\
&\quad + \sum_{i=T}^{ReM} \frac{ReDS_i}{(1 + IRRET)^{i-T}} \\
&= \sum_{i=T}^N \frac{(REV_i - OM_i) \times TAXR_i + DEP_i \times TAXR_i + ReDIN_i \times TAXR_i}{(1 + IRRET)^{i-T}} \\
&\quad + ReD - \sum_{i=T}^N \frac{TC_i}{(1 + IRRET)^{i-T}} - \sum_{i=T}^{ReM} \frac{ReDIN_i + ReDPR_i}{(1 + IRRET)^{i-T}} \\
&= \sum_{i=T}^N \frac{(REV_i - OM_i) \times TAXR_i + DEP_i \times TAXR_i}{(1 + IRRET)^{i-T}} \\
&\quad - (DIN_T \times (1 - TAXR_i) + D_{T-1}) \\
&\quad - \sum_{i=T+1}^{ReM} \frac{ReDIN_i \times (1 - TAXR_i) + ReDPR_i}{(1 + IRRET)^{i-T}} + ReD - \sum_{i=T}^N \frac{TC_i}{(1 + IRRET)^{i-T}}
\end{aligned}$$

The equation clearly shows the collective effects of debt refinancing variables on the equity cash flows. It is also possible to evaluate the impact of any single variable of refinancing on the equity cash flows. When setting ReD equal to D_T , and ReM equal to M , the equation (5.16) models the impact of a change in interest rate by refinancing on equity cash flows. When setting $ReINR$ equal to INR and ReM equal to M , equation (5.16) models the impact of change of debt amount by refinancing. When setting $ReINR$ equal to INR and ReD equal to D_T , the impact of change of debt maturity by refinancing is modeled.

5.2.4 Objective function: equity gain of refinancing

The project sponsors' primary goal is to maximize their equity return. Improvement of equity return is the key factor for them to make decisions about debt refinancing. Therefore, instead of the project value added, the equity gain arising from debt refinancing is used as an objective function for optimization. HM Treasury (2007) defines the debt refinancing gain to equity as the changes in equity distribution

projected to take place after the refinancing, by comparison with the position immediately before the refinancing. It can be calculated as the difference between the *NPV* of the equity cash flows in the post-refinancing model and the pre-refinancing model. Because the equity in the refinanced case is the function of refinancing variables $ReINR$, ReD , ReM and Ψ , therefore, the equity gain by refinancing is also a function of the variables.

$$ReG_T = f(ReINR, ReD, ReM, \Psi) \quad (5.17)$$

$$= NPV_T(ReE) - NPV_T(E)$$

$$\begin{aligned} &= - \left((DIN_T \times (1 - TAXR_T) + D_T) + \sum_{i=T+1}^{ReM} \frac{ReDIN_i \times (1 - TAXR_i) + ReDPR_i}{(1 + IRRET)^{i-T}} + ReD \right) \\ &\quad - \left(- \sum_{i=T}^M \frac{DIN_i \times (1 - TAXR_i) + DPR_i}{(1 + IRRET)^{i-T}} + \sum_{i=T}^M \frac{DD_i}{(1 + IRRET)^{i-T}} \right) \\ &= \left(- (DIN_T \times (1 - TAXR_T) + D_T) - \sum_{i=T+1}^{ReM} \frac{ReDIN_i \times (1 - TAXR_i) + ReDPR_i}{(1 + IRRET)^{i-T}} + ReD \right) \\ &\quad - \left(- (DIN_T \times (1 - TAXR_T) + DPR_T) - \sum_{i=T+1}^M \frac{DIN_i \times (1 - TAXR_i) + DPR_i}{(1 + IRRET)^{i-T}} + \sum_{i=T}^M \frac{DD_i}{(1 + IRRET)^{i-T}} \right) \\ &= (DPR_T - D_T) + \left(\sum_{i=T+1}^M \frac{DIN_i \times (1 - TAXR_i) + DPR_i}{(1 + IRRET)^{i-T}} - \sum_{i=T+1}^{ReM} \frac{ReDIN_i \times (1 - TAXR_i) + ReDPR_i}{(1 + IRRET)^{i-T}} \right) \\ &\quad + \left(ReD - \sum_{i=T}^M \frac{DD_i}{(1 + IRRET)^{i-T}} \right) \end{aligned}$$

and

$$ReG_0 = \frac{ReG_T}{(1 + IRRET)^T} \quad (5.18)$$

where ReG_T is the time $-T$ *NPV* of equity gains arising from debt refinancing, and ReG_0 is the time-zero *NPV* of equity gain arising from debt refinancing.

Equation (5.17) shows that the equity gains from debt refinancing is derived from three components: the difference of the debt principal repayments at the time of

refinancing in the base case and refinanced case, the difference of the tax-shield-adjusted debt service payments after the time of refinancing in the base case and refinanced case, and the difference of the debt drawings in the base case and refinanced case. When the maturity of the debt is extended in the refinanced case, the additional debt service payments beyond the original debt maturity also need to be subtracted from the equity gains.

5.3 Debt Refinancing Optimization

5.3.1 Optimization

The different combination of variables of interest rate, maturity, amount and repayment structure of the new debt facility in a refinancing plan can alter the equity gains. The debt-refinancing plan, which can maximize the equity gain, is defined as optimal; therefore, the objective function is the equity gain from refinancing, which is the function of refinancing variables. The optimization is illustrated in Figure 5.3.

Figure 5.3 Debt refinancing optimization

The optimization programming is shown as follows:

$$MAX \quad ReG_T = f(ReINR, ReD, ReM, \Psi)$$

$$\begin{aligned} \text{Subject To} \quad (1) \quad & ReINR = ReINR_{\min} \\ (2) \quad & M \leq ReM \leq M_{\max}, \quad M_{\max} \leq N \\ (3) \quad & D_T \leq ReD \leq \frac{1}{LLCR_{\min}} \times \sum_{i=T}^{ReM} \frac{ReATOCF_i}{(1 + ReINR_i)^{i-T}} \\ (4) \quad & ReDSCR_i \geq DSCR_{\min} \\ (5) \quad & ReLLCR_i \geq LLCR_{\min} \\ (6) \quad & RePLCR_i \geq PLCR_{\min} \\ (7) \quad & \text{Other necessary constraints} \end{aligned}$$

where $ReINR_{\min}$ is the minimum interest rate in the refinanced case, $M_{\max}$ is the maximum maturity by taking account of minimum tail periods in the refinanced case, $ReDSCR_i$ is the annual debt service cover ratio in the i th year in the refinanced case, $ReLLCR_i$ is the loan life cover ratio in the i th year in the refinanced case, $RePLCR_i$ is the project life cover ratio in the i th year in the refinanced case, $DSCR_{\min}$ is the minimum debt service cover ratio required by the lender in the refinanced case, $LLCR_{\min}$ is the minimum loan life cover ratio required by the lender in the refinanced case, and $PLCR_{\min}$ is the minimum project life cover ratio required by the lender in the refinanced case.

5.3.2 Constraints

Interest rate constraint

Refinancing is normally undertaken after the completion of construction and the demonstration of good operation conditions so that the project risk is significantly reduced. Thus, the interest rate is usually reduced. Debt pricing that can be linked to different debt maturity and lending amount reflects the credit risk. In optimization, the lower interest rate always leads to greater refinancing gains due to lower interest cost. The possible minimum interest rate can be obtained by negotiation with lenders depending on the project credit condition and capital market condition at the time of refinancing.

Maturity constraint

The extended maturity (ReM) cannot exceed the concession period (N) unless the concession is extended too. Lenders often build in a safety cushion after the maturity of the debt facility. The tail period can cover the loan repayment in case of difficulties during the maturity period, and the value of the tail can be measured by $PLCR$. On the other hand, if the maturity is not extended, it will be the same as the original maturity (M).

Debt amount constraint

Dias and Ioannou (1995) derived a mathematical formulation of project debt capacity for one-period privately-financed infrastructure projects. It is a sound theoretical approach but not practical for PPP infrastructure projects which are normally multi-period. Finnerty (1996) developed a borrowing capacity model to determine the maximum amount of debt that a project's cash flow stream will support for a given set of project and loan parameters. It showed that the amount the banks will lend equals a fraction of the present value of the available cash flow stream during a period between completion of the construction phase and final loan repayment. In the optimization framework, the possible maximum amount of the new debt used to refinance the original debt would be a fraction of the present value of the cash available to the debt service during a period between the time of refinancing and the end of the debt. The fraction factor is the inverse of the required minimum loan life cover ratio ($LLCR_{\min}$). At the same time, the debt amount is also subject to other cover ratio constraints. The minimum amount of refinancing is the outstanding balance of the original debt at time of refinancing (D_T).

Debt cover ratio constraint

Lenders calculate cover ratios to assess the project company's ability to repay its debt service. Often they put certain restrictions on those cover ratios to ensure a comfortable margin of safety (Yescombe 2007).

The *DSCR* assesses the project company's ability to repay its debt from its periodic cash flow. The debt service cover ratio in the refinanced case ($ReDSCR_i$) is calculated as

$$ReDSCR_i = \frac{ReATOCF_i}{ReDS_i} \quad (5.19)$$

The *LLCR* assesses the project company's ability to repay its debt over its whole term. The loan life cover ratio in the refinanced case at the calculation date of k ($ReLLCR_k$) is shown as below:

$$ReLLCR_k = \frac{\sum_{i=k}^{ReM} \frac{ReATOCF_i}{(1 + ReINR)^{i-k}}}{ReD_k} \quad (5.20)$$

The *PLCR* assesses the project company's ability to make repayments after the maturity of the debt if there have been difficulties in repaying the debt in time. The value of *PLCR* should be higher than *LLCR*. The project life cover ratio at the calculation date of k in the refinanced case ($RePLCR_k$) is shown as below:

$$RePLCR_k = \frac{\sum_{i=k}^N \frac{ReATOCF_i}{(1 + ReINR)^{i-k}}}{ReD_k} \quad (5.21)$$

Due to features specific to particular projects and sectors, PPP projects may have different requirements on cover ratios. In the PPP sector, the high-risk projects that involve usage/revenue risk generally require higher debt cover ratios than low-risk projects. Yescombe (2207) stated that the minimum initial *LLCR* and *PLCR* requirement is typically around 10% and 15–20% higher than minimum annual *DSCR* respectively. Gatti (2008) summarized cover ratios in different sectors where project finance was utilized, as shown in Table 5.2.

Table 5.2 Debt cover ratios in different PPP sectors

Sector		Average <i>DSCR</i>	Average <i>LLCR</i>
Power	Merchant Plants	2–2.25	2.25–2.75
	With a tolling agreement	1.5–1.7	1.5–1.8
	In cases involving regulated business	1.3–1.5	1.3–1.5
Transportation/shipping		1.25–1.5	1.4–1.6
Telecom		1.2–1.5	n/a
Water		1.2–1.3	1.3–1.4
Waste to energy		1.35–1.4	1.8–1.9
PFI		1.35–1.4	1.45–1.5

Source: Gatti (2008)

5.3.3 Optimization Algorithm

An optimization algorithm is developed and run by Visual Basic programming in the financial model. The logic of the algorithm is shown in Figure 5.4.

Figure 5.4 Optimization algorithm of debt-refinancing plans

There are three iteration loops in the algorithm. The loop of change in amount of new debt is stopped by the condition shown in equation (5.22) which is governed by the debt cover ratio and project cash flow. α is the incremental change of debt amount in iteration calculation. It can be specified by equity investors in different magnitudes.

$$XD > \frac{1}{LLCR_{\min}} \times \sum_{i=T}^{ReM} \frac{ReATOCF_i}{(1 + ReINR_i)^{i-T}} - D_T \quad (5.22)$$

The loop of change in maturity of new debt is stopped by the condition shown in equation (5.23) that is governed by the concession period and tail period to give maximum allowable maturity.

$$XM > M_{\max} - M \quad (5.23)$$

The loop of change in repayment structure is to compare the optimal refinancing plans under different debt repayment schedules. It can finally select the repayment schedule with which the debt-refinancing plan can generate the maximum equity gain.

The new interest rate in a refinancing can be determined subject to the negotiation at the time of refinancing when information on the updated market and project condition becomes available. Therefore, the scenario analysis can be incorporated into the optimization to deliver the optimal debt-refinancing plan under different interest rate scenarios.

CHAPTER 6

CASE STUDIES

This chapter uses three case studies to validate the ORV framework and the DRO model, which were developed in Chapter 4 and Chapter 5 respectively. The three cases are Toll Road BOT Project A, Indonesia; Laibin B Power BOT Project, China; and Labuan Water Supply BOT Project, Malaysia. The working process using the ORV framework and DRO model, and their output of the value of “option to refinance”, the total project *NPV* by incorporating the financing flexibility, the optimal debt refinancing plan and the analysis of its impact on equity cash flow are illustrated in the three BOT projects.

6.1 Case study 1: Toll Road BOT Project A, Indonesia

6.1.1 Project description

Toll Road BOT Project A is one of several BOT toll road projects in Indonesia. The project is kept anonymous due to the issues of confidentiality. The toll road project company is responsible for constructing and operating a 25-kilometer toll road, and will transfer it back to the Indonesian Government at end of the concession. The concession period is 35 years. The key data in the base case of the Toll Road BOT Project A is summarized in Table 6.1.

Table 6.1 Summary of key data in base case of Toll Road BOT Project A

Concession period	35 years
Total project cost	Rp. 3,287 billion
Required project rate of return	12 %
Construction	3 years
Equity: Debt ratio	30:70
Base inflation rate	7%
Tax rate	30%

The original loan profile in the base case is summarized in Table 6.2. It is local loan facility, and constitutes 70% of the total project cost.

Table 6.2 Original loan facility in base case of Toll Road BOT Project A

Debt amount	Rp. 2,300 billion
Maturity	16 years
Grace period	6 years
Interest rate	14%
Repayment	Flexible schedule pre-determined

The local bank loan can be refinanced in order to change the original financing plan of the project. The financing flexibility created by debt refinancing opportunities is represented as “option to refinance”. The following sections demonstrate the

valuation of the “option to refinance” by the ORV framework, and the reflection of its value in the total project value.

6.1.2 Valuation of “option to refinance” by ORV framework

6.1.2.1 DCF analysis of project base case

The base case *NPV* of the project investment is Rp. 2,790,163 million without considering the financing flexibility created by debt refinancing opportunities. The base case cashflow is shown in Appendix 1.

6.1.2.2 Risk analysis of conditions for “option to refinance”

Condition 1: Completion of construction

The construction period is expected to be three years. The total construction cost does not include a foreign component. The raw construction cost in the base case is Rp. 2,734,998 million. The risk factors are shown in Table 6.3. The coefficient of variance of each stochastic risk factor is assumed to be 0.1; therefore the standard deviation is 0.1 μ . In the event of delay in completion, the limit of the penalty is assumed to be 5% of the construction cost. The contingency cost is 10% of the toll facility cost, accounting for 4.1% of the total project cost. There is no early bonus for early completion, but an early service payment can be collected.

Table 6.3 Factors of construction risk in Toll Road BOT Project A

Risk factors	Unit	Distribution function
Base construction cost		
Year 1	Rp. Million	Lognormal distribution (493,471, 49,347 ²)
Year 2	Rp. Million	Lognormal distribution (1,197,973, 119,797 ²)
Year 3	Rp. Million	Lognormal distribution (681,955, 68,195 ²)
Inflation rate		Normal distribution (0.07, 0.007 ²)
Completion time	Year	Lognormal distribution (3, 0.3 ²)

The risk-simulated total construction cost (TCC_{risk}) illustrated in Figure 6.1 is simulated by incorporating risk factors. The detailed simulation result is in Appendix 2.

Figure 6.1 Simulation result of construction risk in toll road BOT project A

Therefore, the probability of success in condition 1 (Ω_1) is 81.05%.

Condition 2: Demonstration of stable revenue streams

The ramp-up period of the traffic is assumed to be five years. The factors of revenue risks are summarized in Table 6.4.

Table 6.4 Factors of revenue risk in Toll Road BOT Project A

Risk factors	Unit	Distribution function
Initial traffic		
Category 1	Vehicle/day	Lognormal distribution ($30,000, 3,000^2$)
Category 2	Vehicle/day	Lognormal distribution ($3,200, 320^2$)
Category 3	Vehicle/day	Lognormal distribution ($2,200, 220^2$)
Growth rate		Normal distribution ($0.07, 0.007^2$)

The risk-simulated revenue (REV_{risk}) is shown in Figure 6.2. The detailed simulation result is in Appendix 3. The projected revenue in year 5 is Rp. 657,617 million, and the fraction factor (a) is assumed to be 95%. Therefore, the probability of success in condition 2 (Ω_2) is 72.33%.

Figure 6.2 Simulation result of revenue risk in Toll Road BOT Project A

Joint probability of condition 1 and 2

The joint probability of success in both conditions (Φ) is $\Omega_1 \times \Omega_2 = 58.62\%$.

6.1.2.3 Conditional option valuation

The conditional “option to refinance” given success in both conditions above is structured as a European call option written on the original loan with the expiration time of the end of year 8, which is just after the three-year construction and five-year ramp-up period for traffic. At the end of year 8, the outstanding balance of the original loan is Rp. 2,070,609 million, which is the strike price of the option. The structure of the conditional “option to refinance” in the Toll Road BOT Project A is summarized in Table 6.5.

Table 6.5 Structure of conditional “option to refinance” in Toll Road BOT Project A

Option type	European call option
Option owner	The Toll Road Project Company
Underlying asset	Original bank loan
Strike price	Rp. 2,070,609 million
Expiration of option	Year 8

A project timeline is illustrated in Figure 6.3 to give a clear overview on the timing of the option in relation to the project lifecycle.

Figure 6.3 Timeline of Toll Road BOT Project A

The details of the drawdown and amortization schedule of the original debt facility are shown in Appendix 1. The net debt cash flows (CF_i^d) combining debt drawings, debt interest payment and principal repayment are shown in Figure 6.4.

Figure 6.4 Net debt cashflow in base case of Toll Road BOT Project A

The data on the term structure of Indonesian government bonds on 2 January 2008 were retrieved from Bloomberg shown in Table 6.6.

Table 6.6 Term structure of Indonesian government bonds (on 2 January 2008)

Year	1	2	3	4	5	6	7	8
Yield (%)	8.2	8.29	8.63	9.05	9.21	9.57	9.616	9.843

Hence, the zero-coupon discount factor can be derived by the term structure, and shown in Table 6.7.

Table 6.7 Zero-coupon discount factors in Toll Road BOT Project A

Year	1	2	3	4
Zero-coupon discount factor (Z_i)	1.0855	1.1803	1.2955	1.436
Year	5	6	7	8
Zero-coupon discount factor (Z_i)	1.5849	1.7757	1.9603	2.1978

Therefore, the forward market value of the original debt obligation ($F(0, 8)$) is

$$F(0, 8) = \sum_{i=1}^{i=8} \frac{Z_T \cdot CF_i^d}{Z_i} = 1,968,691$$

At the expiration of the conditional “option to refinance”, the original debt will have the remaining maturity of eight years. The forward yield volatility of debt market value is assumed to be 0.15. The input and output of the conditional option valuation are summarized in Table 6.8.

Table 6.8 Input and output of conditional option valuation in Toll Road BOT Project A

Input	Unit	Value
Refinancing time (T)	Year	8
Strike price (D_8)	Rp. million	2,070,609
8-year zero-coupon bond price ($P(0, 8)$)		0.4550
Forward market value of original debt obligation ($F(0, 8)$)	Rp. million	1,968,691
Forward volatility (σ_F)		0.15
Output		
Value of conditional option (V_0)	Rp. million	132,269

The final calculation is shown as follows:

$$N(d_1) = N\left(\frac{\ln(F(0, 8) / D_8) + \sigma_F^2 T / 2}{\sigma_F \sqrt{T}}\right) = 0.5371$$

$$N(d_2) = N\left(\frac{\ln(F(0, 8) / D_8) - \sigma_F^2 T / 2}{\sigma_F \sqrt{T}}\right) = 0.3703$$

Thus,

$$V_0 = P(0, 8)(F(0, 8)N(d_1) - D_8 N(d_2)) = 132,269$$

Therefore, the conditional expected value of “option to refinance” given success in completion of construction and demonstration of stable revenue (V_0) is Rp. 132,269 million.

6.1.2.4 Output of ORV framework

The expected value of “option to refinance” (V_{OR}) is Rp. 77,541 million. In other words, the financing flexibility created by debt refinancing opportunities is worth Rp. 77,541 million in this project. The conditional tree is shown in Figure 6.5. The total project *NPV* is thereby increased to Rp. 2,867,704 million by incorporating the value of such financing flexibility.

Figure 6.5 Conditional tree of option valuation in Toll Road BOT Project A

6.1.3 Debt-refinancing optimization by DRO model

In year 8, when the new information on the market and project has been updated, the toll road project company may consider undertaking a debt-refinancing plan. The DRO model developed in Chapter 5 is used to assess the impact of the refinancing plan on the equity return in order to facilitate the decision, and the project company can use the optimal plan generated from the model as a basis to negotiate with lenders. The maximum maturity period for debt repayment is assumed to be 25 years for a 35-year concession as the industry practice for the maximum maturity can ranges from 20 to 30 years. The *DSCR*, *LLCR* and *PLCR* after refinancing are assumed to maintain at least 1.3, 1.4 and 1.5 respectively as the average *DSCR* and *LLCR* found in literature in Table 5.2 range from 1.25 to 1.5 and 1.4 to 1.6 respectively for transportation sector and *PLCR* are normally 15-20%

higher than the minimum *DSCR*. Two scenarios of repayment schedules are considered. They are annuity repayment and equal principal repayment which are the two common repayment schedules used in projects. Three scenarios of interest rates are considered. They are the original interest rate (14%), 100 basis point reduction in the original interest rate (13%), and 200 basis point reduction in the original interest rate (12%). The optimization plans are generated under different scenarios with the impact of other refinancing variables.

The optimal plans under different scenarios generated by the DRO model are shown in Table 6.9.

Table 6.9 Optimal debt refinancing plans in Toll Road BOT Project A

New interest rate in refinancing (<i>ReINR</i>)	Scenario 1: 12%		
Repayment schedule		Annuity	Equal principal
New maturity in refinancing (<i>ReM</i>)	Year	25	25
New debt amount in refinancing (<i>ReD</i>)	Rp. Million	3,240,609	2,417,609
NPV at year 8 of equity gain (<i>ReG_T</i>)	Rp. Million	1,027,407	443,396
NPV at year 0 of equity gain (<i>ReG₀</i>)	Rp. Million	206,925	89,302
Improved equity IRR (<i>ReIRR</i>)		25.10%	23.33%
New interest rate in refinancing (<i>ReINR</i>)	Scenario 2: 13%		
Repayment schedule		Annuity	Equal principal
New maturity in refinancing (<i>ReM</i>)	Year	25	25
New debt amount in refinancing (<i>ReD</i>)	Rp. Million	3,080,609	2,300,609
NPV at year 8 of equity gain (<i>ReG_T</i>)	Rp. Million	872,513	335,355
NPV at year 0 of equity gain (<i>ReG₀</i>)	Rp. Million	175,729	67,542
Improved equity IRR (<i>ReIRR</i>)		24.64%	23.04%
New interest rate in refinancing (<i>ReINR</i>)	Scenario 3: 14%		
Repayment schedule		Annuity	Equal principal
New maturity in refinancing (<i>ReM</i>)	Year	25	25
New debt amount in refinancing (<i>ReD</i>)	Rp. Million	2,932,609	2,194,609
NPV at year 8 of equity gain (<i>ReG_T</i>)	Rp. Million	729,057	237,372
NPV at year 0 of equity gain (<i>ReG₀</i>)	Rp. Million	146,836	47,808
Improved equity IRR (<i>ReIRR</i>)		24.21%	22.79%
Base case IRR	22.18%		

The equity improvement by optimal debt refinancing plans is illustrated in Figure 6.7. The base case equity *IRR* is 22.18%. The maximum equity *IRR* after

refinancing in optimal plans with annuity repayment structure can be increased to 25.10%, 24.64% and 24.21% respectively under the scenarios of new interest rate of 12%, 13% and 14% respectively. The maximum equity *IRR* after refinancing in optimal plans with equal principal repayment structure can be increased to 23.33%, 23.04% and 22.79% under the scenarios of new interest rates of 12%, 13% and 14% respectively. The refinancing plan with annuity repayment schedule can provide higher equity gain than that with equal principal repayment schedule for the Toll Road BOT Project A.

Figure 6.6 Equity improvement by optimal debt-refinancing plans in Toll Road BOT Project A

The impact of debt refinancing at the new interest rates of 12%, 13 % and 14% on the equity cash flows in Toll Road BOT Project A is illustrated in Figure 6.7, Figure 6.8, and Figure 6.9 respectively. The data of the free cash flow to equity after debt refinancing is in Appendix 4. Under the optimal debt-refinancing plan, the equity cash flow is dramatically increased at year 8 because the refinancing largely pays back the equity contribution at the time of refinancing. The equity cash flows in refinanced case are larger than that in the base case from years 9 to 14, partially because the debt maturity is extended from 16 years to 25 years which essentially spreads the debt repayment and lowers the debt service payments in the early years

after refinancing. The original loan in the base case had a flexible repayment structure, and the debt service payments in the base case during this period were relatively high, especially in years 12 and 13. This could be one of the reasons for higher equity cash flows in the refinanced case. From year 15 to 16, the equity cashflows in the refinanced case start to be less than that in the base case. This is partially because the impact of the increased debt amount that can increase the debt service payments starts to be dominant on the equity cash flow over the effect of the extended maturity and decreased interest rate that can lower the debt service payments. In addition, the debt service payment in the base case is relatively low during this period. From year 17 to 25, the equity cash flows in the refinanced case continue to be less than that in the base case. The debt service payment in the base case ended in year 16 as the maturity of the original debt was 16 years. The additional debt service payments resulting from the extension of the debt maturity in refinancing lead to the lower equity cash flows in the refinanced case after year 16. After year 25, the equity cash flows in the refinanced case and base case converge as there is no difference in equity cash flows after the new debt service period between the base case and refinanced case. The annuity and equal principal repayment structure in the optimal refinancing plans result in the same pattern of equity cash flows, but the annuity repayment structure is able to raise more debt in the optimal refinancing plan to suit the cash flows and constraints of the Toll Road BOT Project A. This partially contributes to the better improvement of equity *IRR* by refinancing with the annuity repayment structure compared with the equal principal repayment structure.

Figure 6.7 Impact of optimal debt refinancing plans (at interest rate 12%) on equity cash flows in Toll Road BOT Project A

Figure 6.8 Impact of optimal debt refinancing plans (at interest rate 13%) on equity cash flows in Toll Road BOT Project A

Figure 6.9 Impact of optimal debt refinancing plans (at interest rate 14%) on equity cash flows in Toll Road BOT Project A

6.2 Case study 2: Laibin B Power BOT Project, China

6.2.1 Project description

In 1994, the China Central Government of the People's Republic of China attempted to use the BOT model to develop infrastructure projects and it began a series of pilot BOT projects in 1995. The Laibin B Power BOT project was one of them, and was the second phase of the Laibin power plant. The Central Government allowed the project company to have full foreign ownership, which had never happened before in China. Guangxi Laibin Electric Power was established as the project company to finance, construct, and operate a coal-fired power plant for 18 years, and transfer it back to the local government authority at the end of the concession. The Laibin B plant is located in Laibin County in Guangxi Autonomous Region, which is in the south of China. The plant capacity is 6,300 million kWh of electricity per year with two 360 MW pulverized coal-fired generating units. It is adjacent to the Laibin A plant. The Guangxi Power Industry Bureau (GPIB) as a government entity was responsible for purchasing electricity over the concession period. The Guangxi government guaranteed the annual purchase of a minimum net electrical output of 3500 million kWh by GPIB from the Guangxi Laibin Electric Power. In addition, the Guangxi government also guaranteed the obligation of Guangxi Construction & Fuel Company Ltd (GCFC) to supply fuels to the Guangxi Laibin Electric Power.

The contractual structure of the Laibin B power BOT project is illustrated in Figure 6.10. The project company was owned by Electricite de France International (EDFI) (60%) and GEC Alsthom (40%) respectively. The operator was owned by EDFI (85%), GPIB (7.5%) and Gaungxi Development and Investment Co. Ltd (GDIC) (7.5%). The construction contractor was formed by Alsthom Export and Compagnie Financiere de Valorisation pour L' Ingenierie. The equipment supplier was formed by GEC Alsthom and Electricite de France (EDF).

Figure 6.10 Contractual structure of Laibin B Power BOT project

Source: Wang and Tiong (2000), Ye and Tiong (2000)

The key data in the base case of the Laibin B power project are summarized in Table 6.10.

Table 6.10 Summary of key data in base case of Laibin B Power BOT Project

Concession period		18 years
Total project cost		US\$ 616 million
Equity: Debt ratio		25:75
Required project rate of return		14 %
Construction		3 years
Base inflation rate		3%
Tax holiday		7 years
Tax rate	Year 8–12	16%
	Year 13–18	33%

The original loan profile in the base case is summarized in Table 6.11. It constitutes 75% of the total project cost. The loan is in US dollars, and has currency exposure against revenue denominated in RMB.

Table 6.11 Original loan facility in base case of Laibin B Power BOT Project

Debt amount	French Export Credit: US\$ 300 million Commercial loan: US\$ 190 million
Maturity	12 years
Grace period	3 years
Interest rate	LIBOR (7%) + credit margin (2%)
Repayment	Equal principal repayment

The French Export Credit and Commercial loan can be refinanced in order to change the original financing plan of Laibin B Power BOT Project. The financing flexibility created by debt refinancing opportunities is represented as an “option to refinance”. The following sections demonstrate the valuation of the “option to refinance” by the ORV framework, and the reflection of its value in the total project value.

6.2.2 Valuation of “option to refinance” by ORV framework

6.2.2.1 DCF analysis of project base case

The base case *NPV* of the project investment is US\$ 84.22 million without considering the financing flexibility created by debt refinancing opportunities. The base case cashflow is shown in Appendix 5.

6.2.2.2 Risk analysis of conditions for “option to refinance”

Condition 1: Completion of construction

The total construction cost in the base case was US\$ 559.42 million. The construction was expected to be completed in three-years. The risk factors are listed in Table 6.12. The coefficient of variance of each stochastic risk factor is assumed to be 0.1; therefore the standard deviation is 0.1 of its mean. The standby debt was US\$ 40 million for support. No delay penalty or early completion bonus were involved.

Table 6.12 Factors of construction risks in Laibin B Power BOT Project

Risk factors	Unit	Distribution function
Base construction cost		
Year 1	US\$ Million	Lognormal distribution (101.71, 10.17 ²)
	RMB Million	Lognormal distribution (363.10, 36.31 ²)
Year 2	US\$ Million	Lognormal distribution (176.06, 17.61 ²)
	RMB Million	Lognormal distribution (628.52, 62.85 ²)
Year 3	US\$ Million	Lognormal distribution (98.77, 9.88 ²)
	RMB Million	Lognormal distribution (352.60, 35.26 ²)
Foreign exchange		Normal distribution (8.33, 0.83 ²)
Inflation rate		
US		Normal distribution (0.03, 0.003 ²)
China		Normal distribution (0.04, 0.004 ²)
Completion time	Year	Lognormal distribution (3, 0.3 ²)

The risk-simulated total construction cost (*TCC_Risk*) is illustrated in Figure 6.11. The detailed simulation result is in Appendix 6.

Figure 6.11 Simulation result of construction risk in Laibin B Power BOT Project

Therefore, the probability of success in condition 1 (Ω_1) is 87.34%.

Condition 2: demonstration of stable revenue streams

As the Guangxi Government guaranteed the minimum electricity purchase from Guangxi Laibin Electric Power, the project company did not bear the revenue risk. Therefore, the probability of success in condition 2 (Ω_2) is 1.

Joint probability of condition 1 and 2

The joint probability of success in both condition 1 and 2 (Φ) is $\Omega_1 \times \Omega_2 = 87.34\%$.

6.2.2.3 Conditional option valuation

The conditional “option to refinance” given success in both conditions above is structured as a call option written on the original loan with the expiration time of year 4. The strike price is US\$ 410.90 million, which is the outstanding balance of

the original loan facility at the end of year 4. The structure of the conditional “option to refinance” in the Laibin B power project is summarized in Table 6.13.

Table 6.13 Structure of “option to refinance” in Laibin B Power BOT Project

Option type	European call option
Option owner	Guangxi Laibin Electric Power
Underlying asset	Original loan facility
Strike price	US\$ 410.90 million
Expiration of option	Year 4

A project timeline is illustrated in Figure 6.12 to give a clear overview of the timing of the option in relation to the project lifecycle.

Figure 6.12 Timeline of Laibin B Power BOT Project

The details of the drawdown and amortization schedule of the original debt facility are shown in Appendix 5. The net debt cash flows (CF_i^d) combining debt drawings, debt interest payment and principal repayment are shown in Figure 6.13.

Figure 6.13 Net debt cash flow in case base of Laibin B Power BOT Project

The data on the term structure of US treasury bonds on 1 January 1997 were retrieved from Bloomberg, as shown in Table 6.14.

Table 6.14 Term structure of US treasury bonds (on 1 January 1997)

Year	1	2	3	4
Yield (%)	6.64	6.69	6.74	6.75

Hence, the zero-coupon discount factor can be derived by the term structure, and are shown in Table 6.15.

Table 6.15 Zero-coupon discount factors in Laibin B Power BOT Project

Year	1	2	3	4
Zero-coupon discount factor (Z_i)	1.0687	1.1432	1.2240	1.3100

Therefore, the forward market value of the original debt obligation ($F(0, 4)$) is

$$F(0, 4) = \sum_{i=1}^{i=4} \frac{Z_T \cdot CF_i^d}{Z_i} = 435.91$$

At year of 4, the original debt will have the remaining maturity of eight years. The forward yield volatility of debt market value is assumed to be 0.10. The input and output of the conditional option valuation is summarized in Table 6.16.

Table 6.16 Input and output of conditional option valuation in Laibin B Power BOT Project

Input	Unit	Value
Refinancing Time (T)	Year	4
Strike price (D_4)	US\$ million	410.90
4-year zero-coupon bond price ($P(0, 4)$)		0.7634
Forward market value of original debt obligation ($F(0, 4)$)	US\$ million	435.91
Forward volatility (σ_F)		0.10
Output		
Value of conditional option (V_0)	US\$ million	36.40

The final calculation is shown as follows:

$$N(d_1) = N\left(\frac{\ln(F(0, 4) / D_4) + \sigma_F^2 T / 2}{\sigma_F \sqrt{T}}\right) = 0.6537$$

$$N(d_2) = N\left(\frac{\ln(F(0, 4) / D_4) - \sigma_F^2 T / 2}{\sigma_F \sqrt{T}}\right) = 0.5774$$

Thus,

$$V_0 = P(0, 4)(F(0, 4)N(d_1) - D_4N(d_2)) = 36.40$$

Therefore, the conditional expected value of “option to refinance” given success in completion of construction and demonstration of stable revenue (V_0) is US\$ 36.40 million.

6.2.2.4 Output of ORV framework

The expected value of “option to refinance” (V_{OR}) is US\$ 31.79 million. In other words, the financing flexibility created by debt refinancing opportunities is worth US\$ 31.79. The conditional tree is shown in Figure 6.14. The total project NPV is increased to US\$ 116.01 million by incorporating the option value.

Figure 6.14 Conditional tree of option valuation in Laibin B Power BOT Project

6.2.3 Debt-refinancing optimization by DRO model

In year 4, when the new information on the market and project has been updated, the Guangxi Laibin Electric Power may consider undertaking a debt-refinancing plan. The DRO model developed in Chapter 5 is used to assess the impact of the refinancing plan on the equity return in order to facilitate the decision, and the project company can use the optimal plan generated from the model as a basis to negotiate with lenders. The maximum maturity period for debt repayment is assumed to be 15 years for a 18-year concession. The *DSCR*, *LLCR* and *PLCR* after refinancing are assumed to maintain at least 1.6, 1.7 and 1.8 respectively as the average *DSCR* and *LLCR* found in literature in Table 5.2 range from 1.5 to 1.7 and 1.5 to 1.8 respectively for power sector with a tolling agreement and *PLCR* are normally 15-20% higher than the minimum *DSCR*. Two scenarios of repayment schedules are considered. They are annuity repayment and equal principal

repayment which are the two common repayment schedules used in projects. Three scenarios of interest rates are considered. They are the original interest rate (9%), 100 basis point reduction in the original interest rate (8%), and 200 basis point reduction in the original interest rate (7%). The optimization plans are generated under different scenarios with the impact of other refinancing variables.

The optimal plans under different scenarios generated by the DRO model are shown in Table 6.17.

Table 6.17 Optimal debt refinancing plans in Laibin B Power BOT Project

New interest rate in refinancing (<i>ReINR</i>)	Scenario 1: 7%		
Repayment schedule		Annuity	Equal principal
New maturity in refinancing (<i>ReM</i>)	Year	15	15
New debt amount in refinancing (<i>ReD</i>)	US\$ million	521.80	542.80
NPV at year 4 of equity gain (<i>ReG_T</i>)	US\$ million	123.85	200.95
NPV at year 0 of equity gain (<i>ReG₀</i>)	US\$ million	41.19	66.83
Improved equity IRR (<i>ReIRR</i>)		46.15%	54.11%
New interest rate in refinancing (<i>ReINR</i>)	Scenario 2: 8%		
Repayment schedule		Annuity	Equal principal
New maturity in refinancing (<i>ReM</i>)	Year	15	15
New debt amount in refinancing (<i>ReD</i>)	US\$ million	497.90	516.60
NPV at year 4 of equity gain (<i>ReG_T</i>)	US\$ million	99.99	181.90
NPV at year 0 of equity gain (<i>ReG₀</i>)	US\$ million	33.25	60.49
Improved equity IRR (<i>ReIRR</i>)		42.92%	51.26%
New interest rate in refinancing (<i>ReINR</i>)	Scenario 3: 9%		
Repayment schedule		Annuity	Equal principal
New maturity in refinancing (<i>ReM</i>)	Year	15	15
New debt amount in refinancing (<i>ReD</i>)	US\$ million	475.80	492.30
NPV at year 4 of equity gain (<i>ReG_T</i>)	US\$ million	77.86	164.23
NPV at year 0 of equity gain (<i>ReG₀</i>)	US\$ million	25.89	54.62
Improved equity IRR (<i>ReIRR</i>)		40.04%	48.72%
Base case IRR	31.68%		

The equity improvement of optimal debt refinancing plans is illustrated in Figure 6.15. The base case equity *IRR* is 31.68%. The maximum equity *IRR* after refinancing in optimal plans with annuity repayment structure can be increased to 46.15%, 42.92% and 40.04% respectively under the scenarios of new interest rates of 7%, 8% and 9% respectively. The maximum equity *IRR* after refinancing in optimal plans with equal principal repayment structure can be increased to 54.11%, 51.26% and 48.72% under the scenarios of new interest rates of 7%, 8% and 9%

respectively. The refinancing plan with an equal principal repayment schedule can provide higher equity gain than that with an annuity repayment schedule for the Laibin B Power Project.

Figure 6.15 Equity improvement by optimal debt-refinancing plans in Laibin B Power BOT Project

The impact of debt refinancing at new interest rates of 7%, 8% and 9% on the equity cash flows in the Laibin B Power BOT Project is illustrated in Figure 6.16, Figure 6.17, and Figure 6.18 respectively. The data of the free cash flow to equity after debt refinancing is in Appendix 7. Under the optimal debt-refinancing plan, the equity cash flow is dramatically increased at year 4 because the refinancing largely pays back the equity contribution at the time of refinancing. The equity cash flows in the refinanced case with annuity repayment structure are larger than that in the base case from year 5 to year 9, while the equity cash flows in the refinanced case with equal principal repayment structure are greater than that in the base case from year 5 to year 12. It is partially because the debt maturity is extended from 12 years to 15 years that essentially spread the debt repayment and lower the debt service payment in the early years of refinancing. The equity cash flows in the refinanced case with annuity repayment schedule starts to be less than that in the base case from year 10 to 12. One of the reasons could be that the impact of increased debt amount that can increase the debt service payments may become

dominant on the equity cash flow over the effect of the extended maturity and decreased interest rate that can lower the debt service payments. In addition, the repayment structure of the original loan was equal principal repayment, so the debt service payments of the original loan decreased to a relatively small amount in years 10 to 12, but the debt service payments in the refinanced case under the annuity repayment structure are the same over the whole term of the new debt, and may be relatively higher from year 10 to 12 than that in the base case. During the same period, the equity cash flows in the refinanced case with equity principal repayment schedule are still larger than that in the base case. The equal principal repayment schedule in refinancing is able to raise more new debt that can fit the cash flow pattern and refinancing restrictions of the Labin B Power Project, and sustain a longer period of greater equity cashflow in benchmark to the base case in the early year of refinancing compared with the annuity debt repayment. The debt service payment ended in year 12 in the base case as the maturity of the original debt was 12 years. The additional debt service payments resulting from the extension of the debt maturity lead to a lower equity cash flow in the refinanced case than that in the base case from year 13 to 15. After year 15, the equity cash flows in the refinanced case and base case converge, as there is no difference in equity cash flows after the new debt service period between the base case and refinanced case.

Figure 6.16 Impact of optimal debt refinancing plans (at interest rate 7%) on equity cash flows in Laibin B Power BOT Project

Figure 6.17 Impact of optimal debt refinancing plans (at interest rate 8%) on equity cash flows in Laibin B Power BOT Project

Figure 6.18 Impact of optimal debt refinancing plans (at interest rate 9%) on equity cash flows in Laibin B Power BOT Project

6.3 Case study 3: Labuan Water Supply BOT Project, Malaysia

6.3.1 Project description

The island of Labuan is located in eastern Malaysia adjacent to the State of Sabah. It has been developed as an industrial centre. The available water supply capacity could not provide enough water for the operation of industrial facilities and domestic consumption in the island. The shortage of water supply became a problem due to the rapid industrial development. In order to overcome the problem, the Malaysian government paid to bring water by barge during dry periods at great expense and inconvenience. The Malaysian government also tried to plan to construct a dam on Labuan Island. This required substantial upfront capital expenditure from the government, which, however, wanted to avoid incurring substantial capital commitment. In late 1985, a private company, Ipco, developed a proposal to build, own and operate a water supply facility in Labuan for the government, and subsequently, in December 1986, the Malaysian government approved the proposal from Ipco. On July 10, 1987, the Malaysian government and the project company, Labuan Water Supply Sdn Bhd (LWS) signed a privatization contract that granted the LWS the concession to design, build and operate a water supply plant and to supply water to the Federal Territory of Labuan. This is the Labuan Water Supply BOT Project, which is the first BOT water project in Malaysia.

The project company was responsible for constructing a new water treatment plant, abstracting water from the Sungei Padas in Sabah, treating the water and delivering it by overland and submarine pipeline to storage tanks at Ranca Ranca on the island of Labuan. The Malaysian government was responsible for purchasing the water contracted in the water purchase agreement and distributing water to consumers. The water treatment plant was located on Sabah, approximately 50 km from the storage tanks in Labuan. The concession period was 13 years, with two-stage construction. The treatment capacity was designed to be 20 ML/day (4.4 mgd) after

the first phase of construction. The ultimate capacity was 38 ML/day (8.3 mgd) on completion of the second phase of construction. The storage tanks were designed to hold two million gallons. The contractual structure of the LWS BOT project is illustrated in Figure 7.19. The key data in the base case of the LWS project are summarized in Table 6.18.

Table 6.18 Summary of key data in base case of the Labuan Water Supply BOT Project

Concession period		13 years
Total project cost		MR\$ 128.9 million
Equity: Debt ratio		38:62
Required project rate of return		11%
Construction	Stage 1	Year 0 to Year 1.5
	Stage 2	Year 4
Base inflation rate		5%
Tax holiday		5 years
Tax rate		40%

The original loan profile in the base case is summarized in Table 6.19. It constituted 62% of the total project cost, and the leverage was not aggressive. The loan facility was local commercial bank loans without foreign currency exposure.

Table 6.19 Original loan facility in base case of the Labuan Water Supply BOT Project

Debt amount	MR\$ 80.3 million
Maturity	8 years
Grace period	2 years
Interest rate	10%
Repayment	Flexible schedule pre-determined

The loan can be refinanced in order to change the original financing plan of the LWS BOT Project. The financing flexibility created by debt refinancing opportunities is represented as an “option to refinance”. The following sections demonstrate the valuation of the “option to refinance” by the ORV framework, and the reflection of its value in the total project value.

Figure 6.19 Contractual structure of Labuan Water Supply BOT Project

Source: Cheng (2003)

6.3.2 Valuation of “option to refinance” by ORV framework

6.3.2.1 DCF analysis of project base case

The base case *NPV* of the project investment is MR\$ 4.68 million without considering the financing flexibility created by debt refinancing opportunities. The base case is shown in Appendix 8.

6.3.2.2 Risk analysis of conditions for “option to refinance”

Condition 1: Completion of construction

The total construction cost in the base case was MR\$ 119.60 million, and did not include any foreign component. The completion of the two-staged construction was expected to be in four years. The risk factors are shown in Table 6.20. The coefficient of variance of each stochastic risk factor is assumed to be 0.1; therefore the standard deviation is 10% of its mean. The project contract also specified a penalty and bonus regarding the construction completion time. In the event of delay in completion, the penalty would be MR\$ 35,000 per day for the phase 1 of construction, and MR\$ 17,500 per day for the phase 2 construction. The bonus for early completion for Phase 1 was provided as MR\$ 25,000 per day. The financial support either in the form of equity or standby credit is assumed to be 5% of the construction cost.

Table 6.20 Factors of construction risk in Labuan Water Supply BOT Project

Risk factors	Unit	Distribution function
Base construction cost		
Year 0	MR\$ million	Lognormal distribution (25.01, 2.50 ²)
Year 1	MR\$ million	Lognormal distribution (68.07, 6.81 ²)
Year 2	MR\$ million	Lognormal distribution (11.71, 1.18 ²)
Year 4	MR\$ million	Lognormal distribution (8.40, 0.84 ²)
Inflation rate		Normal distribution (0.05, 0.005 ²)
Completion time		
Phase 1	Year	Lognormal distribution (1.5, 0.15 ²)
Phase 2	Year	Lognormal distribution (4.0, 0.4 ²)

The risk-simulated total construction cost (TCC_Risk) is illustrated in Figure 6.20. The detailed simulation results in Appendix 9.

Figure 6.20 Simulation result of construction risk in Labuan Water Supply BOT Project

Therefore, the probability of success in condition 1 (Ω_1) is 81.70%.

Condition 2: demonstration of stable revenue streams

The Malaysian government guarantees the offtake payment to the LWS, thus the LWS did not bear the revenue risk which was transferred to the Malaysian government. Therefore, the probability of success in condition 2 (Ω_2) is 1.

Joint probability of condition 1 and 2

The joint probability of success in both conditions (Φ) is $\Omega_1 \times \Omega_2 = 81.70\%$.

6.3.2.3 Conditional option Valuation

The conditional “option to refinance” given success in both conditions above is structured as a European call option written on the original loan with expiration at year 5. At the end of year 5, the outstanding debt amount of the original loan is

MR\$ 54.60 million. Therefore, the strike price is MR\$ 54.60 million. The structure of the conditional “option to refinance” in the LWS BOT project is summarized in Table 6.21.

Table 6.21 Structure of conditional “option to refinance” in Labuan Water Supply BOT Project

Option type	European call option
Option owner	The LWS project company
Underlying asset	Original bank loan
Strike price	MR\$ 54.60 million
Expiration of option	Year 5

A project timeline is illustrated in Figure 6.21 to give a clear overview on the timing of the option in relation to the project lifecycle.

Figure 6.21 Timeline of Labuan Water Supply BOT Project

The details of the drawdown and amortization schedule of the original debt facility are shown in Appendix 8. The net debt cash flows (CF_i^d) from combining debt drawings, debt interest payment and principal repayment are shown in Figure 6.22.

Figure 6.22 Net debt cash flow in base case of Labuan Water Supply BOT Project

The term structure of Malaysian government bonds was available from the middle of 2006. Therefore, the data from 22 June 2005 were retrieved from Bloomberg shown in Table 6.22 and is used as a proxy term structure.

Table 6.22 Term structure of Malaysian government bonds (on 22 June 2005)

Year	1	2	3	4	5
Yield (%)	4.040	4.210	4.340	4.400	4.450

Hence, the zero-coupon discount factors can be derived by the term structure and are shown in Table 6.23.

Table 6.23 Zero-coupon discount factors in LWS BOT Project

Year	1	2	3	4	5
Zero-coupon discount factor (Z_i)	1.0412	1.0878	1.1391	1.1924	1.2492

Therefore, the forward market value of the original debt obligation ($F(0, 5)$) is

$$F(0, 5) = \sum_{i=1}^{i=5} \frac{Z_T \cdot CF_i^d}{Z_i} = 45.3171$$

In year 5, the original debt would have a remaining maturity of just three years. The forward yield volatility of debt market value is assumed to be 0.05. The input and output of the conditional option valuation are summarized in Table 6.24.

Table 6.24 Input and output of conditional option valuation in Labuan Water Supply BOT Project

Input	Unit	Value
Refinancing Time (T)	Year	5
Strike price (D_5)	MR\$ million	54.60
4-year zero-coupon bond price ($P(0, 5)$)	NA	0.8005
Forward market value of original debt obligation ($F(0, 5)$)	MR\$ million	45.32
Forward volatility (σ_F)	NA	0.05
Output		
Value of conditional option (V_0)	MR\$ million	0.09

The final calculation is shown as follows:

$$N(d_1) = N\left(\frac{\ln(F(0, 5) / D_4) + \sigma_F^2 T / 2}{\sigma_F \sqrt{T}}\right) = 0.0535$$

$$N(d_2) = N\left(\frac{\ln(F(0, 5) / D_5) - \sigma_F^2 T / 2}{\sigma_F \sqrt{T}}\right) = 0.0424$$

Thus,

$$V_0 = P(0, 5)(F(0, 4)N(d_1) - D_4N(d_2)) = 0.09$$

Therefore, the conditional expected value of “option to refinance” given success in completion of construction and demonstration of stable revenue (V_0) is MR\$ 0.09 million. The value is relatively small partially due to the small scale of the project and the short remaining maturity of the original debt at the time of expiration of the option resulting low volatility.

6.3.2.4 Output of ORV framework

The expected value of “option to refinance” (V_{OR}) is MR\$ 0.07 million. In other word, the financing flexibility created by debt refinancing opportunities is worth MR\$ 0.07 million. The conditional tree is shown in Figure 6.23. The total project NPV is increased to MR\$ 4.75 million by incorporating the value of the financing flexibility.

Figure 6.23 Conditional tree of option valuation in Labuan Water Supply BOT Project

6.3.3 Debt-refinancing optimization by DRO model

In year 5, when the new information on the market and project has been updated, the LWS project company may consider undertaking a debt-refinancing plan. The DRO model developed in Chapter 5 is used to assess the impact of the refinancing plan on equity returns in order to facilitate the decision, and the project company can use the optimal plan generated from the model as a basis to negotiate with lenders. The maximum maturity for debt repayment is assumed to be 11 years for a 13-year concession. The *DSCR*, *LLCR* and *PLCR* after refinancing are assumed to maintain at least 1.2, 1.3 and 1.4 respectively as the average *DSCR* and *LLCR* found in literature in Table xx range from 1.2 to 1.3 and 1.3 to 1.4 respectively for water sector and *PLCR* are normally 15-20% higher than *DSCR*. Two scenarios of repayment schedules are considered. They are annuity repayment and equal

principal repayment which are the two common repayment schedules used in projects. Three scenarios of interest rates are considered. They are the original interest rate (10%), 100 basis point reduction in the original interest rate (9%), and 200 basis point reduction in the original interest rate (8%). The optimization plans are generated under different scenarios with the impact of other refinancing variables.

The optimal plans under different scenarios generated by the DRO model are shown in Table 6.25.

Table 6.25 Optimal debt refinancing plans in Labuan Water Supply BOT Project

New interest rate in refinancing (<i>ReINR</i>)	Scenario 1: 8%		
Repayment schedule		Annuity	Equal principal
New maturity in refinancing (<i>ReM</i>)	Year	10	10
New debt amount in refinancing (<i>ReD</i>)	MR\$ million	60.80	70.50
NPV at year 5 of equity gain (<i>ReG_T</i>)	MR\$ million	6.38	7.98
NPV at year 0 of equity gain (<i>ReG₀</i>)	MR\$ million	3.15	3.95
Improved equity IRR (<i>ReIRR</i>)		16.56%	16.97%
New interest rate in refinancing (<i>ReINR</i>)	Scenario 1: 9%		
Repayment schedule		Annuity	Equal principal
New maturity in refinancing (<i>ReM</i>)	Year	10	10
New debt amount in refinancing (<i>ReD</i>)	MR\$ million	59.40	70.10
NPV at year 5 of equity gain (<i>ReG_T</i>)	MR\$ million	5.30	6.97
NPV at year 0 of equity gain (<i>ReG₀</i>)	MR\$ million	2.62	3.45
Improved equity IRR (<i>ReIRR</i>)		16.31%	16.74%
New interest rate in refinancing (<i>ReINR</i>)	Scenario 1: 10%		
Repayment schedule		Annuity	Equal principal
New maturity in refinancing (<i>ReM</i>)	Year	10	10
New debt amount in refinancing (<i>ReD</i>)	MR\$ million	58.00	69.60
NPV at year 5 of equity gain (<i>ReG_T</i>)	MR\$ million	4.24	5.94
NPV at year 0 of equity gain (<i>ReG₀</i>)	MR\$ million	2.10	2.94
Improved equity IRR (<i>ReIRR</i>)		16.08%	16.51%
Base case IRR	15.12%		

The equity improvement by optimal debt refinancing plans is illustrated in Figure 6.24. The base case equity *IRR* is 15.12%. The maximum equity *IRR* after refinancing in optimal plans with an annuity repayment plan can be increased to 16.56%, 16.31% and 16.08% respectively under the scenarios of new interest rates

of 8%, 9% and 10% respectively. The maximum equity *IRR* after refinancing in optimal plans with equal principal repayment plan can be increased to 16.97%, 16.74% and 16.51% under the scenarios of new interest rates of 8%, 9% and 10% respectively. The refinancing plan with equal principal repayment schedule can provide higher equity gain than that with annuity repayment schedule for the LWS project.

Figure 6.24 Equity improvement by optimal debt-refinancing plans in Labuan Water Supply BOT Project

The impact of debt refinancing at new interest rates of 8%, 9% and 10% on the equity cash flows in the LWS BOT project is illustrated in Figure 6.25, Figure 6.26, and Figure 6.27 respectively. The data of the free cash flow to equity after debt refinancing is in Appendix 10. Under the optimal debt-refinancing plan, the equity cash flow is dramatically increased at year 5 because the refinancing largely pays back the equity contribution at the time of refinancing. The equity cash flows in the refinanced case are greater than that in the base case from year 6 to 8, partially because the debt maturity is extended from 8 years to 10 years which essentially spread the debt repayment and lower debt service payments in the early years of refinancing. The equity cash flows in the refinanced case starts to be less than that in the base case from the year 9 to 10. The debt service payment ended in year 8 in the base case as the maturity of the original debt was 8 years. The additional debt

service payments resulting from the extension of the debt maturity in refinancing lead to the lower equity cash flows in the refinanced case after year 8. After year 10, the equity cash flows in the refinanced case and base case converge, as there is no difference in equity cash flows after the new debt service period between the base case and refinanced case. The optimal refinancing plans with the equal principal repayment structure lead to better improvement on the equity *IRR* compared to that with the annuity principal repayment structure. Both repayment structures result in the same pattern of the equity cash flows, but the equal principal repayment structure is able to raise more debt in an optimal refinancing plan to suit the cash flows and constraints of the LWS BOT project.

Figure 6.25 Impact of optimal debt refinancing plans (at interest rate 8%) on equity cash flows in Labuan Water Supply BOT Project

Figure 6.26 Impact of optimal debt refinancing plans (at interest rate 9%) on equity cash flows in Labuan Water Supply BOT Project

Figure 6.27 Impact of optimal debt refinancing plans (at interest rate 10%) on equity cash flows in Labuan Water Supply BOT Project

6.4 Key Findings of Case Studies

The three case studies have demonstrated that the ORV framework can capture and quantify the value of the flexibility created by the future refinancing opportunities into the project valuation and the DRO model can provide different optimized debt refinancing plans under different scenarios, and served as an analytical tool for the project sponsors to negotiate with lenders with respect to different sector and country context.

It is demonstrated that the “option to refinance” can enhance project value. A high-risk profile can have a negative impact on the expected value of the option because lenders are reluctant to make refinancing deals if significant risks are still prevailing. That is why the debt refinancing for PPP projects is normally carried out after the construction phase or early operation phase. Additional financial support from the project sponsors, banks and public agencies can help to lower the risk. On the other hand, if the refinancing is done at a late stage of the project, the time value of money has gone, and the option value can be decreased.

In terms of different variables in refinancing optimization, generally speaking, refinancing can normally increase the cash flow sharply at the year of refinancing. Decrease in the interest rate can increase the equity cash flows by lowering the interest cost. The extension of the debt maturity may increase the equity cash flows in the early years of a project followed by decrease in the equity cash flows after the year of the original debt maturity.

CHAPTER 7

CONCLUSION AND RECOMMENDATIONS

This chapter concludes the main contribution and results of the research. It also highlights the limitations of the research, and provides recommendations on areas for future research work.

7.1 Conclusion

This research contributes to the knowledge set on understanding the role of debt refinancing in PPP infrastructure projects by delivering the “option to refinance” valuation (ORV) framework and the debt-refinancing optimization (DRO) model.

The financing flexibility created by the future debt refinancing opportunities that the project sponsors can refinance the existing debt for better financial terms at a future date is first recognized and structured as a real option in this research. It is the first attempt to quantify the value of such flexibility in an option-based framework. No existing literature on the area of PPP infrastructure and real options has studied this. It is new contribution to the existing literature by capturing and quantifying this financing flexibility and the modified Black model theory is first used in valuing real options.

Thus, the research objective 1 and 2 have been achieved by structuring the financial flexibility created by the future debt refinancing opportunities as the “option to refinance”. Subsequently, the ORV framework has been developed to value the “option to refinance”, and the value of such financing flexibility and managerial response to the project is reflected in the total project value.

The ORV framework incorporates risk and probability analysis to monitor the project risk profile. The Black model was adjusted and justified to fit in the context of PPP infrastructure projects. In addition, cash flow modeling and Monte Carlo simulation were implemented as calculation components to derive the expected value of “option to refinance”. The final value added to the project is governed by the risk profile of the project, the structure of the original debt facility, the refinancing time, the term structure of the market interest rates, and volatility of the forward market value of debts. The ORV framework has been validated by three BOT case studies from the toll road, power and water sectors. A high-risk profile can have a negative impact on the expected value of the option because lenders are

reluctant to make refinancing deals if significant risks are still prevailing. That is why the debt refinancing for PPP projects is normally carried out after the construction phase or early operation phase. Additional financial support from the project sponsors, banks and public agencies can help to lower the risk. On the other hand, if the refinancing is done at a late stage of the project, the time value of money has gone, and the option value can be decreased.

The ORV framework provides a means to value the financing flexibility created by the future refinancing opportunities inherent in many PPP projects. It helps the project sponsors recognize the value arising from such flexibility at the planning and feasibility stage of the project. It makes a contribution as a valuation tool for project sponsors to assess the feasibility and total value of the project.

This research also provides a new analytical model to optimize debt-refinancing plan that can maximize the equity investors' value. Taking into consideration of project conditions and refinancing parameters, the model provides a generic algorithm that can apply to PPP infrastructure projects.

Thus, the research objective 3 and 4 have been achieved by the development of the generic DRO model. Equity gains arising from the debt refinancing is the objective function. Debt interest rate, amount, maturity, repayment structure and debt service ratios in refinancing are variables and constraints for optimization. The DRO model is able to optimize a debt-refinancing plan to maximize the equity gains arising from it. In addition, it can be used to analyze the impact of debt-refinancing plans on the project equity cash flow. It could be different in projects with different features, base case cashflow pattern, original debt profile and refinancing constraints. Generally speaking, refinancing can normally increase the cash flow sharply at the year of refinancing. Decrease in the interest rate can increase the equity cash flows by lowering the interest cost. The extension of the debt maturity may increase the equity cash flows in the early years of a project followed by decrease in the equity cash flows after the year of the original debt maturity.

The quantitative DRO model provides project sponsors with an important decision tool to gain understanding of debt refinancing on the specific project, and can serve as an analytical tool for them to negotiate with lenders on the terms and conditions of refinancing.

7.2 Limitations

Reality cannot be replicated exactly as it exists. The quantitative ORV framework and DRO model are developed based on theories, which are not able to capture all the aspects of the real situation as infrastructure projects are complex in nature. Especially practicality remains an issue for all real option theories in project valuation. For reasons of simplicity for quantification, the conditional “option to refinance” is assumed to be European for approximation, as it is justified by that early exercise is always encouraged to obtain time value of equity gain. The refinancing set in the ORV framework is assumed to repay the outstanding of the existing debt with no increase in the debt amount.

Some quantitative inputs require subjective judgment and reasonable assumptions. For instance, the risk simulation and option theory of the adjusted Black model is dealing with the expected value of future possibilities. The probability distributions of risk factors need to be reasonably assumed.

The research used three different cases in water, power and transport sectors respectively and in the countries of Indonesia, China and Malaysia respectively based on the data availability. More case studies in different sectors and countries could be conducted to test the generalizability of the ORV framework and the DRO model when project data are available.

7.3 Recommendations for Future Research

There are a lot of research areas worthy of future study as debt refinancing generally lacks academic attentions. A few areas have been identified for future research in following paragraphs.

Debt refinancing can be considered as a re-negotiation process between the project sponsors and lenders on the terms of initial debt. The development of a re-negotiation framework can be studied to capture and quantify the build-in flexibility of the initial debt for the most beneficial terms. The interaction between the project sponsors and lenders need to be analyzed by taking the consideration of different objectives of the two parties.

Rescue debt refinancing can be further investigated, as there is an increasing need to restructure distressed projects and solve cash flow problems of projects. Rescue refinancing is more subject to negotiation between the lenders and project sponsors. How rescue debt refinancing is structured and the negotiation between the project company and lenders are worthy of research.

The valuation of the “option to refinance” can be further developed into a mathematical complex. The term structure of interest rate could be directly modeled, and therefore the American style of the option can be valued. However, it may not be practical for project investors to use as a valuation tool due to its complexity unless a user-friendly interface is developed as well.

The “option to refinance” can interact with other real options in adding value to a project. A framework of a cluster of financing and real options in a PPP infrastructure project can be developed to capture the interaction and valuation of a cluster of options. The theories on compound options and other valuation methods can be used.

The optimization model of debt-refinancing plan could be expanded from the lenders’ perspective, therefore, the pricing or interest rate of a debt facility can be a

dynamic variable interlinked to other variables such as debt amount and maturity. The different objectives of project sponsors and lenders in refinancing can be incorporated into the objective function and the balance of different objectives needs to be searched in the optimization model.

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APPENDICES

Appendix 1.1 to Appendix 4: Case study of Toll Road BOT Project A, Indonesia

Appendix 5.1 to Appendix 7: Case study of Laibin B Power BOT Project, China

Appendix 8 to Appendix 10: Case study of Labuan Water Supply BOT Project,
Malaysia

Appendix 1.1 Base case cash flow summary of Toll Road BOT Project A

(Unit: Rp. Million)

Year	Total	1	2	3	4	5	6	7	8	9	10	11
Revenue	103,444,099	0	0	0	382,739	438,198	501,693	574,388	657,617	752,906	862,002	986,906
Operation & Maintenance cost	15,516,615	0	0	0	57,411	65,730	75,254	86,158	98,643	112,936	129,300	148,036
Tax payable	24,687,688	0	0	0	0	0	4,162	22,700	48,755	77,885	110,535	147,217
After tax operating cash flow	63,239,796	0	0	0	325,328	372,468	422,276	465,530	510,220	562,085	622,166	691,652
Construction cost	2,734,998	528,014	1,371,559	835,424	0	0	0	0	0	0	0	0
Financial upfront cost	25,410	25,410	0	0	0	0	0	0	0	0	0	0
Contingency	134,607	0	70,669	63,939	0	0	0	0	0	0	0	0
Interest during construction	391,665	27,118	124,905	239,643	0	0	0	0	0	0	0	0
Project Cost	3,286,680	580,542	1,567,133	1,139,005	0	0	0	0	0	0	0	0
Total debt drawdown	2,300,676	406,380	1,096,993	797,304	0	0	0	0	0	0	0	0
Beginning balance		0	406,380	1,503,373	2,300,676	2,300,676	2,300,676	2,300,676	2,185,642	2,070,609	1,955,575	1,840,541
Interest payment	2,947,166	0	0	0	322,095	322,095	322,095	322,095	305,990	289,885	273,780	257,676
Debt principal repayment	2,300,676	0	0	0	0	0	0	115,034	115,034	115,034	115,034	230,068
Ending balance		406,380	1,503,373	2,300,676	2,300,676	2,300,676	2,300,676	2,185,642	2,070,609	1,955,575	1,840,541	1,610,473
Total debt service	5,247,842	0	0	0	322,095	322,095	322,095	437,128	421,024	404,919	388,814	487,743
Required Project Rate of Return	12%											
Free Cash Flow to Project		-580,542	-1,567,133	-1,139,005	325,328	372,468	422,276	465,530	510,220	562,085	622,166	691,652
Project NPV	2,790,163											
Free Cash Flow to Equity		-174,163	-470,140	-341,702	3,233	50,374	100,182	28,402	89,196	157,166	233,352	203,909
Equity IRR	22.18%											
DSCR								1.06	1.21	1.39	1.60	1.42

Appendix 1.2 Base case cash flow summary of Toll Road BOT Project A

Year	12	13	14	15	16	17	18	19	20	21	22	23
Revenue	1,129,908	1,293,632	1,481,079	1,695,688	1,941,393	2,222,700	2,544,770	2,787,869	2,983,020	3,191,831	3,415,259	3,654,327
Operation & Maintenance cost	169,486	194,045	222,162	254,353	291,209	333,405	381,715	418,180	447,453	478,775	512,289	548,149
Tax payable	193,346	254,421	326,377	390,765	463,083	539,648	621,776	683,766	733,529	786,776	843,750	904,713
After tax operating cash flow	767,076	845,166	932,540	1,050,569	1,187,101	1,349,648	1,541,279	1,685,923	1,802,037	1,926,280	2,059,220	2,201,466
Construction cost	0	0	0	0	0	0	0	0	0	0	0	0
Financial upfront cost	0	0	0	0	0	0	0	0	0	0	0	0
Contingency	0	0	0	0	0	0	0	0	0	0	0	0
Interest during construction	0	0	0	0	0	0	0	0	0	0	0	0
Project Cost	0	0	0	0	0	0	0	0	0	0	0	0
Total debt drawdown	0	0	0	0	0	0	0	0	0	0	0	0
Beginning balance	1,610,473	1,150,338	575,169	345,101	115,034	0	0	0	0	0	0	0
Interest payment	225,466	161,047	80,524	48,314	16,105	0	0	0	0	0	0	0
Debt principal repayment	460,135	575,169	230,068	230,068	115,034	0	0	0	0	0	0	0
Ending balance	1,150,338	575,169	345,101	115,034	0	0	0	0	0	0	0	0
Total debt service	685,602	736,216	310,591	278,382	131,139	0	0	0	0	0	0	0
Free Cash Flow to Project	767,076	845,166	932,540	1,050,569	1,187,101	1,349,648	1,541,279	1,685,923	1,802,037	1,926,280	2,059,220	2,201,466
Free Cash Flow to Equity	81,475	108,950	621,949	772,187	1,055,962	1,349,648	1,541,279	1,685,923	1,802,037	1,926,280	2,059,220	2,201,466
DSCR	1.12	1.15	3.00	3.77	9.05							

Appendix 1.3 Base case cash flow summary of Toll Road BOT Project A

Year	24	25	26	27	28	29	30	31	32	33	34	35
Revenue	3,910,130	4,183,839	4,476,708	4,790,078	5,125,383	5,484,160	5,868,051	6,278,815	6,718,332	7,188,615	7,691,818	8,230,245
Operation & Maintenance cost	586,520	627,576	671,506	718,512	768,807	822,624	880,208	941,822	1,007,750	1,078,292	1,153,773	1,234,537
Tax payable	969,942	1,039,738	1,114,420	1,194,329	1,279,832	1,371,320	1,469,212	1,573,957	1,686,034	1,805,956	1,939,461	2,090,281
After tax operating cash flow	2,353,668	2,516,525	2,690,782	2,877,237	3,076,744	3,290,216	3,518,631	3,763,036	4,024,548	4,304,367	4,598,584	4,905,428
Construction cost	0	0	0	0	0	0	0	0	0	0	0	0
Financial upfront cost	0	0	0	0	0	0	0	0	0	0	0	0
Contingency	0	0	0	0	0	0	0	0	0	0	0	0
Interest during construction	0	0	0	0	0	0	0	0	0	0	0	0
Project Cost	0	0	0	0	0	0	0	0	0	0	0	0
Total debt drawdown	0	0	0	0	0	0	0	0	0	0	0	0
Beginning balance	0	0	0	0	0	0	0	0	0	0	0	0
Interest payment	0	0	0	0	0	0	0	0	0	0	0	0
Debt principal repayment	0	0	0	0	0	0	0	0				
Ending balance	0	0	0	0	0	0	0	0	0	0	0	0
Total debt service	0	0	0	0	0	0	0	0	0	0	0	0
Free Cash Flow to Project	2,353,668	2,516,525	2,690,782	2,877,237	3,076,744	3,290,216	3,518,631	3,763,036	4,024,548	4,304,367	4,598,584	4,905,428
Free Cash Flow to Equity	2,353,668	2,516,525	2,690,782	2,877,237	3,076,744	3,290,216	3,518,631	3,763,036	4,024,548	4,304,367	4,598,584	4,905,428
DSCR												

Appendix 2.1 Simulation result of construction risk in Toll Road BOT Project A

Summary

Name	TCC_risk
Minimum	2099531
Mean	2705407
Maximum	3299351
Std Dev	185219.1
Variance	3.43E+10
Skewness	7.48E-02
Kurtosis	2.898961
Mode	2725577
Left X	2099531
Left P	0%
Right X	2869605
Right P	81.05%
Diff. X	770074.6
Diff. P	81.05%
5th Perc.	2404161
95th Perc.	3014490
#Errors	0
Filter Min	
Filter Max	
#Filtered	0

TCC_risk <i>in millions</i>	Probability	TCC_risk <i>in millions</i>	Probability
2.22551	0.00502	2.46548	0.09053
2.23151	0.00530	2.47147	0.09924
2.23751	0.00559	2.47747	0.10560
2.24351	0.00588	2.48347	0.11454
2.24951	0.00669	2.48947	0.11879
2.25551	0.00713	2.49547	0.12269
2.26151	0.00730	2.50147	0.12943
2.26751	0.00747	2.50747	0.13927
2.27350	0.00765	2.51347	0.14811
2.27950	0.00782	2.51947	0.15294
2.28550	0.00799	2.52547	0.16641
2.29150	0.00842	2.53147	0.17721
2.29750	0.00887	2.53747	0.18517
2.30350	0.01011	2.54346	0.19747
2.30950	0.01081	2.54946	0.20774
2.31550	0.01126	2.55546	0.21812
2.32150	0.01163	2.56146	0.22564
2.32750	0.01199	2.56746	0.22791
2.33350	0.01767	2.57346	0.24402
2.33949	0.01891	2.57946	0.25453
2.34549	0.02177	2.58546	0.26262
2.35149	0.02474	2.59146	0.27823
2.35749	0.02672	2.59746	0.28874
2.36349	0.02983	2.60346	0.29746
2.36949	0.03298	2.60945	0.31421
2.37549	0.03630	2.61545	0.32549
2.38149	0.03909	2.62145	0.33878
2.38749	0.04358	2.62745	0.35821
2.39349	0.04589	2.63345	0.36686
2.39949	0.04766	2.63945	0.37204
2.40548	0.05136	2.64545	0.38029
2.41148	0.05458	2.65145	0.39282
2.41748	0.05714	2.65745	0.40550
2.42348	0.06012	2.66345	0.41861
2.42948	0.06451	2.66945	0.43306
2.43548	0.06886	2.67544	0.44496
2.44148	0.07435	2.68144	0.46405
2.44748	0.07786	2.68744	0.47788
2.45348	0.08112	2.69344	0.49105
2.45948	0.08591	2.69944	0.49904

**Appendix 2.2 Simulation result of construction risk in Toll Road BOT Project
A**

TCC_risk <i>in millions</i>	Probability	TCC_risk <i>in millions</i>	Probability	TCC_risk <i>in millions</i>	Probability
2.70544	0.51202	2.94540	0.90280	3.18537	0.99712
2.71144	0.52464	2.95140	0.90698	3.19137	0.99726
2.71744	0.54217	2.95740	0.91475	3.19737	0.99741
2.72344	0.54957	2.96340	0.91949	3.20337	0.99755
2.72944	0.56282	2.96940	0.92529	3.20936	0.99769
2.73544	0.57213	2.97540	0.92888	3.21536	0.99784
2.74143	0.58288	2.98140	0.93356	3.22136	0.99798
2.74743	0.59766	2.98740	0.93830	3.22736	0.99829
2.75343	0.61273	2.99340	0.94118	3.23336	0.99862
2.75943	0.62184	2.99940	0.94407	3.23936	0.99895
2.76543	0.62788	3.00540	0.94574	3.24536	0.99909
2.77143	0.63877	3.01139	0.94800	3.25136	0.99919
2.77743	0.64848	3.01739	0.95097	3.25736	0.99929
2.78343	0.66318	3.02339	0.95298	3.26336	0.99939
2.78943	0.67624	3.02939	0.95361	3.26936	0.99949
2.79543	0.68409	3.03539	0.95638	3.27535	0.99959
2.80143	0.69607	3.04139	0.95992	3.28135	0.99970
2.80742	0.70443	3.04739	0.96458	3.28735	0.99980
2.81342	0.71447	3.05339	0.96748	3.29335	0.99990
2.81942	0.72743	3.05939	0.96958	3.29935	0.99990
2.82542	0.73443	3.06539	0.97231		
2.83142	0.74581	3.07139	0.97315		
2.83742	0.75735	3.07738	0.97389		
2.84342	0.77014	3.08338	0.97446		
2.84942	0.78050	3.08938	0.97500		
2.85542	0.79277	3.09538	0.97680		
2.86142	0.79997	3.10138	0.98134		
2.86742	0.80760	3.10738	0.98418		
2.87341	0.81619	3.11338	0.98458		
2.87941	0.82031	3.11938	0.98499		
2.88541	0.82902	3.12538	0.98633		
2.89141	0.83729	3.13138	0.98687		
2.89741	0.84299	3.13738	0.98751		
2.90341	0.85149	3.14337	0.98857		
2.90941	0.85917	3.14937	0.99400		
2.91541	0.87018	3.15537	0.99425		
2.92141	0.87612	3.16137	0.99450		
2.92741	0.88002	3.16737	0.99475		
2.93341	0.88664	3.17337	0.99500		
2.93941	0.89721	3.17937	0.99600		

Appendix 3.1 Simulation result of revenue risk in Toll Road BOT Project A

Summary

Name	REV_risk
Minimum	515494.5
Mean	657619.4
Maximum	871637
Std Dev	52981.12
Variance	2.81E+09
Skewness	0.3299534
Kurtosis	3.262609
Mode	644357.3
Left X	624736
Left P	27.67%
Right X	871637
Right P	100%
Diff. X	246901
Diff. P	72.33%
5th Perc.	575379.8
95th Perc.	749544.5
#Errors	0
Filter Min	
Filter Max	
#Filtered	0

REV_risk	Probability	REV_risk	Probability
552.88943	0.98184	624.11794	0.72967
554.67015	0.98085	625.89865	0.71400
556.45086	0.98006	627.67937	0.70861
558.23157	0.97872	629.46008	0.69866
560.01229	0.97711	631.24079	0.68656
561.79300	0.97593	633.02150	0.67763
563.57371	0.97521	634.80222	0.66138
565.35442	0.97195	636.58293	0.64416
567.13514	0.97022	638.36364	0.63219
568.91585	0.96800	640.14435	0.62037
570.69656	0.96556	641.92507	0.60745
572.47727	0.96177	643.70578	0.59242
574.25799	0.95498	645.48649	0.57259
576.03870	0.94781	647.26721	0.56071
577.81941	0.94303	649.04792	0.54187
579.60012	0.93547	650.82863	0.53211
581.38084	0.93139	652.60934	0.51424
583.16155	0.92529	654.39006	0.50156
584.94226	0.91905	656.17077	0.48925
586.72298	0.91358	657.95148	0.47505
588.50369	0.90671	659.73219	0.46017
590.28440	0.90332	661.51291	0.44305
592.06511	0.89637	663.29362	0.42923
593.84583	0.89067	665.07433	0.41980
595.62654	0.88308	666.85504	0.40835
597.40725	0.87524	668.63576	0.39440
599.18796	0.86790	670.41647	0.37915
600.96868	0.85650	672.19718	0.36579
602.74939	0.85231	673.97790	0.35410
604.53010	0.84333	675.75861	0.33815
606.31081	0.83206	677.53932	0.32802
608.09153	0.82396	679.32003	0.31715
609.87224	0.81567	681.10075	0.30498
611.65295	0.81275	682.88146	0.29488
613.43366	0.80401	684.66217	0.28389
615.21438	0.79024	686.44288	0.27683
616.99509	0.77578	688.22360	0.26651
618.77580	0.76670	690.00431	0.25441
620.55652	0.76122	691.78502	0.24742
622.33723	0.74573	693.56573	0.23951

Appendix 3.2 Simulation result of revenue risk in Toll Road BOT Project A

REV_risk	Probability	REV_risk	Probability	REV_risk	Probability
695.34645	0.23210	766.57495	0.02766	837.80346	0.00077
697.12716	0.21529	768.35567	0.02654	839.58417	0.00073
698.90787	0.20622	770.13638	0.02576	841.36488	0.00069
700.68859	0.19990	771.91709	0.02190	843.14560	0.00065
702.46930	0.19034	773.69780	0.02032	844.92631	0.00061
704.25001	0.18329	775.47852	0.01959	846.70702	0.00057
706.03072	0.17136	777.25923	0.01913	848.48774	0.00053
707.81144	0.16654	779.03994	0.01846	850.26845	0.00049
709.59215	0.16122	780.82065	0.01675	852.04916	0.00045
711.37286	0.15194	782.60137	0.01563	853.82987	0.00041
713.15357	0.14727	784.38208	0.01485	855.61059	0.00036
714.93429	0.13474	786.16279	0.01303	857.39130	0.00032
716.71500	0.12845	787.94351	0.01262	859.17201	0.00028
718.49571	0.12053	789.72422	0.01224	860.95272	0.00024
720.27642	0.11745	791.50493	0.01094	862.73344	0.00020
722.05714	0.11501	793.28564	0.01014	864.51415	0.00016
723.83785	0.10717	795.06636	0.00901	866.29486	0.00012
725.61856	0.10062	796.84707	0.00867	868.07557	0.00008
727.39927	0.09671	798.62778	0.00833	869.85629	0.00004
729.17999	0.08997	800.40849	0.00792	871.63700	0.00000
730.96070	0.08557	802.18921	0.00659		
732.74141	0.08238	803.96992	0.00599		
734.52213	0.07899	805.75063	0.00587		
736.30284	0.07465	807.53134	0.00576		
738.08355	0.06976	809.31206	0.00565		
739.86426	0.06525	811.09277	0.00553		
741.64498	0.06211	812.87348	0.00542		
743.42569	0.05588	814.65420	0.00531		
745.20640	0.05440	816.43491	0.00519		
746.98711	0.05233	818.21562	0.00508		
748.76783	0.05067	819.99633	0.00488		
750.54854	0.04890	821.77705	0.00448		
752.32925	0.04630	823.55776	0.00408		
754.10996	0.04351	825.33847	0.00251		
755.89068	0.04050	827.11918	0.00126		
757.67139	0.03823	828.89990	0.00097		
759.45210	0.03758	830.68061	0.00093		
761.23282	0.03710	832.46132	0.00089		
763.01353	0.03456	834.24203	0.00085		
764.79424	0.03193	836.02275	0.00081		

Appendix 4. Free cash flow to equity under different optimal debt refinancing plans in Toll Road BOT Project A

Rp. million	Refinancing time: year 8					
New interest rate in refinancing	Scenario 1: 12%		Scenario 2: 13%		Scenario 3: 14%	
Repayment Schedule	Annuitiy	Equal principal	Annuitiy	Equal principal	Annuitiy	Equal principal
New Maturity in refinancing (year)	25	25	25	25	25	25
New debt amount in refinancing	3240609	2417609	3080609	2300609	2932609	2194609
NPV at year 8 of equity gains	1027407	443396	872513	335355	729057	237372
NPV at year 0 of equity gains	206925	89302	175729	67542	146836	47808
Improved equity IRR	25.10%	23.33%	24.64%	23.04%	24.21%	22.79%
Free Cash Flow to Equity						
Year 8	1259196	436196	1099196	319196	951196	213196
Year 9	136616	129828	137459	130434	138118	130953
Year 10	199142	206686	200135	207661	200946	208517
Year 11	270787	292950	271927	294294	272889	295486
Year 12	352880	389982	354159	391696	355268	393224
Year 13	446942	499344	448348	501427	449597	503291
Year 14	554718	622821	556234	625273	557609	627473
Year 15	678204	762458	679807	765280	681289	767816
Year 16	819688	920599	821347	923789	822911	926662
Year 17	981791	1099923	983466	1103482	985076	1106691
Year 18	1167513	1303500	1169153	1307429	1170763	1310974
Year 19	1305539	1460090	1307081	1464388	1308632	1468269
Year 20	1414242	1588150	1415607	1592817	1417023	1597035
Year 21	1530183	1724339	1531274	1729375	1532461	1733929
Year 22	1653825	1869224	1654523	1874630	1655362	1879520
Year 23	1785657	2023416	1785818	2029191	1786165	2034417
Year 24	1926196	2187564	1925647	2193708	1925322	2199271
Year 25	2075990	2362367	2074521	2368880	2073307	2374779
Year 26	2690782	2690782	2690782	2690782	2690782	2690782
Year 27	2877237	2877237	2877237	2877237	2877237	2877237
Year 28	3076744	3076744	3076744	3076744	3076744	3076744
Year 29	3290216	3290216	3290216	3290216	3290216	3290216
Year 30	3518631	3518631	3518631	3518631	3518631	3518631
Year 31	3763036	3763036	3763036	3763036	3763036	3763036
Year 32	4024548	4024548	4024548	4024548	4024548	4024548
Year 33	4304367	4304367	4304367	4304367	4304367	4304367
Year 34	4598584	4598584	4598584	4598584	4598584	4598584
Year 35	4905428	4905428	4905428	4905428	4905428	4905428

Appendix 5.1 Base case cash flow summary of Laibin B Power BOT Project

(Unit: US\$ Million)

Year	Total	1	2	3	4	5	6	7	8	9
Revenue	4583.23	0.00	0.00	95.58	260.08	238.35	248.94	256.76	265.90	275.93
Operation & Maintenance cost	2222.70	0.00	0.00	45.31	120.75	124.12	127.48	134.36	133.11	136.91
Tax payable	412.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.69	9.42
After tax operating cash flow	1948.38	0.00	0.00	50.27	139.33	114.23	121.45	122.41	125.10	129.60
Construction cost	559.42	151.11	261.57	146.74	0.00	0.00	0.00	0.00	0.00	0.00
Interest during construction	56.94	5.10	19.03	32.81	0.00	0.00	0.00	0.00	0.00	0.00
Project Cost	616.36	156.21	280.60	179.55	0.00	0.00	0.00	0.00	0.00	0.00
Total debt drawdown	462.27	117.16	210.45	134.66	0.00	0.00	0.00	0.00	0.00	0.00
Beginning balance		0.00	117.16	327.61	462.27	410.90	359.54	308.18	256.82	205.45
Interest payment	208.02	0.00	0.00	0.00	41.60	36.98	32.36	27.74	23.11	18.49
Debt principal repayment	462.27	0.00	0.00	0.00	51.36	51.36	51.36	51.36	51.36	51.36
Ending balance		117.16	327.61	462.27	410.90	359.54	308.18	256.82	205.45	154.09
Total debt service	670.29	0.00	0.00	0.00	92.97	88.34	83.72	79.10	74.48	69.85
Required Project Rate of Return	14%									
Free Cash Flow to Project		-156.21	-280.60	-129.28	139.33	114.23	121.45	122.41	125.10	129.60
Project NPV	84.22									
Free Cash Flow to Equity		-39.05	-70.15	0.00	51.74	25.89	37.73	43.31	50.63	59.75
Equity IRR	31.68%									
DSCR					1.50	1.29	1.45	1.55	1.68	1.86

Appendix 5.2 Base case cash flow summary of Laibin B Power BOT Project

Year	10	11	12	13	14	15	16	17	18
Revenue	283.78	293.52	302.95	313.55	324.08	336.34	348.43	361.90	377.14
Operation & Maintenance cost	140.62	144.23	148.04	151.85	154.68	158.99	163.30	167.38	171.57
Tax payable	10.83	12.54	16.68	47.44	55.90	58.52	61.09	64.19	67.84
<i>After tax operating cash flow</i>	132.34	136.74	138.22	114.26	113.50	118.82	124.04	130.33	137.73
Construction cost	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Interest during construction	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<i>Project Cost</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<i>Total debt drawdown</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Beginning balance	154.09	102.73	51.36	0.00	0.00	0.00	0.00	0.00	0.00
Interest payment	13.87	9.25	4.62	0.00	0.00	0.00	0.00	0.00	0.00
Debt principal repayment	51.36	51.36	51.36	0.00	0.00	0.00	0.00	0.00	0.00
Ending balance	102.73	51.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<i>Total debt service</i>	65.23	60.61	55.99	0.00	0.00	0.00	0.00	0.00	0.00
Free Cash Flow to Project	132.34	136.74	138.22	114.26	113.50	118.82	124.04	130.33	137.73
Free Cash Flow to Equity	67.11	76.13	82.24	114.26	113.50	118.82	124.04	130.33	137.73
Equity IRR									
DSCR	2.03	2.26	2.47						

Appendix 6.1 Simulation result of construction risk in Laibin B Power BOT Project

Summary

Name	Total TCC_Risk
Minimum	482.4974
Mean	569.0328
Maximum	670.793
Std Dev	27.22235
Variance	741.0566
Skewness	8.89E-02
Kurtosis	3.042601
Mode	549.468
Left X	482.4974
Left P	0%
Right X	599.42
Right P	87.34%
Diff. X	116.9225
Diff. P	87.34%
5th Perc.	524.0174
95th Perc.	611.9135
#Errors	0
Filter Min	
Filter Max	
#Filtered	0

REV_risk	Probability	REV_risk	Probability
502.26847	0.00259	539.92759	0.15345
503.20995	0.00271	540.86907	0.16211
504.15143	0.00282	541.81055	0.16978
505.09291	0.00294	542.75203	0.17832
506.03439	0.00404	543.69350	0.18993
506.97586	0.00675	544.63498	0.19613
507.91734	0.01021	545.57646	0.20944
508.85882	0.01082	546.51794	0.21613
509.80030	0.01314	547.45942	0.22847
510.74178	0.01399	548.40089	0.23446
511.68325	0.01550	549.34237	0.24319
512.62473	0.01915	550.28385	0.25276
513.56621	0.02158	551.22533	0.26405
514.50769	0.02409	552.16681	0.27175
515.44917	0.02637	553.10828	0.28482
516.39064	0.02897	554.04976	0.29838
517.33212	0.03166	554.99124	0.30491
518.27360	0.03269	555.93272	0.31498
519.21508	0.03521	556.87420	0.32009
520.15656	0.03697	557.81567	0.33585
521.09803	0.04025	558.75715	0.34942
522.03951	0.04169	559.69863	0.35664
522.98099	0.04630	560.64011	0.37236
523.92247	0.04972	561.58159	0.38410
524.86395	0.05474	562.52306	0.40004
525.80542	0.05776	563.46454	0.41237
526.74690	0.06345	564.40602	0.42311
527.68838	0.06624	565.34750	0.43406
528.62986	0.07054	566.28898	0.44403
529.57133	0.07228	567.23045	0.45780
530.51281	0.07891	568.17193	0.47772
531.45429	0.08223	569.11341	0.49718
532.39577	0.09029	570.05489	0.50947
533.33725	0.09377	570.99637	0.51848
534.27872	0.09980	571.93784	0.52824
535.22020	0.10902	572.87932	0.54717
536.16168	0.11523	573.82080	0.56245
537.10316	0.11861	574.76228	0.57448
538.04464	0.13343	575.70376	0.59101
538.98611	0.14680	576.64523	0.61106

Appendix 6.2 Simulation result of construction risk in Laibin B Power BOT Project

REV_risk	Probability	REV_risk	Probability	REV_risk	Probability
577.58671	0.62009	615.24583	0.95857	652.90495	0.99851
578.52819	0.63222	616.18731	0.96002	653.84643	0.99859
579.46967	0.65357	617.12879	0.96497	654.78790	0.99868
580.41115	0.67096	618.07026	0.96671	655.72938	0.99877
581.35262	0.67976	619.01174	0.96775	656.67086	0.99885
582.29410	0.68976	619.95322	0.96913	657.61234	0.99894
583.23558	0.70486	620.89470	0.96958	658.55382	0.99902
584.17706	0.71568	621.83618	0.97024	659.49529	0.99910
585.11853	0.72680	622.77765	0.97344	660.43677	0.99917
586.06001	0.73621	623.71913	0.97536	661.37825	0.99925
587.00149	0.74955	624.66061	0.97750	662.31973	0.99932
587.94297	0.76019	625.60209	0.97824	663.26121	0.99940
588.88445	0.76959	626.54357	0.97865	664.20268	0.99947
589.82592	0.77691	627.48504	0.97919	665.14416	0.99955
590.76740	0.79197	628.42652	0.98048	666.08564	0.99962
591.70888	0.80996	629.36800	0.98259	667.02712	0.99970
592.65036	0.81853	630.30948	0.98514	667.96860	0.99977
593.59184	0.82897	631.25096	0.98562	668.91007	0.99985
594.53331	0.83885	632.19243	0.98685	669.85155	0.99992
595.47479	0.84512	633.13391	0.98879	670.79303	0.99992
596.41627	0.85449	634.07539	0.99009		
597.35775	0.85926	635.01687	0.99027		
598.29923	0.86486	635.95835	0.99045		
599.24070	0.87155	636.89982	0.99063		
600.18218	0.88352	637.84130	0.99081		
601.12366	0.89132	638.78278	0.99100		
602.06514	0.89549	639.72426	0.99180		
603.00662	0.89825	640.66573	0.99236		
603.94809	0.90541	641.60721	0.99284		
604.88957	0.91059	642.54869	0.99340		
605.83105	0.91513	643.49017	0.99501		
606.77253	0.91975	644.43165	0.99653		
607.71401	0.92509	645.37312	0.99714		
608.65548	0.93030	646.31460	0.99754		
609.59696	0.93714	647.25608	0.99793		
610.53844	0.93972	648.19756	0.99807		
611.47992	0.94473	649.13904	0.99816		
612.42140	0.95150	650.08051	0.99825		
613.36287	0.95368	651.02199	0.99833		
614.30435	0.95648	651.96347	0.99842		

Appendix 7. Free cash flow to equity under different optimal debt refinancing plans in Laibin B Power BOT Project

US\$ million	Refinancing time: year 4					
New interest rate in refinancing	Scenario 1: 7%		Scenario 2: 8%		Scenario 3: 9%	
Repayment Schedule	Annuity	Equal principal	Annuity	Equal principal	Annuity	Equal principal
New Maturity in refinancing (year)	15	15	15	15	15	15
New debt amount in refinancing	521.80	542.80	497.90	516.60	475.80	492.30
NPV at year 8 of equity gains	123.85	200.95	99.99	181.90	77.86	164.23
NPV at year 0 of equity gains	41.19	66.83	33.25	60.49	25.89	54.62
Improved equity IRR	46.15%	54.11%	42.92%	51.26%	40.04%	48.72%
Free Cash Flow to Equity						
Year 4	157.26	178.26	133.36	152.06	111.26	127.76
Year 5	44.64	64.88	44.49	67.27	44.31	69.48
Year 6	51.87	72.11	51.71	74.49	51.54	76.70
Year 7	52.82	73.06	52.66	75.44	52.49	77.65
Year 8	56.47	72.06	56.79	74.44	57.06	76.65
Year 9	61.26	77.30	61.54	79.68	61.79	81.89
Year 10	64.25	80.77	64.50	83.16	64.72	85.36
Year 11	68.87	85.92	69.08	88.30	69.26	90.51
Year 12	70.54	88.14	70.70	90.52	70.83	92.73
Year 13	48.90	64.92	49.26	67.30	49.60	69.51
Year 14	46.82	64.15	47.04	66.53	47.23	68.74
Year 15	50.74	69.48	50.78	71.86	50.81	74.07
Year 16	124.04	124.04	124.04	124.04	124.04	124.04
Year 17	130.33	130.33	130.33	130.33	130.33	130.33
Year 18	137.73	137.73	137.73	137.73	137.73	137.73

Appendix 8. Base case cash flow summary of Labuan Water Supply BOT Project

(Unit: MR\$ Million)

Year	Total	0	1	2	3	4	5	6	7	8	9	10	11	12	13
Revenue	327.88	0.00	0.00	7.37	19.85	25.89	33.98	39.25	41.26	40.92	39.95	29.13	16.40	16.94	16.94
Operation & Maintenance cost	43.23	0.00	0.00	1.11	2.39	2.60	2.78	3.08	3.43	4.00	4.08	4.45	4.81	5.10	5.40
Tax payable	41.73	0.00	0.00	0.00	0.00	0.00	0.00	7.73	9.10	9.47	9.79	5.32	0.08	0.18	0.06
After tax operating cash flow	242.91	0.00	0.00	6.26	17.45	23.29	31.20	28.44	28.73	27.45	26.07	19.37	11.51	11.66	11.48
Construction cost	119.60	25.01	71.47	12.91	0.00	10.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Interest during construction	9.30	0.00	3.00	6.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Project Cost	128.90	25.01	74.47	19.21	0.00	10.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total debt drawdown	80.30	0.00	63.00	17.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Beginning balance		0.00	0.00	63.00	80.30	76.29	69.06	54.60	36.94	18.47	0.00	0.00	0.00	0.00	0.00
Interest payment	33.57	0.00	0.00	0.00	8.03	7.63	6.91	5.46	3.69	1.85	0.00	0.00	0.00	0.00	0.00
Debt principal repayment	80.30	0.00	0.00	0.00	4.02	7.23	14.45	17.67	18.47	18.47	0.00	0.00	0.00	0.00	0.00
Ending balance		0.00	63.00	80.30	76.29	69.06	54.60	36.94	18.47	0.00	0.00	0.00	0.00	0.00	0.00
Total debt service	113.87	0.00	0.00	0.00	12.05	14.86	21.36	23.13	22.16	20.32	0.00	0.00	0.00	0.00	0.00
Required Project Rate of Return	11%														
Free Cash Flow to Project		-25.01	-74.47	-12.95	17.45	13.08	31.20	28.44	28.73	27.45	26.07	19.37	11.51	11.66	11.48
Project NPV	4.68														
Free Cash Flow to Equity		-25.01	-11.47	0.00	0.00	7.99	9.84	5.32	6.56	7.13	26.07	19.37	11.51	11.66	11.48
Equity IRR	15.12%														
DSCR					1.45	1.57	1.46	1.23	1.30	1.35					

Appendix 9.1 Simulation result of construction risk in Labuan Water Supply BOT Project

Summary

Name	TCC_Risk
Minimum	79.64935
Mean	116.2465
Maximum	148.745
Std Dev	10.40067
Variance	108.174
Skewness	-0.1720567
Kurtosis	3.171216
Mode	114.0022
Left X	79.64935
Left P	0%
Right X	125.58
Right P	81.70%
Diff. X	45.93066
Diff. P	81.70%
5th Perc.	98.88753
95th Perc.	132.4233
#Errors	0
Filter Min	
Filter Max	
#Filtered	0

REV_risk	Probability	REV_risk	Probability
86.90439	0.00588	100.72351	0.07395
87.24987	0.00647	101.06899	0.08031
87.59534	0.00813	101.41447	0.08554
87.94082	0.00868	101.75995	0.08684
88.28630	0.00910	102.10543	0.09133
88.63178	0.00933	102.45090	0.09453
88.97726	0.00956	102.79638	0.10139
89.32273	0.00979	103.14186	0.10890
89.66821	0.01013	103.48734	0.11582
90.01369	0.01110	103.83282	0.12182
90.35917	0.01151	104.17830	0.12842
90.70465	0.01192	104.52377	0.13322
91.05013	0.01323	104.86925	0.13559
91.39560	0.01395	105.21473	0.14152
91.74108	0.01566	105.56021	0.14587
92.08656	0.01630	105.90569	0.15426
92.43204	0.01681	106.25116	0.16050
92.77752	0.01751	106.59664	0.17382
93.12299	0.01811	106.94212	0.18419
93.46847	0.01839	107.28760	0.19245
93.81395	0.01867	107.63308	0.19997
94.15943	0.01895	107.97856	0.21217
94.50491	0.02053	108.32403	0.21857
94.85038	0.02176	108.66951	0.22668
95.19586	0.02340	109.01499	0.23787
95.54134	0.02391	109.36047	0.24742
95.88682	0.02793	109.70595	0.25648
96.23230	0.02968	110.05142	0.26779
96.57778	0.03224	110.39690	0.27389
96.92325	0.03345	110.74238	0.28540
97.26873	0.03518	111.08786	0.29901
97.61421	0.03772	111.43334	0.30786
97.95969	0.04153	111.77882	0.31448
98.30517	0.04508	112.12429	0.33321
98.65064	0.04796	112.46977	0.34854
98.99612	0.05086	112.81525	0.35634
99.34160	0.05415	113.16073	0.36983
99.68708	0.05940	113.50621	0.38247
100.03256	0.06769	113.85168	0.39909
100.37804	0.06887	114.19716	0.41526

Appendix 9.2 Simulation result of construction risk in Labuan Water Supply BOT Project

REV_risk	Probability	REV_risk	Probability	REV_risk	Probability
114.54264	0.42816	128.36177	0.89129	142.18089	0.99394
114.88812	0.43993	128.70725	0.89918	142.52637	0.99497
115.23360	0.44666	129.05272	0.90748	142.87185	0.99604
115.57908	0.46190	129.39820	0.91326	143.21733	0.99671
115.92455	0.47830	129.74368	0.92002	143.56281	0.99714
116.27003	0.48996	130.08916	0.92249	143.90829	0.99739
116.61551	0.49931	130.43464	0.93300	144.25376	0.99764
116.96099	0.51503	130.78011	0.93380	144.59924	0.99788
117.30647	0.52557	131.12559	0.93764	144.94472	0.99903
117.65194	0.53989	131.47107	0.94430	145.29020	0.99911
117.99742	0.55724	131.81655	0.94802	145.63568	0.99920
118.34290	0.57245	132.16203	0.94955	145.98115	0.99929
118.68838	0.58577	132.50751	0.95092	146.32663	0.99938
119.03386	0.60032	132.85298	0.95634	146.67211	0.99947
119.37934	0.61064	133.19846	0.95788	147.01759	0.99956
119.72481	0.62562	133.54394	0.95859	147.36307	0.99965
120.07029	0.64028	133.88942	0.96035	147.70855	0.99973
120.41577	0.65631	134.23490	0.96215	148.05402	0.99982
120.76125	0.66679	134.58037	0.96567	148.39950	0.99991
121.10673	0.67427	134.92585	0.96930	148.74498	0.99991
121.45220	0.68514	135.27133	0.97001		
121.79768	0.69469	135.61681	0.97210		
122.14316	0.70662	135.96229	0.97610		
122.48864	0.71659	136.30777	0.97692		
122.83412	0.72585	136.65324	0.97990		
123.17960	0.73641	136.99872	0.98142		
123.52507	0.74919	137.34420	0.98216		
123.87055	0.76342	137.68968	0.98240		
124.21603	0.76984	138.03516	0.98263		
124.56151	0.78069	138.38063	0.98286		
124.90699	0.79153	138.72611	0.98374		
125.25246	0.80454	139.07159	0.98548		
125.59794	0.81814	139.41707	0.98656		
125.94342	0.83026	139.76255	0.98794		
126.28890	0.83409	140.10803	0.98912		
126.63438	0.84188	140.45350	0.99102		
126.97986	0.84923	140.79898	0.99184		
127.32533	0.85996	141.14446	0.99234		
127.67081	0.86847	141.48994	0.99277		
128.01629	0.87736	141.83542	0.99329		

Appendix 10. Free cash flow to equity under different optimal debt refinancing plans in Toll Road BOT Project A

MR\$ million	Refinancing time: year 5					
New interest rate in refinancing	Scenario 1: 8%		Scenario 2: 9%		Scenario 3: 10%	
Repayment Schedule	Annuity	Equal principal	Annuity	Equal principal	Annuity	Equal principal
New Maturity in refinancing (year)	10	10	10	10	10	10
New debt amount in refinancing	60.80	70.50	59.40	70.10	58.00	69.60
NPV at year 8 of equity gains	6.38	7.98	5.30	6.97	4.24	5.94
NPV at year 0 of equity gains	3.15	3.95	2.62	3.45	2.10	2.94
Improved equity IRR	16.56%	16.97%	16.31%	16.74%	16.08%	16.51%
Free Cash Flow to Equity						
Year 5	16.04	25.74	14.64	25.34	13.24	24.84
Year 6	12.97	8.77	13.12	8.45	13.28	8.16
Year 7	13.64	10.44	13.76	10.20	13.89	9.99
Year 8	12.73	10.58	12.83	10.41	12.93	10.28
Year 9	11.71	10.62	11.77	10.54	11.84	10.48
Year 10	4.59	4.59	4.60	4.59	4.62	4.61
Year 11	11.51	11.51	11.51	11.51	11.51	11.51
Year 12	11.66	11.66	11.66	11.66	11.66	11.66
Year 13	11.48	11.48	11.48	11.48	11.48	11.48