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Transport PPP Decisions in Korea: Value for Money Assessment and Risk Quantification

by

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ABSTRACT

Value for money (VFM) assessment has been adopted worldwide as a public private partnership (PPP) decision methodology. In terms of quantitative assessment, this method considers only the public sector cost, assuming completion delay does not occur between delivery alternatives, so it is difficult to use where systematic completion delays in the conventional delivery are expected to occur like in Korea. Therefore, in this research a Modified VFM methodology was developed to consider completion delay as well as public sector cost, using the VFM assessment and the Net Present Value (NPV) technique. In addition, various risks including transferable risks (completion delay, construction cost and traffic volume risk) were quantified in order to examine the impact of the transferable risks on PPP decisions, through historical observations and a literature review. In total six case studies (2 National Highways, 2 National Expressways and 2 National Railways) were conducted, reflecting Build-Transfer-Operate (BTO) and Build-Transfer-Lease (BTL), the most popular PPP options in Korea. The biggest difference between the BTO and the BTL options is that the private sector makes a profit from end users' tariffs in the BTO option, whereas it makes a profit using the annual lease fee from the government in the BTL option.

The most important finding is that a completion delay in the conventional delivery can be a decisive factor on the quantitative PPP decisions because of the resulting benefit difference between conventional delivery and PPP options. As this completion delay for conventional delivery becomes longer, the probability that PPP schemes are favourable increases. In addition, the critical completion delay, making the Modified VFM zero, varies depending on not only whether to include the construction cost risk and the traffic volume risk, but also on the PPP options considered. Another important finding is that, when including construction cost risk, the viability of PPP options in roads increases, whereas that in railways decreases. This is because the average winning bid ratio (winner's price divided by estimated price) of turn-key/alternative bids in roads, used in the calculation of the asset cost of the public sector comparator (PSC) according to the BTL guidelines of Korea, is higher than historical observations that include construction cost risk, whereas in railways it is lower than historical observations that include construction cost risk. This difference between roads and railways seems to arise from the fact that railways are usually delivered separately using six major work element contracts, while roads are usually delivered by a single contract, suggesting that separate contracts lead to greater cost overruns than a single contract. In addition, when reflecting traffic volume risk, the most appropriate delivery option, from a Government perspective, for road/railway cases with tariffs changes from the BTL to the BTO option. This is because traffic volume risk directly results in a shortfall in revenue, which makes the BTO

option more favourable to the public sector. However, in the case of railways, the BTL option seems to be practically adopted because the revenue stream is so small that the BTO option is not affordable for the private sector, even considering the maximum governmental subsidy condition. For the success of a BTO project in Korea, a new traffic volume risk sharing scheme is also suggested, sharing revenue shortfall or excess according to the investment of each participant.

Overall, this research suggests that, considering the transferable risks and the revenue stream size of each transport programme, the BTL option is the most appropriate for the National Railways, whereas the BTO is the most appropriate option for the National Expressways, provided that the BTO viability can be achieved in terms of the internal rate of return. With respect to the National Highway programme, the BTL option can be considered as an alternative to conventional delivery on a case by case basis. Finally, considering the land transport programme (roads and railways) of Korea, a meta-analysis indicates that the Modified VFM is positively influenced by project size, completion delay, benefit cost ratio, discount rate and consumer price index, whereas it is negatively influenced by the five year exchequer bond interest rate. In addition, the BTO option and Gyeonggi province (surrounding Seoul) respectively have a bigger positive influence on the Modified VFM than the BTL option and Gyungnam province (adjacent to Busan).

Dedication

I DEDICATE THIS THESIS TO MY BELOVED FAMILY

MY WIFE, YANGIN AHN,

WHO GAVE ME HER LOVING SUPPORT

AND PUT HER LIFE ON HOLD FOR MY STUDY

MY DAUGHTER, JINHEE PARK AND YUJIN PARK,

WHO REPRESENT A GOOD FAMILY AND A BETTER LIFE

MY PARENTS, HOGWEON PARK AND JUNGSOON JUNG,

WHO GAVE ME LIFE AND ENDURING LOVE

MY PARENTS-IN-LAW, CHOONBAE AHN AND YOUNGSUN KOH,

WHO GAVE ME THE MOST SPECIAL PERSON IN MY LIFE

AND

THIS THESIS IS ALSO DEDICATED IN LOVING MEMORY

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DECLARATION OF AUTHORSHIP

I, JI HONG PARK

declare that the thesis entitled

Transport PPP decisions in Korea: Value for Money Assessment and Risk Quantification

and the work presented in the thesis are both my own, and have been generated by me as the result of my own original research. I confirm that:

- this work was done wholly or mainly while in candidature for a research degree at this University;
- where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
- where I have consulted the published work of others, this is always clearly attributed;
- where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;
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- none of this work has been published before submission

Signed: …………………………………………………………………………..

Date: ……………………28 June 2014………………………………………….

List of Abbreviations

ADB	Asian Development Bank
AHP	Analytical Hierarchy Process
BAI	Board of Audit and Inspection of Korea
BBO	Buy-Build-Operate
BCR	Benefit Cost Ratio
BLT	Build-Lease-Transfer
BOO	Build-Own-Operate
BOOT	Build-Operate-Own-Transfer
BOT	Build-Operate-Transfer
BROT	Build-Rehabilitate-Operate-Transfer
BTL	Build-Transfer-Lease
BTO	Build-Transfer-Operate
CAPM	Capital Asset Pricing Model
CCEJ	Citizen's Coalition for Economic Justice
CERIK	Construction Economy Research Institute of Korea
DBFO	Design-Build-Finance-Operate
EC	European Commission
EIB	European Investment Bank
EP	Estimated Price
EPEC	European PPP Expertise Centre
EU	European Union
EUR	Euro (European monetary unit)
FHWA	Federal Highway Administration of the United States
GBP	Great Britain Pound
GDP	Gross Domestic Product
GOF	Goodness of Fit
GR	Global Resistance
IBRD	International Bank of Reconstruction and Development
IMF	International Monetary Fund
KDI	Korea Development Institute

KEC	Korea Expressway Corporation
KRC	Korea Railroad Corporation
KRIHS	Korea Research Institute for Human Settlements
KRNA	Korea Railway Network Authority
KRW	Korean Won
KTX	Korea Train eXpress
LEC	Long Term Expenditure Contract
M. VFM	Modified Value For Money
MCS	Monte Carlo Simulation
MLTM	Ministry of Land, Transport and Maritime Affairs of Korea
MOSF	Ministry of Strategy and Finance of Korea
MRG	Minimum Revenue Guarantee
NAO	National Audit Office
NGO	Non-governmental Organisation
NPV	Net Present Value
OECD	The Organisation for Economic Co-operation and Development
PCKT	Passenger Car Kilometres Travelled
PDF	Probability Distribution Function
PFI	Private Finance Initiative
PIMAC	Public Private Investment Management Centre
PPAIF	Public-Private Infrastructure Advisory Facility
PPP	Public Private Partnership
PSC	Public Sector Comparator
PVIFA	Present Value Interest Factor of an Annuity
ROT	Rehabilitate-Operate-Transfer
SPV	Special Project Vehicle
UNESCAP	United Nations Economic and Social Commission for Asia and Pacific
USD	United States Dollar
VFM	Value for Money
VKT	Vehicle Kilometres Travelled
WACC	Weighted Average Cost of Capital
WBR	Winning Bid Ratio

CHAPTER 1 Introduction

1.1 Background

For decades, and especially since the 1980s, Public Private Partnerships (PPPs) have been playing an important role in public infrastructure service provision (Araújo and Sutherland, 2010), helping governments provide public services within the available budget and within a reasonable timeframe (EIB, 2005, Quinet and Vickerman, 2004). In addition, governments are expected to obtain several advantages through PPPs, such as better value for money (VFM), risk transfer and quality of service, from the innovation and creativity of the private sector (Katz, 2006, Kwak et al., 2009, Papajohn et al., 2011). In addition, some research around world (Arthur Andersen and Enterprise LSE, 2000, Ball et al., 2007, FHWA, 2011, Sarmento, 2010, Fitzgerald, 2004, NSW Auditor-General, 2006, Ugrate et al., 2013) supports the superiority of PPPs in terms of producing better VFM.

For these reasons, many countries all over the world have used PPPs as a procurement method. Since 1990 more than 5,200 infrastructure projects in more than 139 low and middle income countries have used PPPs as a procurement system for public infrastructure; 1,373 transport projects have already been implemented by PPPs in such countries (World Bank and PPAIF, 2013). With respect to the EU region, about 1,540 PPP projects have been awarded between 1990 and 2011, representing a capital value of more than EUR 250 billion (EPEC, 2012, Kappeler and Nemoz, 2010). In Korea, there are 461 PPP projects in progress and the proportion of private investment to public investment for infrastructure has grown by 4.5 times from 4 % in 1998 to 18 % in 2008 (MOSF and KDI, 2011).

Furthermore, the role of PPPs is expected to grow because governments need to seek new breakthroughs to address the growing demands on infrastructure service in the context of declining funds (Girmscheid, 2009). According to the OECD, considering Gross Domestic Product (GDP) growth and the current existing stock, between USD 269 billion and USD 350 billion per year is expected to be invested in roads and rail over the period to 2030 in OECD countries, and PPPs are recommended as a means of delivering additional finance for land transport investment (OECD, 2006, OECD, 2007).

However, notwithstanding the present popularity and the promising future prospect of PPPs, much criticism has been made regarding the justification of the implementation of PPPs as an alternative to conventional delivery. This criticism is usually about whether PPP options produce greater VFM than the conventional delivery or whether the performance expected was achieved, or whether the procurement option selected was appropriate. The main issues can be different depending on countries' precise PPP system, PPP organisational structure and socio-economic atmosphere.

For examples, regarding Public Finance Initiative (PFI) projects in the UK, much of the criticism is related to failure to provide VFM (GR, 2011), the higher cost than conventional delivery (UNISON, 2010, House of Commons Treasury Select Committee, 2011, Shaoul et al., 2012) and the excessive profit of the private sector (Monbiot, 2010). Pollock et al. (2007) claimed that there is no evidence that PFI is more efficient than public procurement in terms of cost and time. In addition, Shaoul (2005) and Carrillo et al. (2008) argued that risk transfer calculation in the VFM assessment involves a subjective and arbitrary process and Graffney et al. (1999) and Broadbent et al. (2003) pointed out that a small change in the discount rate could make for a very different result. Other than that, based on British experience, Vickerman (2003) claimed that the complexity of organisational structures in transport service provision led to difficulties in the introduction of private finance.

When it comes to Korea, most of the criticism is regarding the failure of traffic volume forecast (Jung, 2011, Lee, 2011) and the related minimum revenue guarantee (MRG) cost, which is considered to be too excessive for the public sector, in Build-Transfer-Operate (BTO) projects (Kang, 2012). In addition, Son (2012) claimed that the construction subsidy in BTO projects is excessive, so that it is difficult to determine the merits of PPP projects. In regards to construction cost, Lee (2008) argued that unit construction cost per kilometre in BTO road projects is more expensive than in conventionally delivered projects. Other than that, the public express strong dissatisfaction about the much higher tariff level in the BTO projects than in the public sector projects. (Shim and Shin, 2010, Jeon, 2011). Due to this criticism, the question whether PPPs could be proper alternatives to conventional delivery has been raised constantly from the public in Korea (Lee, 2008, Kang, 2012).

Fundamentally, much of this criticism seem to be more or less related to the appropriateness of PPP decisions; making the right decision seems to be the Government's essential obligation because they need to explain if and why PPPs are better than the conventional option and to persuade their taxpayers (Park, 2007). With respect to PPP decisions, although the VFM assessment is practically the most common PPP decision methodology on whether to use a PPP option or not (Akintoye et al., 2003), it seems impossible to make a unanimous judgement to be applied to all countries (Grout, 2005) because each country has its own distinctive socio-economic and cultural environment.

The VFM assessment, composed of a quantitative and qualitative approach (HM Treasury, 2006), developed in the UK, mainly compares the public sector cost of the PPP procurement and the conventional delivery to select a procurement option for a certain project. Theoretically, however, it considers economy (spending less), efficiency (productivity) and effectiveness (outcome) (HMSO, 1999), assuming that there is no difference in completion time or effectiveness between the delivery systems (Grimsey and Lewis, 2005, Hoose, 2011, MOSF, 2009a).

However, seemingly it is very difficult to accept this assumption in some countries where PPPs could be the only hope to provide infrastructure services because the public funds are so limited that these services cannot be provided on time. In this case, the VFM assessment with the public sector comparator could be meaningless for poor developing countries (Leigland and Shugart, 2006).

In the same way, in cases where there are systematic completion delays between conventional delivery and PPP alternatives, as in Korea, the current PPP decision methodology seems to have a limitation in terms of quantitative assessment due to this assumption. With respect to systematic completion delay in Korea, according to Ahn (2006), among 197 road projects completed between 2001 and 2005, 15 5 projects (86.5 per cent) were delayed, and among the delayed projects 134 projects (79 per cent) were delayed due to lack of budget. In addition, according to CERIK (2011), due to lack of budget, actual completion is delayed by 46 per cent on average, compared with planned construction duration in public works. This is the main cause of completion delay due to the unusual national budget system in Korea, the long term expenditure contract (LEC) system (Kim et al., 2008b).

According to the LEC system[1], an infrastructure project starts by reflecting its first-year's expenditure in the Budget Book settled by the National Assembly, even if the total expenditure of the project is not secured there. This means that with the LEC system, infrastructure construction can start with the yearly expenditure not determined by the National Assembly. Using this system, too many infrastructure projects, compared with the size of the budget, tend to be implemented by reason of political necessity such as balanced regional development

[1] LEC is provided in Article 21 of the Act on Contracts, to which the State is a party. The inefficiency of LEC is criticised by non-governmental organisations (NGOs) like the Citizen's Coalition for Economic Justice (CCEJ). The CCEJ (2010) criticised it for inducing too many projects to start without considering the available size of the budget.

policy. As a result, each project under construction experiences a budget shortfall and a systematic completion delay occurs.

In addition, regarding the qualitative approach in Korea, several systematic research projects on qualitative VFM have been conducted, using interview techniques (Gil, 2012) and analytical hierarchy process techniques (Yang et al., 2007). However, reviewing several PPP pre-qualification reports,[2] qualitative VFM assessment does not seem to be practically implemented yet in Korea and the Korean government seems to put a quantitative approach before a qualitative approach in the VFM calculation, as most governments do in reality (Grimsey and Lewis, 2005). Accordingly, the quantitative VFM result seems to be critical in the PPP decision in Korea.

Therefore, this research will primarily focus on the development of a new quantitative PPP decision methodology considering the completion delay of the conventional delivery, and then examine the impact of the completion delay in conjunction with other transferable risks, such as construction cost risk and traffic volume risk on PPP decisions, based on the new methodology.

1.2 Research Objectives

Many countries in the world have adopted the VFM assessment, generally divided into a quantitative element and a qualitative element (HM Treasury, 2006), in deciding whether to use PPPs or not. Though the qualitative assessment has become more important in PPP decisions (Grimsey and Lewis, 2005), it seems that factors influencing qualitative assessment are different depending on countries (Morallos and Amekudzi, 2008) and no concrete methods of qualitative assessment have yet been provided in each country's PPP guidelines (KDI, 2012). In addition, the qualitative assessment could inherently have a credibility issue (Amaratunga et al., 2002, Stake, 2010) and could particularly be vulnerable to a government policy or an appraiser's subjectivity (Lim et al., 2011). Therefore, this research will be restricted to the quantitative element.

[2] Several projects include the Bongdam-Songsan National Expressway project, the Osan-Gwangju National Expressway project, the Bujeon-Masan National Railway project and the Sosa-Wonsi National Railway project.

This research starts from two questions: 1) How can the completion difference between the conventional and the PPP delivery be included in the VFM assessment quantitatively in terms of theoretical context? and 2) What impact on PPP decisions can be expected from transferable risks, such as completion delay, construction cost risk and traffic volume risk in terms of the Korean practical context?

The first question is related to how it is possible to overcome the limitations of the assumptions of current quantitative VFM assessment. Quantitative VFM assessment used in many countries takes into account only the public sector cost, assuming that the completion delay does not exist between the conventional and PPP deliveries (Grimsey and Lewis, 2005, Hoose, 2011, MOSF, 2009a). In some countries like Korea, where a systematic completion delay in the conventional delivery is expected due to lack of public funds, it seems somewhat problematic to compare procurement alternatives by only the public sector cost, although these produce quantitatively different social benefits in terms of net present value. In addition, two of the core reasons for using PPPs are the reduction of the public sector cost and on-time completion compared with the conventional delivery (EC, 2003, EIB, 2005, ADB, 2008), and these can be estimated quantitatively. Therefore, in terms of quantitative assessment, it seems to be important to consider the public sector cost as well as completion delay in the conventional delivery at the same time; this procedure overcomes the limitations of the assumption.

The other question is related to risk quantification using historical observations. To date, not only is PPP research on risk quantification using historical observation very rare, but there is also seemingly no PPP research on risk quantification considering the Korean transport characteristics. As a result, although it is recommended that quantified risk costs are included in the VFM assessment according to Korea's Build-Transfer-Lease (BTL) guidelines (MOSF, 2009a), it is practically impossible to do so in Korea. Considering that optimal risk transfer is at the heart of PPPs (Arthur Andersen and Enterprise LSE, 2000, Sun et al., 2010), the current status of the Korean VFM practice without quantified risk cost seems to have a limitation from the viewpoint of a reasonable PPP decision.

Consequently, **the first** main objective of this research project is to develop a new quantitative PPP decision methodology in terms of theoretical context, taking into account the completion delay in the conventional delivery. **The second** main objective is to examine the impact of transferable risks, such as completion delay, construction cost and traffic volume on PPP decisions, in three transport programmes (the National Highway, the National Expressway and the National Railway) in terms of the practical Korean context, using this new methodology and six case studies. **The third** main objective is that , based on the results from the case studies, the influence factors on PPP decisions in land transport (roads and railways) will be scrutinised. In order to achieve the three main objectives of this research, several sub-objectives are set out as follows:

1-1) to identify the features of PPPs and to compare PPP decision-making in Korea with the rest of the world

1-2) to develop a new PPP decision-making methodology considering completion delay

2-1) to quantify transferable risks for PPP decisions on roads and railways in Korea

2-2) to examine the impact of transferable risks on PPP decisions on roads and railways in Korea

2-3) to explore the most favourable procurement option for roads and railways in Korea considering the transferable risks

3-1) to scrutinise the influence of the factors on the PPP decisions in the land transport of Korea

Since PPPs were introduced in the world, no quantitative PPP decision methodology taking into account the completion delay of a delivery method seems to have been developed to date. Therefore, the most important feature of this research is the development of a new PPP decision methodology, given the completion delay in the conventional delivery. In addition, in order to quantify the construction cost risk in Korea, the construction cost risk is first defined using a winning bid ratio and construction cost overrun risk, and the concept of critical completion delay, making the most favourable procurement option change, is first introduced in this research. Other than that, considering the scarcity of PPP research on risk quantification using historical observations because of limited access to data and publication constraints due to commercial confidentiality, this research is significant and well worth pursuing.

As a result, this thesis will make an important contribution to knowledge through the development of a new PPP decision-making methodology, considering the completion delay in the conventional delivery, and through revealing the impact of transferable risks such as completion delay, construction cost and traffic volume on PPP decisions in the transport sector in Korea.

1.3 Previous Studies

Generally speaking, PPPs are closely related to optimal risk allocation and how to manage risks in order to maximise VFM (Froud, 2003, Fitzsimmons et al., 2009, Gil, 2011), supplementing a lack of public funds with private funds. For the success of a project and the achievement of VFM, it is crucial to select a suitable procurement option and a qualified concessionaire. In addition, the success of a PPP can be achieved when the responsibilities of the two sectors are clearly identified, allocated and maintained (Vickerman, 2002).

Therefore, the main research on PPPs has been focused on risk, success factor and relationships, decision methodology, concessionaire selection and finance (Kwak et al., 2009, Tang et al., 2010), and these topics are closely interconnected with each other. With respect to this research, previous studies regarding PPP decision methodology and risk, among many research topics, are reviewed here.

Research on PPP decision methodology

Many researchers have developed various kinds of PPP evaluation or decision support model to examine the feasibility of PPPs for a certain project, and depending on the viewpoint, these could be divided into two categories: evaluation or decision support model for the private sector and the public sector.

From the viewpoint of the private sector, PPP evaluations or decision support models are mainly related to how attractive a project is because it needs to show how financially feasible or how risky it is, so that private investors can decide whether to invest in or not. With respect to financial evaluation models, Ranasinghe (1999) analysed the viability of a Build-Operate-Transfer (BOT) project in Sri Lanka by a financial feasibility model considering total cost, revenue and risks. In addition, Ye and Tiong (2000) developed the net present value (NPV)-at-risk model incorporating the weighted average cost of capital and dual risk-return methods[3], and Ho and Liu (2002) used an option pricing-based model in order to evaluate the financial viability of privatised infrastructure projects.

Regarding the decision support model for the private sector, Ozdoganm and Talat Birgonul (2000) suggested a decision support framework, including government guarantee and risk

[3] The dual risk-return method is a common method combining various risks and return on capital employed in order to assess the viability of the capital investment decision of private sector.

sharing scenarios, to solve a complicated decision-making problem for a hydropower plant BTO project in Turkey. In addition, Salman et al. (2007) identified 21 decision factors, such as forecast of future demands and return on investment, affecting the feasibility of BOT projects, and analysed their inter-relationships and their effect on the feasibility through the introduction of a decomposed evaluation model: it produces the viability index for BOT projects, composed of the decision factors and their weights from surveys. Furthermore, Ng et al. (2010) established a structural equation model (SEM) to evaluate the feasibility of a PPP project from the perspective of all stakeholders, claiming that not only technical but also social aspects are crucial to the feasibility of a project.

When it comes to the viewpoint of the public sector, PPP decision models have usually focused on economic efficiency, since they are different to the private sector decision models that primarily focus on return on capital employed. In fact, the common methodology for the analysis of economic efficiency, such as the NPV technique or cost-benefit analysis, has been widely used in addressing transport investment decision-making by many researchers like Quinet and Vickerman (2004), Layard and Glaister (1994) and Pearce and Nash (1981). For example, Girmscheid (2009) used a NPV model based on cash flow to evaluate the economic efficiency of the public sector delivery and PPP delivery with respect to the decision to opt for a PPP to maintain municipal streets.

Other than that, Ahmadjian and Collura (2012) developed a four-step decision-making framework in order to select an operating body for existing toll roads in the US. The framework involves: 1) alternative identification, 2) NPV assessment considering monetary factor for each alternative, 3) weight analysis considering quantitative and qualitative variables for each decision maker, and 4) comparison of results from 2) and 3).

However, as Akintoye et al. (2003) pointed out, the VFM assessment is practically the most common PPP decision methodology on whether to use a PPP alternative or not for a project because through this assessment the PPP scheme can be justified to achieve more economic efficiency than conventional procurement, even though it could be inappropriate to find one unique VFM test meeting all conditions and situations (Grout, 2005).

Using the VFM assessment methodology, Shin (2006) claimed that from the viewpoint of the public sector cost, the BTL approach is more favourable than the BTO approach for the Incheon International Airport Railway project connecting Seoul and Incheon International Airport in Korea. Park (2007) claimed that the BTL option is more favourable than the BTO option in sewage treatment facilities in Korea. In addition, Gil (2011) suggested how to share traffic volume risk between the public and the private sector and the optimal PPP model between BTO and BTL for road and railway sector in Korea. Other than that, Bain (2010) demonstrated that the generally assumed relationship between the discount rate and the procurement option selection, that any reduction in the discount rate makes the conventional procurement favourable, could be changed by the size and shape of the cost profile.

Research on risk

Research on risk in the context of PPP is largely concerned with risk identification and risk analysis in order to help establish how to allocate risks between the public and the private sector. Seemingly the reason for active research on risk is that risk is a key issue in PPP contract making, and the success of a PPP contract primarily depends on risk allocation between the two parties (Marques and Berg, 2011).

With respect to risk identification, many researchers, such as Zayed and Chang (2002), Lam and Chow (1999), Xenidis and Angelides (2005) and Schaufelberger and Wipadapisut (2003), have tried to classify risks or to determine critical risk factors in a certain risk in PPPs as an initial step towards risk identification.

Risk allocation between the public and the private sector in PPPs has also been actively researched by many researchers. With respect to Private Finance Initiative (PFI) in the UK, based on a questionnaire survey, Li et al. (2005) argued that the public sector should take the land acquisition risk and political risk, while the project risk should be taken by the private sector; legal risk needs to be shared by the both sectors. In other research (Roumboutsos and Anagnostopoulos, 2008, Ke et al., 2010) using Li et al.'s questionnaire on China/Hong Kong and Greece, the results were very similar to the earlier research though there were some regional distinguishing differences.

In addition, regarding risk analysis or risk quantification in PPPs, researchers have also developed risk assessment models based on various methodologies. Tah and Car (2000) developed a risk assessment model using fuzzy logic and hierarchical risk breakdown structure, and Thomas et al. (2006) suggested a risk probability and impact assessment framework based on a fuzzy-fault tree[4] and the Delphi method[5]. In addition, Zhang and Zou (2007) proposed a fuzzy analytical hierarchy process (AHP) model to support decision-making of the stakeholders in joint venture projects.

[4] A fuzzy-fault tree method is a graphical risk analysis using a deductive approach to determine the risks, quantified by the fuzzy logic, contributing to a designated impact. The fuzzy logic is useful in quantifying linguistic variables.

[5] The Delphi method is one of qualitative future forecast methods: it collects experts' opinions on a subject over and over again, exchanges and develops them in order to forecast the subject's future.

However, in the practical aspects, it seems that Monte Carlo Simulation (see Section 3.5.3) is almost the only risk quantification methodology recommended by the guidelines of various countries, such as Australia (2008b), Hong Kong (2008b) and Canada (2011), because this method is able to give powerful solutions for decision-making (Shim et al., 2005b). Since Pouliquen (1972) used this method in feasibility studies of the port and highway projects supported by the International Bank for Reconstruction and Development (IBRD), many researchers have adopted this decision-making method regarding risks (Lam and Tam, 1998, Malini, 1999, Lee et al., 1999, Jung et al., 2001, Grimsey and Lewis, 2002, Lee, 2003, Molenaar, 2005, Salling and Leleur, 2011) and in developing a risk analysis model (Sadeghi et al., 2010). However, despite various studies, most research uses assumed probability distribution, not from historical observations, because of data availability. In this case, there is always possibility that subjectivity can affect the simulation results (Lee, 2003) because the experience and knowledge of an individual or a group, utilised for the assumption of the probability distribution, can be biased.

As suggested above, no quantitative PPP decision methodology considering the completion delay of the conventional delivery seems to have ever developed to date and research on risk quantification using historical observations is very rare. Therefore, in order to determine the impact of transferable risks, such as completion delay, construction cost risk and traffic volume risk, on PPP decisions from the viewpoint of a quantitative evaluation, this research will develop a new PPP decision methodology, taking into account completion delay in the conventional delivery; quantified risks from historical observations are included for the purpose of the exclusion of subjectivity.

1.4 Research Procedure

The research procedure, shown in Figure 1-1, is largely made up of five steps, set out across nine chapters, in order to achieve the research objectives.

To begin with, the first step deals with the research background, research objectives and previous studies, which provide a robust basis to this research in Chapter 1.

The next step is a literature review (Chapter 2) and methodology (Chapter 3). Chapter 2, covering the research objectives 1-1, deals with the generality of PPPs, the characteristics of the transport and PPP systems of Korea, and PPP decision-making, examining why completion delay needs to be considered in a quantitative VFM, which PPP types and transport programmes should be considered, and what the key factor is in the PPP decision-making.

In addition, Chapter 3, covering research objective 1-2, deals with research methodologies, including the development of a new PPP decision methodology (a modified VFM), risk quantification, impact analysis (such as single-value estimation, sensitivity analysis and the Monte Carlo Simulation), the selection of case studies, and meta-analysis.

The third step, provided in Chapters 4, 5 and 6 in order to cover research objectives 2-1, 2-2 and 2-3, is to find out the impact of transferable risks on the PPP decisions in three transport programmes (the National Highway, the National Expressway and the National Railway), using two case studies per programme. Therefore, each chapter is largely composed of risk quantification through historical observations and a literature review, alongside case studies.

The fourth step, provided in Chapters 7 and 8 in order to cover research objectives 2-2, 2-3 and 3-1, is to synthesise the impact of transferable risks, such as completion delay, construction cost risk and traffic volume risk, on PPP decisions from the three transport programmes and to determine the most appropriate procurement option for each transport programme. In particular, in Chapter 8, in order to draw a more generalised and transferable conclusion, which is usually hard to find, on the land transport programme, including roads and railways, meta-regression analysis is conducted.

In the final step, main conclusions on the main research objectives are provided in Chapter 9. As well as this, the contribution and limitations of this research will also be discussed in this chapter.

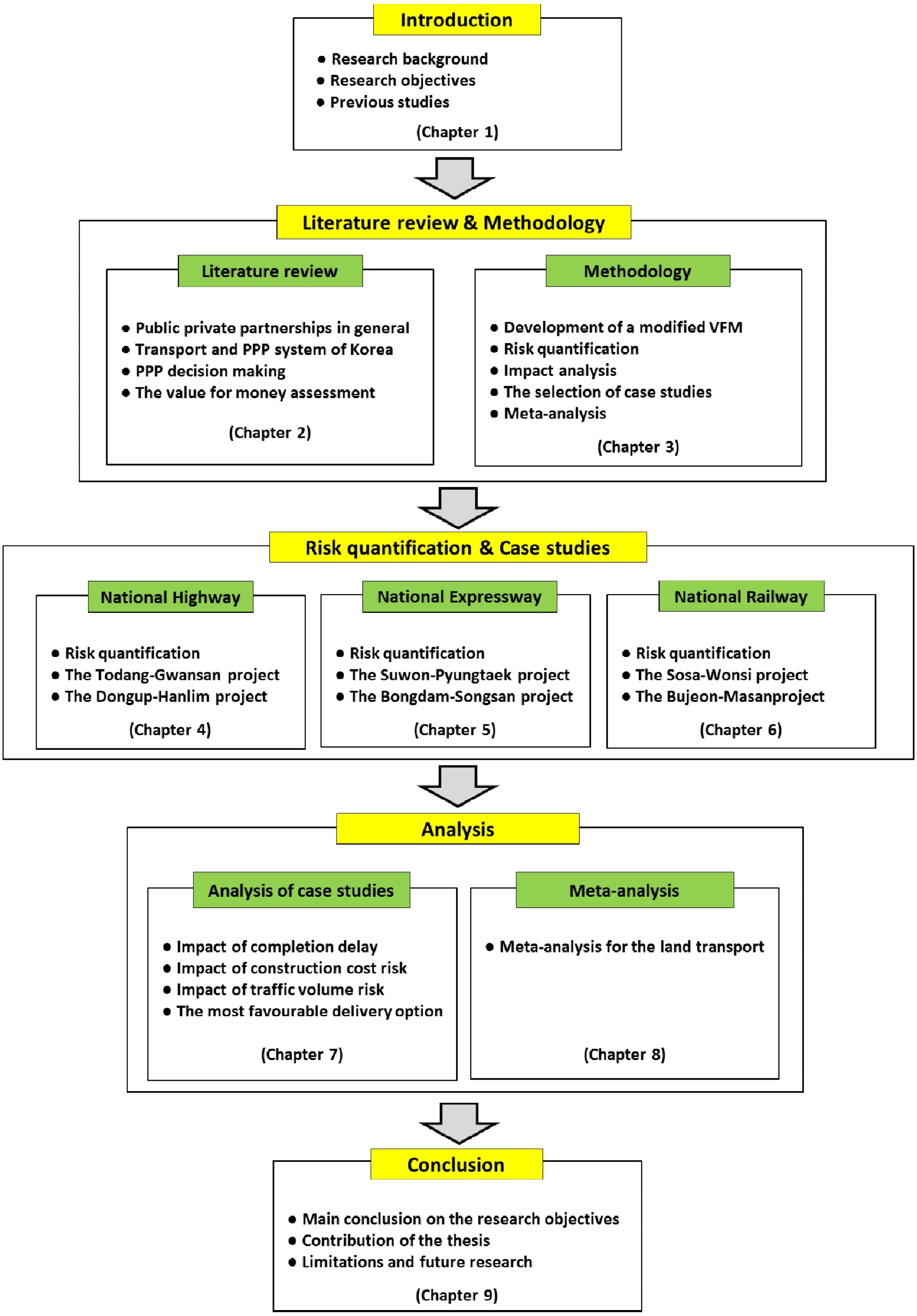


Figure 1-1: Research procedure

CHAPTER 2 PPPs in Transport

2.1 Introduction

Exploring the generalities on PPPs, the transport and PPP system of Korea and the PPP decision methodology through literature reviews, this chapter examines why completion delay needs to be considered in a quantitative VFM, which PPP types and transport programmes should be considered, what the key factor is in the PPP decision-making, and why quantitative VFM is important in the PPP decisions in Korea, covering the research objective 1-1 through literature review. This chapter is composed of four sections: 1) the generalities on PPPs, 2) transport and PPP system of Korea, 3) PPP decision-making, and 4) the VFM assessment.

In the first section (2.2), the generalities on PPPs are explained, exploring the meaning of PPPs, why governments want to use PPPs, the classification of PPPs, the advantages and disadvantages of PPPs, and PPP status and prospect in transport. In doing so, in particular, it scrutinises quantitative assessment factors for PPP decisions, considering the reasons for using PPPs and why this research considers BTL and BTO as PPP options.

In addition, in the next section (2.3), the main features of the Korean PPP system are probed for the purpose of providing background to the Korean PPP system. To this end, this section deals with the characteristics of transport of Korea and the Korean PPP system, explaining the importance of land transport (roads/railways), the difference between BTO and BTL, the issues on PPPs of Korea and the PPP implementation procedures.

In the third section (2.4), similarities and differences in PPP decision-making are reviewed, using information from countries including Korea and the UK. In doing so, what the key factor in PPP decision is will also be revealed.

Finally, the last section (2.5) focuses on the limitations of current Korean VFM assessment practice and why systematic completion delay in the conventional delivery in Korea should be added to a quantitative VFM, exploring the generalities of VFM assessment as well as VFM assessment comparison among countries.

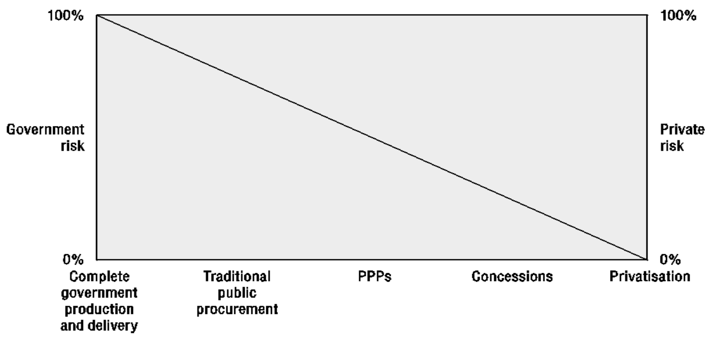
2.2 PPPs

2.2.1 The meaning of PPPs

The concept of PPPs

PPPs, generally speaking, mean the participation of the private sector through a contract between a public agency and a special purpose vehicle (SPV[6]) in public projects or services which, in the past, used to be delivered by the public sector (Papajohn et al., 2011). This means that through PPPs the public sector and the private sector need to cooperate to achieve a common objective, the provision of public infrastructure services.

According to Burger (2008) and the OECD (2008), PPPs are procurement methods that fill the gap between complete government delivery and privatisation by mixing government risks and private risks properly, as seen in Figure 2-1. Therefore, it is very difficult to find a single definition of PPPs which can be used universally (Grimsey and Lewis, 2005); sometimes it is said that it may be clearer to find delivery systems that are not included in PPPs (Grimsey and Lewis, 2004b). This is because PPPs may have a number of types which consist of various combinations of the public and the private sectors. Nevertheless, many researchers and institutions have tried to define a PPP.



Source: Burger (2008) and OECD (2008)

Figure 2-1: The spectrum of combinations of public and private participation for PPPs

Though there is a little difference in defining the PPP, as shown in Table 2-1, the characteristic common to all definitions seems to be “a public service delivery by the private sector through contractual arrangement/relationship and risk sharing between the public and the private sector”.

[6] The SPV means a legal entity that undertakes a PPP project. On behalf of the private sector, the SPV negotiates the contract agreements with the public sector (UNESCAP, 2011).

Table 2-1: Definition of PPPs[7] from various researchers and institutions

Sources	Definitions
Grimsey and Lewis (2004)	*"A risk-sharing relationship based on a shared aspiration between the public sector and one or more partners from the private and/or voluntary sectors to deliver a publicly agreed outcome and/or public service".*
Kwak et al. (2009)	*"A cooperative arrangement between the public and private sectors that involves the sharing of resources, risks, responsibilities, and rewards with others for the achievement of joint objectives"*
IMF (2006)	*"Arrangements under which the private sector supplies infrastructure assets and infrastructure-based services that traditionally have been provided by the government. In addition to private execution and financing of public investment, PPPs have two other important characteristics: there is an emphasis on service provision, as well as investment, by the private sector; and significant risk is transferred from the government to the private sector. PPPs are involved in a wide range of social and economic infrastructure projects, but they are mainly used to build and operate hospitals, schools, prisons, roads, bridges and tunnels, light rail networks, air traffic control systems, and water and sanitation plants"*
EC (2004)	*"The term public-private partnership ("PPP") is not defined at Community level. In general, the term refers to forms of cooperation between public authorities and the world of business which aim to ensure the funding, construction, renovation, management or maintenance of an infrastructure or the provision of a service"*
EIB (2005)	*"A PPP should - have been initiated by the public sector - involve a clearly defined project - involve the sharing of risks with the private sector - be based on a contractual relationship which is limited in time - have a clear separation between the public sector and the Borrower."*
OECD (2008)	*"An agreement between the government and one or more private partners (which may include the operators and the financiers) according to which the private partners deliver the service in such a manner that the service delivery objectives of the government are aligned with the profit objectives of the private partners and where the effectiveness of the alignment depends on a sufficient transfer of risk to the private partners"*

Source: Grimsey and Lewis (2004b), Kwak et al. (2009), IMF (2006), EC (2004), EIB (2005) and OECD (2008)

Why governments want to use PPPs

In order to understand PPPs more clearly, it is essential to know why governments use PPPs as one of their procurement alternatives. Marty (2008) argued that the determinants of government commitment in PPPs are budgetary constraints, fiscal opportunism and economic efficiency across the whole life of a project. In addition, according to EIB (2005), the main reason for using PPPs is that governments are able to provide infrastructure services within a reasonable time, which would be impossible considering the limitations of the public sector budget. EC (2003) and ADB (2008) also pointed out that, due to financial shortages in the public sector,

[7] In Korea, a PPP is simply defined as "a public service delivery by the private funds" according to the Act on Promotion of Private Capital into Social Overhead Capital Investment (the PPP Act), so it seems that the importance of risk sharing between two parties is underestimated in a PPP. However, in other PPP advanced country like the UK, the definition of PPP (or PFI) includes the concept of risk sharing.

PPPs have prospered and with PPPs governments are expected to gain operating efficiencies as well as additional financial resources.

With respect to significant incentives to use PFIs in the UK, The House of Commons (2011) point out that so far the majority of PFIs do not seem to increase government debt or the deficit; with PFIs, government departments can afford new investment without using their assigned budget. In Korea, there are three main reasons[8] to resort to PPPs: 1) supplementing lack of public funds, 2) bringing forward benefit occurring time and 3) utilising creativity and efficiency in infrastructure provision (MOSF, 2009b, MOSF, 2009c). Accordingly, though there are some differences across institutions and countries, the main reason for using PPPs in the public sector seems the shortages in public funds and the resulting delayed infrastructure provision when using public procurement.

Consequently, from the viewpoint of the public sector, a PPP seems to mean “a public service delivery by the private sector through a contractual arrangement/relationship and risk sharing between the public and the private sector, with a view to overcoming shortages in public funds and the resulting delayed infrastructure provision”.

2.2.2 Classification of PPPs

Several institutions have suggested somewhat broad categories with respect to PPP classification. According to the European Commission (EC, 2003), PPPs can be largely divided into three categories: 1) opportunities for private involvement in traditionally procured projects (e.g. service contracts, operation and management, contracts, leasing), 2) integrated project development and operation opportunities (e.g. BOT and Design-Build-Finance-Operate (DBFO)), 3) partnership project development and investment opportunities (e.g. concessions and private divestiture).

The World Bank (2011) has also suggested four sub-types of PPPs: management and lease contract, concessions (e.g. Rehabilitate-Operate-Transfer (ROT)), greenfield project (e.g. Build-Lease-Transfer (BLT), BOT) and divestitures.[9]

[8] From a viewpoint of international comparisons, the reason to use PPPs in Korea is more detailed and explicit than international organisations (such as EC and ADB) suggest though the main reason is quite similar.

[9] Divestitures mean the cases that a private company buys full or part of the equity in the state-owned company through an asset sale, public offering, or mass privatisation programme (World Bank, 2011).

Other than that, the ADB (2008) has grouped PPPs into six basic forms: service contracts, management contracts, affermage or lease contracts, BOT and similar arrangements, concessions and joint ventures.

Additionally, the probably more widely accepted classification of PPPs is related to how much risk is transferred from the public to the private sector or the extent to which the private sector is involved in PPPs (OECD, 2008, Tvarno, 2011, Kwak et al., 2009).

Accordingly, considering the broad categories from international institutions and the extent of both risk transfer to the private sector and private participation, the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP, 2011) has suggested the classification of PPP models shown in Table 2-2. As seen in Table 2-2, there can be diverse types of PPPs in terms of ownership of capital assets, responsibility of investment and who takes on the risk.

Table 2-2: Classification of PPP models

Broad category	main variants	Ownership of capital assets	Responsibility of investment	Assumption of risk	Duration of contract (years)
Supply and management contract	Outsourcing	Public	Public	Public	1 - 3
	Maintenance management	Public	Public/Private	Private/Public	3 - 5
	Operational management	Public	Public	Public	3 - 5
Turnkey		Public	Public	Private/Public	1 - 3
Affermage/Lease	Affermage	Public	Public	Private/Public	5 - 20
	Lease*	Public	Public	Private/Public	5 - 20
Concessions	Franchise	Public/Private	Public/Private	Private/Public	3 - 10
	BOT**	Public/Private	Public/Private	Private/Public	15 - 30
Private ownership of assets and PFI type	BOO/DBFO	Private	Private	Private	Indefinite
	PFI***	Private/Public	Private	Private/Public	10 - 20
	Divestiture	Private	Private	Private	Indefinite

* Build-Lease-Transfer (BLT) is a variant.
** Build-Operate-Transfer (BOT) has many other variants such as Build-Transfer-Operate (BTO), Build-Own-Operate-Transfer (BOOT) and Build-Rehabilitate-Operate-Transfer (BROT).
*** The Private Finance Initiative (PFI) has many other names. In some cases, asset owener may be transferred to, or retained by the prubic sector.

Source: UNESCAP (2011)

However, despite various classifications, there is apparently no single PPP model meeting all conditions with respect to a project's local, technical and financial features, and therefore the most appropriate PPP model should be designated given the country's socio-economic circumstances, the maturity of its PPP market and the financial and technical characteristics of the projects and sectors concerned (UNESCAP, 2011). For example, in the UK, PPPs usually mean PFIs of three types: 1) free-standing projects, where the private sector is assumed to recover entire costs from the end user tariff, 2) joint ventures, where the private sector takes the initiative despite the contribution of the public sector and 3) services sold to the public sector (e.g. DBFO) (Allen, 2001). Among them the most popular type seems to be DBFO in the UK, reflecting the UK's PPP system and socio-economic environment. One the other hand, according to MOSF (2009b) types of PPPs in Korea are largely categorised into "profit-oriented PPP" (i.e. BTO) and "lease-oriented PPP" (i.e. BTL) considering Korea's institutions and market[10].

Consequently, it seems that PPP research on specific region or country needs to consider how PPPs are classified and what type is mostly used in order to reflect the characteristic of each region or country. Therefore, this research will consider the most popular PPP types in Korea, BTO and BTL, in deciding which procurement option is the most favourable, including conventional delivery.

2.2.3 Advantages and disadvantages of PPPs

There are many advantages and disadvantages, which are shown in Table 2-3, when using PPPs for infrastructure provision. Although types of PPPs can vary from country to country, it is no exaggeration to say that all countries try to obtain all these advantages in using PPPs.

Advantages

Looking at the major advantages, first of all, PPPs make it possible to do better whole-of-life evaluation and to obtain better VFM by eliminating the so-called "optimism bias" which makes conventional delivery seem better than it really is (Katz, 2006, Kwak et al., 2009, Harris, 2005).

The next advantage is that through the PPP system the private sector has a tendency to minimise whole-of-life costs by optimising design and operation in order to be selected as a concessionaire (Katz, 2006, Grimsey and Lewis, 2004b, Kwak et al., 2009, Harris, 2005). From

[10] In Korea, no PPP projects has been launched without governmental subsidy which consists of compensation cost and construction support. Considering the revenue stream of transport projects, the Korean government supports approximately 30 to 50 percent of the total project cost, which is the sum of compensation cost and construction cost. Therefore, strictly speaking, "profit-oriented PPPs (i.e. BTO)" in Korea are different from free-standing projects in the UK.

the viewpoint of the government sector, other than government budget, the government sector can access additional capital sources without causing a budget deficiency through off-balance sheet financing (Katz, 2006, Grimsey and Lewis, 2004b, Kwak et al., 2009).[11]

Table 2-3: Advantages and disadvantages from various researchers

	Advantages	Disadvantages
Quantitative	① better whole-of-life evaluation without an optimism bias and value for money ② optimisation of design and operation in order to minimise whole-of-life costs ③ completion of project at the lowest cost and in the shortest time period ④ transferring risks from the government sector to the private sector ⑤ allowing the public sector to avoid up-front capital costs and reduce public sector administration costs	① high tendering and negotiation costs ② either bankruptcy or very large profits of the private sector due to long term project could create political problems for the government, causing it to intervene ③ limited competition in PPP projects or PPPs monopoly could cause higher costs ④ likelihood of high cost since the private sector cannot borrow capital to finance projects as cheaply as the public sector
Qualitative	⑥ access to additional capital without causing budget deficiency ⑦ off-balance sheet financing ⑧ assurance of good maintenance and service quality ⑨ facilitating innovation in infrastructure development ⑩ promotion of local economic growth and employment opportunities, and development of new business sector	⑤ relatively new concepts that are not well understood in some countries ⑥ difficulties of ensuring good performance ⑦ lack of appropriate knowledge and skills to implement such long-term projects in both the public and private sector ⑧ likelihood of project delay due to political debates, public opposition, and complex negotiation processes

Source: Katz (2006), Kwak et al. (2009), Harris (2005), Grimsey and Lewis (2004b), Papajohn et al. (2011) and Regan et al. (2009)

Most importantly, with PPPs the government sector can transfer the risks and responsibilities which are provided in the contract to the private sector (Grimsey and Lewis, 2004b, Katz, 2006, Kwak et al., 2009). The innovation and creativity from the private sector to develop transport infrastructure could also represent an advantage when using PPPs (Kwak et al., 2009, Harris, 2005).

With respect to the innovation and creativity, in fact, it is difficult to find the results of the innovation and creativity independently or separately in PPP practices because they are usually shown as a lumped form of whole life cost saving, early completion or enhanced service quality,

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[11] PPP projects are sometime delivered on-balance sheet financing and sometimes off-balance sheet. When PPP projects are delivered by a project company acting as the government's private sector counterparty, the government's balance sheets will be affected by whether the company itself is classified as a public or a private entity (OECD, 2012).

mixed with other advantages. Government officials in Korea, therefore, tend to consider PPPs as merely financial alternatives to public delivery, emphasising the role of off-balance sheet financing and ignoring the effectiveness resulting from the engineering innovation and creativity, because standard design guidelines which most PPPs are subject to prevent them from achieving cost reductions with respect to the innovation and creativity (Perkins, 2013). Also, recent research (Blanc-Brude et al., 2009) showed that there were little differences in construction cost between PPPs and conventional delivery and this research seems to support their viewpoint. Accordingly, they tend to think that a project implemented by a PPP alternative is almost identical to one by conventional option except where project funds come from.

However, their viewpoints on PPPs seem to be problematic because it has already been shown that, when a project is planned considering whole life cost concept, combing project stages such as design, construction and operation like PPPs, whole life cost effectiveness can be achieved in procurement practices. Theoretically, there is high possibility of saving more whole life cost when a project is reviewed at the earlier stages such as planning and design (Smith, 2002, TRB, 2010, Miller et al., 2009) because more innovative and creative measures can be reflected well at the earlier stages, through the selections of procurement, route, location, material and construction method.

In particular, regarding procurement choice, PPPs that bundle project stages can always allow some reductions in whole life cost (Nisar, 2007, Burger and Hawkesworthsworth, 2011). For example, some PPP road projects, such as E18 (Muurla-Lohja) in Finland (Vehviläinen, 2007), M25 in the UK (NAO, 2010), the Peninsular Link Project in Australia and Port Man Project in Canada (FHWA, 2011), show the competitiveness in terms of whole life cost, compared with conventional delivery. In addition, according to Ugrate et al. (2012), through innovation in design under PPP contracts, the LBJ Expressway (IH-635 managed lanes, Dallas, Texas, USA) reduced “construction costs by USD 970 million from an initial estimate of USD 2.875 billion”. As well as this, the comparison engineering materials and building methods at design stage can also reduce whole life cost including initial cost and maintenance cost (Wimsatt et al., 2009). Talking broadly, it may be said that these types of whole life cost savings were achieved by the innovation and creativity due to the adoption of PPPs that bundle project stages.

Additionally, PPPs can have high possibility of obtaining more revenue through more creative methods (such as sales promotions and subsidiary enterprises) than conventional delivery. It is because the revenue increase using sales promotions or subsidiary enterprises (e.g. such as service stations on the National Expressway) is directly connected to the profit increase for the private sector in PPPs. For example, in order to promote usage, some PPP expressway projects

(Cheonan-Nonsan, Daegu-Pusan and Seoul-Chuncheon) in Korea use TV commercials that emphasize user benefits like the reduction of travel time and fuel expenses.
Therefore, it is more reasonable to consider the innovation and creativity factors in the private sector in whole life perspective as well as the advantages of off-balance sheet financing in deciding whether to use PPP options or not.

Disadvantages

However, several disadvantages also exist when implementing PPPs for public services. To begin with, unlike with conventional delivery, PPPs can cause high transaction costs in the tendering and negotiation process, which can be criticised for not being efficient compared with conventional delivery (Katz, 2006, Dudkin and Välilä, 2005, NAO, 2004).

Next, although when launching a PPP, a good performance is expected, in reality it is very difficult to ensure how good the performance from the private sector is (Katz, 2006) seemingly because of poor regulation.

In addition, limited competition in PPP projects could cause unexpected higher costs. According to Kim et al. (2008a), about 60 per cent of PPP projects were implemented without competition in Korea between 2000 and 2007[12], and as a result the PPP system has been suspected of wasting available public funds (CCEJ, 2009).

Another important disadvantage is that high financial cost[13] could be an obstacle in using PPPs. The financial cost of the private sector is usually higher than that of the public sector for two reasons. Firstly, commercial banks tend to think that lending money to the private sector is more risky than lending to the public sector, so the private sector needs to pay an extra premium to borrow money compared with the public sector, which can do that at a risk-free rate (Palmer,

[12] It seems that collusion still exists in construction market in Korea notwithstanding eradication efforts of the Korean government. In the past (before 2010), when construction company led PPP projects, the collusion practice in construction market seems to have spread out to PPP market though it is abnormal from a viewpoint of international PPP market. However, nowadays financial firms usually leads PPP projects and PPP market seems to be free from collusion practice.

[13] Theoretically, the financial cost of the private sector is not always more expensive than that of the public sector. However, the equity risk that taxpayers take on is usually ignored in PPP decisions, so the financial cost of the public sector becomes cheaper (Jenkinson, 2003, Grout, 1997). In addition, in reality the efforts of the public sector to transfer risks to the private sector as much as they can also make the financial cost of the private sector increase (Meaney and Hope, 2012).

2000, Broadbent et al., 2003, Ball et al., 2007).[14] In addition, project financing for the private sector requires extra costs and fees such as funding fees (Palmer, 2000). For example, in the UK, to borrow senior debt[15] for PFI project, the private sector needs to pay typically 2 or 4 percentage points higher than the government sector does (Spackman, 2002, Accounts Commission, 2002). According to the PPP pre-qualification report on the Osan-Gwangju BTO project conducted in 2009 in Korea, the financial cost to the public sector was 5.42 per cent (five-year exchequer bond), while that of the private sector was from 7.0 per cent (senior debt) to 12.0 per cent (subordinated debt) (Yeo and Yu, 2009).

Considerations for better PPP decisions

When deciding whether to use PPPs or not, each country has to consider these advantages and disadvantages. As shown in Table 2-3, the advantages and disadvantages of PPPs can be classified into quantitative and qualitative. Most quantitative factors are related to whether the public sector cost goes up or down and how early a project can be completed by PPPs. Accordingly, a quantitative PPP decision methodology seems to need to take completion time as well as the public sector cost into account, considering that the impact of the completion time as well as the public sector cost can be quantified for a reasonable PPP decision.

In addition, when PPP schemes and conventional delivery provide clearly different completion times, namely different effectiveness, from each other, as in Korea, it seems somewhat problematic to compare only the public sector cost for the selection of procurement option in terms of quantitative assessment.

Consequently, for a better PPP decision, it is reasonable to take not only the public sector cost but also the completion time into account in the quantitative PPP decision methodology.

[14] Superficially it seems to be reasonable to use cheap public funds by issuing additional exchequer bonds instead of expensive private funds. However, it is practically impossible to replace private funds with public funds by issuing additional exchequer bonds because issuing additional exchequer bonds for infrastructure provision can cause the following problems around: 1) fairness among budget-consuming fields, 2) fiscal sustainability (balanced fiscal finance), 3) sovereign credit rating, and 4) fund delivery for a specific, urgent project (MOSF, 2009c).

[15] Debt in finance is largely divided into senior debt and subordinate debt in terms of priority. Senior debt takes priority over subordinate debt (or "junior debt") owed by the debtor, so when the debtor goes bankrupt the senior debt must be repaid prior to any debt held by other creditors.

2.2.4 PPP status and prospects in transport

Status of world PPP market

According to the World Bank Private Participation in Infrastructure Database[16] (World Bank and PPAIF, 2013), from 1990 to 2011, globally 5,240 projects in the fields of energy, telecom, transport and water and sewage sectors, started using PPPs amounting to 1,826.9 billion USD. From the viewpoint of total investment, the telecom sector is the biggest, occupying 44.9 per cent of the total PPP market, followed by the energy sector (34.5 per cent) and the transport sector (17.0 per cent).

With respect to the transport sector, during the same period, 1,373 projects amounting to 310.7 billion USD were implemented to construct or operate airports, railroads, roads and seaports. Among the transport sector, roads make up the largest area of investment, occupying 51.7 per cent of the total transport PPP market, followed by seaports (19.5 per cent).

Table 2-4: The status of PPP projects from 1990 to 2011

		Projects		Investment	
		Number	%	Billion USD	%
Energy		2,283	43.6	630.41	34.5
Telecom		822	15.7	820.62	44.9
Transport		1,373	26.5	310.65	17.0
	Airports	(145)	(10.6)	(33.96)	(10.9)
	Railroads	(116)	(8.4)	(55.71)	(17.9)
	Roads	(731)	(53.2)	(160.49)	(51.7)
	Seaports	(381)	(27.7)	(60.49)	(19.5)
Water and sewage		762	14.5	65.16	3.6
total		5,240	100	1826.85	100

Source: World Bank and PPAIF (2013)

Prospect of transport PPP market

The OECD (2006) estimated annual world infrastructure expenditure between 2000 and 2030 for selected sectors (road, rail, telecom, energy and water), as shown in Table 2-5. With respect to road and rail, according to the OECD (2006), during the same period, the annual expenditure requirements were calculated to approximately from 269 to 350 billion USD, with a range of ± 20 per cent fluctuation, using a model having the current existing stock of road or rail and GDP growth as key drivers. In addition, the difference between this amount and available public

[16] http://PPI.worldbank.org

funds is recommended to be added using PPPs (OECD, 2007), so the transport PPP market in the future seems likely to experience growth.

Table 2-5: Annual world infrastructure expenditure as a percentage of World GDP

Type of infrastructure	2000-10 (billion USD)	Approximate % of world GDP	2010-20 (billion USD)	Approximate % of world GDP	2020-30 (billion USD)	Approximate % of world GDP
Road	220	0.38	245	0.32	292	0.29
Rail	49	0.09	54	0.07	58	0.06
Telecom	654	1.14	646	0.85	171	0.17
Electricity	127	0.22	180	0.24	241	0.24
Water	576	1.01	772	1.01	1037	1.03

1. Estimates apply to the years 2005, 2015 and 2025
2. Transmission and distribution only
3. Only OECD countries, Russia, China, India and Brazil are considered here

Source: OECD (2006)

2.3 Transport and PPP system of Korea

2.3.1 Transport in Korea

Transport share and investment

With respect to the transport demand share among transport modes in Korea, roads and railways are the major transport modes from the viewpoint of passenger numbers as well as freight. For example, according to the Ministry of Land, Transport and Maritime Affairs (MLTM) (2011c), roads occupied 81.4 per cent of the total passenger transport demand in passenger-kilometres/year, followed by railways with 15.9 per cent as of 2008. In addition, regarding freight transport, roads and railways occupied 71.1 and 8.1 per cent of the total freight transport in tonne-kilometres/year respectively as of 2008.

Table 2-6: The investment in transport from the Korean Government budget

(Unit: ten million KRW, %)

	Road	Railway	Urban rail	Airport	Seaport	Others*	Total
2004	81,180 (54.3)	33,761 (22.6)	8,675 (5.8)	3,617 (2.4)	16,724 (11.2)	5,588 (3.7)	149,545
2006	73,567 (48.1)	32.941 (21.5)	12,953 (8.5)	3,918 (2.6)	19,402 (12.7)	10,081 (6.6)	152,862
2008	79,259 (46.7)	40,345 (23.8)	14,108 (8.3)	2,109 (1.2)	20,605 (12.1)	13,277 (7.8)	169,703
2010	77,281 (45.8)	42,020 (24.9)	11,492 (6.8)	666 (0.4)	18,565 (11.0)	18,619 (11.0)	168,643

Note: 1. The bracketed values are percentages of each sector to total investment.
2. Others include logistic facilities and relating infrastructures like access road

Source: MLTM (2011c)

As a result, transport investment in Korea has focused on roads and railways. According to MLTM (2011c), as shown in Table 2-6, the Korean government has invested approximately 15 to 17 trillion KRW[17] in the transport infrastructure annually between 2004 and 2010, and in doing so it has concentrated on roads and railways (including urban rail), which have occupied about 46 to 54 per cent and 28 to 32 per cent of the total investment respectively. Consequently, this research will concentrate on road and railway among the transport modes in Korea, given the transport demand share and the transport investment in Korea.

[17] 1million KRW = 541.3 GBP (as of 27 May 2012)

Roads

In terms of modern paved roads, roads in Korea started to be built between the 1970s and 1980s with the help of the IBRD and the ADB. After the 1980s, following the rapid growth of the Korean economy and the expansion on car ownership[18], the road network was expanded to support increasing transport demands. By December of 2012, the total length of the roads was 105,930 km and car registration exceeded 18 million. In Korea, road authority and responsibility of construction and operation differ depending on the classification of roads.

Table 2-7: Classification of Roads in Korea

(As of 2012)

Classification	Road Authority	Responsibility		Length in use (km)
		Construction	Operation & maintenance	
Total				105,930
National Expressway	Minister of the MLTM	Minister of the MLTM (KEC[a]) (PPP company[b])	Minister of the MLTM (KEC) (PPP company)	3,912[c] (3,493) (419)
National Highway	Minister of the MLTM (Mayor of City)	Minister of the MLTM (Mayor of city)	Minister of the MLTM (Mayor of city)	13,797 (2,232)
Metropolitan Road	Mayor of metropolitan city	Mayor of metropolitan city	Mayor of metropolitan city	19,072
Provincial Road	Governor of province (Mayor of city)	Governor of province (Mayor of city)	Governor of province (Mayor of city)	18,196 (3,841)
City Road	Mayor of city	Mayor of city	Mayor of city	27,086
County Road	Governor of county	Governor of county	Governor of count	23,865

Source: MLTM (2012a)

Note: a) The Korea Expressway Corporation (KEC) constructs and operates the National Expressways as a proxy of the Minster of the MLTM. b) As of 2012, about 10 per cent of the National Expressway network is constructed or operated by BTO companies according to the contract awarded from the Korean government. c) The planned length of the National Expressway is 4,468km and its length in use is 3,912 km as of 2012

As seen in Table 2-7, the Minister of the MLTM is responsible for the construction and operation of the National Expressway and the National Highway (excluding the National Highway in city areas), while with respect to other roads the responsibility of construction and operation lies with local governments.

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[18] The changes of the gross net income (GNI) per capita and car ownership are as follows:

	1970	1980	1990	2000	2010	2011	2012
GNI per capita (USD)	254	1,645	6,147	11,292	20,562	22,451	22,708
Car ownership (vehicles)	126,600	571,754	3,394,803	12,059,276	17,941,356	18,437,313	18,870,533

Source: Bank of Korea and MLTM

With respect to the National Expressway, the first of these was the Seoul-Pusan Expressway, which was planned to support the development of the national economy and to manage freight transport in the 1970s. As of 2012, Korea has a plan by 2020 to have in total 5,470km long National Expressways (35 routes) which have been designated by Road Act, and nearly 87 per cent of them (3,912 km) has already been constructed and been operated by the Korea Expressway Corporation (KEC) or PPP companies. In addition, the fund for the construction of National Expressway consists of governmental budget, funds from issuing KEC bonds and toll revenue. Usually, government supports the full expenses of feasibility study, design and land acquisition, and half of the construction cost.

When it comes to the National Highway, this is defined as an arterial road, being designated by a presidential decree; it connects major cities, ports, airports and industrial facilities. The total length of the National Highways in 2012 was 13,797 km. The Minister of the MLTM is responsible for approximately 90 per cent of the National Highways, and the mayor of each city constructs and maintains about 10 per cent of them, which run through the city area (MLTM, 2009). To construct and maintain a National Highway, the MLTM has respectively five regional offices and 18 Highway management offices in Korea. The funds for construction and maintenance of the National Highways are delivered by the governmental budget.

With respect to the application of PPP scheme in road sector, since 1997 only the BTO scheme has been used for some profitable National Expressway projects and no PPP scheme has been applied to the National Highway projects to date.

Railways

The history of railways in Korea began in 1899 with the completion of the Seoul-Incheon National Railway. At that time, railways in Korea were constructed by Japan and the US with the purpose of colonial exploitation for natural resources like iron and coal. As a result, the modern railway networks, such as the Seoul-Pusan and the Seoul-Mokpo, were formed in the early 20th century (MLTM, 2010a). In the middle of the 1990s, the Korean government planned to construct the High Speed Railway using high speed trains (Korea Train eXpress, KTX) to prevent serious road congestion. The Seoul-Taegu High Speed Railway was opened in 2004, and the Taegu-Pusan section was completed in 2010.

As shown in Table 2-8, railways in Korea are largely classified into three categories: the High Speed Railway, the National Railway and the Urban Railway. In Korea, the Korea Railway Network Authority (KRNA), on behalf of the MLTM, is in charge of the construction and maintenance of the High Speed Railway and the National Railway, and Korea Railroad Corporation (KRC) is responsible for the operation of railways and trains. The funds for rail construction come from the national budget, the funds by issuing the KRNA bonds and rail use fee from the KRC.

With respect to the Urban Railway, which means underground metros or light/heavy railways in a metropolitan city, the metropolitan city usually establishes a public sector authority to build, operate and maintain urban railways. However, in some cases, local governments seem to prefer PPP companies instead of public sector authorities because the initial construction cost can be a great economic burden.

In contrast to the road sector, not only the BTO scheme but also the BTL scheme has been applied to the National Railway and the Urban Railway. The first PPP project in rail sector was the Incheon International Airport Railway project (which used BTO). However, after the BTL scheme was introduced in 2005, the BTL scheme has been predominant in the railway sector.

Table 2-8: The length of railways in Korea

(Unit: km)

Classification	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Total	3,515	3,526	3,540	3,551	3,797	3,862	3,874	3,899	3,885	3,912
High Speed Railway (KTX)	-	-	-	-	240	240	240	240	240	240
National Railway	3,123	3,125	3,129	3,140	3,135	3,152	3,152	3,159	3,140	3,138
Urban Railway	394	401	410	410	422	470	482	500	504	534

Source: MLTM (2010a)

Future investment plan

In order to support sustainable economic growth and balanced national development, the transport network in Korea is expected to expand in the future, as shown in Fig 2-2. According to MLTM (2011c), by the year 2020, over the period between 2011 and 2020 the total investment on arterial roads and railways, including 70 road and 72 rail projects, is expected to be approximately 142 trillion KRW. From the viewpoint of total length, the Korean government has a blueprint that by 2020 the National Expressway network will be expanded to 5,470 km, from 3,776 km in 2009, and the National Railway, including the High Speed Railway, will be expanded to 4, 995km, from 3,378 km in 2009. In addition, the Korean government expect that transport shares of railways in terms of passenger-kilo metres/year and tonne-kilo metres/year will increase to 27.3 per cent and 18.5 per cent respectively (MLTM, 2011c).

Given the various road and railway programmes in Korea, this research will address the National Highway, the National Expressway and the National Railway, considering the availability of historical observations.

Source: MLTM (2011c)

Figure 2-2: The National Transport Network Master Plan [19](2001-2020) of Korea

[19] According to the Transport System Efficiency Act in Korea, the National Transport Network Master Plan is established every twenty year and this can be amended considering the changes in economic or political environments. The most recent amendment was made in 2012.

2.3.2 The PPP system of Korea

History

The Korean government implemented 93 PPP projects on the basis of individual laws such as the Toll Road Act and the Harbour Act from 1968 to 1994 before the legislation of the Act on Promotion of Private Capital into Social Overhead Capital Investment (the PPP Act) which introduced PPPs into Korea. However, considering these projects were intended only to remedy temporary shortfalls in the government budget, though they could be one of various PPP types, they differ from the current popular PPP types (BTO/BTL), where autonomy was granted from the government sector not only in financing but also in construction and operation (Park, 1999).

The first legal framework of PPP system was introduced when the PPP Act was made in August 1994 and enacted from 1 January 1995. After that, in December 1998 the PPP Act was wholly amended. The two main contents that were amended were the introduction of diverse PPP implementation schemes including solicited and unsolicited schemes, and the adoption of risk sharing mechanisms such as the MRG and the buyout right (Kim, 2008). The second amendment of the PPP Act was made in January 2005 to expand eligible facilities for PPPs, which were centred on transport infrastructures by then, to social infrastructures that are closely related to people's everyday lives, such as schools, healthcare facilities, culture and sport centres, and public rental housing. At the same time, the PPP Act introduced BTL schemes to enable private investment in social infrastructure as well as transport infrastructure (MOSF and KDI, 2011).

Representative PPP types of Korea: BTO and BTL

Basically, the Korean PPP system has no limitation on what types of PPP should be used, so all types of contractual schemes, including BTO, BOT, Build-Own-Operate (BOO) and BTL, are possible in Korea (MOSF, 2009b). Regardless of the PPP types, PPPs seem to be favourable to the public sector in terms of tax revenue because the project company in a PPP project pays taxes such as corporate tax in Korea and this implies that PPPs could generate more benefits (great public sector cost savings), compared with conventional delivery.

Among these schemes, BTO and BTL are most popular. They are considered the standard PPP types, for the reasons that the private sector cannot own social infrastructure according to the Urban Planning Act and even without this act the private sector needs to pay several taxes such as asset acquisition and registration tax[20] to own assets (Wang, 2005). In fact, BTO and BTL are

[20] Asset acquisition tax: 1-3% of the standard value based on the current prices; registration tax: 1.6-4% of the standard value based on the current prices.

a variant of BOT and BLT respectively (UNESCAP, 2011). Though it seems that there are little differences excepting when ownership is transferred to public sector, the time of ownership transfer can make a difference between BTO (or BTL) and BOT (or BLT) due to the different taxation scheme[21] in Korea between BTO (or BTL) and BOT (or BLT). According to Wang (2005), BTO scheme is more favourable to the private sector than BOT scheme in Korea, because the private sector does not have to pay property tax, local education tax and business place tax due to the difference in the ownership transfer time.

However, these differences do not seem to affect the choice of BTO or BOT because the tax difference in regard to ownership is not included in VFM calculation in the name of competitive neutrality (Grimsey and Lewis, 2005). Other than that, for the private sector, the advantage in taxation in BTO can be a disadvantage to BOT in terms of subsidy; the reduction in private sector cost due to tax exemption in BTO can also mean the reduction in governmental subsidy in Korea. Accordingly, the impact of the difference in tax in deciding whether to use BOT or BTO can be diluted from the viewpoint of public sector or private sector in Korea. In addition, although many countries suggest various incentives like tax exemption or deduction to encourage private sector participation in PPPs, with a view to easing the infrastructure budget constraint (UNESCAP, 2011, Posautz, 2012, Lehman and Tregoning, 2004), these incentives could cause distortion of competition in the end (Posautz, 2012).

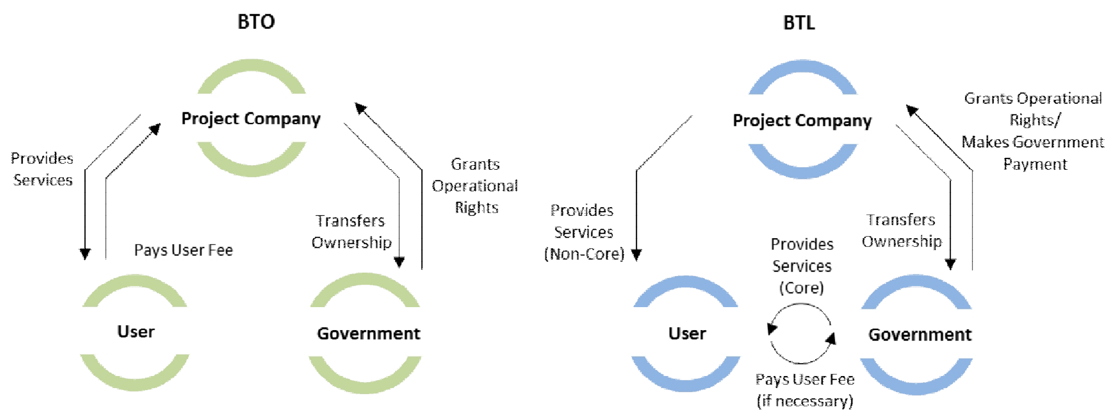
Figure 2-3 shows the structure of the BTO and the BTL schemes in Korea. In the BTO scheme, as soon as a facility is built the ownership is transferred to the government sector, and the right to operate this facility is granted to the project company (or the SPV), and it collects a user fee from end users by providing public services, so that it can gain a return on its investment for a specified period of time according to the contract.

[21] The taxation differences between BOT and BTO in Korea are shown in the table below.

Tax items		BOT	BTO
National tax	Value added tax		
	- Construction period	Refund of purchase tax amount	Refund of purchase tax amount
	- Operation period	Taxation (10%)	Taxation (10%)
	Education tax	Tax-free	Tax-free
	Corporate tax	10-22% of tax base	10-22% of tax base
	Agricultural special tax	Tax-free	Tax-free
Local tax	Acquisition tax	Tax-free*	Tax-free
	Registration tax	Tax-free*	Tax-free
	Property tax	Annually 0.3 % of the standard value based on the current prices	Tax-free
	Local education tax	Annually 20% of property tax	Tax-free
	Business place tax	Annually 250 KRW per 1 m^2 of building area	Tax-free

(Note) According to the Local Tax Act (Article 106 and Article 126), acqution tax and registration tax can be exempt under the condition that the real estate is transferred to the central or local government. The original table was modified by inserting some other tax items and tax rates.

Source: Wang (2005)



Source: MOSF and KDI (2011)

Figure 2-3: Structure of the BTO and the BTL in Korea

However, in the BTL scheme, though the general structure is not significantly different from the BTO scheme, the project company of a BTL project receives a lease fee from the government to gain a return on its investment, instead of collecting use fees from end users. Therefore, the BTL scheme is usually recognised to be appropriate to urgent social projects that find it hard to obtain funds from the private sector because of the low return, or that are expected to take a long time to provide services because of the limited access to government budget, such as schools, military accommodation, public housing, child-care facilities, senior citizen housing, welfare facilities, and cultural facilities (Kim, 2008).

Table 2-9: Differences between the BTO and the BTL scheme in Korea

	BTO	BTL
Investment recovery	User fee + construction subsidy + MRG	Lease fee (fixed revenue)
Project risk	Demand risk on concessionaire	Little demand risk on concessionaire
Return	High risk, high return	Low risk, low return
Eligibility	Both solicited and unsolicited projects	Solicited project only
Facility types	Facilities that investment recovery is possible with user fee (e.g., roads, railways, ports etc.)	Facilities that invest recovery is impossible with end user fee (e.g., schools, military accommodations, public housing, cultural facilities etc.)

Note: 1. MRG = minimum revenue guarantee, 2. The MRG system for the unsolicited method and the solicited method was abolished respectively in 2006 and in 2009.

Source: Kim (2010a) and Shim et al. (2005a)

The differences in the BTO and the BTL scheme are summarised in Table 2-9. Given these differences, the BTO and the BTL scheme are usually called “a profit-oriented PPP” and “a lease-oriented PPP” respectively.

Issues of PPPs of Korea

Although the PPP system of Korea has contributed to the infrastructure provision, many criticisms have been made and issues regarding PPPs have been raised from the National Assembly of Korea and the media.

- **BTO**

In particular, most criticisms have been concentrated on BTO projects. According to Lee (2005), the major issues in BTO projects can be summarised as follows: the excessive MRG, the low competition in selecting concessionaire and expensive construction cost, and the high charge to the end user. Among these issues, the excessive MRG seems to be the most important issue. Regarding the MRG cost burden of the public sector, reporters like Jung (2011) and Kang (2012) have pointed out that the excessive MRG is due to the inaccurate traffic volume forecasts in PPP projects. Although the MRG was completely abolished in 2009, regarding the contracts awarded with the MRG condition before 2009, the government needs to pay the MRG cost every year. According to the Board of Audit and Inspect of Korea (BAI, 2012), as an MRG cost, 2.1 trillion KRW was already paid to the private sector, and the public sector is expected to pay approximately18.8 trillion KRW to the private sector in the future.

The construction cost is also problematic in BTO projects. Son (2012) claimed that the construction subsidy in BTO projects is excessive, so that it is difficult to determine the merits of PPP projects. In addition, Lee (2008) argued that unit construction cost per kilometre in BTO road projects is more expensive than in conventionally delivered projects, which is due to the low competition in BTO projects. According to Kim et al. (2008a), the number of concessionaire bidders in PPP projects is just 1.88 on average, while in the conventionally delivered projects the number of bidders was between 57 and 180 from 2002 to 2007.

Other than that, the public express strong dissatisfaction about the much higher tariff level in the BTO projects than in the public sector projects. For example, according to a document submitted to National Assembly of Korea from the MLTM in 2011 (Table 2-10), the tariff level of five National Expressways, completed over the last five years, was on average 1.06-2.89 times higher than conventionally delivered projects. As a result, some members of the National Assembly of Korea, such as Sungsoon Kim and Ilpyo Hong, claimed that the Korean government needs to take necessary actions to reduce higher tariff in BTO road projects (Shim and Shin, 2010, Jeon, 2011).

Table 2-10: Tariff level of the BTO National Expressways

National Expressway	Completion	Length	Tariff level for a car (KRW)		
			PPP (A)	Conventionally delivered* (B)	A/B
Seoul Outer Ring	01/12/2007	36km	4,300	2,600	1.65
Busan-Ulsan	01/12/2008	47km	3,500	3,100	1.13
Seoul-Chuncheon	01/07/2009	61km	5,900	3,500	1.69
Yongin-Seoul	01/07/2009	23km	1,800	1,900	1.06
Incheon Grand bridge	01/10/2009	21km	5,500	1,900	2.89
Suwon-Pyungtaek	01/10/2009	39km	2,800	2,000	1.40

Note: Conventionally delivered means when each project is assumed to be delivered by the Korea Expressway Corporation (KEC).

Source: MLTM

- **BTL**

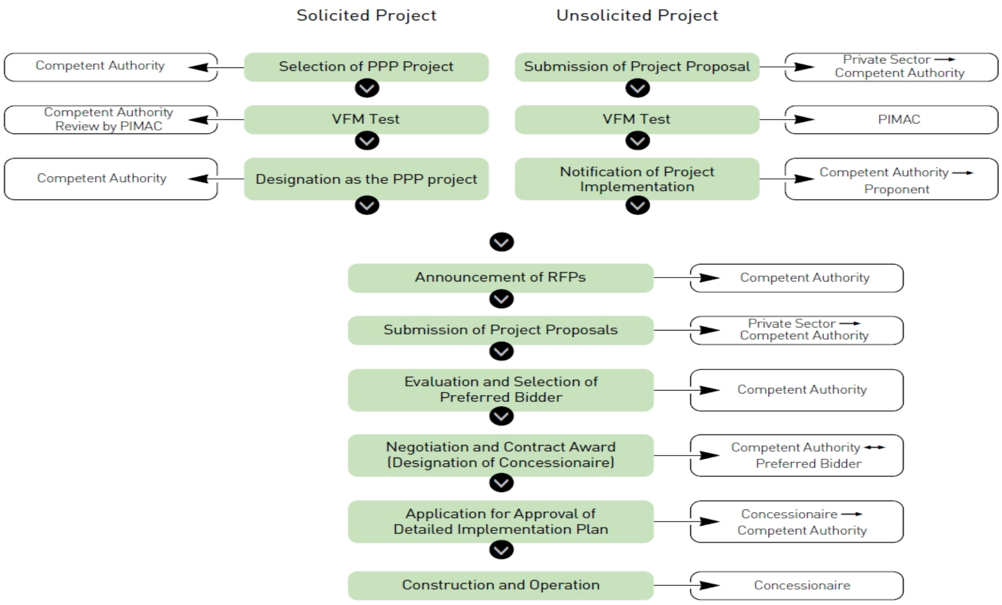
The BTL scheme is relatively free from criticisms compared with the BTO scheme because it was introduced in 2005 with a view to solving the problems created by the BTO scheme. However, it seems that payment mechanisms not relating to performance in the BTL scheme could be a critical issue in the future.

Generally speaking, the payment mechanism depends on the PPP procurement method, which in turn is related to the nature of output procured. For example, BTO or BOT systems use a real-toll usage payment reflecting project demand over the specified time lengths, while DBFO systems in the UK provide a shadow-toll usage payment and the performance-based DBFO provides payment on the basis of service availability (Aziz and Ahmed, 2007). In addition, the recent payment mechanism reflects not only service availability but also service management, safety performance (measured by the number of accidents) and even congestion management (measured by mean journey times, variability of journey times or delay times) (Mackie and Smith, 2005). In the UK, the Highways Agency provides payment based on the traffic demand with adjustments considering lane closure and safety performance, based on so-called shadow tolls (Highway Agency, 2011).

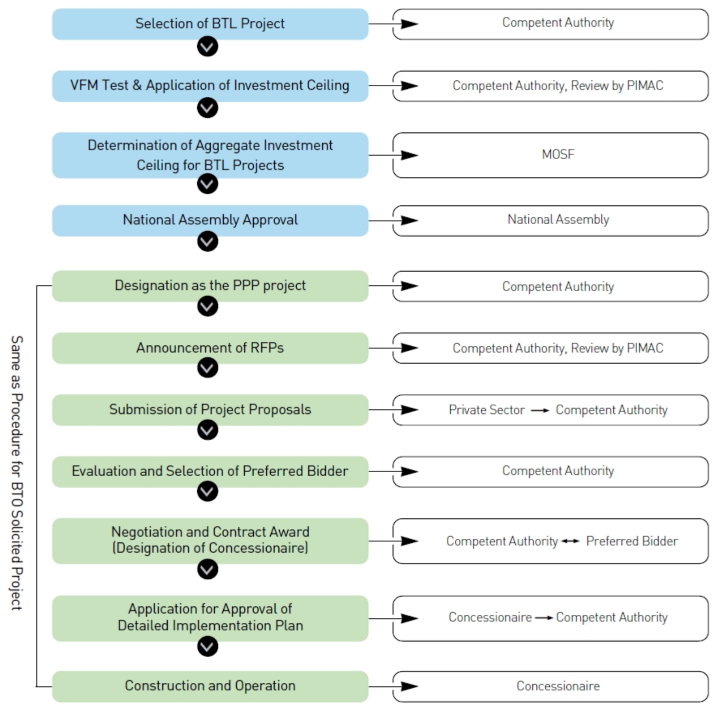
In Korea, the government could reduce payments reflecting the level of service such as infrastructure safety, durability and user satisfaction, and payment mechanism should be provided in a PPP contract considering the infrastructure characteristics (MOSF, 2009a, MLTM and Gaya railway corp., 2007). However, to date, no payment reduction in BTL project has been reported in Korea, which could be an issue for the BTL scheme in the future. Although BTO payments reflect demand side outputs and BTL payments reflect supply side outputs, it seems that payments without the evaluation of the level of service are unlikely to meet with public approval. In addition, it seems that the performance-based DBFO will be a good alternative to the BTL if the payment mechanisms do not work well in the BTL scheme in Korea.

PPP implementation procedure

In Korea, there are two ways to initiate PPPs, according to the PPP Act and relating guidelines: the solicited route and the unsolicited route. The BTO scheme, as seen in Figure 2-4 (a), can be implemented by the above two methods, whilst the BTL scheme can be carried out only by the solicited project method, as seen in Figure 2-4 (b), according to the PPP legal framework of Korea.



(a) Implementation procedure for BTO projects



(b) Implementation procedure for BTL projects

Source: MOSF and KDI (2011)

Figure 2-4: Implementation procedures for BTO and BTL projects

As shown in Figure 2-4 (a), in the solicited project route, the government asks the private sector to join a certain project by announcing a request for a proposal, including a project plan, and implementation terms and conditions. Before selecting a PPP project, project evaluation using diverse analysis, such as economic appraisal and VFM assessment, is performed in the name of the PPP pre-qualification test at preliminary feasibility stage, which will be explained in detail later (see 2.4.2). The PPP pre-qualification test is usually performed by the Public Private Investment Management Centre (PIMAC) on the behalf of the Ministry of Strategy and Finance, which is affiliated to the KDI. If the PPP pre-qualification test shows a positive result, the government designates the project as a PPP project. Through a bidding and negotiation process, the contract between the government and the private sector is awarded.

However, in the unsolicited project route (Figure 2-4 (a) and (b)), a PPP project is initiated from the private sector. The private sector can propose a PPP project to the government, considering the government policy direction and public needs if it is sure that it can gain sufficient profitability. If the private sector proposes a PPP project, the government sector reviews whether the project accords with the governmental infrastructure provision plan and policy or not, and if so, the government performs the PPP pre-qualification test through the PIMAC. The subsequent procedure is the same as with the solicited project route.

Status and prospect of PPPs of Korea

According to the MOSF and the MLTM (SOC work group, 2012), between 2004 and 2011, the total infrastructure investment amounted to between 23.6 and 37.7 trillion KRW, or between 2.8 and 3.3 per cent of GDP, as seen in Table 2-11. In addition, during the same period, the private capital investment from the BTO and the BTL projects occupied between 6.2 and 13.2 per cent of the total infrastructure investment.

Table 2-11: Investment status on infrastructure

(Unit: trillion KRW)

		2004	2006	2008	2009	2010	2011	2012
Public investment		21.9	22.6	24.9	31.3	35	33.1	29.4
	Government budget	17.4	18.4	20.5	25.5	25.1	24.4	23.1
	Others[1]	4.5	4.2	4.4	5.8	9.9	8.7	6.3
Private investment[2]		1.7 (7.2%)[3]	2.9 (11.4%)	3.8 (13.2%)	3.9 (11.1%)	2.7 (7.2%)	2.2 (6.2%)	2.7 (8.5%)
Total		23.6 (2.85%)[4]	25.5 (2.81%)	28.7 (2.80%)	35.2 (3.31%)	37.7 (3.21%)	35.3 (2.85%)	32.1 (-)

Note: 1. Others mean the investment of the public corporations in Korea which construct or operate infrastructures such as National Highways, National Railways, International Airports, Seaports, Containers Wharfs and Water facilities. 2. Private investment means the private capital investment from the BTO and the BTL projects awarded by the Korean government. 3. The bracketed percentage values in the private investment row mean the proportion of private investment to total investment. 4. The bracketed percentage values in the total row mean the proportion of the total investment on infrastructure to gross domestic product.

Source: MOSF and MLTM, quoted from SOC work group (2012)

As shown in Table 2-12, with respect to the PPP projects, according to the MOSF and KDI (2011), there are 461 PPP projects in progress in Korea as of September 2009, among which there are 169 BTO projects and 292 BTL projects. All in all, about 54 per cent (251 projects) are in operation, 34 per cent (156 projects) are under construction and 11 per cent (54 projects) are in a preparatory phase following the awarding of the contract.

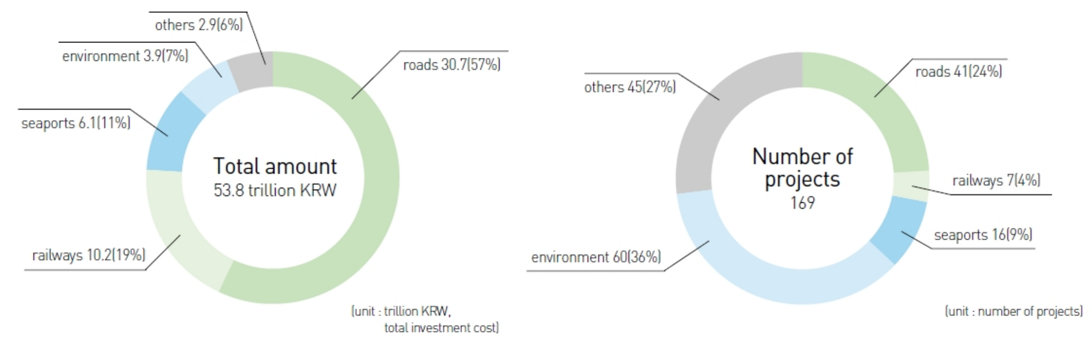
Table 2-12: Status of PPP projects in progress

(As of September 2009, unit: number of projects)

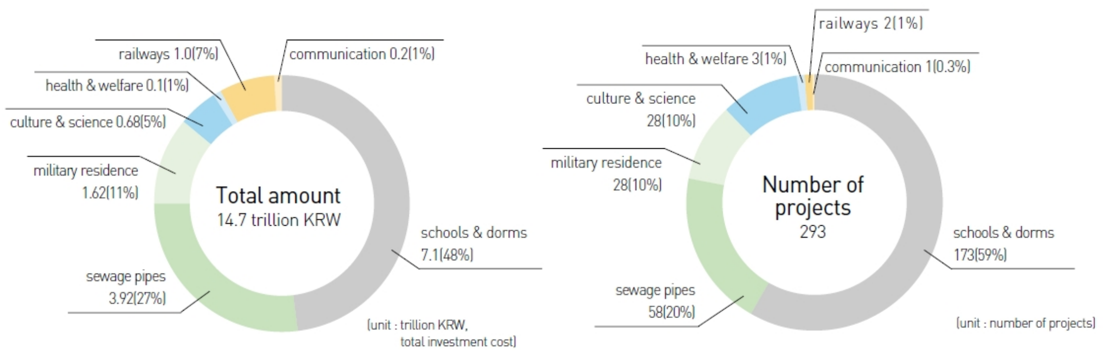
	BTO projects			BTL projects	Total
	National	Local	Sub total		
Under Operation	24	82	108	145	251
Under Construction	15	31	46	110	156
Contract Awarded	8	9	17	37	54
Total	47	122	169	292	461

Source: MOSF and KDI (2011)

Looking into the composition of BTO projects shown in Figure 2-5 (a), with respect to the total investment cost, transport infrastructure such as roads, railways and seaports occupies 87 per cent, in other words 47.0 trillion KRW among 53.8 trillion KRW, while in the light of number of projects environmental facilities item occupies primarily with 36 per cent, or 60 projects.



(a) BTO projects



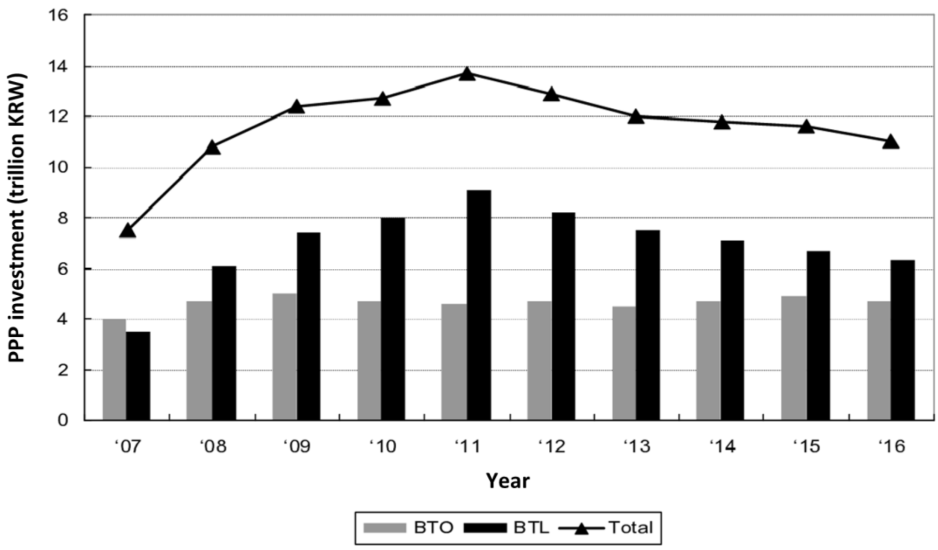
(b) BTL projects

Source: MOSF and KDI (2011)

Figure 2-5: Composition of BTO and BTL projects

In BTL projects shown in Figure 2-5 (b), schools and dormitories item occupy 48 per cent with 7.1 trillion KRW, followed by sewage pipes with 27 per cent, or 3.92 trillion KRW from the viewpoint of total cost. With respect to the number of projects, the schools and dormitories item is also the primary element. It occupies 59 per cent with 173 projects, followed by sewage pipes with 20 per cent, or 58 projects.

With respect to the prospect of the PPPs of Korea, as shown in Figure 2-6, Kim (2008) estimated that, based on the Five-year National Fiscal Management Plan (2007-2011) of Korea, the total investment of the BTO project from the public sector and the private sector will grow to 46.6 trillion KRW on average and that of BTL projects will be 69.9 trillion KRW between 2007 and 2016.



Source: Kim (2008)

Figure 2-6: Prospects of PPP investment in Korea

2.4 PPP decision-making

2.4.1 Examples from other countries

Deciding on an appropriate procurement method for infrastructure services is critical in the project procurement process. Globally, decisions on whether to use PPP schemes or which PPP scheme is appropriate for a project are usually made through a procurement option assessment, where the government selects an appropriate procurement method producing the best VFM as well as the highest suitability for project objectives and outcomes.

UK

In the UK, after an investment decision is made for a project, delivery authorities contemplate the most appropriate procurement method and deliberate on how to compose and manage procurement procedure (HM Treasury, 2008). According to the Department of Finance and Personnel of Northern Island (DFP, 2010), in the procurement option assessment, delivery authorities evaluate the suitability of the various PPP schemes and traditional delivery in terms of the VFM assessment by the HM Treasury, through which it is essential to compare various options in order to offer the best VFM. In addition, the VFM assessment is conducted at programme level, project level and procurement level (HM Treasury, 2006) and through this process an appropriate procurement option is clearly determined.

With respect to the procurement options, there could be a series of choices considering the characteristics of the infrastructure service. For example, a PPP guidance for local authorities (4PS, 2004) suggests six procurement options for highway services: in-house provision, traditional procurement, partnering contracts, service outsourcing, concession or franchise, PFI or DBFO.

Australia

Australia has a procurement option analysis procedure for PPP decisions that is similar to the UK's. The key issue in the procurement option analysis is which type of delivery system produces the best VFM, in terms of meeting the project objectives and outcomes (Australian Government, 2008a). In determining a procurement option, various delivery models are considered. These include: PPPs; construct-only (lump sum or fixed price contract); design and construct; design, construct and maintain; construction management; alliance contracting; or managing contractor model. The VFM evaluation is used as the background for the procurement option analysis, and consideration factors for this analysis include determining core versus noncore services, VFM, analysis of market capability and appetite and public interest. The VFM drivers are used as the basis for this assessment (Australian Government, 2008d).

Hong Kong

In Hong Kong, when the strategic need for infrastructure services has been determined, a procurement option analysis, including PPP options, is implemented in a feasibility or business case study. The procurement option analysis is usually implemented twice (stage 1 and stage 2). At stage 1 usually high level cost estimates are gathered from a market-testing exercise and, using these data, different options are compared, and at stage 2 a detailed public sector comparator for the VFM analysis is required (Efficient Unit, 2008a).

British Columbia, Canada

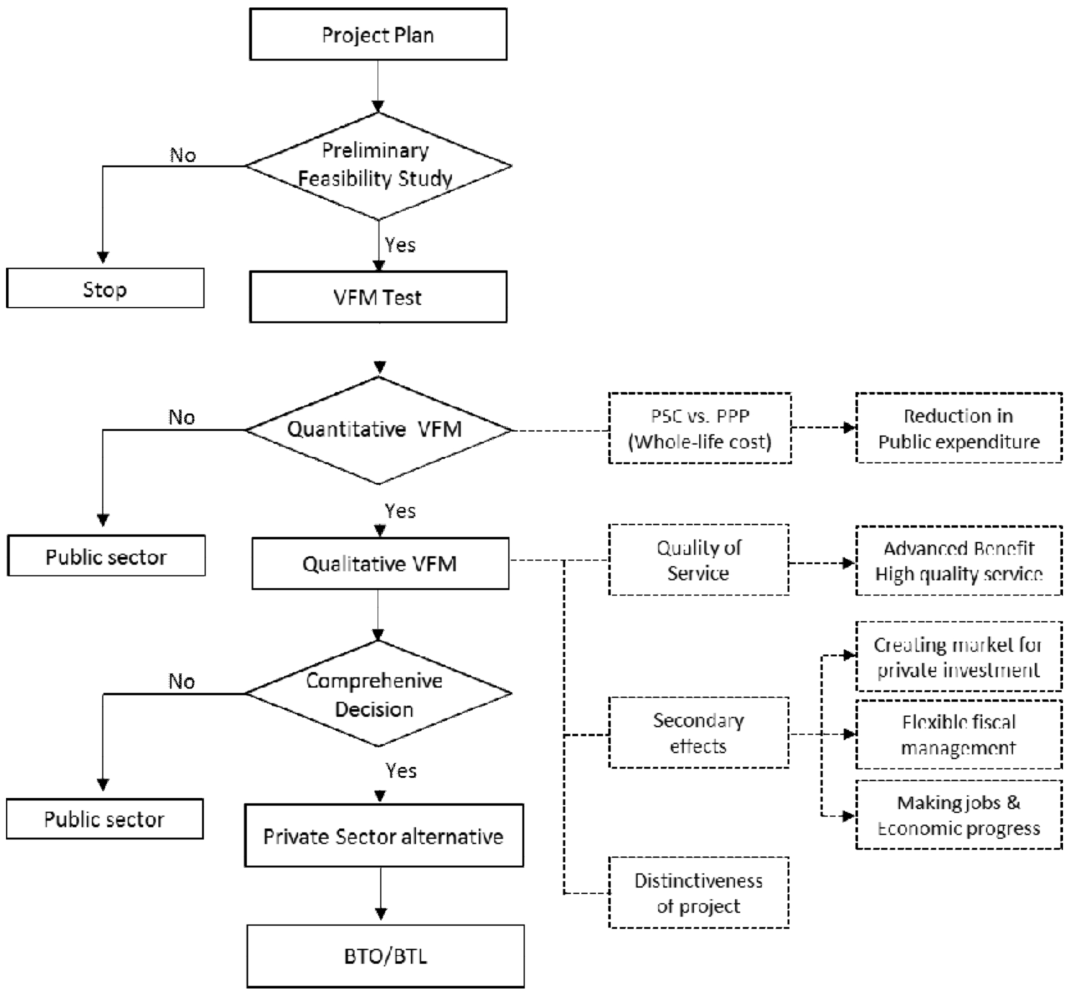
When it comes to British Columbia, Canada, the evaluation of procurement options is mainly composed of two steps. The first step is to identify the main project objectives and to assess a variety of procurement options, including both conventional and PPP schemes, in terms of the qualitative context. The second step provides a more detailed quantitative analysis: this uses risk analysis with the Monte Carlo Simulation and financial analysis with a public sector comparator (Partnerships British Columbia, 2011). It seems that this quantitative analysis means, in practice, a VFM analysis.

2.4.2 Korea

According to the Construction Technology and Management Act and the National Finance Act, the procedure for public works in Korea mainly consists of seven phases: 1) a preliminary feasibility study, 2) a feasibility study, 3) a basic design, 4) a final design, 5) a tender/bid, 6) construction, and 7) operation and maintenance. In terms of whether to use PPP schemes or not for a project, PPP decisions are usually made through the pre-qualification test for PPPs by the Public PIMAC under the Ministry of Strategy and Finance (MOSF) after the preliminary feasibility study, where a project is scrutinised for compliance with economy and governmental policy.

In the PPP pre-qualification test shown in Figure 2-7, the VFM assessment is largely divided into three steps: quantitative VFM test, qualitative VFM test and comprehensive decision. The first step is the quantitative VFM test, where the whole-life cost is compared between the PPP and the public sector option in terms of the reduction in public sector expenditure. As a PPP option, the BTO option is usually used in the National Expressways, while in the National Railway both BTL and BTO are used though the BTL has predominated recently. After conducting the quantitative VFM test, if the result shows that the PPP scheme is cheaper than the conventional delivery in terms of whole-of-life public cost, the project will proceed to the second step.

The second step is the qualitative VFM test. The qualitative VFM test considers the improvement of service quality, various secondary effects like flexible fiscal management, and the distinctiveness of the project. At the final stage, the comprehensive decision stage, even if the project proceeds to the qualitative VFM test, if the comprehensive decision stage gives a negative result, the project cannot be carried out by PPP schemes. After passing the preliminary feasibility study and the PPP pre-qualification test, the project can be designated a PPP project by a competent authority (e.g. MLTM for roads and rail), which is shown in Figure 2-4 (a) and (b).



Source: MOSF, quoted from NABO (2007)

Figure 2-7: PPP pre-qualification test process

2.4.3 Summary

As mentioned above, many countries have a procurement option assessment process before the procurement stage and after the investment decision stage. In selecting an appropriate option, including various traditional delivery options and PPP options, the VFM assessment seems to be used as a key factor in many countries. In Korea, the PPP pre-qualification test[22] seems to be similar to the procurement option assessment process that many other countries have. In addition, the VFM assessment seems to be a key factor in PPP decisions, as in other countries.

[22] Strictly speaking, the PPP pre-qualification test in Korea is different from procurement option assessment in other countries in that it considers only what to choose between public delivery and PPP delivery (BTL/BTO), without deliberating various alternative options like in-house provision, service outsourcing and partnering contract.

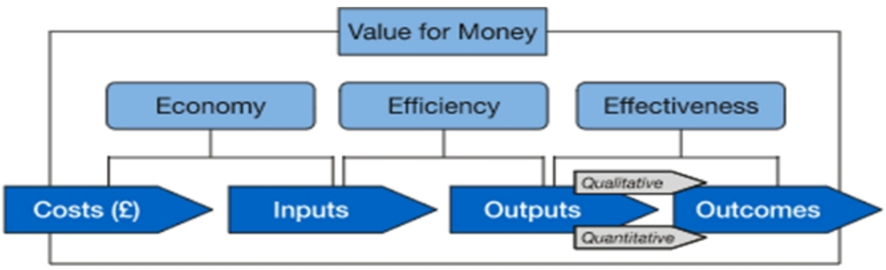
2.5 The VFM assessment

2.5.1 Definition

The VFM assessment was introduced and institutionalised first in the UK. In November 1994, HM Treasury announced that they would not approve a public sector procurement for capital project if it had not prepared a private participation plan or if its private participation plan had not been found to be uneconomic (Grout, 1997). As the HM Treasury used private funds more and more, they were under an obligation to explain why they try to use private funds instead of public ones. That is, they had to prove that their PFI system was better than public sector procurement from the viewpoint of VFM (Park, 2007).

According to the HM Treasury (2006) VFM is defined as "the optimum combination of whole-of-life costs and quality (or fitness for purpose) of the good or service to meet the user's requirement". A more detailed definition of VFM is found in Improvement Network sponsored by the Audit Commission and Chartered Institute of Public Finance and Accountancy. According to Improvement Network (2009), VFM is defined as follows:

> *... Value for money is about obtaining the maximum benefit with the resource available. VFM is about achieving the right local balance between* ***economy, efficiency and effectiveness****, the 3ES – spending less, spending well and spending wisely.*
>
> (Improvement Network, 2009)



Source: Improvement Network (2009)

Figure 2-8: Schematic diagram for VFM

Figure 2-8 explains the relationship between VFM and the three elements, economy, efficiency and effectiveness. Firstly, economy is related to the costs and inputs which are needed to provide a public service; from an economic viewpoint, how low the cost is to provide a public service is very important. Second, efficiency is the relationship between inputs and outputs, namely productivity, which means how much the government receives from its inputs. It seems that these two elements of VFM can be measured quantitatively. Lastly, effectiveness is about secondary effects such as quality, and sustainability due to outputs, so it can be measured quantitatively and qualitatively depending on effects. Therefore, a high VFM can be achieved when a balance among these three elements is optimised, namely, when, from a specified delivery method, successful outcomes with relatively low costs and high productivity are expected (Improvement Network, 2009).

All in all, VFM is a qualitative and quantitative approach to estimate outcomes, productivity and the whole-life costs of a project, and can also be a useful tool to decide how the government could achieve maximum benefits from constrained resources.

2.5.2 The VFM assessment: quantitative and qualitative approach

A complete VFM requires not only the quantitative assessment but also consideration of qualitative factors. In order to identify the best outcome, qualitative factors that have not been explicitly valued should be considered (Australian Government, 2008b).

Quantitative VFM

Quantitative VFM can be simply calculated by comparing the public sector costs from a so-called public sector comparator (PSC) and a PPP alternative, as shown in Figure 2-9 (a). Explaining the quantitative VFM in detail, from the viewpoint of the NPV, the whole-of-life public costs of a PSC and a PPP are compared; the VFM means the NPV difference between PSC whole-of-life public costs and PPP whole-of life public costs, assuming that there is no completion delay (MOSF, 2009a).

The components of PSC can be different between countries. For example, as shown in Figure 2-9 (b) the PSC in the UK consists of tax, optimism bias, risks, operation cost and capital cost, while in Australia it is made up of transferable risk, competitive neutrality, raw PSC and retained risk, which are the same as in Korea. However, the raw PSC in Australia means capital cost and operation cost in the UK, and transferable risk and retained risk in Australia correspond to risk and optimism bias in the UK. In addition, competitive neutrality in Australia corresponds to tax in the UK (Shim et al., 2006). This means that the components of PSC between two countries are not quite different. Therefore, from now on, referencing the components of PSC in Australia and Korea, the following five major components will be examined.

- **Reference project**

When constructing a PSC, the first step is to identify the reference project. According to Partnerships Victoria (2001), the reference project is "the most likely and efficient form of public sector delivery that could be employed to satisfy all elements of the output specification, as outlined in the project brief, based on current best practice. Therefore, the reference project should reflect the most likely and achievable procurement approach by the relevant department to satisfy all elements of the output specification if the project were to proceed on a traditionally funded basis". In addition, generally, the PSC and the PPP are assumed to provide "the same level of service" when analysing VFM, and the reference project means the project providing "the same level of service" (MOSF, 2009a).

- **Raw PSC**

Raw PSC means the base costs of the reference project, which includes construction costs, operation costs (including maintenance costs) and revenues, when the reference project is implemented by conventional public procurement and owned by the public sector (Partnerships Victoria, 2001, MOSF, 2009a).

- **Transferable risks**

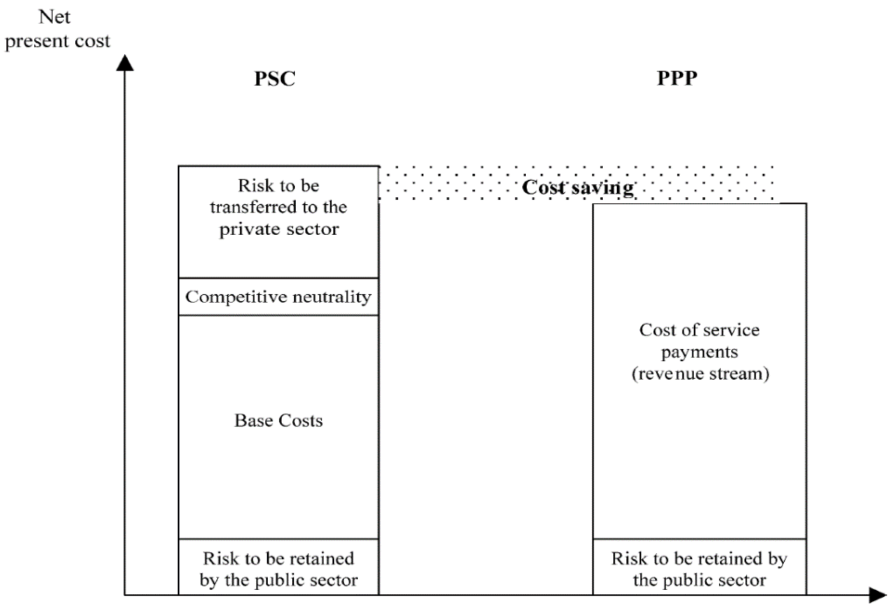
Transferable risks means those risks that are transferred to the private sector when the public sector uses a PPP option (Australian Government, 2008b, MOSF, 2009a). As VFM can be realised by risk transfer from the public sector to the private sector under PPP arrangement, transferable risks are at the heart of VFM assessment. In order to determine the value of transferable risks, the availability of historical observations on cost items that are interested in is essential; however, the possibility of collecting these data differs by country. With respect to risk transfer, in Australia saved cost by PPP arrangement was reported at 9 per cent compared with the net present risk-adjusted cost of PSC (Fitzgerald, 2004).

- **Retained risks**

Retained risk means those risks that are not transferred to the private sector under the PPP arrangement because retained risks are located outside of the project (Australian Government, 2008b, MOSF, 2009a). For an example, even if a National Expressway project is delivered using private funds, the Korean government retains the responsibility for raising user fees, which is a kind of retained risk.

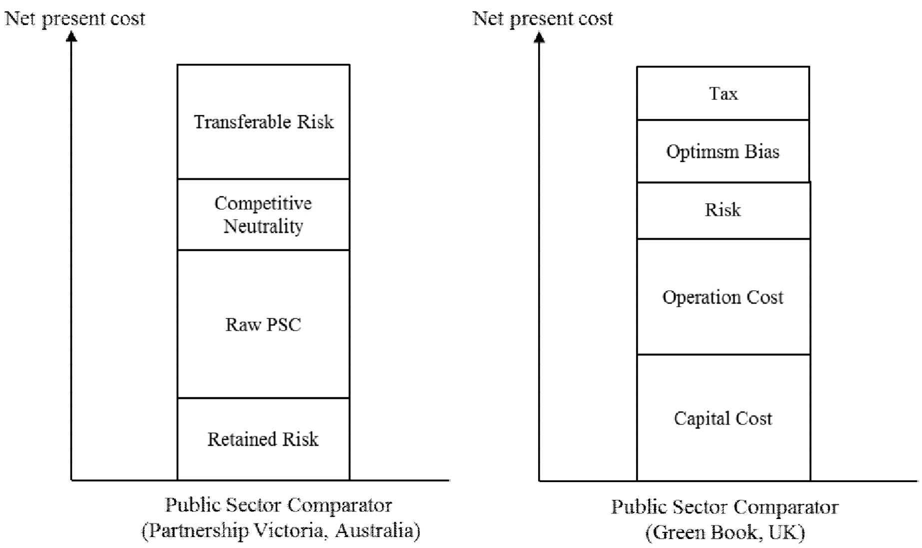
- **Competitive Neutrality**

To compare a PSC with a PPP fairly, unfair items such as tax should be adjusted for, to ensure that there is competitive neutrality in the PSC calculation. Competitive neutrality means that the public sector and the private sector compete with each other on a level playing ground to conduct a certain project. Therefore, in light of competitive neutrality, unfair cost items needs to be adjusted in the VFM calculation (Sun et al., 2010, MOSF, 2009a).



Source: Grimsey and Lewis (2005)

(a) Comparison of a PSC and a PPP alternative



Source: Shim et al. (2006)

(b) Comparison of a PSC between Australia and the UK

Figure 2-9: Comparison of a PSC and a PPP alternative

Qualitative VFM

It seems that qualitative VFM has become more important in the VFM assessment. With respect to qualitative VFM, HM Treasury revised the VFM assessment guidelines in 2004 with a view to transferring the focus of VFM from quantitative to qualitative (Shim et al., 2006). In Korea, qualitative VFM was simultaneously institutionalised when quantitative VFM was introduced in 2005.

What is to be assessed in qualitative VFM can be different depending on the country. For example, according to HM Treasury (2006), assessment items in the UK are largely categorised into three groups: 1) viability (objectives and outputs, operational flexibility, equity, efficiency and accountability), 2) desirability (risk management, innovation, contract duration, residual values, incentive and monitoring, and life-cycle cost), 3) achievability (market interest and other issues). In Korea, however, assessment items are composed of the improvement of service quality, the ease of contract management, risk transfer, secondary effect and project specialty (MOSF, 2009b).

In addition, in terms of how to assess the qualitative items, though the methodologies are not explicitly suggested in the PPP or VFM guidelines of the UK and Korea, generally speaking there are many qualitative assessment methods available, such as observation, interviews and documentary analysis (Berg, 2001). For instance, Gil (2012) conducted qualitative VFM assessment on transport projects in Korea using interview technique in order to find an optimum PPP procurement option and Yang et al. (2007) tried the quantitative estimation of qualitative decision factors using an analytic hierarchy process (AHP) technique.

Limitations of current Korean VFM assessment practice

There are two limitations in the current Korean VFM assessment practice.

The first is that, although qualitative VFM has already been introduced into the Korean PPP system, qualitative VFM does not seem to play a role in PPP decisions in the Korean PPP practice. With respect to qualitative VFM, reviewing the PPP pre-qualification test reports on several projects[23] by the PIMAC or the Korea Transport Institute (KOTI), all reports made almost the same judgement that the project needs to be implemented by a PPP option, considering the following (which are not related to the project and seem to be vague): 1) the

[23] Examples of projects include the Bongdam-Songsan National Expressway project, the Osan-Gwangju National Expressway project, the Bujeon-Masan National Railway project and the Sosa-Wonsi National Railway project.

improvement of service quality due to the innovation and creativity of the private sector, 2) the efficiency of contract management utilising private sector experts, 3) the effectiveness of risk transfer, and 4) the management efficiency of the private sector. In addition, according to KDI (2012), the qualitative VFM result should be used as a mere reference in the PPP decisions. Accordingly, the qualitative VFM test does not seem to be practically implemented yet in Korea though there is systematic research on qualitative VFM using interview techniques (Gil, 2012) and AHP techniques (Yang et al., 2007). This implies that quantitative VFM can also be critical in PPP decisions in Korea, which is very similar to the argument of Grimsey and Lewis (2005) that most governments recognise the importance of qualitative VFM, suggesting qualitative factors in VFM calculation; however, in reality the quantitative VFM usually takes precedence in the VFM evaluation.

The second is that the assumption that there is no completion delay between PPP options and conventional option does not seem to be appropriate in Korea, where systematic completion delay is expected in the conventional delivery due to the unusual national budget system, the LEC system (Kim et al., 2008b). In order to estimate the quantitative VFM, not only the effects but also timing (construction duration and completion) of a PSC and a PPP are assumed to be the same (MOSF, 2009a, Grimsey and Lewis, 2005, Hoose, 2011). However, it seems problematic if the completion delay between a PSC and a PPP option is ignored in the quantitative VFM calculation though it clearly occurs in Korea. In addition, although the qualitative VFM assessment could deal with the completion time difference and the resulting social benefit difference between a PSC and a PPP, it is more reasonable to deal with these differences in the quantitative VFM, partly because they could be assessed in a quantitative context and partly because qualitative VFM does not seem to play a role in PPP decision-making in Korea.

Consequently, the social benefit difference due to the completion delay needs to be included in the quantitative VFM (Morallos and Amekudzi, 2008) and a new quantitative VFM reflecting the completion time difference needs to be developed considering the Korean PPP system and its real world use.

2.5.3 VFM assessment comparison among countries

Although the VFM assessment method is used widely in the procurement option analysis, including in PPP decision and procurement process, the shapes are different with countries. Based on PPP or VFM guidelines of five countries (the UK, Australia, Korea, Hong Kong and

Canada (British Columbia)), as seen in Table 2-13, several factors are explored: definition, composition, application level, PSC components, discount rate and qualitative appraisal factor.

First, with respect to definition, the UK, Hong Kong and Canada (British Columbia) have their own definitions, while Australia and Korea do not. The definitions in the first three countries, though there are differences in terminology, are similar in focusing on the best outcomes (economy, efficiency and effectiveness) for the public need.

Second, the VFM assessment is usually composed of a quantitative and a qualitative assessment. However, in Hong Kong it is not clear whether qualitative assessment is considered or not. In addition, as mentioned above, qualitative VFM is used as a formality in PPP decisions in Korea.

Third, the application level also seems to be similar in these countries, in that each country uses the VFM assessment in the selection of procurement option and procurement bid process. However, the details in the application are different. For example, the VFM guideline of the UK (HM Treasury, 2006) provides for the use of the VFM assessment three times for the selection of procurement option (programme level, project level and procurement level), while other countries' guidelines do not provides such a detailed description.

Fourth, when it comes to PSC components, they differ by country. A PSC consists of a raw PSC, competitive neutrality, transferable risk and retained risk in Australia, Korea and Hong Kong, while in Canada (British Columbia) it is composed of capital costs, operating costs, life-cycle costs, transferred risk, insurance and taxation. Recently the UK even uses Outline Business Case (OBC), composed of asset cost, operation cost, optimism bias, risk and tax, instead of PSC.

Fifth, the discount rates used in the VFM assessment are completely different for the different countries, given their socio-economic status. In addition, the basis of discount rate also differs by country. For example, the UK uses a social time preference rate based discount rate, while Australia and Canada (British Columbia) use a capital asset pricing model (CAPM) and weighted average cost of capital (WACC) model based discount rate respectively.

Finally, regarding qualitative assessment, the UK has very detailed and clear factors for qualitative assessment. However, other countries just suggest qualitative factors as an example (e.g. Australia and Korea) or do not have explicit qualitative factors (e.g. Hong Kong and Canada (British Columbia)).

In summary, reviewing the VFM assessment in several countries, although definition, composition and application level are similar, PSC components, discount rate and qualitative factors are quite different with countries. Therefore, considering this research is regarding quantitative PPP decisions in Korea, it seems reasonable that PSC components and discount rate in the VFM assessment should be related to the Korean context reflecting the socio-economic status and regulation of Korea.

Table 2-13: Comparison of VFM assessment in several countries

UK	
Definition	'The optimum combination of whole-of-life costs and quality (or fitness for purpose) of the good or service to meet the user's requirement'
Composition	Quantitative + qualitative appraisal
Application level	Programme level (stage 1), project level (stage 2), procurement level (stage 3)
Components of PSC	Outline Business Case (OBC), Full Business Case (FBC) Asset cost, operation cost, optimism bias, risk, tax
Discount rate	3.5% (real term) based on the social time preference rate
Qualitative appraisal factors	1) viability; project level outputs, operational, flexibility, equity, efficiency, and accountability, 2) desirability; risk management, innovation, contract duration and residual value, incentives and monitoring, lifecycle costs, 3) achievability; market interest, time scale, transaction cost
Remark	Overall judgement made based on qualitative and quantitative assessments. Balance between quantitative and qualitative test is emphasized.
Australia	
Definition	Not explicit
Composition	Quantitative + qualitative appraisal
Application level	Procurement option analysis, procurement
Components of PSC	Raw PSC, competitive neutrality, transferable risk, retained risk
Discount rate	3 risk bands (very low, low, medium) based on the capital asset pricing model (CAPM)
Qualitative appraisal factors	(Examples) service delivery, operational requirements, interface/relationship, project management and a range of design considerations
Remark	In Australia, delivery method whether to use PPP or not is determined by procurement option analysis, where VFM assessment is used.
Korea	
Definition	Not explicit
Composition	Quantitative + qualitative appraisal
Application level	Preliminary feasibility study level, procurement level
Components of PSC	Raw PSC, competitive neutrality, transferable risk, retained risk
Discount rate	Discount rate provided by KDI (e.g. 6% (real term) for BTO, 6% (nominal term) for BTL)
Qualitative appraisal factors	(Examples) the improvement of service quality, the easiness of contract management, risk transfer, secondary effects and project specialty
Remark	Qualitative appraisal is not practically implemented.
Hong Kong	
Definition	'Value for money refers to the best available outcome taking account of all benefits, cost, and risks over the whole life of the procurement, combining economy, efficiency and effectiveness'.
Composition	Quantitative (it is not clear whether qualitative analysis is used or not)
Application level	PPP feasibility study stage, procurement stage
Components of PSC	Raw PSC, competitive neutrality, transferable risk, retained risk
Discount rate	The Economic Analysis and Business Facilitation Unit (EABFU) provides advice on discount rates to be used in calculating the net present value and internal rate of return.
Qualitative appraisal factors	Not explicit
Remark	PPP feasibility study is implemented at Business Case development stage.
Canada (British Columbia)	
Definition	'Also commonly referred to as value for taxpayer dollars, VFM describes the benefits to the public expected to be realized through a particular procurement method, and can be quantitative and/or qualitative in nature'.
Composition	Quantitative + qualitative appraisal
Application level	Procurement option analysis, procurement stage
Components of PSC	Capital costs, operating costs, life-cycle costs, transferred risk, insurance and taxation
Discount rate	Discount rate based on the weighted average cost of capital (WACC) of the private sector, reflecting minimum rate of return, which investors would require in deciding to invest in a project.
Qualitative appraisal factors	Not explicit
Remark	PSC is used as one of quantitative assessment methods in procurement option analysis stage.

Source: HM Treasury (2006), Australian Government (2008b), MOSF (2009a), MOSF (2009b), Efficient Unit (2008a), Partnerships British Columbia (2011) and Morallos and Amekudzi (2008)

2.6 Conclusion

This chapter has reviewed the generalities on PPPs, transport status and PPP system of Korea, and PPP decision methodology through a literature review. Based on the literature review, the following conclusions are drawn.

The first conclusion concerns the necessity of a new quantitative PPP decision methodology reflecting systematic completion delay in the conventional delivery in Korea.

Considering the common characteristics to various definitions and why governments want to use PPPs, a PPP seems to mean a public service delivery by the private sector through a contractual arrangement/relationship and risk sharing between the public and the private sector, with a view to overcoming the shortages in public funds and the resulting delays in infrastructure provision. In addition, the advantages that the public sector wants to achieve by using PPP schemes are mainly related to public sector cost savings and early completion compared with the conventional delivery, which can be quantified. Besides, though most governments recognise the importance of qualitative VFM, suggesting the inclusion of qualitative factors in VFM calculation, in reality the quantitative VFM usually takes precedence in the VFM evaluation (Grimsey and Lewis, 2005).

Accordingly, for better PPP decisions, it is reasonable to take not only the public sector cost but also completion time into account in a quantitative PPP decision methodology. With respect to Korea, in particular, it seems necessary to develop a new quantitative PPP decision methodology considering the completion delay between the conventional and the PPP scheme, partly because systematic completion delay in the conventional delivery exists due to the unusual national budget system, the LEC system, and partly because qualitative VFM is practically conducted as a formality.

The next conclusion concerns PPP types and transport programmes that should be considered in this research. It seems that PPP research on a specific country needs to consider how PPPs are classified and what type is mostly used in order to reflect the characteristic of each country. Additionally, considering the transport demand and the transport investment in Korea, roads and railways are the most important transport modes in Korea. Therefore, summing up, this research will consider Korea's most popular PPP types, BTO and BTL, focusing on roads and railways, in deciding which procurement option is most favourable of the three considered (this includes conventional delivery).

Another important conclusion is that VFM assessment is worldwide used as a key factor in PPP decisions. Reviewing PPP decision-making in several countries, they all have a procurement option assessment process (or a similar stage) before the procurement stage and after the investment decision stage. In selecting an appropriate option, including the conventional and the PPP schemes, the VFM assessment seems to be the key factor used worldwide.

Finally, reviewing the VFM assessment in several countries, definition, composition and application levels are quite similar, whereas PSC components, discount rate and qualitative factors are quite different among countries. Therefore, considering that this research concerns quantitative PPP decisions in Korea, it seems reasonable that PSC components and discount rate in the VFM assessment should be related to the Korean context and reflect the socio-economic status and regulation of Korea.

CHAPTER 3 Research Methodology

3.1 Introduction

One of the main objectives of this research is to find out the impact of transferable risks on the PPP decision at a project level as well as at a programme level, and this is naturally related to which procurement option is the most favourable for each transport programme (the National Highway, the National Expressway and the National Railway). In addition, with respect to the land transport programme including roads and railways, the causes and the effects of PPP decisions are also examined in this research. To this end, various methodologies are employed in this research. Regarding the employed methodology, this chapter consists of six sections covering research objective 1-2: 1) the VFM analysis; 2) the Modified VFM; 3) risk quantification; 4) impact analysis; 5) case studies; and 6) meta-analysis.

Firstly, as the most common PPP decision methodology, the VFM analysis is reviewed in terms of quantitative assessment (3.2). In this section, a quantitative formulation taking into account the Korean context is discussed, and the problems related to completion delay are also addressed in the later part. In order to consider the completion delay in the VFM analysis, a Modified VFM assessment is developed by adapting the NPV technique to the VFM in the next section (3.3). Along with the development of the Modified VFM, the question of how to select a proper discount rate for the Modified VFM is also dealt with here.

Another important section in this chapter concerns risk quantification (3.4). In this section, the risks that need to be transferred from the public sector to the private sector are identified and how to quantify these is scrutinised as well. In addition, other risk factors considered in this research are also reviewed. When it comes to the impact analysis section (3.5), some impact analysis methodologies, including single-value estimation, sensitivity analysis and Monte Carlo Simulation, are considered. In this research, six case studies from three transport programmes (two for each) are also employed to determine the impact of transferable risks on the Modified VFM and PPP decisions. These will be discussed in section (3.6).

Finally, the causes and the effects of PPP decisions in the land transport programme (roads and railways) are addressed in this study, with meta-analysis used as a methodology in section (3.7).

3.2 The VFM analysis

The most common PPP decision methodology

Many countries have used PPPs as a delivery method with a view to overcoming shortages in public funds and the resulting delays in infrastructure provision (EIB, 2005). However, to date, from the viewpoint of public sector costs, doubts about PPPs have also been raised by various researchers, for example Shaoul et al. (2012), and institutions, for example UNISON (2010). As a PPP decision methodology, the VFM assessment, assuming that timing (construction duration and completion) is the same for the conventional and PPP alternatives (Grimsey and Lewis, 2005, MOSF, 2009a), is the most commonly used in deciding whether to use a PPP alternative or not for a project. Through this assessment, a PPP scheme can be justified if it is better than conventional procurement (Akintoye et al., 2003) in terms of economics (spending less), efficiency (higher productivity) and effectiveness (better outcome) (HMSO, 1999), even though it could be impossible to find one unique VFM test meeting all conditions and situations (Grout, 2005).

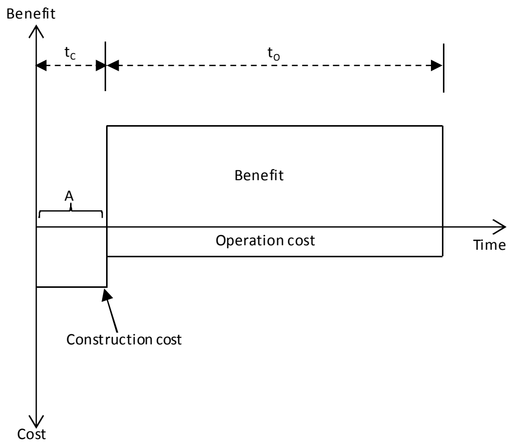
Quantitative VFM in the Korean context

Generally, in the light of quantitative assessment, the current VFM approach assumes that efficiency and effectiveness from a PSC and a PPP are the same (MOSF, 2009a, Grimsey and Lewis, 2005, Hoose, 2011), so the only thing to be compared is the public sector cost. The public sector cost in a PSC includes construction cost, including design cost, operation cost, and other costs which the public sector should pay, while that of a PPP covers construction support from the public sector, MRG cost in BOT and lease fee in BTL. Therefore, the current VFM concept can be expressed as follows from the viewpoint of present value:

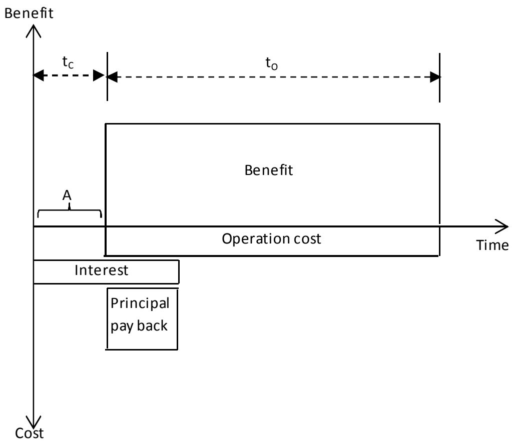
$$\mathbf{VFM} = \sum_{i=0}^{n} \frac{C_{PSC}}{(1+d)^{i}} - \sum_{i=0}^{n} \frac{C_{PPP}}{(1+d)^{i}} \tag{3-1}$$

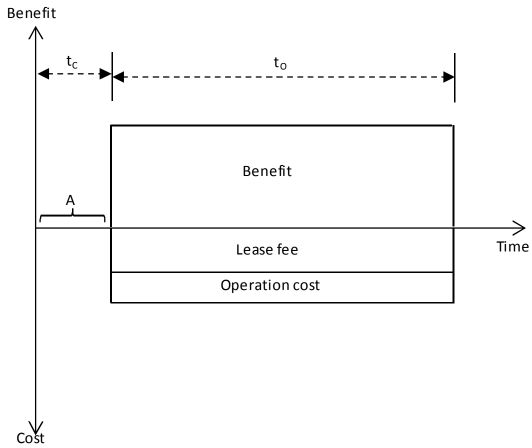
where *C* is public sector cost, *d* is a discount rate, and *n* (= construction period (t_C) + operation period (t_O)) is an analysis period. From equation (3-1), if VFM is positive, then the PPP project can be launched. Conversely, if VFM is negative, then the PPP system adoption will be discarded.

As illustrated in the schematic drawing of the current VFM test of a PPP (a BTL scheme is considered) project in Korea (Figure 3-1), an ideal PSC (b) and a PPP (c) have the same benefit (effectiveness) but a different public sector cost from each other. For a simple discussion, Figure 3-1 (a), explaining an ideal conventional public work, assumes that the public sector cost of a PSC includes the construction cost and the operation cost. Moreover, in Figure 3-1 (c), lease fee and operation costs are considered as a PPP cost. In the Korean context, the construction cost of an ideal PSC is assumed to be delivered by the issuing of a five-year exchequer bond, as stipulated in Korea's BTL guidelines (MOSF, 2009a). Therefore, as a result of issuing a five-year exchequer bond, during the construction period (t_C) the public sector pays only the interest on the principal, after which it pays the interest and principal. Figure 3-1 (b) describes an ideal PSC scheme. This is actually the same as Figure 3-1 (a) except for investment cost delivery. According to the current VFM test, if the discounted PPP cost (e.g. lease fee and operation cost) is cheaper than the discounted PSC cost (e.g. construction cost and operation cost), the PPP option will be selected as a procurement method.



(a) An ideal conventional public works scheme





(b) An ideal PSC (c) A PPP

Figure 3-1: Schematic drawing of an ideal PSC and a PPP for the current VFM test

According to the BTL guidelines (MOSF, 2009a) and the general guidelines for a feasibility study (KDI, 2008b) of Korea, capital expenditure between a PSC and a PPP can be summarised as in Table 3-1. As seen in Table 3-1, the cost items that need to be included in the VFM calculation is largely composed of the government base cost items and the risk adjustment cost items. However, with respect to the risk adjustment cost, the guidelines do not provide how to estimate them. Accordingly, the VFM calculation in Korea is conducted without the inclusion of the risk adjustment cost.

Table 3-1: Summary of capital expenditure between a PSC and a PPP

	PSC	PPP	
		BTO	BTL
Asset cost	Building cost - Investigation - Design - Construction	Building cost - Investigation - Design - Construction	Building cost - Investigation - Design - Construction
	Compensation cost	Compensation cost*	Compensation cost*
	Additional cost - Traffic impact assessment - Environmental impact assessment - Inspection - Insurance	Additional cost - Traffic impact assessment - Environmental impact assessment - Inspection - Insurance	Additional cost - Traffic impact assessment - Environmental impact assessment - Inspection - Insurance
	Operation facility cost	Operation facility cost	Operation facility cost
	-	Business reserve	Business reserve
	Tax and public utilities' charge	Tax and public utilities' charge	Tax and public utilities' charge
	Financial cost	Financial cost	Financial cost
Operation cost	Management cost	Management cost	Management cost
	Maintenance cost	Maintenance cost	Maintenance cost
	Government Monitoring cost	Government Monitoring cost	Government Monitoring cost
Other cost	-	Subsidy, MRG cost	Lease fee
Government Base Cost (①)	(BTO) Asset cost + Operation Cost – Revenue (BTL) Asset cost + Operation Cost	Subsidy + MRG cost	Lease fee + Operation cost
Risk adjustment Cost (②)	Cost overrun + Time overrun	-	-
Total government whole-of-life cost	①+②		

Note: If compensation cost is given to the concessionaire from the central or local government for free, this should be excluded in the asset cost estimation and lease fee calculation.

Source: MOSF (2009a) and KDI (2008b)

Therefore, considering the government base cost in Table 3-1, from the viewpoint of BTO and BTL schemes, equation 3-1 can be expressed as follows (Park and Preston, 2013b):

$$\text{VFM}_{BTO} = \boldsymbol{Whole\ life\ cost_{PSC} - Whole\ life\ cost_{BTO}}$$

$$= \boldsymbol{(AC_{PSC} + OC_{PSC} - \ Revenue) - (Subsidy_{BTO} + MRG_{BTO})} \tag{3-2}$$

$$\text{VFM}_{BTL} = \boldsymbol{Whole\ life\ cost\ _{PSC} - Whole\ life\ cost_{BTL}}$$

$$= \boldsymbol{(AC_{PSC} + OC_{PSC}) - (Lease\ fee\ _{BTL} + OC_{BTL})} \tag{3-3}$$

where AC_{PSC} = asset cost in the PSC, OC_{PSC} = operation cost in the PSC, $Subsidy_{BTO}$ = government subsidy including compensation cost and construction subsidy in the BTO, *Revenue* = the government's revenue income when the government uses conventional delivery that can be obtained, MRG_{BTO} = MRG cost from the government in the BTO, $Lease\ fee\ _{BTL}$ = the lease fee that the government pays to the private sector in the BTL and OC_{BTL} = operation cost in the BTL.

Questions for the current quantitative VFM

However, in cases where there are systematic completion delays between conventional delivery and PPP alternatives, as in Korea, the current PPP decision methodology seems to have a limitation in terms of quantitative assessment as a result of this assumption. In addition, current quantitative VFM methodology seems to represent the finance authority which does not want to spend money, if possible, on the fiscal management aspect. However, for the transport decision makers or transport service consumers, the time when the transport service is available seems to be also as important as spending less. The transport service provision timing is related to the completion time of the transport project.

With respect to the systematic completion delays in Korea, according to Ahn (2006), among 197 road projects completed between 2001 and 2005, 155 projects (86.5 per cent) were delayed, and among the delayed projects, 134 projects (79 per cent) were delayed due to lack of funds. This is the main cause of completion delay due to the unusual national budget system in Korea, i.e. the LEC system (Kim et al., 2008b). According to the LEC system, an infrastructure project starts by reflecting its first-year expenditure in the Budget Book, as settled by the National Assembly, even if the total expenditure of the project is not secured in the Budget Book. This means that, with the LEC system, infrastructure construction can start even though its yearly expenditure has not been determined by the National Assembly. Using this system, too many infrastructure projects, compared with the size of the budget, tend to be implemented by reason of political necessity, such as balanced regional development policy. As a result, each project under construction experiences budget constraints and a systematic completion delay occurs.

In addition, many developing or under-developed countries seem to want PPPs not because a PPP is cheaper than a PSC but because without PPPs it is very difficult for them to provide infrastructure services to the public at all, given their insufficient public funds. With insufficient public funds, completion time delay or a delay in the time when an infrastructure service starts to be provided seems to be inevitable in these countries, if they try to provide infrastructure services using a conventional delivery system. In this case, as Leigland and Shugart (2006) have pointed out, the current VFM assessment using a PSC could be meaningless for these countries because, in practice, they cannot make an investment on infrastructure like the public sector comparator option due to lack of public funds and the public sector comparator is an impossible alternative. For this reason, it is necessary to develop a new PPP decision-making methodology reflecting systematic completion delay in the conventional delivery in Korea.

3.3 The Modified VFM

3.3.1 The development of the Modified VFM analysis

Adoption of the NPV technique

In order to reflect a completion delay in the conventional delivery for a new PPP decision methodology, the construction investment difference, as well as the social benefit difference due to delay in time when an infrastructure service starts to be provided between a PSC and a PPP, needs to be reflected.

As depicted in Figure 3-2 (a), a real conventional public work with completion delay (t_D) due to a lack of budget has two points of difference in relation to an ideal one. The first is completion time, which is delayed from point A (t_C) to point B ($t_C + t_D$). Due to this construction completion time difference (B-A = t_D), a PPP option seems to bring the benefit occurring forward by an early infrastructure service provision, compared with a conventional option. Another is the construction period and construction investment intensity. A real conventional public work seems to have a longer construction period ($t_C + t_D$) – and a weaker investment intensity of construction cost – than an ideal conventional public work without budget constraints.

In this case with a construction completion time difference (t_D), instead of the current VFM test, it seems that some different approach is needed for decision-making on whether to use PPP system or not. To consider public sector cost (excluding private sector cost) and effectiveness (benefit) at the same time for procurement option selection, the NPV technique can be adopted. This has been widely used in addressing infrastructure decision-making by many researchers, such as Quinet and Vickerman (2004), Layard and Glaister (1994) and Pearce and Nash (1981).

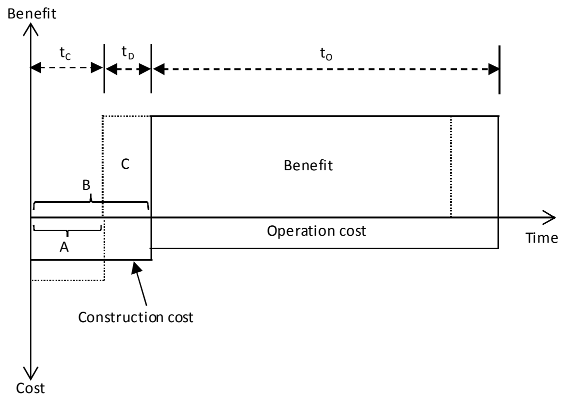
Development of the Modified VFM

In order to identify which option is better between a PSC and a PPP, the difference in NPV between a PPP and a PSC can be considered as follows (Park and Preston, 2013b):

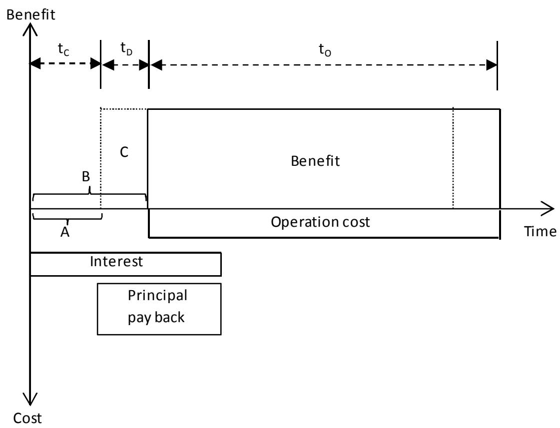
$$\boldsymbol{\Delta \mathrm{NPV} = NPV_{PPP} - NPV_{PSC}}$$

$$= \left\{ \sum_{i=0}^{t_C+t_O} \frac{B_{PPP}}{(1+d)^i} - \sum_{i=0}^{t_C+t_O} \frac{C_{PPP}}{(1+d)^i} \right\} - \left\{ \sum_{i=0}^{t_C+t_D+t_O} \frac{B_{PSC}}{(1+d)^i} - \sum_{i=1}^{t_C+t_D+t_O} \frac{C_{PSC}}{(1+d)^i} \right\}$$

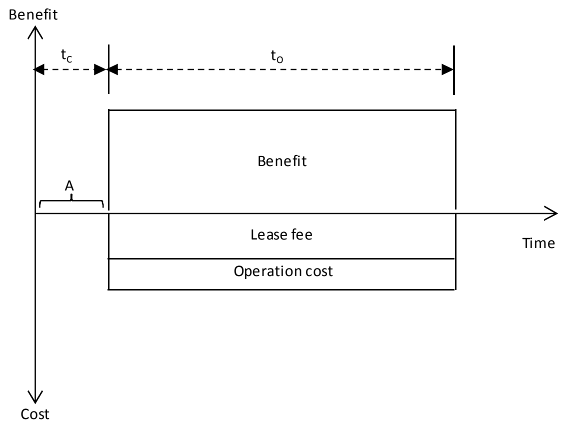
$$= \underbrace{\left\{ \sum_{i=0}^{t_C+t_D+t_O} \frac{C_{PSC}}{(1+d)^i} - \sum_{i=0}^{t_C+t_O} \frac{C_{PPP}}{(1+d)^i} \right\}}_{\text{The difference of discounted public sector cost between PSC and PPP}} + \underbrace{\left\{ \sum_{i=0}^{t_C+t_O} \frac{B_{PPP}}{(1+d)^i} - \sum_{i=0}^{t_C+t_D+t_O} \frac{B_{PSC}}{(1+d)^i} \right\}}_{\text{The difference of social benefit between PSC and PPP}} \quad (3\text{-}4)$$



(a) An real conventional public work



(b) An ideal PSC



(c) A PPP

Figure 3-2: Schematic drawing of an ideal PSC and a PPP for a Modified VFM test

From equation (3-4), the first bracketed part is the difference in the discounted public sector cost between a PSC and a PPP, which means the difference between the discounted sum of interest cost, principal pay back and operation cost in Figure 3-2 (b) and the discounted lease fee and operation cost in Figure 3-2 (c) (a BTL option is considered as an example). The second bracketed part is the difference in the social benefits between a PSC and a PPP, which means the discounted area C in Figure 3-2 (b). Finally, the NPV difference can be reduced as follows:

$$\boldsymbol{\Delta \mathrm{NPV} = \widetilde{VFM} + \Delta \mathrm{B}} \tag{3-5}$$

where $\widetilde{VFM}$ is the difference in the discounted public sector cost between a PSC and a PPP with a different investment cost input time, and ΔB is the difference in the benefit between a PSC and a PPP due to the construction completion time difference.

If there is no construction completion difference, $\widetilde{VFM}$ will become VFM, and then ΔB will be zero because the size of the benefit is the same between a PSC and a PPP. In this case, equation (3-5) can be expressed simply as follows:

$$\boldsymbol{\Delta \mathrm{NPV} = VFM} \tag{3-6}$$

Therefore, the NPV difference (ΔNPV) between a PPP and a PSC can be considered as an extended form of the current VFM analysis, and it could be used when a certain project implemented by the public sector has a construction completion time difference, as compared with a PPP system. If the NPV difference (ΔNPV) between a PPP and a PSC is defined as a *Modified VFM*, it can be considered a more generalised form, explaining not only the construction cost input difference but also the infrastructure provision time difference between a PSC and a PPP (Park and Preston, 2013b). As an indicator showing which procurement option between a PSC and a PPP is viable, if the Modified VFM (ΔNPV) of a certain project is positive then a PPP option can be adopted for the project.

The Modified VFM in the Korean context

In addition, considering the BTO and the BTL scheme in Korea, equation (3-5) can be decomposed based on main cost items as follows (Park and Preston, 2013b):

$$\boldsymbol{M.VFM_{BTO} = Whole\ life\ cost_{PSC} - Whole\ life\ cost_{BTO} + \Delta \mathrm{B}}$$

$$\boldsymbol{= (AC_{PSC} + OC_{PSC} - Revenue) - (Subsidy_{BTO} + MRG_{BTO}) + \Delta \mathrm{B}} \tag{3-7}$$

$$\boldsymbol{M.VFM_{BTL} = Whole\ life\ cost_{PSC} - Whole\ life\ cost_{BTL} + \Delta \mathrm{B}}$$

$$= (AC_{PSC} + OC_{PSC}) - (Lease\ fee_{BTL} + OC_{BTL}) + \Delta B \tag{3-8}$$

where $M.VFM$ = Modified VFM, AC_{PSC} = the asset cost in the PSC, OC_{PSC} = the operation cost in the PSC, $Revenue$ = the government's revenue income when the government uses conventional delivery, $Subsidy_{BTO}$ = the government subsidy in the BTO, MRG_{BTO} = the MRG cost in the BTO, $Lease\ fee_{BTL}$ = the lease fee that the government pays to the private sector in the BTL in the BTL and OC_{BTL} = the operation cost in the BTL.

Therefore, when deciding which model between a BTO and a BTL is favourable when factoring in a completion delay, the following equation will be used:

$$M.VFM_{BTL-BTO} = M.VFM_{BTL} - M.VFM_{BTO}$$

$$= (Subsidy_{BTO} + MRG_{BTO} + Revenue) - (Lease\ fee_{BTL} + OC_{BTL}) \tag{3-9}$$

Using equation (3-9), if $M.VFM_{BTL-BTO}$ is positive for a certain project, it is better to use the BTL scheme for the project; in other cases, the BTO is better.

The application of the Modified VFM

The Modified VFM (the NPV difference, ΔNPV) can be applied to any projects with a construction completion time difference between the conventional public works system and the PPP system, especially in developing or under-developed countries suffering from lack of public funds. However, before using this methodology, the construction completion time difference between a PSC and a PPP needs to be quantified.

3.3.2 The selection of the discount rate for the Modified VFM

3.3.2.1 General considerations for the selection of the discount rate

To calculate the present value in the Modified VFM, it is important to select an appropriate discount rate. When selecting a discount rate, there are three general questions to be answered: 1) which kind of discount rate needs to be used, a financial one or an economic one, 2) whether to use the same or different discount rate for alternatives, 3) the theory based on the discount rate.

A financial or economic discount rate

The first question to be considered is whether to adopt a financial discount rate or an economic discount rate. With respect to the VFM calculation, the guidelines of many countries, including Ireland, Australia and Korea (but not the UK), suggest that a financial discount rate considering the public sector's borrowing costs should be used because the VFM calculation considers financial cash flows between the PSC and the PPP alternative, differing from the decision on whether to invest using a cost-benefit analysis with an economic discount rate (Australian Government, 2008c, Irish Government, 2006, PIMAC, 2005). However, the Green Book (HM Treasury, 2003) in the UK does not seem to use a financial discount rate in the VFM calculation; instead using a pure time preference-based discount rate. Other than that, there is another view that an economic discount rate is more appropriate than a financial one in the VFM calculation, as government officials tend to have a standpoint of considering social benefits arising from infrastructure provision more than borrowing costs when selecting a procurement option (Shugart, 2009, Charko, 2011).

Same or different for alternatives

The next consideration is whether the same discount rate should be applied to the PSC and PPP alternatives or not. In the UK and Korea, regardless of whether a PSC or a PPP is involved, the same discount rate should be applied according to the guidelines. In contrast to these countries, however, the PPP guidelines of Australia provide that a different discount rate between a PSC and a PPP may be used in bidding, even though the same discount rate should be used when deciding which alternative to invest in at the initial stage (Australian Government, 2008c, New South Wales Government, 2007).

There are two different views on this point. One is that cash flow in the PSC (if the public sector pays for the facility) is a cost for the public sector, while the cash flow in the PPP is the revenue of the private sector, which is riskier. Therefore, a higher discount rate should be used in a PPP than a PSC (Grout, 2003). Another is that cash flow from a PPP contract is guaranteed by the public sector, and that therefore a SPV can also have risk-free cash flow by public sector, so it is reasonable that a risk-free discount rate, the same as is used in a PSC, should be used for a PPP (Davis, 2005).

Based theory

The last question concerns theories about where discount rate comes from and how to deal with systematic risk. The discount rate in the UK is calculated on the basis of the social time preference rate[24], and a single discount rate is used for a PSC and a PPP, so this approach ignores the impact of the systematic risk being transferred to the private sector on cash flows (Gray et al., 2010, Shugart, 2009). However, the Capital Asset Pricing Model (CAPM)[25]-based discount rate used in Australia is able to consider systematic risk by adding risk premiums to the risk-free discount rate, so various discount rates are provided for projects with different risk bands,[26] which is one of the important merits of the CAPM process (Grimsey and Lewis, 2005).

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[24] Like individuals, as a whole, society also prefers to enjoy goods (or services) sooner rather than later and to delay costs to next generations, which is known as 'social time preference'. The social time preference rate (STPR) is "the rate at which society values the present compared to the future" (HM Treasury, 2003).

[25] In Australia, a discount rate is estimated by the CAPM, which considers the risk-free rate of return and the risk premium of the market (Partnerships Victoria, 2010). A discount rate is calculated by the CAPM as follows:

$$R_a = R_f + \beta_a (R_m - R_f)$$

where R_a = discount rate, R_f = risk-free rate of interest, R_m = rate of return of market, β_a = the asset beta, the sensitivity of the expected excess asset returns to the expected excess market returns, and $R_m - R_f$ = risk premium of market.

[26] The Department of Treasury and Finance of Australia recommends a 4.95 per cent risk-free rate of interest (in nominal terms) and a 6 per cent risk premium (in real terms), and suggests that the asset betas for different project sectors (Partnerships Victoria, 2010). The discount rate in real terms for different project sectors is as follows:

< Discount rates in Australia >

<table>
<tr><th rowspan="2">Risk band</th><th rowspan="2">Project sector</th><th>Risk free rate</th><th>Asset beta</th><th>Market risk premium</th><th>Risk premium</th><th>Discount rate</th></tr>
<tr><th>R_f</th><th>β_a</th><th>$R_m - R_f$</th><th>$\beta_a (R_m - R_f)$</th><th>$R_a = R_f + \beta_a (R_m - R_f)$</th></tr>
<tr><td>Very low</td><td>Accommodation and related services</td><td rowspan="3">***4.95% (nominal)***
↓
1.89%
(real)</td><td>***0.3***</td><td rowspan="3">***6% (real)***</td><td>***1.8% (real)***</td><td>**3.7% (real)**</td></tr>
<tr><td>Low</td><td>Water, transport and energy</td><td>***0.5***</td><td>***3% (real)***</td><td>**4.9% (real)**</td></tr>
<tr><td>Medium</td><td>Telecommunications, media and technology</td><td>***0.9***</td><td>***5.4% (real)***</td><td>**7.3% (real)**</td></tr>
<tr><td>Remark</td><td colspan="6">1. The data in italic are provided from the Victorian government's PPP Guidelines (2010).
2. 3% Inflation rate is assumed to calculate discount rate.
3. Risk-free rate in real terms is calculated in the following way: (1+0.0495)/(1+0.03) -1 = 0.0189, namely 1.89%</td></tr>
</table>

Source: Partnerships Victoria (2010)

3.3.2.2 The discount rate for Modified VFM

Characteristics of the research considered

Although there are many viewpoints regarding selecting discount rates in the VFM calculation, no consensus seems to have been reached (Grimsey and Lewis, 2004a) regarding the above three considerations. Moreover, countries have somewhat different guidelines for the VFM calculation, which take into account their socio-economic environments. Consequently, the discount rate for this research will be adopted considering the characteristics of the decision-making methodology, the socio-economic environment, the decision-making stage and factors that are necessary in the decision-making process.

To begin with, it seems reasonable to assume that the economic discount rate and not the financial rate in real terms should be used for the Modified VFM: this is because the Modified VFM considers the social benefit difference between a PSC and a PPP due to completion delay, whereas the VFM is considered as a special case of the Modified VFM with no completion delay.

In addition, the same discount rate will be applied to the PSC and the PPP in the Modified VFM on the grounds that this research considers PPP decisions at the initial stage, such as the feasibility or pre-feasibility study. At this stage, decision-making refers to the delivery method not to selecting which corporate body will deliver in the bidding process.

When it comes to the size of the discount rate, the same discount rate as the Korean government officially uses will be applied to the Modified VFM, which considers the socio-economic environment in Korea. According to KDI (PIMAC, 2005) and MOSF (2009a), a financial discount rate of 6 per cent in nominal terms is recommended for a BTL scheme. However, considering other countries, such as Australia and the UK, this rate seems too small when inflation is excluded. For example, 4.9 per cent in real terms is used for transport infrastructure in Australia (Partnerships Victoria, 2010), which is much higher than the 6 per cent in nominal terms considering inflation. In the UK, although 3.5 per cent in real terms is considered in the PFI, this has been criticised for being too low (Coulson, 2008).

Before 2004 an economic discount rate of 7.5 per cent in real terms was used in Korea at the project assessment stage (KDI, 2001), although after revisions to the general preliminary feasibility study guidelines the economic discount rate was reduced to 6.5 per cent in real terms (KDI, 2004b). Additionally, according to some studies on the discount rates published in 2008

(KDI, 2008a, KDI, 2008b), 5.5 per cent in real terms was suggested for the economic discount rate, reflecting discount rates calculated by the social time preference rate and CAPM.

Discount rate for the Modified VFM

All in all, as stated above, in this research, depending on the decision-making time of a case study, an economic discount rate of 7.5, 6.5 and 5.5 per cent in real terms will be used, irrespective of whether it is a PSC or a PPP in the Modified VFM.

Decision-making time	Economic discount rate
Before 2004	7.5 per cent
From 2004 to 2008	6.5 per cent
After 2009	5.5 per cent

Discussion

As already reviewed, there are some disagreements on the selection of discount rate among researchers and PPP guidelines in deciding whether to use PPP options or not, because there are many arguments regarding risk premium and the relevant theory (Grimsey and Lewis, 2004a, Harrison, 2010). In addition, with respect to the discount rate for public projects, the debate on what rate should be used to discount future costs and benefits has been existing since the early 20th century and four alternative approaches have been developed: 1) social rate of time preference, 2) social opportunity cost, 3) weighted average method, and 4) shadow price of capital method (Boardman et al., 2001). The essence of these approaches is that each has a different viewpoint on how public projects affect domestic consumption, private business investment, and international borrowing costs (Zhuang et al., 2007). Stiglitz (1994) argued that the market rate of interest for private consumption goods is not appropriate for the social discount rate when evaluating projects because of market imperfections such as taxes, risks, information asymmetry and externalities, and pointed out that, in general, neither the social rate of time preference nor the marginal rate of transformation in the private sector is appropriate for discount rate. It is said, however, that social discount rate is somewhere in between social time preference rates (which is related to the earning rate on personal savings) and social opportunity cost of capital (which is related to the marginal earning rate of private business investment), though not always (Pearce and Nash, 1981).

As seen in Table 3-2, the discount rates in real term used in some countries show a range between 3and 15 per cent. The variety in the discount rate seems to come from the degree of economic development and how it is produced (Harrison, 2010). The highest rates (12-15 per cent) are considered in developing countries like Philippines and India, while the lowest rates (3-3.5 per cent) are used in developed countries like Germany and Norway. As previously reviewed, the theoretical basis for producing the discount rate is dependent on each country. The UK uses the social time preference rate for the discount rate. Australia and Canada (British Columbia) use the CAPM-based discount rate and the WACC-based discount rate respectively. In addition, Korea uses the rate determined from a specialised agency (KDI) by considering existing theories (social time preference rate and CAPM) and socio-economic environments.

Table 3-2: Discount rates in real term in selected countries

Country	Agency	Discount rate (year)
Philippines		15 (2007)
India		12 (2007)
International Multi-lateral Development Banks	World Bank	10-12 (2007)
	Inter-American Development Bank	12 (2007)
	European Bank for Reconstruction and Development	10 (2007)
	African Development Bank	10-12 (2007)
New Zealand	Treasury and Finance Ministry	8 (2008)
Canada	Treasury Board	8 (2007)
China		8 (2007)
South Africa		8 (2004)
United States	Office of Management and Budget	7 (2007)
South Korea	Korea Development Institute	5.5[A] (2008)
European Union	European Commission	5 (2006)
Italy	Central Guidance to Regional Authorities	5 (2007)
Australia	Partnership Victoria	4.9[B] (2010)
The Netherlands	Ministry of Finance	4 (2003)
France	Commissariat General du Plan	4 (2003)
United Kingdom	HM Treasury	3.5 (2007)
Norway		3.5 (2007)
Germany	Federal Finance Ministry	3 (2007)

(Note) 1. A is from KDI (2008 a), B is calculated considering transport project using Partnerships Victoria (2010) and others are collected from Harrison (2010). 2. Years in brackets mean the collection year of each discount rate from various literature.

Source: Harrison (2010), Partnerships Victoria (2010) and KDI (2008a)

However, more important thing is the size of the discount rate selected. In calculating the Modified VFM, the net present value of a project with future public sector cost and social benefit difference between delivery options is essentially dependent on the discount rate selected, especially when public sector costs have a different time frame with social benefit differences (Harrison, 2010). Generally, considering initial costs like construction cost are spent first, with the social benefits difference occurring later in the benefit cost analysis in a transport project, it seems that the higher the discount rate is, the less attractive the project is as a result of its lower net present value. However, it is not easy to predict the impact of the discount rate in PPP decisions because even when the discount rate change is infinitesimally small, the PPP decision can be different (Grimsey and Lewis, 2005) and the change of size and shape of the cost profile of a project also make an impact on PPP decision in forecasting the effect of the discount rate on PPP decisions (Bain, 2010).

As the structure of public sector cost and social benefit difference in the Modified VFM is different from the VFM, it seems more difficult to know the possibility of the change of PPP decision according to the discount rate selected. Consequently, a sensitivity analysis will be adopted in the thesis, along with single value estimation, in order to find out the impact on the discount rate change on the Modified VFM or PPP decision.

3.4 Risk quantification

3.4.1 Risk identification and allocation

Risk is usually said to exist where the odds of various future output can be known on the basis of mathematics (probability) or the experience from similar situation (Smith et al., 2009, Mun, 2006). With respect to risk in PPP decisions, it is important to find out how to identify major risk and how to quantify them. Generally speaking, risk identification and risk quantification are a part of risk management framework, composed of various different processes; risk identification and allocation, risk assessment and analysis, risk mitigation, risk monitoring and control (Institute of Civil Engineers, 1998, Molenaar, 2005, Park, 2007). The first step to reflect risks in PPP decision is to identify risks and allocate them. It is known that some advanced countries such as the UK and Australia use risk matrices or risk registers for risk identification and allocation in project planning phase and feasibility assessment stage. Unlike these countries, in Korea, there is no guideline for risk identification and allocation until now, and the discussion on risks starts from contract negotiation stage between public sector and private sector. Therefore, it seems that if it is possible to identify and allocate risks in early stage it is very helpful to reduce risks in a real situation (Park, 2007).

However, through more than fifteen year experiences Korea have developed standard contract forms for BTO and BTL projects with respect to risk identification and allocation. Therefore, in this thesis, risks in PPPs in construction and operation periods are mainly identified and allocated based on Table 3-3, the typical risk identification and allocation table (Shim et al., 2005a) considering conventional public sector procurement, road BTO project (BTO 1), rail BTO project (BTO 2) and BTL project by analysing previous contracts. As seen in Table 3-3, there are little differences between BTO and BTL contract in terms of risks in construction and operation periods except revenue risk. Regarding revenue risk, in principle, government takes demand risk in BTL project, while in BTO project private sector takes it all because minimum revenue guarantee (MRG) system of BTO project in Korea was abolished in 2006 and 2009. Very importantly, as shown in Table 3-3, government can transfer risks about making assets and providing services, which is in shaded cells, to private sector, so that government usually takes risks regarding project environments. In addition, this risk allocation in PPP of Korea corresponds with the basic risk allocation principle which a party that can manage a certain risk well should takes that risk, and also coincides with the generality which cause contributor of a certain risk should take the risk (Park, 2007).

Table 3-3: Risk identification and allocation in PPP projects in Korea

	Risks	Conventional	BTO 1	BTO 2	BTL	Remark
Construction	Land acquisition	G	G	G	G	
	Civil complaint (not regarding construction)	G	G	G	G	Political force majeure
	Civil complaint regarding construction	G	P	P	P	
	Sponsor problem (Equity investment delay etc.)	G	P	P	P	
	Lender problem (Loan delay etc.)	G	P	P	P	
	Delivery difficulties and inflation of labour force and material	G	P (G)	P(G)	P	Government takes inflation risk to negotiated level
	Builder problem (bankruptcy, lack of ability)	G	P	P	P	
	Improper design	G	P	P	P	
	Use of improper construction technologies	G	P	P	P	
	Change of law & regulation during construction	G	G	G	G	
	Change of total project cost by government	G	G	G	G	
	Approval responsibility during construction	G	P (G)	P (G)	P (G)	Government gives administration support for approval
	Amendment of laws causing significant impact to PPP	G	G	G & P (90% /10%)	G	Political force majeure
	National moratorium or payment delay	G	-	G & P (90%/10%)	-	Political force majeure
	War or rebellion during construction	G	G & P (90%/10%)	G & P (90%/10%)	G & P	Political force majeure
	Restriction of currency exchange and overseas remittance	G	G & P (90% /10%)	G & P (80% /20%)	G & P	Political force majeure
	Cultural assets excavation	G	G & P (80%/20%)	G	G & P	
	Dangerous material treatment, site contamination due to nuclear disposal or radioactivity	G	G & P (80%/20%)	G & P (80%/20%)	G & P	Non-political force majeure
	Natural disaster during construction	G	G & P (80%/20%)	G & P (80%/20%)	G & P	Non-political force majeure
	Strike over the nation	G	G & P (80%/20%)	G & P (80%/20%)	G & P	Non-political force majeure
Operation	Restriction of the right to decide usage fee	G	G	G	-	
	Excessive operation and management cost beyond expectation	G	P	P	P	
	Change of government policy, governmental request, change of total project cost and amendment of Tax Law	G	G	G	G	
	Service quality lower than minimum requirement and loss due to this problem	G	P	P	P	
	Operation and maintenance of subsidiary enterprise	G	P	-	P	
	Unexpected decrease in market demand	G	G&P (G: 60~80% for first 25 year, P: lower than 50%,)	G&P (G: 50~80%, P: lower than 50%,)	G	
Construction /operation	Confiscation by government	-	G	G	G	
	Changes of the institution of taxation and finance	G	G	G	-	Amendment of Corporate Tax Law
	Confiscation by government	-	G	G	G	
	Changes of the institution of taxation and finance	G	G	G	-	Amendment of Corporate Tax Law
	Difficulties in loan and decrease in profitability due to economic crisis (including interest rate and exchange rate fluctuation)	G	G&P (80%/20%)	G&P (80%/20%)	G&P	Non-political force majeure
	Improper or not having insurance	G	P	P	P	
	Residual value risk	-	P	P	P	

(Note) 1. Conventional means public conventional procurement, and BTO 1, BTO 2 and BTL means Suwon-Pyungtaek Expressway projects (contract 2005), New Bundang rail project (contract 2005) and BTL standard contract respectively. 2. 'G', 'P' and 'G&P' mean 'government', 'private sector' and 'government and private sector' respectively. 3. The original table was modified by adding risks from road project, eliminating unnecessary data, correcting data and shading cells.

Besides, from Korean's BTL guideline (MOSF, 2009a), several risk factors can also be identified in the calculation of the Modified VFM; construction deflator, consumer price index, five-year exchequer bond interest rate and three-year non-guaranteed corporate bond interest rate. However, they do not seem to be transferable because there are related to project environments. According to the guidelines, construction deflator is used to calculate the yearly lease fee and consumer price index is used to convert nominal terms to real terms. In addition, five-year exchequer bond interest rate is used to estimate BTL lease profitability for private sector and three-year non-guaranteed corporate interest rate is used to calculate BTL finance interest rate for private sector.

3.4.2 Risks transferable to the private sector

Optimum risk transfer

Risk transfer is at the heart of PPPs and the essence is how to reflect risk cost when building a PSC for the Modified VEM. According to Cooper et al. (2005), the body best able to manage risks at the lowest cost should take responsibility for risk management in PPPs. Therefore, optimum risk transfer is essential to achieve the best VFM in using PPPs (Arthur Andersen and Enterprise LSE, 2000, Sun et al., 2010). With respect to optimum risk transfer, when it comes to the PPP decisions at the initial stage (the stage that this research is concerned with), selecting transferable risks and their quantification is the most important element because the cost of transferable risks needs to be included in the Modified VFM.

Transferable risks in this research

Regarding which risks should be transferred to the private sector in PPPs, Li et al. (2005) argued that the public sector should take land acquisition risk and political risk, while project risk and revenue risk should be taken by the private sector; legal risk needs to be shared by both sectors. In other research (Roumboutsos and Anagnostopoulos, 2008, Ke et al., 2010) using Li et al.'s questionnaire on China/Hong Kong and Greece, the results were largely similar to the former research in the way that project risk and revenue risk, which is directly related to traffic volume risk, should be transferred to the private sector.

According to Korea's BTL guidelines (MOSF, 2009a), transferable risks means a construction cost risk and a completion delay in conventional delivery, which can be considered in building a PSC. When it comes to the BTO option, traffic volume risk is designed to be transferred fully to the private sector because of the abolition of a MRG system. In addition, as seen in Table 3-3, the risks transferable to private sector are almost related to construction costs, completion time, operation costs and revenue stream, which is directly related to traffic volume risk. However, in the case of operation costs[27], it is difficult to find their reference costs in Korea so it is impossible to consider operation cost overruns for the Modified VFM assessment.

Consequently, this research will consider construction cost risk, completion delay risk and traffic volume risk as risks transferable to the private sector, given the literature reviewed and the availability of historical observations.

3.4.3 How to quantify transferable risks

3.4.3.1 Construction cost risk

Construction cost for the Modified VFM calculation

Along with the question of which risks are considered as transferable risks, how to quantify these risks also must be included in the calculation of the Modified VFM. With respect to construction cost risk, in the Korean context, the construction cost used in the Modified VFM calculation can be conceptually expressed using estimated price, winning bid ratio and construction cost overrun, as follows (Park and Preston, 2013b):

$$\text{CHA } \boldsymbol{CC = CC_{competion} = CC_{contract} + \Delta CC_{completion-contract}}$$

$$\boldsymbol{= CC_{contract} \times \left\{1 + \frac{\Delta CC_{completion-contract}}{CC_{contract}}\right\}}$$

$$\boldsymbol{= EP \times WBR \times (1 + \alpha) = EP \times application\ ratio} \tag{3-10}$$

where CC = construction cost used in the Modified VFM assessment, $CC_{completion}$ = construction cost at completion, $CC_{contract}$ = construction cost at construction start, $\Delta CC_{completion-contract}$ = the construction cost increase between completion and construction start, EP = estimated price,[28] WBR = winning bid ratio and α = construction cost overrun ratio $\left(\frac{\Delta CC_{completion-contract}}{CC_{contract}}\right)$.

[27] Though operation costs are not considered as transferable risks, some of them are quantified to be used in the Monte Carlo Simulation.

[28] Estimated price means the construction price that the delivery authority uses for the bidding process after reviewing the designed price. Therefore, the estimated price could be slightly different from the designed price, usually by ± 2 per cent (Kim et al., 2008a). Nonetheless, the designed price will be used

Public works in Korea are delivered using turn-key bid, alternative bid or design-bid-build. In turn-key or alternative bids, the designer who is selected through a bidding process becomes the contractor for the project, whereas in design-bid-build bid the designer and the contractor are different each other. The difference between turn-key and alternative bids is a design scope. In turn-key bid the design scope is all the parts of the project, whereas in alternative bid it is restricted to main part of the project which a delivery authority determines.

With respect to equation (3-10), according to Korea's BTL guidelines (MOSF, 2009a), the construction cost of a PSC in the Modified VFM is calculated using the designed price for construction and an average winning bid ratio of turn-key/alternative bids[29] in similar projects without considering construction cost overrun. This means that an average winning bid ratio of turn-key/alternative bids can be used instead of $\mathrm{WBR} \times (1 + \alpha)$ in equation (3-10). This is because a construction cost increase is usually not allowed in turn-key/alternative bids except in regard to inflation or cases in which the delivery authority is responsible for it. As a result, the public sector does not have to consider construction cost overrun when estimating a PSC.

However, although it is true that some projects use the turn-key/alternative bid system, the typical bid system in conventional delivery is in fact design-bid-build. Additionally, it still remains unknown how much construction cost rises from start of construction to completion when the three bid systems (turn-key, alternative and design-bid-build) are considered in each transport programme in Korea.

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instead of the estimated price to calculate the construction cost of a PSC under the assumption that the estimated price is the same as the designed price (because the estimated price is usually not open to the public). The designed price is mainly calculated using the Standard Estimation book, which is published annually by the Korea Institute of Construction Technology on behalf of the MLTM. In order to calculate the designed price, the quantities of cost items, such as materials, labour and equipment for construction, are estimated using this book at the design stage, and then the designed price is calculated by multiplying these quantities by unit costs from the market (Kim et al., 2005). However, there are some difficulties in instantly considering new construction technology or project market price with this method, so since 1997 the Korean Government has been accumulating detailed historical work costs for later use.

[29] Strictly speaking, winning bid ratio does not exist in turn-key/alternative bid because these bid systems use not only the price part but also the technology part to select a bid winner. Therefore, the exact expression is not "winning bid ratio" but the "ratio of bid winner" price to estimate the price in turn-key/alternative bid. However, "winning bid ratio" is usually used instead of this exact expression, so this term is used in this study.

For this reason, in this study a substitute for an average winning bid ratio of turn-key/alternative bids, named as an application ratio in equation (3-10), is developed using historical observations, and accordingly the application ratio risk means the construction cost risk. An application ratio is composed of the winning bid ratio risk and the construction cost overrun risk, as quantified from historical observations.

Construction cost overrun risk (α)

Construction cost on completion is usually composed of contract construction cost, inflation and cost increment by construction quantity increase due to design changes.[30]

From the historical observations obtained, it is impossible to know how much of the cost increment was incurred in a certain project, so some assumptions are needed. According to KDI (2004a), among construction cost increments approved by the finance authority between start and completion, design change accounts for 53.7, 50.7 and 62.4 per cent in the National Highways, the National Expressways and the National Railways, respectively. Using this information, cost increment by design changes can be calculated, and adding an assumption that design changes occur equally throughout the construction period, the construction cost on completion can be calculated in real terms. With respect to the inflation rate, according to the general guidelines for preliminary feasibility studies (KDI, 2008b) and Korea's BTL guidelines (MOSF, 2009a), the construction deflator[31] provided by the Bank of Korea is recommended for construction cost, so this inflation index will be used for the calculation of construction cost overrun risk in real terms.

Regarding the measurement of the construction cost overrun, the inflation effect should firstly be eliminated from the construction cost on completion to find out how much the construction cost changes are due to design changes. Then, the construction cost overrun (α) in real terms adjusted for design changes can be defined as follows (Park and Preston, 2013b):

$$\boldsymbol{\alpha} = \frac{\boldsymbol{Construction\ cost_{completion} - Construction\ cost_{contract}}}{\boldsymbol{Construciton\ cost_{contract}}} \times \mathbf{100}\ \% \qquad (3\text{-}11)$$

[30] There are many factors that can cause a design to change. Unexpected geological conditions, construction plan changes, traffic demand changes and unit price changes could be significant causes of design change. In this research, design changes mean all the changes occurring in the construction period which mean the construction price changes (excluding inflation), irrespective of the factor responsible for these changes.

[31] Construction deflator means the construction investment deflator referred to in Expenditure on Gross Domestic Product on National Accounts.

where $construction\ cost_{completion}$ means construction cost on completion in real terms adjusted for design changes, and $construction\ cost_{contract}$ means construction cost in real terms when the construction contract was awarded.

Winning bid ratio risk

Winning bid ratio means the proportion of contract construction cost to estimated construction cost. In the absence of a calculation, this is directly available from the historical observations in each transport programme.

3.4.3.2 Completion delay

Definition

Completion delay in construction refers to the time overrun beyond what was initially planned, such as the completion date specified in a contract (Assaf and Al-Hejji, 2006), and it can occur due to various unanticipated changes in circumstances: 1) contract management; 2) site conditions; 3) changes in requirements or design; 4) weather; 5) unavailability of labour, material, or equipment; 6) defective plans and specifications; and 7) the owner's interference (Bramble and Callahan, 2011).

Systematic completion delay in Korea

However, in Korea, completion delays are expected to occur more systematically due to the unusual national budget system, i.e. the LEC system. With respect to systematic completion delays in Korea, according to Ahn (2006), among 197 road projects completed between 2001 and 2005, 155 projects (86.5 per cent) were delayed, and among the delayed projects 134 projects (79 per cent) were delayed due to a lack of funds.

According to the LEC system,[32] an infrastructure project starts by reflecting its first-year expenditure in the Budget Book, as settled by the National Assembly, even if the total expenditure of the project is not secured in the Budget Book. Using this system, too many infrastructure projects compared with the size of the budget tend to be implemented by reason

[32] The LEC is outlined in Article 21 of the Act on Contracts, to which the State is a party. The inefficiency of the LEC is criticised by NGOs like the Citizen's Coalition for Economic Justice (CCEJ). CCEJ (2010) criticised it for inducing too many projects to start without considering the available budget.

of political necessity, such as a balanced regional development policy. As a result, each project under construction experiences budget constraints and a systematic completion delay occurs.

How to estimate completion delay

With the LEC system, although a construction contract is awarded based on the total construction cost and construction duration in the first-year, the contract is renewed every year considering the yearly budget allocated to the project and resulting in a completion delay. Accordingly, for a government official who is in charge of contract, it is impossible to know how long it will take to complete a project under the LEC system. However, when awarding a contract, the contract usually takes five years to be the construction duration, considering a standard construction duration suggested by KDI (2008a) and MLTM (2010c), based on the project delivery practice[33] of Korea.

Usually real construction duration can be shortened or lengthened depending on project size and construction difficulty, so it is more reasonable for a government official to adjust construction duration considering project characteristics when awarding contracts. However, it is not easy for him/her to do so, because they are usually so conservative that they cannot feel the need to use different construction duration in a situation that standard construction duration (5 years) was already provided by KDI. In addition, it seems that sometimes they can feel so risky to do so considering the annual inspection from the Board of Audit and Inspection (therefore, it seems that KDI needs to provide more detailed standard construction duration reflecting project size and construction difficulty).

As practical evidence, according to the contract details of 24 National Highway projects (Lee, 2007), awarded by Wonju Regional Construction Management Office, a five-year construction duration was applied to all the contracts regardless of project size. Then, considering the yearly budget for each project, completion duration was lengthened in each contract.

Considering the LEC system and a standard construction duration used in Korea, it is assumed in this research that the normal construction duration is five years in the conventional delivery as well as in the PPP options if there is no confinement in the construction funds.

In addition, although, in light of the Korean context, the budget constraint is the main reason for completion delay in conventional delivery (CERIK, 2011, Kim et al., 2008b, Ahn, 2006), there could be a variance in completion delay related to project characteristics: size, geological or

[33] In order to complete a project earlier, a large project is usually delivered by several small projects of a proper size; by doing so the Korean government can also widen the effects of public investment to more contractors and more people.

topographical conditions and main work types (e.g. tunnel and bridge). With respect to project size, a smaller project could have shorter construction duration than a larger project. However, as there is practically no detailed standard construction duration considering project size, it is difficult to estimate construction delay from historical construction duration observations. When it comes to the other characteristics, the historical observations do not have sufficient information on them. Accordingly, for a simple consideration, a completion delay in the conventional delivery is assumed to occur only due to lack of funds.

3.4.3.3 Traffic volume risk

Why traffic volume risk occurs in Korea

Traffic volume risk in Korea can be explained in various ways. According to Cho (2011), the reasons why forecast traffic volume differs so greatly from actual traffic volume can be summarised as follows: 1) uncertainty of surrounding related development plans; 2) uncertainty of surrounding future socio-economic indices; 3) low reliability of origin-destination (O-D) trip data; 4) limitation of the forecasting model itself; and 5) absence of standardised guidelines for traffic volume forecasting.

In order to enhance the accuracy of traffic volume forecasting, the Korean government has been developing the National Transportation Database since 2001, which includes the following elements: 1) regional passenger and freight O-D (purpose, mode, item etc.); 2) trip generation characteristics of major transport facilities; 3) traffic counting data on main points; 4) transport thematic map; 5) transport indices; and 6) bibliographic data (Cho, 2011).

Traffic volume risk

Traffic volume risk in this research is defined as the proportion of actual traffic volume to forecast traffic volume, as shown in equation (3-12):

$$\textbf{Traffic volume risk} = \frac{\textbf{Traffic volume}_{\textbf{actual}}}{\textbf{Traffic volume}_{\textbf{forecast}}} \tag{3-12}$$

where Traffic volume $_{\text{actual}}$ = actual traffic volume in operation and Traffic volume $_{\text{forecast}}$ = forecast traffic volume at the design stage.

As appropriate traffic volume observations for the National Highways and the National Expressways are not available, the road traffic volume inaccuracy in Korea by Kim (2007) will inevitably be utilised. According to Kim (2007), the traffic volume inaccuracy (I) is defined as follows:

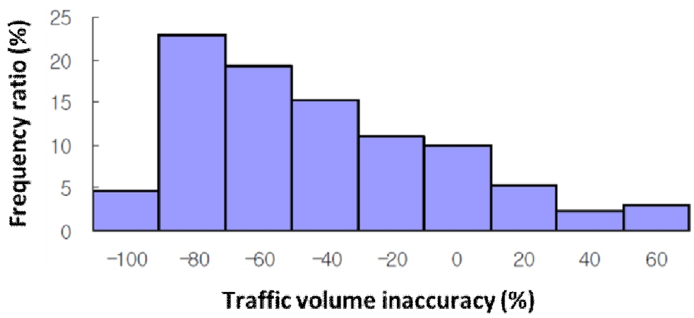
$$\mathbf{I} = \frac{T_a - T_f}{T_f} \times \mathbf{100\ (\%)} \tag{3-13}$$

where I = traffic volume inaccuracy, T_a = actual traffic volume and T_f = forecast traffic volume.

Using this information, equation (3-12) can be expressed as follows (Park and Preston, 2013b):

$$\textbf{Traffic volume risk} = \mathbf{I + 1} = \frac{\textbf{Traffic volume}_{\textbf{actual}}}{\textbf{Traffic volume}_{\textbf{forecast}}} \tag{3-14}$$

As the traffic volume inaccuracy from 171 road projects by Kim (2007) is not provided by raw data but by frequency bar graph, shown in Figure 3-3, traffic volume risk is calculated by digitising the graph.



Source: Kim (2007)

Figure 3-3: Traffic volume inaccuracy in roads

With respect to railways, the changes of railway traffic volume in Korea are gathered from various literatures as a form of raw data (the details are given in Table 6-3).

3.4.4 Other risk factors considered

Apart from the transferable risks used in this research, some other risk factors that identified in section 3.4.1 are also quantified for the Monte Carlo Simulation of the Modified VFM. These risk factors include operation costs (See 4.2.1.1, 5.2.2.1 and 6.2.2.1), construction deflator and consumer price index (See 4.2.2.2), five-year exchequer bond interest rate and three-year non-guaranteed corporate bond interest rate (See 4.2.2.3). Though operation costs can be transferable risks according to Table 3-3, they are not considered as transferable risks in this thesis because it is difficult to find their reference costs in Korea and it is impossible to consider operation cost overruns for the Modified VFM. Therefore, operation costs are considered separately here. In addition, though construction deflator, consumer price index, five-year exchequer bond interest rate and three-year non-guaranteed corporate bond interest rate are important in the Modified VFM calculation, it is difficult to consider them as transferable risks because they are related to project environments not a specific project. Accordingly, they are considered separately here.

3.4.5 Probability distribution functions

In order to use risk factors in the Monte Carlo Simulation, each risk factor is quantified, if possible, as a form of probability distribution function (PDF). To determine the best PDF for a risk factor, a goodness of fit (GOF) test with a Chi squared test[34] (χ^2) was implemented at the significance level 0.05 using @Risk 5.7.[35]

If the Chi squared test statistic is smaller than the critical value of the statistical hypothesis test at the significance level 0.05 $\left(e.g.\, \chi^2 < {\chi^2}_{0.05}\right)$ or the p value is larger than 0.05, then the null hypothesis (H_o), stating that the sample data come from the stated distribution, is accepted within the significance level 0.05. When a risk factor has a PDF passing the Chi squared test, the PDF will be used for the Monte Carlo Simulation. Otherwise, the distribution histogram will be used.

[34] The Chi squared (χ^2) statistics estimate the extent to which the expected frequency of the fitted distribution compares with that of a histogram of observed data (Vose, 1996). The following formula shows the Chi squared statistics:

$$\chi^2 = \sum_{i=1}^{n} \frac{\{O(i) - E(i)\}^2}{E(i)}$$

where n is number of bins, $O(i)$ is the observed frequency of the ith histogram class or bar and $E(i)$ is the expected frequency from the fitted distribution of x-values falling within the x-range of the ith histogram bar.

[35] @Risk 5.7 is risk analysis and simulation add-in for Microsoft Excel by Palisade Corporation. This software makes it possible to use the Monte Carlo Simulation as well as probability distribution fitting.

3.5 Impact analysis

In order to establish the impact of transferable risks on the PPP decisions in the transport infrastructure of Korea, this research compares the Modified VFM results, including transferable risks, with those based on the BTL guidelines (MOSF, 2009a). To estimate the Modified VFM with quantified risks, there are largely two kinds of approaches: 1) deterministic approaches like single-value estimation and sensitivity analysis; and 2) probabilistic approaches like Monte Carlo Simulation (Tanaka et al., 2005, Park, 2007). In this research, which uses single-value estimation, sensitivity analysis and Monte Carlo Simulation, the impact of the transferable risks on the Modified VFM and PPP decisions will be examined in order to assess the changes of the most appropriate procurement option depending on reflecting each transferable risk.

3.5.1 Single-value estimation

The impact of transferable risks on the PPP decision will be mainly assessed using the single-value estimation method, reflecting the mean value (expected value) of the probability distribution of each transferable risk on the Modified VFM calculation. By doing so, how much each transferable risk influences PPP decisions will be examined, comparing the Modified VFM results with each risk and those without each risk.

3.5.2 Sensitivity analysis

Why a sensitivity analysis?
A sensitivity analysis is probably the most representative approach among the deterministic techniques. A sensitivity analysis usually considers the effects of risk variables, considered to be critical to a decision-making, on decision-making. Therefore, future uncertainty from risk variables, the vulnerability of a procurement option decision or a determinant value regarding decision-making can be examined (HM Treasury, 2003, MLTM, 2010c). In other words, a sensitivity analysis is conducted with a view to finding how a determinant for a transport decision-making can be changed, depending on the variation of risk variables, such as discount rate and construction cost.

A sensitivity analysis can be developed into a scenario analysis, which is a complicated sensitivity analysis. A scenario analysis can reveal the changes of a determinant for a decision-making by using scenarios, which are combinations of simultaneous changes of risk variables (Van Groenendaal and Kleijnen, 1997).

However, there are some shortcomings to a sensitivity analysis, as follows: 1) equal probability of occurrence is assumed in all cases even if some scenarios have an extremely low probability of occurrence; 2) correlations between the variables are not considered; and 3) too many scenarios in projects are needed, considering the number of items and activities and their combination (Tanaka et al., 2005).

Use in this research

In this research, a sensitivity analysis is used to find out how the Modified VFM ($M.VFM_{BTO}$, $M.VFM_{BTL}$ and $M.VFM_{BTL-BTO}$) results can vary depending on the changes (fluctuation from -20 to +20 per cent) of calculation factors, such as discount rate and construction deflator, which are estimated based on Korea's BTL guidelines (MOSF, 2009a). In addition, in terms of the impact of the transferable risks on the Modified VFM, a sensitivity analysis is not used because the analysis can be done more comprehensively using the Monte Carlo Simulation.

3.5.3 The Monte Carlo Simulation

Why Monte Carlo Simulation is preferred

Although there could be various risk assessment methodologies, such as fuzzy set theory and decision tree analysis, it seems that Monte Carlo Simulation is almost the only risk quantification methodology recommended in the guidelines of various countries such as Australia (2008b), Hong Kong (2008b) and Canada (2011) because this method is able to give powerful solutions for decision-making (Shim et al., 2005b).

To use Monte Carlo Simulation, the probabilistic distribution of the cost items or activities being analysed should firstly be defined. Random numbers are then generated over and over to calculate the resulting value, as with the Modified VFM, until the iteration meets the confidence level. Finally, the repeated simulation results are displayed by histograms or accumulated frequency distribution curves. In addition, the correlations[36] between variables can also be

[36] In this research, the following correlations are considered using @Risk 5.7: 1) between winning bid ratio and construction cost overrun; 2) between construction deflator and consumer price index; 3) five-year exchequer bond rate and three-year non-guaranteed corporate bond interest rate.

considered in Monte Carlo Simulation because this simulation considers the probabilistic distribution of main variables at the same time (Palisade Corporation, 2010).

Monte Carlo Simulation using historical observations

With Monte Carlo Simulation, defining the probabilistic distribution of risk factors is very important in simulating results. If there are proper historical observations, the probabilistic distribution can be defined from these data, while if these are absent then this distribution can be assumed by personal or organisational intuitions and decisions (Park, 2007). However, when the probability distribution is assumed, there is always the possibility that subjectivity can affect the simulation results, which can be one of the faults of this method (Lee, 2003).

Table 3-4: Research using Monte Carlo Simulation in transport

Researchers	Purpose of research	Project
Pouliquen (1972)	Feasibility analysis to supplement sensitivity analysis for IBRD projects to support underdeveloped countries	Lighterage port project (Somalia), Tanzan highway project (Zambia)
Lam and Tam (1998)	Investment decision making for BOT project considering traffic demand risk	Neilingding Crossing (near Hong Kong)
Malini (1999)	Development of probabilistic simulation model for BOT project	Municipal bridge (India)
Lee et al. (1999)	Development of risk analysis framework for PPP Expressway project	Seoul Beltway, Daejeon-Dangjin Expressway (South Korea)
Ye and Tiong (2000)	Development of NPV-at-risk model for the investment of BOT project	Power plant project (hypothetical)
Jung et al. (2001)	Establishment of financial risk assessment model for BOT light rail project	Light rail project (South Korea)
Grimsey and Lewis (2002)	Establishment of risk assessment model for PPP project from the viewpoint of procurer, sponsor and lender	Almond Valley and Seafield Sewage Project (Scotland)
Lee (2003)	Development of evaluation model for ITS project	Daejeon ITS project (South Korea)
Molenaar (2005)*	Development cost estimation validation process	Highway Megaprojects (US)
Girmscheid (2009)	Analysis of economic efficiency of PPP	Municipal street maintenance (Swiss)
Sadeghi et al. (2010)	Development of fuzzy Monte Carlo framework to consider uncertainty	Highway overpass project
Salling and Leleur (2011)	Development of CBA-DK software model for transport decision-making	Transport appraisal (Denmark)

Note: Research with (*) used probabilistic density function from historical observations

From a review of the literature on the use of Monte Carlo Simulation in the transport area, it appears that since Pouliquen (1972) used this method in feasibility studies of the port and highway projects supported by IBRD, previous research adopting this method has primarily focused on financial or economic analysis (Lam and Tam, 1998, Malini, 1999, Lee et al., 1999, Jung et al., 2001, Grimsey and Lewis, 2002, Lee, 2003, Molenaar, 2005, Salling and Leleur, 2011). Other than that, this method has been used for developing a risk analysis model (Sadeghi et al., 2010).

As seen in Table 3-4, research using probabilistic distribution from historical observations is very rare and this research is also differentiated from other research in using historical observations that reflect project realities in Korea.

Use in this research

In this research, Monte Carlo Simulation is used to find out the changes of the Modified VFM and the selection of procurement options for case studies by using PDFs for risk variables (transferable risks and other risks), compared with the results from a single-value estimation method.

3.6 Case studies

One of the main objectives of this research is to determine the impact of the transferable risks (completion delay, construction cost risk and traffic volume risk) on PPP decisions with respect to the National Highways, the National Expressways and the National Railways in Korea.

To this end, six different projects (two projects for each transport mode) in two project groups have been considered: Group 1) involves three projects where a PPP decision has already been made, so these projects are under construction or are in operation; Group 2) involves three projects where a PPP decision has not already been made or that are awaiting commencement after procurement option decision-making. Candidate projects are shown in Table 3-5 and in Figure 3-3.

Table 3-5: Candidate projects for case study

Transport programme			National Highway	National Expressway	National Railway
Group 1	**Project**		**Todang-Gwansan**	**Suwon-Pyungtaek**	**Sosa-Wonsi**
	Status	Stage	Construction	Operation	Construction
		Delivery option	Conventional	BTO	BTL
		Completion	2012	2006	2016
		Tariff	-	○	○
		MRG	-	○	-
		Subsidy/lease fee	-	○	-
	Case study	PPP type	BTL	BTO, BTL	BTO, BTL
		MRG	-	○	○
Group 2	**Project**		**Dongup-Hanlim**	**Songsan-Bongdam**	**Bujeon-Masan**
	Status	Stage	Waiting for construction	PPP decision completed	Feasibility stage
		Delivery option	Conventional	BTO	BTL
		Construction	Uncertain	Uncertain	Uncertain
		Tariff	-	○	○
		MRG	-	-	-
		Subsidy/lease fee	-	○	○
	Case study	PPP type	BTL	BTO, BTL	BTL
		MRG	-	-	-

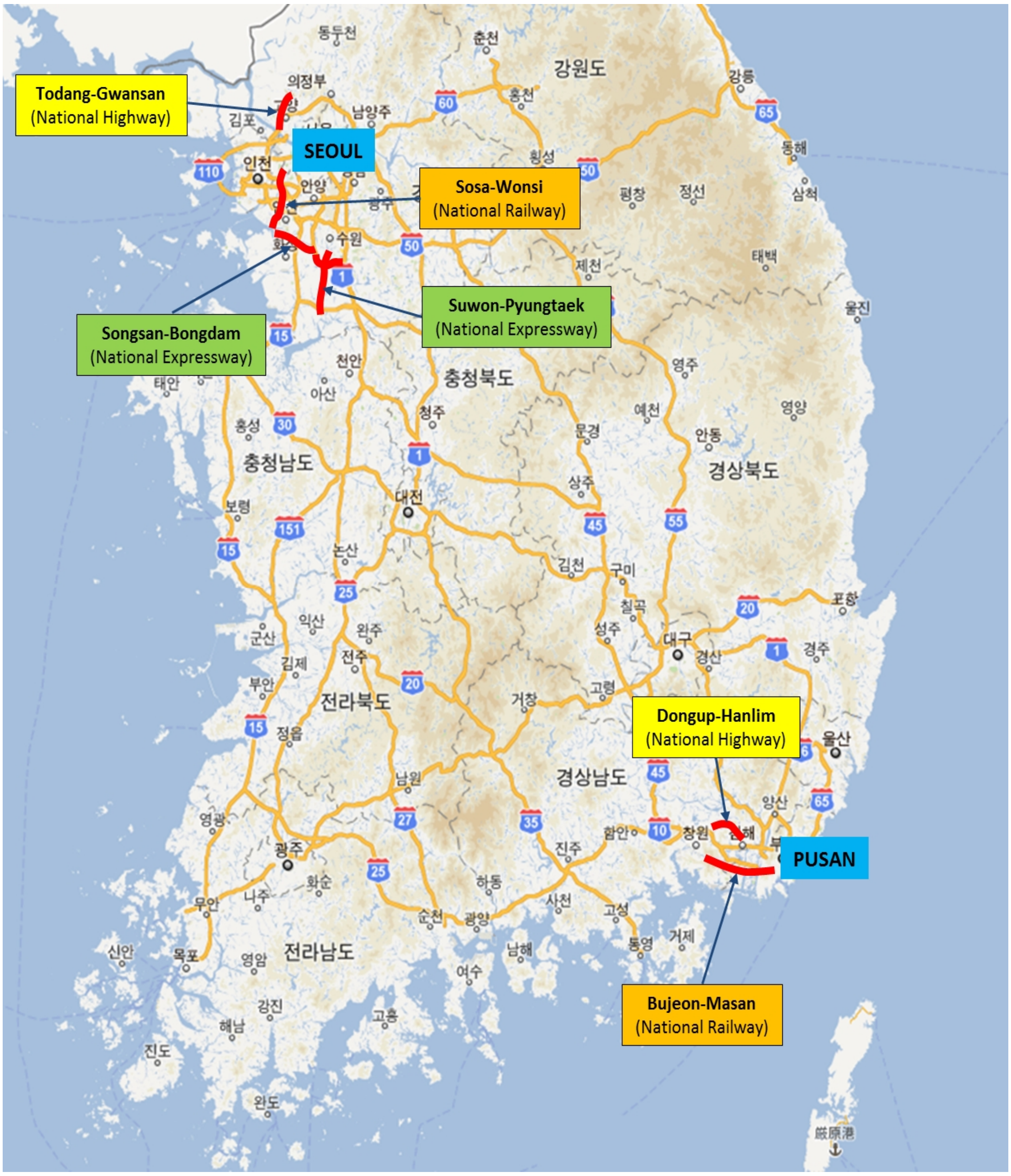
For the case studies in Group 1, whether the PPP decision made in the past was appropriate will be scrutinised through the Modified VFM assessment with quantified risks. In addition, Group 2 case studies will provide some new information on PPP decisions for these projects before commencement, so they could be helpful to justify the procurement option already selected by providing a more robust basis – or indeed to change the existing procurement option by pointing to a more reasonable alternative.

With respect to the National Highway programme, as the National Highways do not have any experience in PPP procurement to date, many options for case study projects are available. Among many projects, the Todang-Gwansan project (Gyeonggi Province) and the Dongeup-Hanlim project (Gyungnam Province) are selected for Group 1 and Group 2 respectively. The Todang-Gwansan case is selected as a Group 1 project because it is a recent project with a high benefit-cost ratio (more than 2.0) in the National Highway programme. Similarly, the Dongup-Hanlim case is selected as a Group 2 project because it is one of the projects waiting to start in the very near future with a moderate benefit-cost ratio (about 1.2). The case studies for the National Highways will consider only BTL schemes because they are toll-free roads, which are different from other transport programmes, i.e. the National Expressway and the National Railway.

Being different from the National Highway programme, the National Expressway programme has many PPP experiences with BTO schemes. As a Group 1 project, the Suwon-Pyungtaek project is chosen because it is the most recently completed project in this programme with a BTO scheme. In addition, the Songsan-Bongdam is selected as a Group 2 project because this project is waiting to start the PPP procedure in the near future (the PPP decision to use the BTO option was made in 2012).

When it comes to the National Railway programme, projects using PPP schemes are relatively rare. Although there has been one BTO project (the Incheon International Airport Railway), since 2005 the BTL option has been predominant in the National Railways. Therefore, case study projects are selected from among BTL projects. Firstly, the Sosa-Wonsi case is considered as a Group 1 project because it is the biggest BTL project ever undertaken in Korea. Along with this, the Bujeon-Masan project is considered for Group 2 because it has already undergone a PPP pre-qualification test and it is easy to obtain project details from the PPP pre-qualification report.

As shown in Figure 3-4, the case studies are located either in Gyeonggi Province (surrounding Seoul) or Gyungnam Province (near Busan).



Source: map.google.com

Figure 3-4: Location of case study projects

3.7 Meta-analysis

Meta-analysis and previous research

Since the beginning of the 20th century, many efforts have been made to draw a powerful conclusion, which is objective as well as trustworthy, by synthesising available findings from various pieces of literature or case studies under the name of "systematic review" (Oh, 2002, Higgins and Green, 2011) in various research fields, especially in medical treatment (Simpson and Pearson, 1904, Cochran, 1937) and agriculture (Fisher et al., 1932).

Although in some regions, such as North America, the term "systematic review" is interchangeable with "meta-analysis", "systematic review" in fact refers to the whole process of identifying, appraising, selecting, synthesising and presenting all available evidence, whereas "meta-analysis" refers only to the statistical techniques used in mixing and extracting studies to produce results (Cochrane Collaboration, 2002, Higgins and Green, 2011).

Usually a meta-analysis means using a statistical method for summarising available specific or subjective findings from the literature or case studies into a more general or objective conclusion (Crombie and Davies, 2009). The term was first used by Glass in 1976. According to Glass (1976), meta-analysis simply refers to "the statistical analysis of large collections of analysis results from individual studies" in order to integrate findings, and it is also called as "analysis of analyses". The meta-analysis is widely used, including in psychology, education and economics, to say nothing of medical research and agriculture (Button, 1995).

As well as other research fields, many pieces of research have been conducted using meta-analysis in transport research fields, with the main topics including the following: 1) valuing travel time saving (Wardman, 2004, Zamparini and Reggiani, 2007, Shires and de Jong, 2009); 2) property value in relation to transport infrastructure (Nelson, 2004, Debrezion et al., 2007); 3) elasticity of transport demand (Goodwin et al., 2004, Brons et al., 2002); and 4) transport safety (Elvik, 2001, Bunn et al., 2003, de Blaeij et al., 2003).

The objective of meta-analysis

The typical objective of meta-analysis is to analyse comprehensively the relationship between outcome estimates and their related variables from the pool of findings from the literature or case studies, by producing systematic explanation of differences in the outcomes (Debrezion et al., 2007, Smith and Huang, 1995). In other words, using a meta-analysis, the impact of the variables on the outcome estimates, such as direction and magnitude, can be examined (Jang and Shin, 2011). Through this process, outcome estimates from various studies can be scrutinised in regard to whether they are statistically more or less than a base value, and some general or transferable conclusions can be drawn (Brons et al., 2002). In order to achieve the objective of meta-analysis, the procedure, though not sequential, is usually separated into five fundamental phases: 1) formulation of research problem; 2) collection of studies; 3) identification of relevant variables and model composition; 4) statistical analysis; and 5) description of findings (Zamparini and Reggiani, 2007).

Meta-regression

Generally speaking, when analysing heterogeneous research work, the ranges of research fields and statistical issues which need to be addressed, are so wide that the statistical methods employed in meta-analysis can be diverse (Button, 1995). Among various meta-analysis techniques, meta-regression is powerful when examining the relationship between one or more quantitative variables and outcome results. Though meta-regression was adopted for the purpose of handling heterogeneity problems between prior studies in meta-analysis, it is nowadays recommended for use in almost all meta-analysis sectors because it provides greater knowledge and a clearer explanation about the relationship between causes and effects as well (Chang, 2012, Higgins and Green, 2011). Meta-regression is seen to be different from simple multiple regression in two respects, although these are superficially similar. First, more influence on the relationship is expected in larger studies than in smaller studies because studies are weighted by the standard errors of their respective effect value. Second, meta-regression considers the residual heterogeneity among case studies (Higgins and Green, 2011, Chang, 2012).

With respect to meta-regression, from the viewpoint of the relationship between causes and effects, the general functional form can be expressed as follows (Button, 1995, Florax et al., 2002):

$$\boldsymbol{Y = f(P, X, R, T, L) + \epsilon} \tag{3-14}$$

where Y = the variable under study, P = the set of causes of the outcome Y, X = the characteristics of the set of objects under examination affected by P in order to determine the outcome Y, R = the characteristics of research method, T = the time period covered by the study, L = the location of each study conducted, ϵ = the error term

Fixed-effects model and random-effects model

Meta-regression basically attempts to explore variation in effects (the Modified VFM in this research) through the independent variables composing the regression model. According to

Morton et al. (2004), although a meta-regression could take various forms, among them the fixed-effects model and random-effects model are the most popular in the literature.

The fixed-effects model assumes that the effects are random samples selected from one true value. In other words, the effect sizes are assumed to have only within-study variance without between-study variance. As a result, the variance in the meta-regression means the within-study variance (σ_i^2) comes only from the sampling error. Additionally, the weight (w_i) of each effect size is expressed as the reciprocal of the variance (w_i= 1/σ_i^2). Assuming a single true effect size (θ), the effects (y_i) can be statistically expressed as follows (Harbord and Higgins, 2008, Debrezion et al., 2007):

$$y_i \sim N(\theta, \sigma_i^2) \tag{3-15}$$

or equivalently:

$$y_i = \theta + \varepsilon_i \quad \text{where } \varepsilon_i \sim N(0, \sigma_i^2) \tag{3-16}$$

by replacing the mean (θ) with a linear predictor, $x_i\beta$:

$$y_i = x_i\beta + \varepsilon_i \quad \text{where } \varepsilon_i \sim N(0, \sigma_i^2) \tag{3-17}$$

where β is a k × 1 vector of coefficients, including a constant, and x_i is a 1 × k vector of covariate values in study *i*.

A random-effects model, on the other hand, assumes that the variance is composed of two different parts: the within-study variance (σ_i^2), and the between-study variance (τ^2). Thus, the weight of each effect size can be expressed as the reciprocal of each total variance (w_i= 1/($\sigma_i^2 + \tau^2$). Statistically, assuming that the true effects (θ_i), which vary between studies, follow a normal distribution around a mean effect (θ) with between-study variance (τ^2), the effects (y_i) can be expressed as follows (Harbord and Higgins, 2008, Debrezion et al., 2007):

$$y_i|\theta_i \sim N\left(\theta_i, \sigma_i^2\right), \ \text{ where } \ \theta_i \sim N(\theta, \tau^2) \tag{3-18}$$

so:

$$y_i \sim N(\theta, \sigma_i^2 + \tau^2) \tag{3-19}$$

or equivalently:

$$y_i = \theta + u_i + \varepsilon_i \ \text{ where } u_i \sim N(0,\ \tau^2) \text{ and } \varepsilon_i \sim N\left(0, \sigma_i^2\right) \tag{3-20}$$

by replacing the mean (θ) with a linear predictor, $x_i\beta$:

$$y_i = x_i\beta + u_i + \varepsilon_i \text{ where } u_i \sim N(0, \tau^2) \text{ and } \varepsilon_i \sim N\left(0, \sigma_i^2\right) \quad (3\text{-}21)$$

In the event that the between-study variance does not exist, the result of the random-effects model is the same as the fixed-effects model, so the random-effects model can be regarded as an extension of a fixed-effects model allowing for residual heterogeneity. Therefore, the fixed-effects model is not usually recommended because it does not consider residual heterogeneity (Harbord and Higgins, 2008) though this can be picked up by case specific dummy variables.

Use of meta-regression in this research

In this research, based on the Modified VFM values with various conditions from six cases, the impact of some quantitative and qualitative variables on the Modified VFM in the land transport programme (roads and railways) of Korea is also examined, including the direction and magnitude of the impact.

In order to verify the direction and size of causes on the Modified VFM values from the six case studies in the land transport programme, the STATA-based meta-regression algorithm (*metareg*[37]) using the random-effects meta-regression model will be employed.

[37] Metareg is STATA command requiring STATA 8.0 or above, performing random-effects meta-regression on study-level summary data. This programme was originally written by Stephen Sharp in 1998 and then significantly rewritten by Roger M. Harbord and Julian P. T. Higgins in 2008. In this study, STATA Special Edition 12.1 was used for meta-regression analysis.

3.8 Methodological framework

The methodologies mentioned in this chapter are shown in Figure 3-5. By employing these methodologies, the impact of the transferable risks on the PPP decisions in each transport mode will be scrutinised and the most appropriate procurement options for the transport mode will be reviewed. As well as this, in the light of the land transport programme (roads and railways) of Korea, the question of which causes can lead to what effects on the Modified VFM will also scrutinised.

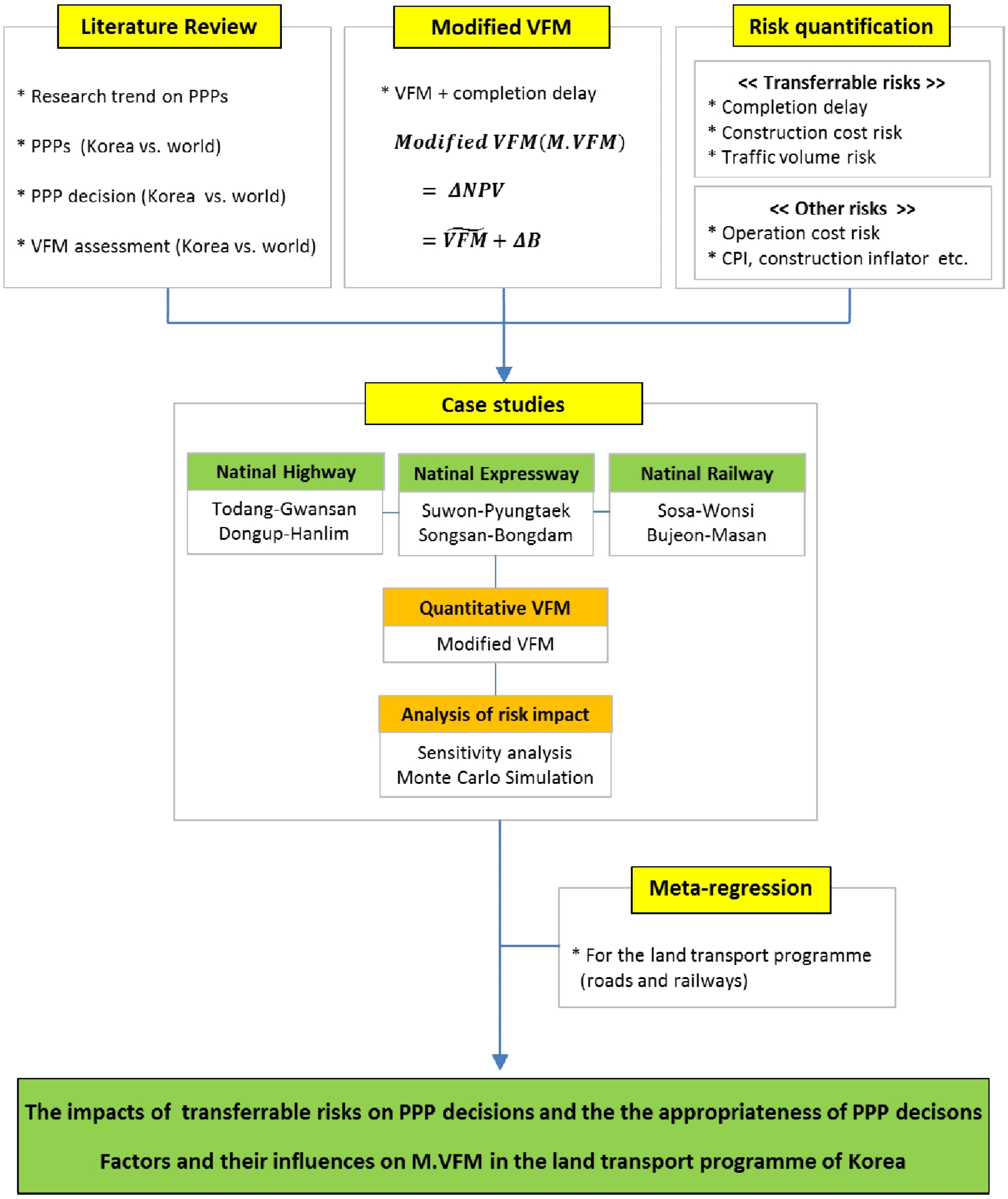


Figure 3-5: The methodological framework

3.9 Conclusion

As described above, this chapter deals with the research methodologies employed in order to achieve the objectives of this research. The essence of the chapter relates to the following: 1) the development of the Modified VFM; 2) the impact of transferable risks on the PPP decision through case studies; and 3) the use of meta-analysis to scrutinise the causes and effects on the PPP decision in the land transport programme.

Firstly, as the most common PPP decision-making methodology, the VFM is popular in many countries using PPPs. Despite its popularity, however, it seems difficult to find a unique VFM test meeting all the socio-economic conditions. For example, in some countries where the public sector cannot deliver sufficient (or any) funds without the help of the private sector, it is difficult to provide infrastructure services properly (i.e. on time and on budget). When using the VFM approach for PPP decisions, these countries have to pretend that a PSC could be a possible alternative (despite this being impossible). In this case, the VFM assessment using a PSC could be meaningless (because a PSC is a nearly impossible alternative). Therefore, from the viewpoint of the Korean context, considering completion delay in the conventional delivery, the Modified VFM was developed to overcome the limitation of the VFM analysis, not including completion delay in terms of a quantitative assessment.

Next is the impact of transferable risks on the PPP decision through case studies. To begin with, the transferable risks identified were completion delay, construction cost risk and traffic volume risk, and how to quantify them was also described in this chapter. In addition, in order to verify the impact of transferable risks on the PPP decision, the single-value estimation method will be mainly used, also subordinately adopting a sensitivity analysis and the Monte Carlo Simulation. With respect to the selection of case studies, six cases were selected taking into account transport programmes and project stages: 1) the National Highway programme, and the Todang-Gwansan and the Dongup-Hanlim; 2) the National Expressway, and the Suwon-Pyungtaek and the Bongdam-Songsan; and 3) the National Railway, and the Sosa-Wonsi and the Bujeon-Masan.

Lastly, in order to induce some general or transferable conclusion in the land transport programme from specific results in roads and railways, a meta-regression analysis, using the Modified VFM result data with various conditions, is employed in this research. Through meta-regression analysis, factors and their influences on the Modified VFM in the land transport programme (roads and railways) of Korea will be examined.

CHAPTER 4 The National Highway Case Studies

4.1 Introduction

The objective of this chapter is to determine the impact of transferable risks on the Modified VFM and the PPP decisions in the National Highway programme, using two case studies. The Todang-Gwansan National Highway case and the Dongup-Hanlim National Highway case are considered in this chapter, as explained in Chapter 3. Therefore, this chapter is largely made up of three sections covering the research objectives 2-1, 2-2 and 2-3: 1) quantified risks for the National Highways; 2) case study 1: the Todang-Gwansan case; and 3) case study 2: the Dongup-Hanlim case.

To begin with, risk quantification is conducted in section 4.2; this applies not only to transferable risks but also to other risks like operation costs and inflations, based on historical observation and the literature. Three transferable risks are considered in this section: construction cost risk (winning bid ratio risk and construction cost overrun), traffic volume risk and completion delay in conventional delivery. Other than that, eight risk variables are also quantified: operation costs (general maintenance cost/VKT, re-pavement cost/VKT and road structure maintenance cost/VKT), construction deflator, consumer price index, five-year exchequer bond interest rate, and three-year non-guaranteed corporate bond (AA-) interest rate. The risk quantification is performed using the @ Risk 5.7 software package.

In the Todang-Gwansan case (4.3) and in the Dongup-Hanlim case (4.4), the impacts of transferable risks on the Modified VFM and the PPP decisions are explored, using impact analyses such as single-value estimation, sensitivity analysis and the Monte Carlo Simulation, which are explained in Chapter 3 (3.5).

In short, for the calculation of the Modified VFM using single-value estimation and sensitivity analysis, analysis input data are estimated by following Korea's BTL guidelines (MOSF, 2009a) because the guidelines provide reference points for all the factors. When it comes to the Modified VFM using the Monte Carlo Simulation, analysis factors are used as a form of the probability distribution, quantified from historical observations. By doing so, the question of how the PPP or procurement decisions could be changed will be scrutinised, when they are reflected simultaneously in the Modified VFM.

4.2 Quantified risks for the National Highways

4.2.1 Transferable risks

4.2.1.1 Construction cost risk

Construction cost risk in the National Highway programme is estimated using the historical observations collected from 140 National Highway projects completed from 2006 to 2010. From equation (3-10), construction cost risk is composed of estimated price (EP), winning bid ratio (WBR) and construction cost overrun (α). Among these, EP (designed price in this research) is a constant for a project, so WBR and construction cost overrun are considered the risk factors.

Construction cost overrun

Construction cost overrun risk in real terms for the National Highways can be estimated from equation (3-11); the quantified PDF is shown in Figure 4-1. The mean value (expected value) is 9.98 (per cent), which means that the construction cost of a National Highway project is expected to increase, on average, by 9.98 (per cent) on the contract construction cost in real terms.

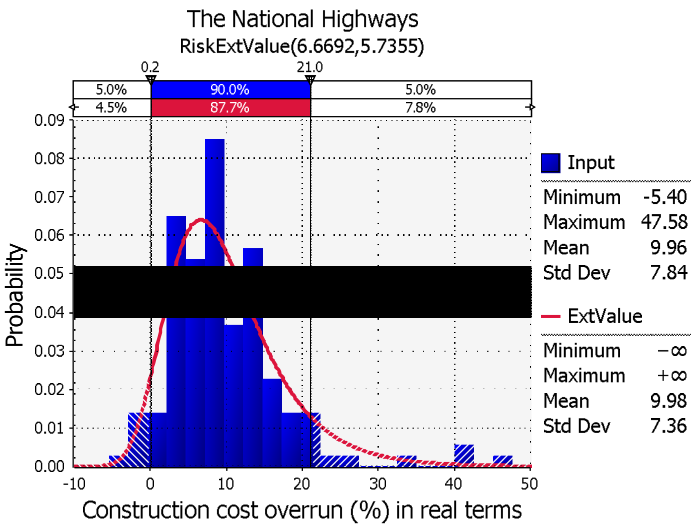


Figure 4-1: The PDF for construction cost overrun risk in the National Highways

WBR

WBR means the proportion of the bid winner's price (contract price) to the EP for a project. The WBR is directly obtained from the historical observations. In contrast to construction cost overrun risk, there are no PDFs passing the Chi square test (χ^2), so WBR risk is expressed as a form of frequency distribution, shown in Figure 4-2. From Figure 4-2, the mean value of WBR is 76.9 (per cent), which is the expected value of the winning bid ratio for a National Highway project.

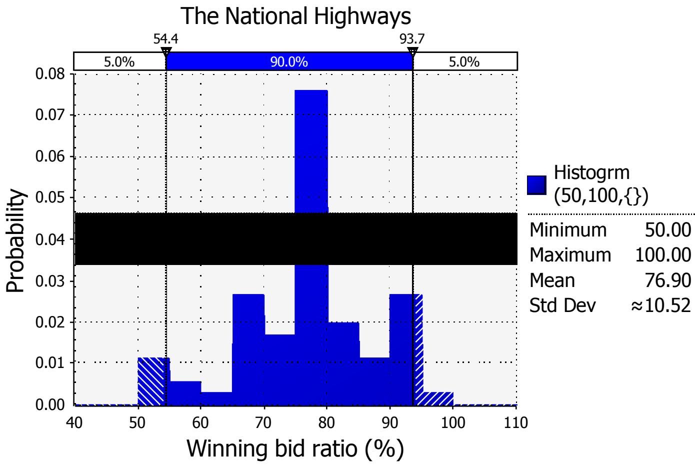


Figure 4-2: Frequency distribution for WBR in the National Highways

Application ratio

Based on construction cost risk and WBR estimated above, the application ratio in equation (3-10), meaning construction cost risk, can be calculated. Therefore, the mean value of the application ratio becomes 84.58 (per cent)[38], which will be used in order to estimate the Modified VFM using single-value estimation and sensitivity analysis. For the Monte Carlo Simulations (MCS) of the Modified VFM, the PDF of construction cost overrun and the frequency distribution of WBR will be used, shown in Figure 4-1 and Figure 4-2 respectively.

4.2.1.2 Completion delay

From the historical observations, the probability distribution of the completion delays in the National Highways is shown in Figure 4-3. As this makes clear, completion delay in conventional delivery is, on average, 7.74 years. Considering five years to be the standard construction duration (KDI, 2008a, MLTM, 2010c), as discussed in Chapter 3, 2.74 years of completion delay is expected to occur when using conventional delivery for a National Highway

[38] 84.58 (%) = 0.769 × (1+ 0.0998)

project. Though a PDF for completion delay can be obtained, it is not used for the MCS because the MCS requires too many calculation sheets in order to use the PDF of completion delay.

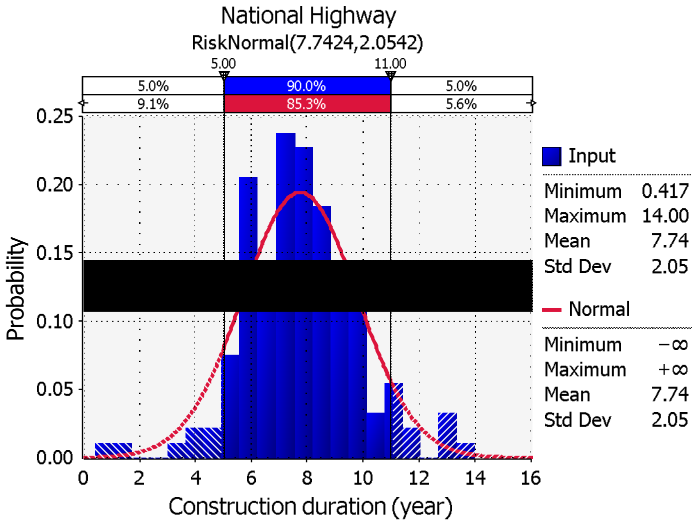


Figure 4-3: Construction duration in the National Highways

4.2.1.3 Traffic volume risk

As stated in Chapter 3 (3.4.3.3), from the bar graph of traffic volume inaccuracy in road sector, traffic volume risk, shown in Figure 4-4, can be generated according to equation (3-14). As seen in Figure 4-4, traffic volume risk is, on average, 0.686 in the road sector.

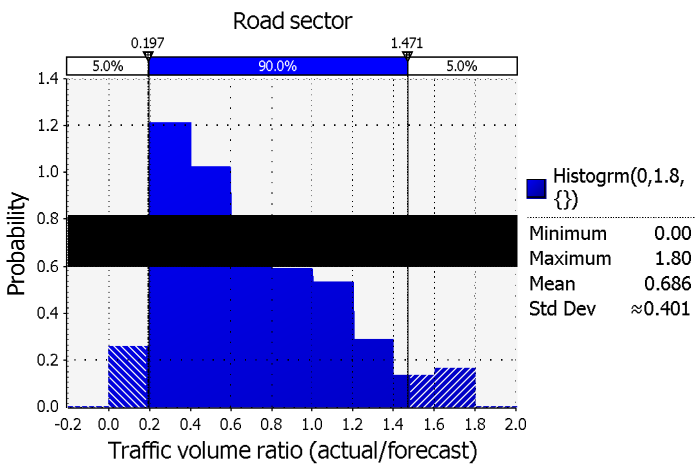


Figure 4-4: Traffic volume risk in the road sector

4.2.2 Other risk variables

4.2.2.1 Operation cost

In this study, the historical observations of the operation cost in the National Highway sector come from 18 regional National Highway Management Offices (NHMOs), not from individual projects. Therefore, the historical observation data concerns the executed budget in the respective NHMO from 2006 to 2010. Taking into account the availability of historical observations, operation cost is composed of four elements[39]: management cost, general maintenance cost, re-pavement cost and road structure maintenance cost.

In order to use operation cost items as risk factors for the calculation of the Modified VFM, operation cost items need to be transformed by a scale factor because conditions such as length and traffic volume differ between a case study and the National Highways operated by NHMOs. As a scale factor, although length or traffic volume could be used, it is more reasonable to consider vehicle kilometre travelled[40] (VKT) in each regional NHMO each year because this measure reflects the concept of length and traffic volume simultaneously. However, management cost/VKT is excluded from the risk variables because management cost seems to be close to a fixed cost and not a variable (as it is according to VKT).

Accordingly, the following three risk variables relating to operation cost are considered: 1) general maintenance cost/VKT, 2) re-pavement cost/VKT, and 3) road structure maintenance cost/VKT. Using the historical observations regarding operation cost and VKT in each NHMO

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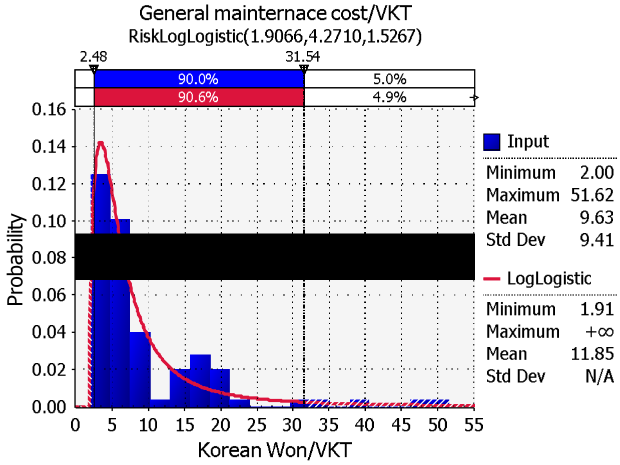
[39] Management cost includes the expenses for National Highway Office management and overloaded vehicle enforcement, but doses not includes personnel cost. So, it is considered additionally when estimating the Modified VFM. General maintenance cost means total expenses for road maintenance, such as pavement repair and road sweeping. In addition, re-pavement cost means additional pavement cost needed when initial pavement is damaged after starting operation, and road structure maintenance cost is to maintain road structures such as bridges, tunnels, culverts and drainage.

[40] In this study, VKT is calculated as VKT = total length weighted annual average daily traffic (AADT, passenger car nit) × total length× 365days. In addition, in order to consider passenger car unit, the same passenger car equivalent (PCE), assuming flat land as used in Statistical Yearbook of Traffic Volume (2011), is applied in this study, which is as follows.

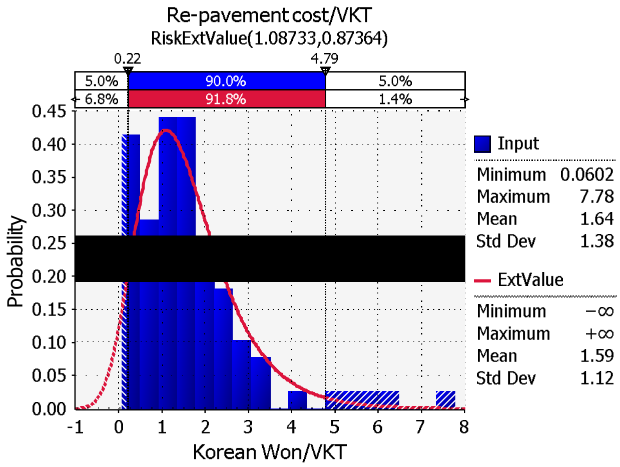
Classification	Small size	Medium size	Large size
Flatland	1	1.5	2
Hilly area	1.2	3	
Mountain area	1.5	5	

Source:MLTM (2011d)

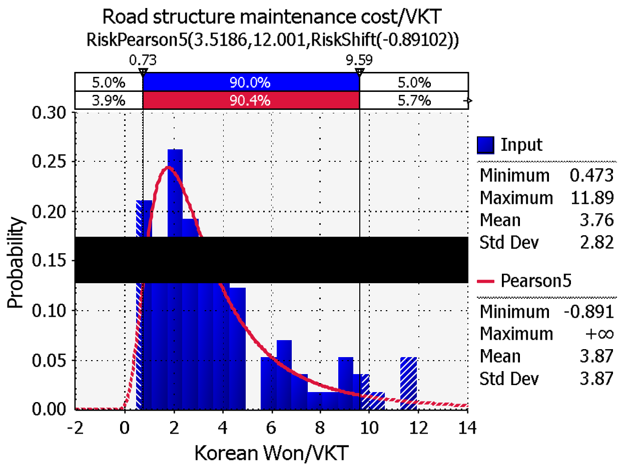
from 2006 to 2010, three risk variables (at the 2005 price) can be estimated, shown in Figure 4-5.



(a) General maintenance cost/VKT



(b) Re-pavement cost/VKT

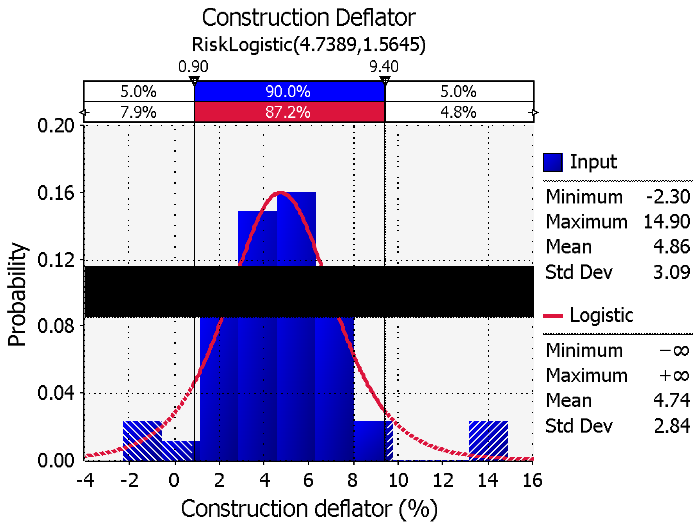


(c) Road structure maintenance cost/VKT

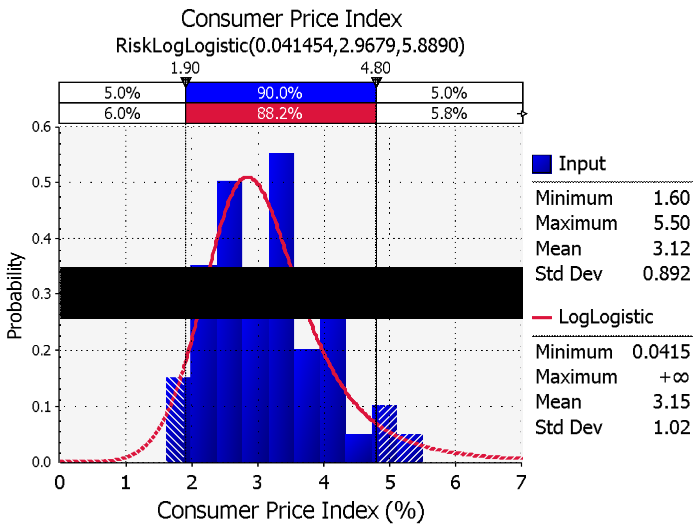
Figure 4-5: Operation cost risks in the National Highways

4.2.2.2 Inflation

In the calculation of the Modified VFM, factors relating to cost and benefits need to be estimated in real terms. Most of the calculation factors are already prepared without taking into account the effect of inflation; however, some factors, such as lease fee, newly estimated in nominal terms, need to be transformed into real terms by removing inflation. According to Korea's BTL guidelines (MOSF, 2009a), the yearly lease fee in nominal terms is calculated by reflecting the construction deflator to yearly private investment, and this needs to be converted to real terms by the consumer price index. Construction deflator and consumer price index, shown in Figure 4-6, can be quantified using quarterly observations from 2000 to 2012, provided by the Bank of Korea.



(a) Construction deflator

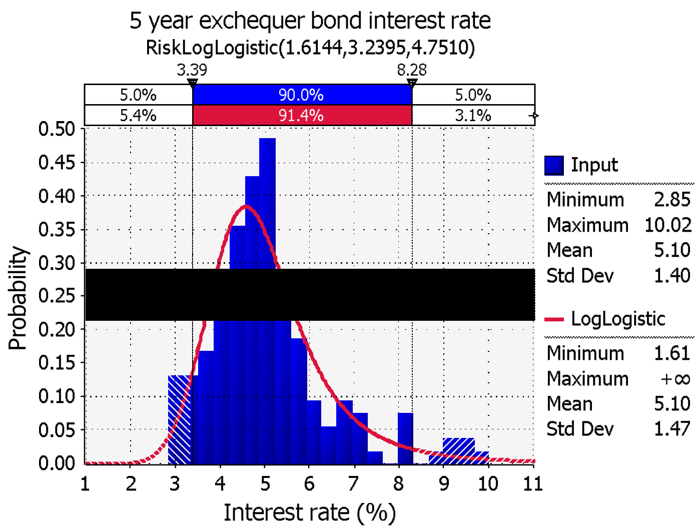


(b) Consumer price index

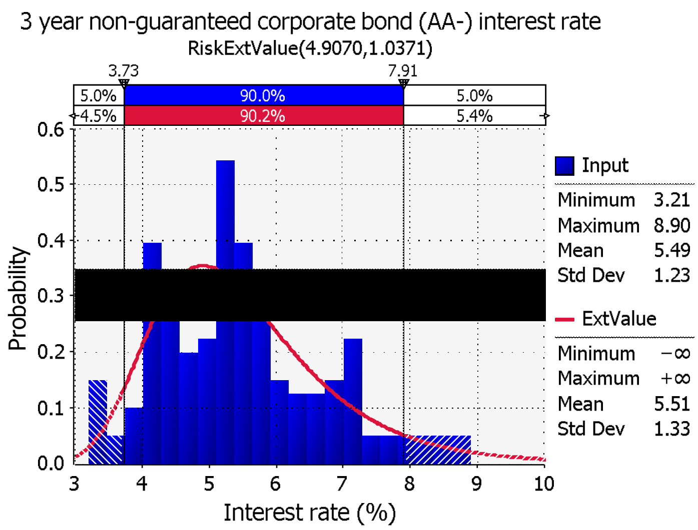
Figure 4-6: Inflation risks in Korea

4.2.2.3 Factors relating BTL viability

According to Korea's BTL guidelines (MOSF, 2009a), BTL lease profitability is expressed as a "five-year exchequer bond interest rate + a mark-up", where a mark-up is composed of a premium for long term investment and a risk premium for construction and operation. In a similar way, the BTL finance interest rate for the private sector is estimated by applying an additional rate to the three-year non-guaranteed corporate bond (AA-) interest rate, which is the base rate. As a result, for the Monte Carlo Simulation, the five-year exchequer bond interest rate and three-year non-guaranteed corporate bond (AA-) interest rates need to be quantified. Based on the historical fluctuations from 2000 to 2012, provided by the Korea Bond Information Service, they can be quantified as shown in Figure 4-7.



(a) five-year exchequer bond interest rate



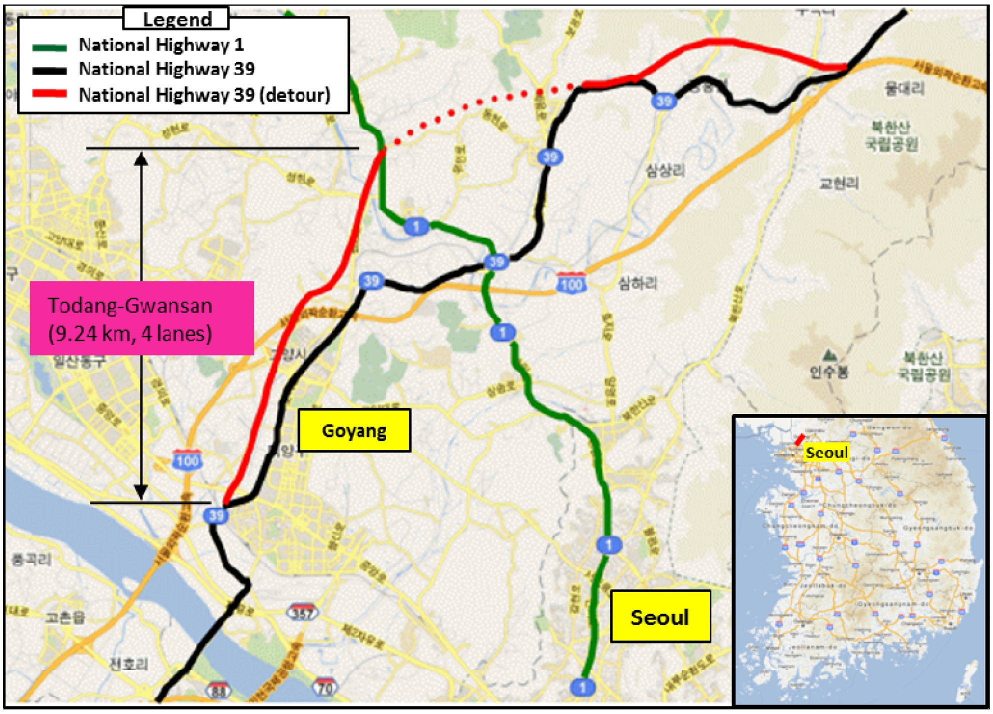
(b) three-year non-guaranteed corporate bond (AA-) interest rate

Figure 4-7: Interest rates of exchequer bond and corporate bond

4.3 Case 1: The Todang-Gwansan case

4.3.1 Project overview

Todang-Gwansan, a part of National Highway number 39 (Figure 4-8), has been under construction since 2005 for the purposes of creating a new detour around the city centre of Goyang City near Seoul. According to the Statistical Yearly Book of Traffic Volume (MLTM, 2011d), in 2010 the existing road had 42,094 vehicles using it daily, on average, which is beyond the marginal transport ability[41] (41,300) of a four-lane Nation Highway (MLTM, 2010b). In particular, the existing road runs though the city centre of Goyang City, so its function as a trunk road has been severely weakened. Therefore, in order to maintain the arterial function of the National Highway, the Korean government planned to build a detour around Goyang city in 2000: they expected that the traffic congestion in the local area would be improved and transport costs would be reduced when the detour was completed.



Source: map.google.com

Figure 4-8: The location map of the Todang-Gwansan case

[41] According to MLTM (2010b), as a rule of thumb, the Korean government uses the concept of the marginal transport ability of a road. The marginal transport ability (41,300) of a four-lane National Highway is estimated by considering level of service (D).

The key features of the Todang-Gwansan case are as follows:

- Title: The Todang-Gwansan National Highway (39) Project
- Location: Todang-dong ~ Gwansan-dong, Goyang City, Gyeonggi Province
- Length: 9.24km (four lanes)
- Construction cost: 198.2 (estimated, billion KRW, 2002 price)
- Benefit cost (B/C) ratio: 2.14

4.3.2 Analysis factors and assumptions for the Modified VFM

Analysis factors

The National Highway programme has not experienced any PPP system so far, so a hypothetical PPP project reflecting the decision-making time needs to be considered for use in the Modified VFM. In terms of PPP options, only the BTL option is considered in this case because the National Highways are all toll-free roads and so without a revenue stream a stand-alone type of PPP such as a BTO, cannot be adopted. In addition, in terms of the design stage, the PPP decision is assumed to be taken in 2002, three years (a two years' final design and a one year's administration such as presentations for residents) earlier than the start of construction. Other factors are estimated by following Korea's BTL guidelines (MOSF, 2009a).

Basic factors for the Modified VFM are as follows:

- PPP model: Build-Transfer-Lease
- Discount rate: 7.5 per cent (real)
- Decision-making time: 2002
- Price base year: 2002
- Five-year exchequer bond interest rate[42]: 6.9 per cent (nominal)
- Construction deflator[43]: 3.51 per cent (nominal, on average from 1999 to 2002)

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[42] The five-year exchequer bond interest rate is calculated by a weighted average method, which applies 0.1, 0.2, 0.3 and 0.4 to the first, second, third and fourth quarter value (MOSF, 2009a). The quarterly five-year exchequer bond interest rate is provided by the Korea Bond Information Service (http://www.kofiabond.or.kr).

[43] Construction deflator means the construction investment deflator in Expenditure on Gross Domestic Product on National Accounts, which is provided by the Bank of Korea (http://ecos.bok.or.kr). According to the BTL guidelines of Korea (MOSF, 2009a), it is used in the calculation of the private sector

- Consumer price index[44]: 3.50 per cent (nominal, on average from 1999 to 2002)
- BTL lease profitability[45]: 8.9 per cent (nominal)
- BTL finance interest rate[46]: 8.51per cent (nominal)
  (Three-year non-guaranteed corporate bond (AA-) interest rate (7.01 per cent)[47] + 1.5 per cent)
- BTL finance terms: level debt service[48] during operation period
- BTL finance structure: equity 15 per cent, debt 85 per cent
- Operation period: 30 years, construction duration: five years

Assumptions

The case study was analysed under four assumptions: 1) the normal construction duration is five years in the conventional case as well as in the PPP delivery if there is no restriction on construction funds; 2) a completion delay in the conventional delivery occurs only due to lack of a budget; 3) when using a PPP delivery, a completion delay does not occur; and 4) without completion delay, all deliveries produce the same social benefit.

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investment for the lease fee calculation. For a more accurate private sector investment calculation, it is used instead of the consumer price index.

[44] The consumer price index is also provided by the Bank of Korea (http://www.bok.or.kr).

[45] BTL lease profitability is expressed as "five-year exchequer bond interest rate + mark-up rate" and mark-up is composed of a premium for long term investment and risk premium for construction and operation (MOSF, 2009a). According to research (Jung et al., 2006) and newspaper reports (Jung, 2005, Lee, 2009), the mark-up rate is distributed from 0.5 per cent to 2.25 per cent. Given that there is no advanced BTL projects for road programme and road projects usually takes 35 years for construction and operation, 2.0 per cent of mark-up rate is considered for the National Highways in this research.

[46] BTL finance interest rate is expressed as a "three-year non-guaranteed corporate bond interest rate + mark-up rate" (MOSF, 2009a) and, according to Kim et al. (2005), the mark-up rate is distributed from 0.66 per cent to 2.00 per cent. Considering there is no advanced BTL projects for roads and road projects usually takes 35 years for construction and operation, 1.5 per cent of mark-up rate is used for the National Highways.

[47] Three-year non-guaranteed corporate bond interest rate is also provided by the Korea Bond Information Service (http://www.kofiabond.or.kr). It is estimated in the same way as the five-year exchequer bond interest rate, following the BTL guidelines of Korea (MOSF, 2009a)

[48] Level debt service means principal and interest payment scheme that a debtor pays back a creditor annually an equal amount of money including principal and interests.

4.3.3 Main calculation items for the Modified VFM analysis

From equation (3-8), the main calculation items for the Modified VFM are the asset cost of a PSC (AC_{PSC}), the operation cost of a PSC (OC_{PSC}) and a BTL (OC_{BTL}), the lease fee of a BTL ($Lease\ fee_{BTL}$) and the benefit difference (ΔB).

Asset cost of the PSC ($\boldsymbol{AC_{PSC}}$)

The basic asset cost of this project is shown in Table 4-1. Building cost and compensation cost in brackets are collected from feasibility review report on the Goyang City detour (MLTM, 2011a); other costs for which historical observations are not available are estimated using the governmental cost estimate standard.[49]

Table 4-1: Basic asset cost for the PSC and the BTL

(Unit: billion KRW, real term, 2002 price)

Asset cost items		PSC [BTL guideline]	BTL
Building cost	Investigation	1.8 (2.0)	1.8 (2.0)
	Design	5.3 (6.0)	5.3 (6.0)
	Construction	175.5 (198.2)	175.5 (198.2)
	Sub total	**182.5**	**182.5**
Compensation cost		**0** (16.4)	**0** (16.4)
Additional cost		**10.6** Design inspection 1.0 Construction inspection 5.9 Environmental impact assessment 1.3 Traffic impact assessment 0.1 Disaster impact assessment 0.2 Cultural asset survey 1.1 Insurance 1.0	**11.0** Design inspection 1.0 Construction inspection 5.9 Environmental impact assessment 1.3 Traffic impact assessment 0.1 Disaster impact assessment 0.2 Cultural asset survey 1.1 Insurance 1.4
Operation facility cost		**0.9**	**0.9**
Business reserve		**0**	**5.7** Business commence cost 5.4 Stock issue cost 0.3
Total		**194.0**	**200.2**

Note: 1. Compensation cost is provided by the Korean government so it is not included in the Modified VFM assessment. 2. The bracketed values are from the feasibility review report on the Goyang City detour project (MLTM, 2011a). 3. Insurance cost for a PSC is contractor's all risk insurance(1.0), while insurance cost for a BTL is composed of contractor's all risk (1.0), advanced loss of profits (0.3), employer's liability (0.01) and performance guarantee (0.1)

[49] The cost items using the governmental cost estimate standard are as follows: 1) design inspection cost, 2) construction inspection cost, 3) environmental impact study cost, 4) traffic impact assessment cost, 5) disaster impact assessment cost, and 6) cultural asset survey cost.

In addition, operation facility cost, business reserve and insurance cost refer to the PPP pre-qualification report on the Bongdam-Songsan National Expressway project (PIMAC, 2009b). In particular, insurance cost is estimated by considering insurance premium rates used in the report.

According to Korea's BTL guidelines (MOSF, 2009a), the building cost items of the PSC are calculated by multiplying the historical observations by 88.55 (per cent),[50] the average WBR of turn-key/alternative bid in National Highway projects between 2002 and 2011 (MLTM, 2012b).

In order to calculate the public sector cost of the PSC, total building costs (including investigation, design, and construction) can be distributed annually over the construction period according to the yearly distribution ratios from the preliminary feasibility study guidelines (KDI, 2008a). For additional costs, however, there are no yearly cost distribution ratios in the preliminary feasibility guideline, so the yearly distribution ratios, used in the PPP pre-qualification report on the Bongdam-Songsan National Expressway (PIMAC, 2009b), are used for the Modified VFM calculation. In addition, operation facility cost is assumed to be invested in the fifth year of construction. In summary, Table 4-2 shows the yearly cost distribution ratios for the asset cost of the PSC.

In addition, in order to consider completion delay, new yearly distribution ratios developed by interpolation, based on yearly distribution ratios in five-year constructions, are applied to the VFM and the Modified VFM analysis.

Table 4-2: Standard yearly cost distribution ratios for asset cost of the PSC

Year	Investigation cost	Design cost	Construction cost	Additional cost	Operation facility cost
1	1	1	0.05	0.336	0.336
2	0	0	0.15	0.135	0.135
3	0	0	0.25	0.26	0.26
4	0	0	0.35	0.202	0.202
5	0	0	0.2	0.067	0.067
Total	1	1	1	1	1

Source: KDI (2008a), PIMAC (2009a)

Operation cost for the PSC and the BTL (OC_{PSC}, OC_{BTL})

With respect to the PSC (OC_{PSC}), yearly base operation costs are estimated by multiplying the mean values of the operation costs[51] (KRW/VKT) from the historical observations and the

[50] The details are shown in Appendix A.

[51] Management cost/VKT = 1.68 KRW/VKT, general maintenance cost/VKT = 11.85 KRW/VKT, re-pavement cost/VKT = 1.59, and road structure maintenance cost/VKT = 3.87 KRW/VKT

yearly VKT of this case from the feasibility review report of the Goyang City detour project (MLTM, 2011a). In addition, personnel cost[52] is considered in addition to operation cost because the historical observations do not include a cost entry to cover this.

However, in general, the maintenance costs (among the operation cost items) tend to gradually increase over time because of the facility's increasing decrepitude. In order to consider decrepitude, the preliminary feasibility guidelines (KDI, 2008b) suggest relative yearly maintenance cost ratios for 30 years. However, the historical observations for maintenance costs per VKT are estimated, unfortunately, from the executed budget in 18 NHMOs, not from an individual National Highway section, so it would appear that they include diverse decrepitude ranges for National Highways maintained by 18 NHMOs. Inevitably, for a simple calculation, the historical observations are assumed to be collected from the National Highways with 15 years of decrepitude in this research.

Accordingly, yearly maintenance costs are finally calculated by reflecting the yearly normalised maintenance cost ratios, shown in Table 4-3, on the yearly base maintenance costs. The yearly ratios are estimated by calculating the proportions of yearly maintenance cost in the National Expressways, provided by KDI (2004b), to the maintenance cost of the 15th year.

Table 4-3: Yearly cost distribution ratios for maintenance costs of the PSC

Year	1	2	3	4	5	6	7	8	9	10
Maintenance cost (KRW/4 lane km)	0.93	1.11	1.31	1.55	1.82	2.13	2.49	2.88	3.32	3.8
Normalised ratio	0.14	0.17	0.2	0.23	0.27	0.32	0.38	0.43	0.5	0.57
Year	11	12	13	14	15	16	17	18	19	20
Maintenance cost (KRW/4 lane km)	4.32	4.87	5.45	6.04	6.63	7.23	7.81	8.36	8.89	9.37
Normalised ratio	0.65	0.73	0.82	0.91	**1**	1.09	1.18	1.26	1.34	1.41
Year	21	22	23	24	25	26	27	28	29	30
Maintenance cost (KRW/4 lane km)	9.82	10.22	10.58	10.9	11.18	11.43	11.64	11.82	11.97	12
Normalised ratio	1.48	1.54	1.6	1.64	1.69	1.72	1.76	1.78	1.81	1.81

Source: KDI (2004b)

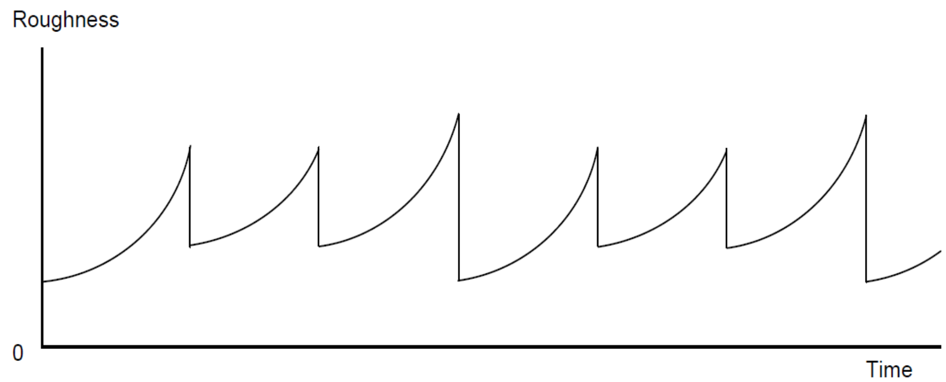
According to KDI (2004b), Table 4-3 was created based on historical observations from the Joongbu Expressway in Korea and the yearly maintenance costs were estimated by logistic regression based on historical observation for 10 years from the start of operations. According

[52] Considering yearly salary/person and its inflation, total personnel of 18 National Highway Management Offices and length in terms of four-lane kilometres, the personnel cost of 3,490,881 (KRW/four-lane kilometre; the 2005 price) will be used in this research.

to theoretical approach in road maintenance, whole life pavement performance curve (shown as roughness in Figure 4-9) looks spiky when optimal maintenance is provided (Rouse and Chiu, 2009, Tsunokawa and Schofer, 1994, Harvey, 2012). Therefore, whole life maintenance cost can also be spiky, similar to whole life pavement performance curve when optimum maintenance is provided, which is quite different from Table 4-3.

There could be three reasons that make this difference. Firstly, due to lack of budget, optimum maintenance could not be achieved in Korean practice. When roads are not maintained appropriately because maintenance funds are not available, the maintenance cost graph can be different from the spike graph like Figure 4-9, where roughness is improved when timely maintenance is provided as time passes. Secondly, the condition of road sections can be different even though they were constructed by the same project. Road authorities in Korea invest maintenance funds considering the condition of sections and fund availability, so historical maintenance cost observations considering the whole road length can be different from the spike graph considering a small (or ideal) size road section. Thirdly, there are various maintenance cost items with different maintenance periods and when they are overlapped total maintenance cost graph can be different from being spiky like Figure 4-9.

Therefore, though Table 4-3 seems to be oversimplified from the theoretical perspective, it seems that it can be carefully utilised in the calculation of maintenance costs, considering the impact of lack of maintenance funds, the superimposition of various maintenance cost items with different maintenance periods and its being from historical observations.



Source: ATC (2006), quoted from Harvey (2006)

Figure 4-9: Illustrative whole life pavement curve with rehabilitations and reconstructions

When it comes to operation cost of the BTL (OC_{BTL}), because there are no cases in which BTL scheme is applied in the National Highway, the same operation cost as was used in the PSC is applied as the BTL operation cost.

Lease fee for the BTL **($\boldsymbol{Lease\ fee_{BTL}}$)**

According to Korea's BTL guidelines (MOSF, 2009a), the lease fee in nominal term is paid equally every year for operation period (n) reflecting rate of return (k), and it is calculated as follows:

$$Lease\ fee = \frac{P}{PVIFA_{(N,k)}} = \frac{P}{\sum_{n=1}^{N} \frac{1}{(1+k)^n}} \tag{4-1}$$

where N = operation period, k = rate of return, P = the private sector investment principal and the interest which is converted to the present value at construction completion time (if the BTL project includes subsidiary enterprises, the investment principal and interest should be reduced as much as the profit of them), and $PVIFA$ = Present value Interest Factor of an Annuity, which is equivalent to the reciprocal of the capital recovery factor (Rogers and Duffy, 2012).[53]

The private sector investment principal and interest (P) is calculated reflecting the BTL finance structure (debt ratio), the finance terms and the interest rate. From Table 4-1, the asset cost delivered in total by the private sector amounts to 200.2 (billion KRW, 2002 price) in real terms. Using the BTL finance structure, 15 per cent (30.0) is delivered as equity, and 85 per cent (170.2) as debt. The asset cost in nominal terms delivered annually can be calculated by applying construction deflator to real prices. Therefore the principal of the private sector investment is 240.6 (billion KRW, nominal term), which is the sum of (a) and (b) in Table 4-4.

In addition, according to the finance terms (the level debt service during the operation period), during the construction period only interest is paid, and during the operation period an even amount (including both principal and interest) in nominal terms is paid annually by borrowing debt in nominal terms during the construction period. Therefore, the interest during construction period by borrowing debt amounts to 28.7 (billion KRW, nominal terms), (c) in Table 4-4.

Summing the principal and interest, the private sector investment (P) is in total 269.3 (billion KRW, in nominal terms) at the construction completion time. Consequently, in this case study, the lease fee in nominal terms for the BTL is calculated as follows:

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[53] PVIFA can be expressed by the reciprocal of the capital recovery factor $\left(\sum_{1}^{n} \frac{1}{(1+k)^i} = \left[\frac{(1+k)^n - 1}{k(1+k)^n}\right]\right)$. The details are given in Appendix B.

$$PVIFA_{(30,0.089)} = \sum_{i=1}^{30} \frac{1}{(1+0.089)^i} = 10.3654$$

$$Lease\ fee = \frac{269.3}{PVIFA_{(30,0.089)}} = \frac{269.3}{10.3654} = 25.9773\ \text{(billion KRW, nominal)}$$

Considering consumer price index and economic discount rate, the lease fee in nominal terms in each year will be transformed into real terms to be applied to the Modified VFM.

Table 4-4: Calculation of the private sector investment

(Unit: billion KRW)

Year	Equity (15%)		Debt (85%)		Interest (nominal)
	Real (2002 price)	Nominal	Real (2002 price)	Nominal	
2005	3.8	4.2	21.5	23.8	
2006	4.2	4.8	23.6	27.1	2.0
2007	7.0	8.3	39.7	47.2	4.3
2008	9.5	11.7	54.1	66.5	8.4
2009	5.5	7.0	31.2	39.7	14.0
Total	30.0	36.1 (a)	170.2	204.5 (b)	28.7 (c)
Private sector investment (P = a + b + c)			269.3		

Social benefit difference (ΔB)

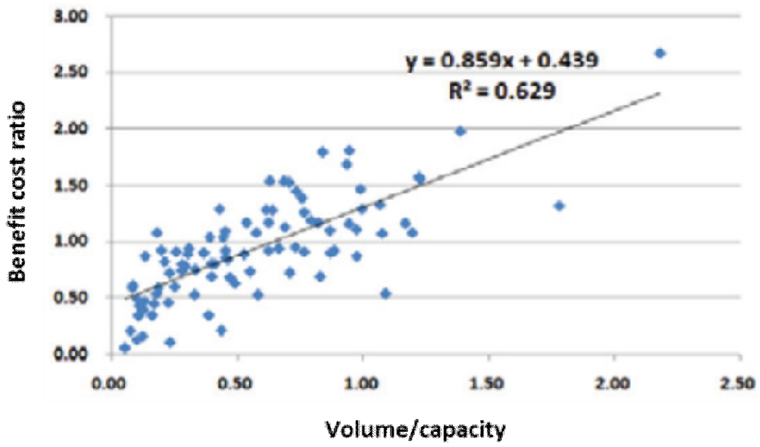
Social benefits for the Modified VFM analysis for this case study are collected from the feasibility review report on the Goyang City detour project (MLTM, 2011a). The social benefit difference (ΔB) beween the PSC and the BTL alternative, considering the completion delay on conventional delivery, can be calculated using these data.

According to the preliminary feasibility study guideline for roads and railway in Korea (KDI, 2008a), the social benefits of roads and railways in Korea mainly consist of the valuation of vehicle operating cost (VOC) saving, the valuation of travel time (VOT) saving, the valuation of accident costs (VAC) saving and the valuation of environment cost (VEC) saving.

With respect to the relationship of traffic volume and social benefit, it seems that social benefits can vary when actual traffic volume is different from the forecast because traffic volume can have an influence on the benefit factors above directly or indirectly. In order to establish this relationship, it appears necessary to conduct a new traffic demand analysis for the case. However, if this is difficult in practical terms, this relationship could be estimated roughly using an empirical method.

With respect to this, Kim et al. (2011) researched the relationship between benefit cost ratio[54] (BCR) and volume-capacity ratio (V/C) based on the preliminary feasibility study on 91 National Highway projects in order to estimate the approximate economic feasibility of the National Highway projects. According to Kim et al. (2011), as shown in Figure 4-10, the relationship between BCR and V/C is as follows:

$$\boldsymbol{BCR = 0.859 \times \frac{V}{C} + 0.439\ (R^2 = 0.629)} \tag{4-2}$$



Source: Kim et al. (2011)

Figure 4-10: Relationship between BCR and volume/capacity in the National Highway

Although this relationship seems to show roughly that BCR is 0.439 when V/C is zero, the relationship is used for this research for a simple calculation. If roads in Korea are assumed to

[54] According to the feasibility study guidelines of Korea (KDI, 2008b), in order to measure the economic feasibility of a project, three methodologies regarding benefit and cost can be used in Korea: 1) benefit cost ratio (BCR), 2) net present value (NPV), and 3) internal rate of return (IRR). Among them, BCR is mainly used in the feasibility study of a project because it is easy to understand and also makes it easy to consider project size. Usually when the BCR of a project is greater than or equal to 1, the project is considered economically feasible in Korea. The formulation of BCR is as follows:

$$\mathrm{BCR} = \sum_{t=0}^{n} \frac{B_t}{(1+r)^t} \Bigg/ \sum_{t=0}^{n} \frac{C_t}{(1+r)^t}$$

Where, B_t = benefit at t, C_t = cost at t, r = discount rate, and n = project duration (construction and operation) follow the above relationship, as traffic volume becomes *k* times, social benefit changes to *b*[55] times as follows:

$$\boldsymbol{b = \frac{B + \Delta B}{B} = k + \frac{0.439\,(1 - k)}{BCR}} \tag{4-3}$$

Where, B = the social benefit with current traffic volume, ΔB = the social benefit change when traffic volume changes to k times, BCR = the benefit cost ratio.

In this case study (BCR = 2.14), from equation (4-3), when the traffic volume drops to 68.6 per cent of the forecast one, the social benefits also drop to 75.0 per cent of the forecast one.

[55] The detailed derivation for equation (4-3) is given in Appendix C.

4.3.4 Analysis

4.3.4.1 The Modified VFM (with no completion delay)

To verify the impact of the inclusion of construction cost risk and traffic volume risk on the Modified VFM when there is no completion delay in the conventional delivery, four different Modified VFM ($M.VFM_{BTL}$) using the mean value of each risk are conducted: 1) $M.VFM_{BTL}$ without risks; 2) $M.VFM_{BTL}$ with construction cost risk; 3) $M.VFM_{BTL}$ with traffic volume risk; and 4) $M.VFM_{BTL}$ with both risks (construction cost risk and traffic volume risk). The results of $M.VFM_{BTL}$ are shown in Table 4-5.

Table 4-5: The Modified VFM results according to risk inclusion

(Discounted value, billion KRW, 2002 price)

	PSC		BTL		ΔB	$M.VFM_{BTL}$
	AC_{PSC} (a)	OC_{PSC} (b)	$Lease\ fee_{BTL}$ (d)	OC_{BTL} (e)	(f)	(a+b)-(d+e)+f
1) $M.VFM_{BTL}$ (+no risks)	109.6	16.8	104.8	16.8	0.0	4.8
2) $M.VFM_{BTL}$ (+const. risk)	105.0	16.8	104.8	16.8	0.0	0.2
3) $M.VFM_{BTL}$ (+volume risk)	109.6	12.2	104.8	16.8	0.0	0.2
4) $M.VFM_{BTL}$ (+both risks)	105.0	12.2	104.8	16.8	0.0	-4.4

Note: 1. $M.VFM_{BTL}$ (+no risks) = the Modified VFM value without considering risks based on the BTL guidelines of Korea, $M.VFM_{BTL}$ (+const. risk) = the Modified VFM value considering the mean values of winning bid ratio risk and construction cost overrun risk, $M.VFM_{BTL}$ (+volume risk) = the Modified VFM value considering the mean value of traffic volume risk, and $M.VFM_{BTL}$ (+both risks) = the Modified VFM value considering the mean values of winning bid ratio risk, cost overrun risk and traffic volume risk.
2. AC_{PSC} = Asset cost in the PSC, OC_{PSC} = Operation cost in the PSC, $Lease\ fee_{BTL}$ = Lease fee in the BTL, OC_{BTL} = Operation cost in the BTL and ΔB = social benefit difference between the PSC and the BTL.

***$M.VFM_{BTL}$* with no risk inclusion**

Considering an average WBR of turn-key/alternative bids (88.55 per cent) in National Highway projects between 2002 and 2011 (MLTM, 2012b) in calculating the asset cost of the PSC, $M.VFM_{BTL}$ (Table 4-5, the first row) shows that it is feasible to implement this project with the BTL, indicating the value of 4.8 (billion KRW) in the BTL.

***$M.VFM_{BTL}$* with construction cost risk**

From equation (3-10), an application ratio, indicating construction cost risk, consists of WBR risk and construction cost overrun risk. Using the mean values for WBR risk (76.90 per cent,

Figure 4-2) and construction cost overrun risk (9.98 per cent, Figure 4-1), the asset cost of the PSC can be freshly calculated.

The result (Table 4-5, the second row) shows that $M.VFM_{BTL}$, taking in account the construction cost risk, is 0.2 (billion KRW), which is 4.6 (billion KRW) lower than $M.VFM_{BTL}$ with no risk inclusion. This is because the mean values of WBR and construction cost overrun make an application ratio of 84.58 per cent (0.769 × (1+0.0998)), which is 3.97 per cent lower than the average winning bid ratio of turn-key/alternative bids (84.58 per cent) used.

This means that $M.VFM_{BTL}$ with no risk inclusion based on Korea's BTL guidelines (MOSF, 2009a) could be exaggerated by as much as the difference of 3.97 per cent more than the situation in reality.

***M.VFM$_{BTL}$* with traffic volume risk**

To verify the impact of traffic demand risk on $M.VFM_{BTL}$, the mean value of traffic volume risk (68.6 per cent, Figure 4-4) is applied. The result (Table 4-5, the third row) shows that the $M.VFM_{BTL}$ decreases by 4.6 (billion KRW). The decrease in $M.VFM_{BTL}$ is due to the decrease in the operation cost in the PSC by the VKT decrease in the project from traffic volume reduction (from 100 to 68.6 per cent).

***M.VFM$_{BTL}$* with both risks**

Table 4-5 (the last row) shows that the BTL scheme is not the best option for this project with $M.VFM_{BTL}$ value of -4.4 (billion KRW) when construction cost risk and traffic volume risk are included. Compared with $M.VFM_{BTL}$ with no risk inclusion, the value decreases by 9.2 (billion KRW), among which the impact of construction risk and traffic volume risk occupies, respectively, 4.6 and 4.6 (billion KRW).

All in all, from the viewpoint of the $M.VFM_{BTL}$ with no completion delay, it seems that the conventional delivery is more favourable than the BTL scheme when construction cost and traffic volume risks are included.

4.3.4.2 The Modified VFM (with completion delay)

Impact of a completion delay in the conventional delivery

To verify the impact of a completion delay in the conventional delivery on the PPP decision-making, $M.VFM_{BTL}$ with completion delay (0 to 4 years) is conducted. $M.VFM_{BTL}$ is calculated by considering a completion delay of conventional delivery, which affects not only the yearly asset cost input but also the social benefit difference between the PSC and the BTL.

$M.VFM_{BTL}$ results are shown in Table 4-6. In the no risk inclusion case, $M.VFM_{BTL}$ soars from 4.8 to 76.9 (billion KRW) as completion is delayed from 0 to 4 years. Similarly, in the risk (construction cost risk and traffic volume risk) inclusion case, it rises from -4.4 to 46.6 (billion KRW) according to completion delay. This is because the increase in the social benefit difference between the PSC and the BTL due to a completion delay is bigger than the decrease in the public sector cost in the PSC due to discounting.

Additionally, taking into account the mean value of the completion delay (2.74 years, Figure 4-3) in the National Highway projects, the BTL scheme is better than the conventional option for this project.

Table 4-6: The Modified VFM result with completion delay

(Discounted value, billion KRW, 2002 price)

	Delay (year)	PSC		BTL		ΔB	$M.VFM_{BTL}$
		AC_{PSC} (a)	OC_{PSC} (b)	$Lease\ fee_{BTL}$ (d)	OC_{BTL} (e)	(f)	(a+b)-(d+e)+f
No risk inclusion	0	109.6	16.8	104.8	16.8	0.0	4.8
	1	105.5	15.6	104.8	16.8	25.5	25.0
	2	101.6	14.5	104.8	16.8	49.2	43.7
	2.74	98.7	13.8	104.8	16.8	65.8	56.6
	3	97.8	13.5	104.8	16.8	71.3	61.0
	4	94.1	12.6	104.8	16.8	91.9	76.9
Risk inclusion	0	105.0	12.2	104.8	16.8	0.0	-4.4
	1	101.1	11.4	104.8	16.8	19.2	10.0
	2	97.3	10.6	104.8	16.8	37.0	23.2
	2.74	94.5	10.0	104.8	16.8	49.4	32.3
	3	93.6	9.8	104.8	16.8	53.5	35.4
	4	90.1	9.2	104.8	16.8	69.0	46.6

Note: 1. AC_{PSC} = Asset cost in the PSC, OC_{PSC} = Operation cost in the PSC, $Lease\ fee_{BTL}$ = Lease fee in the BTL, OC_{BTL} = Operation cost in the BTL and ΔB = the social benefit difference between the PSC and the BTL. 2. Risk inclusion = construction cost risk (winning bid ratio and construction cost overrun) and traffic volume risk included

Critical completion delay

In order to find out a critical completion delay in the conventional delivery, which makes the $M.VFM_{BTL}$ zero, a linear regression analysis was conducted using Table 4-6. As seen in Figure 4-11, depending on whether construction cost risk and traffic volume risk are included or not, the regression line of $M.VFM_{BTL}$ differs.

In the no risk inclusion case, when the linear regression line is extended, it meets the horizontal axis at -0.35 year (-4.20 months). This means that even if the conventional delivery completes this project earlier than the BTL by up to 0.35 years (4.2 months), the BTL is better than the conventional delivery. In other words, even if the construction in the BTL starts up to 0.35 years (4.2 months) later (as the result of a negotiation delay or a financial problem) than the conventional delivery, the BTL is more favourable than the conventional delivery.

In the same way, regarding $M.VFM_{BTL}$ with risk inclusion, the intercept of the horizontal axis (the critical completion delay) becomes 0.26 years (3.12 months). This means that if the completion in the conventional delivery is delayed more than 0.26 years (3.12 months), the BTL becomes better than the conventional delivery. In other words, when more than 0.26 years (3.12 months) of completion delay is expected in the conventional delivery, the BTL is a more appropriate delivery option even if $M.VFM_{BTL}$ is negative without completion delay.

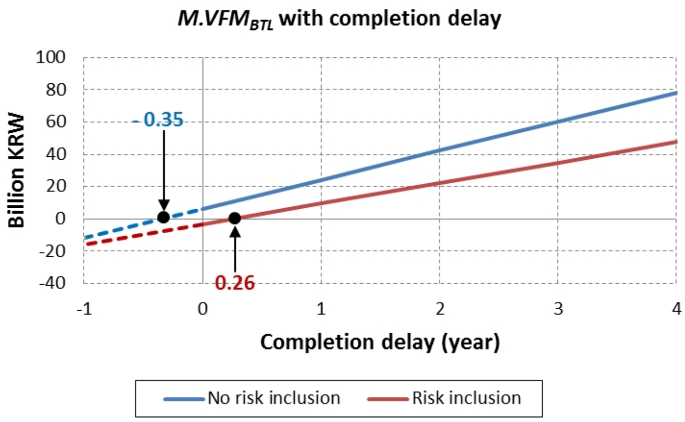


Figure 4-11: The Modified VFM result according to completion delay

In addition, considering that critical completion delay in this project is less than the mean value (2.74 years, Figure 4-3) of completion delay in National Highway projects, the BTL option seems to be more favourable for this project case.

4.3.4.3 Sensitivity analysis

$M.VFM_{BTL}$ results can be different depending on how large values are used as analysis factors. In order to examine the behaviour of $M.VFM_{BTL}$, according to the change of analysis factors, a sensitivity analysis is conducted. For a sensitivity analysis, the following eight analysis factors are considered: 1) BTL construction cost; 2) BTL operation cost; 3) BTL finance interest rate; 4) discount rate; 5) BTL lease profitability; 6) construction deflator; 7) consumer price index; and 8) the size of social benefits.

The changes of $M.VFM_{BTL}$ with risk inclusion and 2.74 year delay are shown in Figure 4-12, when the analysis factors vary by from -20 to 20 per cent on each factor's given value. The summary of sensitivity analysis is shown in Table 4-7.

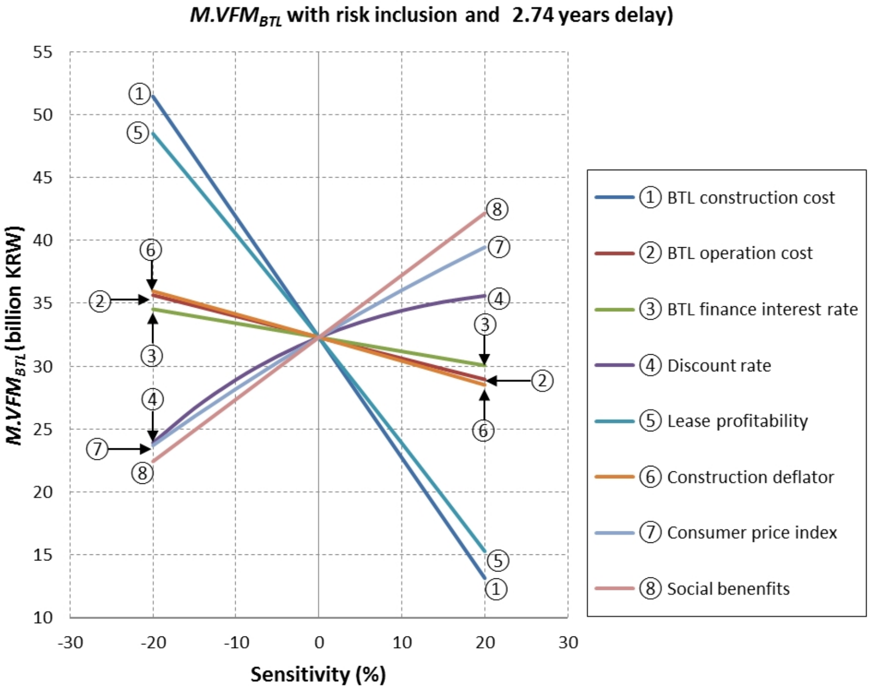


Figure 4-12: Sensitivity analysis of analysis factors (risk inclusion, 2.74 year delay)

Table 4-7: Sensitivity of analysis factors on the Modified VFM

Analysis factors	$M.VFM_{BTL}$ changes due to the increase of analysis factors		
	Increase /decrease	Unit change (billion KRW)	Reasons
1. BTL construction cost	Decrease	-0.96	The increase of BTL construction cost makes private investment and lease fee rise, so $M.VFM_{BTL}$ decreases.
2. BTL operation cost	Decrease	-0.19	The increase of BTL operation cost naturally makes $M.VFM_{BTL}$ decrease.
3. BTL finance interest rate	Decrease	-0.14	The increase of BTL finance interest rate makes lease fee rise, so $M.VFM_{BTL}$ decreases
4. Discount rate	Increase	0.29	The increase of discount rate makes cost items fall. Among them, lease fee has a largest drop, so $M.VFM_{BTL}$ decreases.
5. Lease profitability	Decrease	-0.83	The rise of lease profitability makes lease fee rise, so $M.VFM_{BTL}$ decreases
6. Construction deflator	Decrease	-0.19	The rise of construction deflator makes private investment and lease fee increase, so $M.VFM_{BTL}$ decreases.
7. Consumer price index (CPI)	Increase	0.39	Nominal lease fee is converted to real term by consumer price index. The rise of CPI makes lease fee in real term drop, so $M.VFM_{BTL}$ increases.
8. Social benefits	Increase	0.49	The rise of social benefits makes the social benefit difference grow, so $M.VFM_{BTL}$ increases.

Note; Unit change means the change of $M.VFM_{BTL}$ when an analysis factor rises by 1 per cent on its given value.

Sensitivity analysis results, given in Figure 4-12, show that $M.VFM_{BTL}$ values with risk inclusion and 2.74 year delay are always positive, which means the BTL option is better than the conventional option.

Among the eight analysis factors, as seen in Table 4-7, as discount rate, consumer price index or social benefits go up, $M.VFM_{BTL}$ rises with a positive slope; this is mainly because these factors make the lease fee drop. However, when other factors go up, $M.VFM_{BTL}$ falls with a negative slope because these make the lease fee rise or lead directly to an increase in the public sector cost (BTL operation cost) in the BTL.

Other than that, the sensitivity results show that, among the factors, BTL construction cost and lease profitability are most influential for the Modified VFM with the steepest slopes when they rise by from -20 to 20 per cent point based on each factor's given value. Accordingly, an individual appraiser who feels pressure to show the viability of the BTL may be vulnerable to adjusting BTL construction cost and lease profitability. For this reason, in reality, according to Kim (2011), BTL construction cost applied to a VFM analysis is less (93.8 per cent on average) than PSC construction cost without reason.

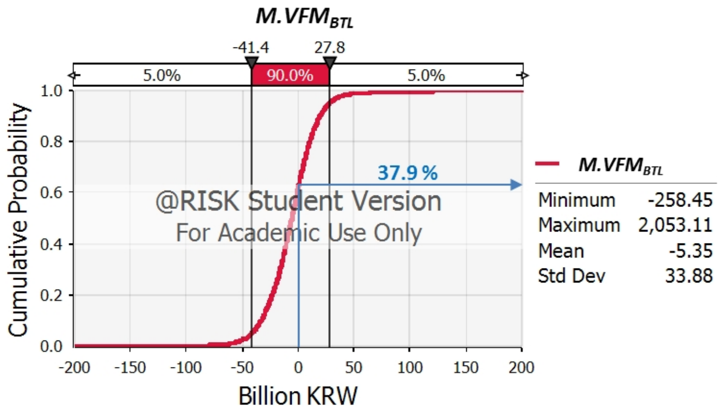
4.3.4.4 The Monte Carlo Simulations

The MCS is conducted to identify the impact of the 11 risk variables shown in Figure 4-1~Figure 4-7, which are from historical observations: WBR, construction cost overrun, traffic volume, three operation costs (general maintenance cost/VKT, re-pavement cost/VKT and road structure maintenance cost/VKT), construction deflator, consumer price index, five-year exchequer bond interest rate, and three-year non-guaranteed corporate bond interest rate.

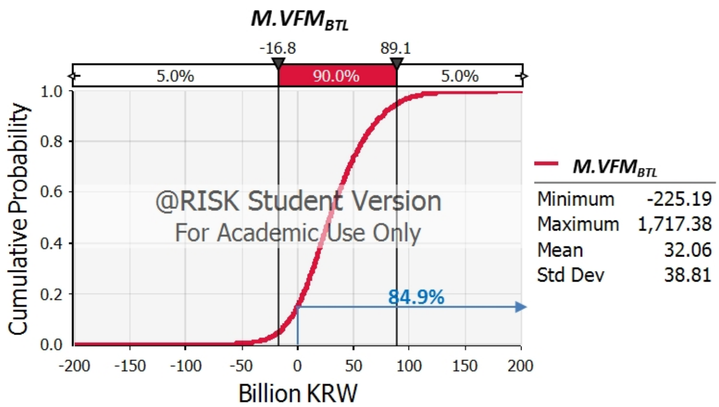
Figure 4-12 shows the MCS results with no completion delay and with a 2.74-year completion delay. In the case of no completion delay (Figure 4-13 (a)), $M.VFM_{BTL}$ is distributed between -41.4 and 27.8 (billion KRW) with 90 per cent probability and the mean value is -5.4 (billion KRW). Additionally, the probability that $M.VFM_{BTL}$ is positive is 37.9 per cent, which shows that the BTL scheme is not the best option for this project.

In addition, in the case of a 2.74-year completion delay (Figure 4-13 (b)), $M.VFM_{BTL}$ is distributed between -16.8 and 89.1(billion KRW) with 90 per cent probability and the mean value is 32.1(billion KRW). The probability that $M.VFM_{BTL}$ is positive is 84.9 per cent, which shows that the BTL scheme is feasible for this project.

From the MCS results, as the completion delay goes up, the mean value $M.VFM_{BTL}$ and the probability that the BTL is better also go up. In addition, when considering the average completion delay of the National Highway projects (2.74 years), the BTL scheme seems to be better than the conventional delivery for this project, which is the same result as single-value estimations.



(a) No delay



(b) 2.74 year completion delay

Figure 4-13: Probability distribution of the Modified VFM

4.4 Case 2: The Dongup-Hanlim case

4.4.1 Project overview

Along with the National Expressway 10 (Soonchun-Busan), the National Highway 14 is a main east and west corridor in Changwon and Gimhae region (Figure 4-14). There was serious traffic congestion in urban areas like Dongup and Jinyoungup, so the Korean government planned to build two small detours in this local region in 2000.

According to the Statistical Yearly Book of Traffic Volume (MLTM, 2011d), the National Highway 14 near Dongup and Jinyoungup had an annual average daily traffic volume of 38,621 vehicles in 2010. Although this is not beyond the marginal transport ability[56] (41,300) of a four-lane National Highway (MLTM, 2010b), there was serious traffic congestion in this section because of urbanisation around Dongup and Jinyoungup.

Source: map.google.com

Figure 4-14: The Dongup-Hanlim case location map

[56] According to MLTM (2010b), as a rule of thumb, the Korean government uses the concept of the marginal transport ability of a road. The marginal transport ability (41,300) of four-lane National Highways is estimated by considering level of service (D).

As seen in Figure 4-14, the first detour, the Dongup Detour, started to be constructed from 2003 and is expected to be completed at the end of 2013. The Dongup-Hanlim project is the second detour constructed in order to ease traffic congestion in Jinyoungup area; work is expected to start on it after 2013.

The overview of the Dongup-Hanlim National Highway project is as follows:

- Title: The Dongup-Hanlim National Highway (14) project
- Location: Jinyoungup ~ Hanlim, Gimhae, Gyungnam Province
- Length: 7.29 km (four lanes)
- Construction cost: 159.8 (estimated, billion KRW, 2007 price)
- BCR: 1.23

4.4.2 Analysis factors assumptions for the Modified VFM

As with the Todang-Gwansan case, only a BTL option is considered as a PPP alternative (and for the same reason). In addition, this case study assumes that the PPP decision is made in 2011 and construction starts in 2013, considering that the final design was completed in 2011. Other factors are estimated by following Korea's BTL guidelines (MOSF, 2009a). The basic analysis factors for the Modified VFM are as follows:

- PPP model considered: Build-Transfer-Lease
- Decision-making time: 2011
- Price base year: 2011
- Discount rate: 5.5 per cent (real)
- Construction deflator:[57] 5.56 per cent (average between 2007 and 2011)
- Consumer price index:[58] 3.38 per cent (average between 2007 and 2011)
- Five-year exchequer bond interest rate:[59] 3.77 per cent (2001)

[57] Construction deflator means construction investment deflator in Expenditure on Gross Domestic Product on National Accounts, which is provided by the Bank of Korea (http://ecos.bok.or.kr).

[58] Consumer price index, which is used as inflation in operation period, is provided by the Bank of Korea (http://ecos.bok.or.kr).

[59] The five-year exchequer bond interest rate is calculated by a weighted average method, which applies 0.1, 0.2, 0.3 and 0.4 to the first, second, third and fourth quarter value (MOSF, 2009a). The quarterly five-year exchequer bond interest rate is provided by the Korea Bond Information Service (http://www.kofiabond.or.kr).

- BTL Lease profitability:[60] 5.77 per cent (five-year exchequer bond interest rate + 2.0 per cent)
- BTL finance interest rate:[61] 5.85 per cent (three-year non-guaranteed corporate bond [62](AA-), 4.35 per cent + 1.5 per cent)
- BTL finance structure: equity 15 per cent, debt 85 per cent
- BTL finance terms: level debt service during operation period
- Operation period: 30 years
- Standard construction duration: five years

In addition, the same assumptions (see 4.3.2) used in the Todang-Gwansan case are also used in this case.

4.4.3 Main calculation items for the Modified VFM analysis

From equation (3-8), the main calculation items for the Modified VFM are the asset cost of a PSC (AC_{PSC}), the operation cost of a PSC (OC_{PSC}) and a BTL (OC_{BTL}), the lease fee of a BTL ($Lease\ fee_{BTL}$) and the benefit difference (ΔB).

Asset cost of the PSC (AC_{PSC})

Table 4-8 shows the basic asset cost of this project. At the time of making the decision, 2011, the final design stage was already finished, so the expenditure on investigation and design was neglected in both the PSC and the BTL. The bracketed construction cost figure is collected from

[60] BTL lease profitability is expressed as "five-year exchequer bond interest rate + mark-up rate" and mark-up is composed of a premium for long term investment and risk premium for construction and operation (MOSF, 2009a). According research (Jung et al., 2006) and newspaper reports (Jung, 2005, Lee, 2009), the mark-up rate is distributed from 0.5 per cent to 2.25 per cent. Considering that there is no advanced BTL projects for road programme and road projects usually takes 35 years for construction and operation, 2.0 per cent of the mark-up rate is considered for the National Highways in this research.

[61] BTL finance interest rate is expressed as a "three-year non-guaranteed corporate bond interest rate + mark-up rate" (MOSF, 2009a) and, according to Kim et al. (2005), the mark-up rate seems to be distributed from 0.66 per cent to 2.00 per cent. Considering that there are no advanced BTL projects for roads and that road projects usually take 35 years for construction and operation, 1.5 per cent of mark-up rate is used for the National Highways.

[62] Three-year non-guaranteed corporate bond interest rate is also provided by the Korea Bond Information Service (http://www.kofiabond.or.kr). It is estimated in the same way as the five-year exchequer bond interest rate, following the BTL guidelines of Korea (MOSF, 2009a).

the final design report for the Dongup-Hanlim National Highway (MLTM, 2011b), and, using the governmental cost estimation standards,[63] most of the additional costs are estimated. Operation facility cost, business reserve and insurance cost refer to the pre-qualification report on Bongdam-Songsan National Expressway project (PIMAC, 2009b).

According to Korea's BTL guidelines (MOSF, 2009a), the construction cost is obtained by multiplying bracketed construction value by 88.55 per cent, a WBR of turn-key/alternative bids in the National Highway projects between 2002 and 2011(MLTM, 2012b).

Table 4-8: Basic asset cost for the PSC and the BTL

(Unit: billion KRW, real term, 2011 price)

<table>
<tr><th colspan="2">Asset cost items</th><th>PSC
[BTL guideline]</th><th>BTL</th></tr>
<tr><td rowspan="4">Building cost</td><td>Investigation</td><td>0</td><td>0</td></tr>
<tr><td>Design</td><td>0</td><td>0</td></tr>
<tr><td>Construction</td><td>156.7
(176.9)</td><td>156.7
(176.9)</td></tr>
<tr><td>Sub total</td><td>156.7</td><td>156.7</td></tr>
<tr><td colspan="2">Compensation cost</td><td>0
(34.6)</td><td>0
(34.6)</td></tr>
<tr><td colspan="2">Additional cost</td><td>9.7
Construction inspection 6.6
Environmental impact assessment 1.0
Traffic impact assessment 0.1
Disaster impact assessment 0.2
Cultural asset survey 0.9
Insurance 0.9</td><td>10.2
Construction inspection 6.6
Environmental impact assessment 1.0
Traffic impact assessment 0.1
Disaster impact assessment 0.2
Cultural asset survey 0.9
Insurance 1.4</td></tr>
<tr><td colspan="2">Operation facility cost</td><td>1.0</td><td>1.0</td></tr>
<tr><td colspan="2">Business reserve</td><td>0</td><td>6.4
Business commence cost 6.0
Stock issue cost 0.4</td></tr>
<tr><td colspan="2">Total</td><td>167.4</td><td>174.2</td></tr>
</table>

Note: 1. Compensation cost is provided by the Korean government, so it is not included in the Modified VFM assessment. 2. The bracketed values are from the final design report for the Dongup-Hanlim project (MLTM, 2011b). 3. Insurance cost for a PSC is contractor's all risk insurance(0.9), while insurance cost for a BTL is composed of contractor's all risk (0.9), advanced loss of profits (0.4), employer's liability (0.01) and performance guarantee (0.1)

In addition, yearly asset costs of the PSC are distributed in Table 4-2 (shown for the Todang-Gwansan case).

[63] The cost items using the governmental cost estimate standards are as following: 1) construction inspection cost; 2) environmental impact assessment cost; 3) traffic impact assessment cost; 4) disaster impact assessment cost; and 5) cultural asset survey cost.

Operation cost for the PSC and the BTL (OC_{PSC}, OC_{BTL})

In the same way as the Todang-Gwansan case, the yearly base operation costs for the PSC (OC_{PSC}) is calculated by multiplying the mean values of the operation costs (KRW/VKT) from the historical observations and the VKT of this project from the final design report for Dongup-Hanlim National Highway (MLTM, 2011b). Yearly maintenance costs are estimated by considering the decrepitude of road (Table 4-3).

When it comes to the operation costs of the BTL (OC_{BTL}), because there are no cases in which the BTL scheme is applied in the National Highways, the same operation cost as used in the PSC is applied as the operation cost of the BTL.

Lease fee for the BTL ($Lease\ fee_{BTL}$)

According to Korea's BTL guidelines (MOSF, 2009a), the yearly lease fee in nominal terms is calculated as equation (4-1). The asset cost of the BTL in real terms in Table 4-8 is delivered as a form of equity (15 per cent) and debt (85 per cent), according to the BTL finance structure. Considering construction deflator, the principal of the private sector investment becomes 221.1 (billion KRW, nominal term), which is the sum of (a) and (b) in Table 4-9. In addition, according to the finance terms, the interest amounts to 17.2 (billion KRW, nominal terms), (c) in Table 4-9. Summing the principal and interest, the private sector investment (P) at construction completion time is a total of 238.2 (billion KRW, nominal terms) in Table 4-9.

Table 4-9: Calculation of the private sector investment

(Unit: billion KRW)

Year	Equity (15%)		Debt (85%)		Interest (nominal)
	Real (2011 price)	Nominal	Real (2011 price)	Nominal	
2013	2.6	3.0	15.0	16.7	
2014	3.7	4.4	21.1	24.9	1.0
2015	6.3	7.8	35.6	44.1	2.5
2016	8.5	11.1	48.4	63.4	5.0
2017	5.0	6.9	28.0	38.8	8.7
Total	26.1	33.2 (a)	148.1	187.9 (b)	17.2 (c)
Private sector investment (P = a + b + c)			238.2		

Consequently, in this case study, the yearly lease fee in nominal terms for the BTL is calculated as follows:

$$PVIFA_{(30,0.0577)} = \sum_{i=1}^{30} \frac{1}{(1+0.0577)^i} = 14.1103$$

$$Lease\ fee = \frac{238.20}{PVIFA_{(30,0.0577)}} = \frac{238.20}{14.1103} = 16.881\ \text{(billion KRW, nominal)}$$

Considering the consumer price index and economic discount rate, the yearly lease fee in nominal terms will be transformed into real terms to be applied to the Modified VFM.

Social benefit difference (ΔB)

Social benefits for the Modified VFM analysis are collected from the final design report for Dongup-Hanlim National Highway project (MLTM, 2011b). As with the Todang-Wondang case, using equation (4-3) and social benefit data, the social benefit difference (ΔB) beween the PSC and the BTL alternative, considering the completion delay of conventional delivery, can be calculated.

Considering equation (4-3) and the BCR (=1.23) of this case, when the traffic volume drops to 68.6 per cent of the forecast one, the social benefits also drop to 79.8 per cent of the forecast one.

4.4.4 Analysis

4.4.4.1 The Modified VFM (with no completion delay)

In the same way as the Todang-Gwansan case, to verify the impact of the inclusion of construction cost risk and traffic volume risk on the Modified VFM when there is no completion delay in the conventional delivery, four different Modified VFMs ($M.VFM_{BTL}$) using the mean value of each risk are conducted: 1) $M.VFM_{BTL}$ without risks; 2) $M.VFM_{BTL}$ with construction cost risk; 3) $M.VFM_{BTL}$ with traffic volume risk; and 4) $M.VFM_{BTL}$ with both risks (construction cost risk and traffic volume risk). The results of $M.VFM_{BTL}$ are shown in Table 4-10.

Table 4-10: The Modified VFM results according to risk inclusion

(Discounted value, billion KRW, 2011 price)

	PSC		BTL		ΔB	$M.VFM_{BTL}$
	AC_{PSC} (a)	OC_{PSC} (b)	$Lease\ fee_{BTL}$ (d)	OC_{BTL} (e)	(f)	(a+b)-(d+e)+f
1) $M.VFM_{BTL}$ (+no risks)	103.2	13.7	102.4	13.7	0.0	0.8
2) $M.VFM_{BTL}$ (+const. risk)	98.9	13.7	102.4	13.7	0.0	-3.5
3) $M.VFM_{BTL}$ (+volume risk)	103.2	9.9	102.4	13.7	0.0	-2.9
4) $M.VFM_{BTL}$ (+both risks)	98.9	9.9	102.4	13.7	0.0	-7.3

Note: 1. $M.VFM_{BTL}$ (+no risks) = the Modified VFM value without considering risks based on the BTL guidelines of Korea, $M.VFM_{BTL}$ (+const. risk) = the Modified VFM value considering the mean values of winning bid ratio risk and construction cost overrun risk, $M.VFM_{BTL}$ (+volume risk) = the Modified VFM value considering the mean value of traffic volume risk, and $M.VFM_{BTL}$ (+both risks) = the Modified VFM value considering the mean values of winning bid ratio risk, cost overrun risk and traffic volume risk.
2. AC_{PSC} = Asset cost in the PSC, OC_{PSC} = Operation cost in the PSC, $Lease\ fee_{BTL}$ = Lease fee in the BTL, OC_{BTL} = Operation cost in the BTL and ΔB = social benefit difference between the PSC and the BTL.

$M.VFM_{BTL}$ with no risk inclusion

Considering an average WBR of turn-key/alternative bids (88.55 per cent) in the National Highway projects between 2002 and 2011 (MLTM, 2012b) in calculating the asset cost of the PSC, $M.VFM_{BTL}$ (Table 4-10, the first row) shows that it is feasible to implement this project with the BTL, indicating the value of 0.8 (billion KRW) in the BTL.

$M.VFM_{BTL}$ with construction cost risk

From equation (3-10), using the mean values of WBR risk (76.90 per cent, Fig 4-2) and construction cost overrun risk (9.98 per cent, Figure 4-1), construction cost risk can be freshly calculated as 84.58 per cent (=0.769 × (1+0.0998)). The result (Table 4-10, the second row) shows that *M.VFM*$_{BTL}$ considering the construction cost risk is -3.5 (billion KRW), which is 4.3 (billion KRW) lower than the figure with no risk inclusion. This is because the mean value of construction cost risk is 3.97 per cent lower than an average WBR of turn-key/alternative bids (84.58 per cent).

This means that *M.VFM*$_{BTL}$ with no risk inclusion based on Korea's BTL guidelines (MOSF, 2009a) could be exaggerated by as much as the difference of 3.97 per cent more than the situation in reality.

M.VFM*$_{BTL}$ *with traffic volume risk

To verify the impact of traffic demand risk on *M.VFM*$_{BTL}$, the mean value of traffic volume risk (68.6 per cent, Figure 4-4) is applied. The result (Table 4-10, the third row) shows that the *M.VFM*$_{BTL}$ decreases to -2.9 (billion KRW). The decrease in *M.VFM*$_{BTL}$ is due to the decrease in the operation cost in the PSC by the VKT decrease in the project from traffic volume reduction (from 100 to 68.6 per cent).

M.VFM*$_{BTL}$ *with both risks

Table 4-10 (the last row) shows that the BTL scheme is not the best option for this project with *M.VFM*$_{BTL}$ value of -7.3 (billion KRW), when construction cost risk and traffic volume risk are included. Compared with *M.VFM*$_{BTL}$ with no risk inclusion, the value decreases by 8.1 (billion KRW), among which the impact of construction risk and traffic volume risk occupies, respectively, 4.4 and 3.7 (billion KRW).

All in all, from a viewpoint of the *M.VFM*$_{BTL}$ with no completion delay, it seems that the conventional delivery is more favourable than the BTL scheme when construction and traffic volume risks are included.

4.4.4.2 The Modified VFM (with completion delay)

Impact of a completion delay in the conventional delivery

As with the Todang-Gwansan case, to verify the impact of a completion delay in the conventional delivery on the PPP decision-making, *M.VFM*$_{BTL}$ with completion delay (0 to 4 years) is calculated. *M.VFM*$_{BTL}$ is calculated by considering a completion delay of conventional delivery, which affects not only yearly asset cost input but also the social benefit difference between the PSC and the BTL.

$M.VFM_{BTL}$ results are shown in Table 4-11. In the no risk inclusion case, $M.VFM_{BTL}$ soars from 0.8 to 30.0 (billion KRW) as a completion is delayed from 0 to 4 years. Similarly, in the risk (construction cost risk and traffic volume risk) inclusion case, it rises from -7.3 to 11.1 (billion KRW) according to the completion delay. This is because the increase in the social benefit difference between the PSC and the BTL due to a completion delay is bigger than the decrease in the public sector cost in the PSC due to discounting.

Additionally, considering the mean value of the completion delay (2.74 years, Figure 4-3) in the National Highway projects, the BTL scheme is better than the conventional option for this project, which is the same result as in the Todang-Gwansan case.

Table 4-11: The Modified VFM result with completion delay

(Discounted value, billion KRW, 2011 price)

	Delay (year)	PSC		BTL		ΔB	$M.VFM_{BTL}$
		AC_{PSC} (a)	OC_{PSC} (b)	$Lease\ fee_{BTL}$ (d)	OC_{BTL} (e)	(f)	(a+b)-(d+e)+f
No risk inclusion	0	103.2	13.7	102.4	13.7	0.0	0.8
	1	100.2	12.9	102.4	13.7	11.8	8.8
	2	97.2	12.3	102.4	13.7	23.0	16.4
	2.74	95.0	11.8	102.4	13.7	30.9	21.6
	3	94.3	11.6	102.4	13.7	33.5	23.4
	4	91.5	11.0	102.4	13.7	43.6	30.0
Risk inclusion	0	98.9	9.9	102.4	13.7	0.0	-7.3
	1	96.0	9.4	102.4	13.7	8.5	-2.2
	2	93.2	8.9	102.4	13.7	16.6	2.6
	2.74	91.0	8.6	102.4	13.7	22.3	5.8
	3	90.4	8.5	102.4	13.7	24.2	7.0
	4	87.7	8.0	102.4	13.7	31.5	11.1

Note: 1. AC_{PSC} = Asset cost in the PSC, OC_{PSC} = Operation cost in the PSC, $Lease\ fee_{BTL}$ = Lease fee in the BTL, OC_{BTL} = Operation cost in the BTL and ΔB = the social benefit difference between the PSC and the BTL. 2. Risk inclusion = construction cost risk (winning bid ratio and construction cost overrun) and traffic volume risk included

Critical completion delay

In order to determine a critical completion delay in the conventional delivery, which makes the $M.VFM_{BTL}$ zero, a linear regression analysis was conducted using Table 4-11. As seen in Figure 4-15, depending on whether construction cost risk and traffic volume risk are included or not, the regression line of $M.VFM_{BTL}$ differs.

In the no risk inclusion case, when the linear regression line is extended, it meets the horizontal axis at -0.17 year (-2.04 months). This means that even if the conventional delivery completes this project earlier than the BTL by up to 0.17 years (2.04 months), the BTL is better than the conventional delivery. In other words, even if the construction in the BTL starts up to 0.17 years

(2.04 months) later (for reasons including a negotiation delays or a financial problem) than the conventional delivery, the BTL is more favourable than the conventional delivery.

In the same way, regarding $M.VFM_{BTL}$ with risk inclusion (construction cost risk and traffic volume risk), the intercept of the horizontal axis (the critical completion delay) becomes 1.51 years (18.12 months). This means that if the completion in the conventional delivery is delayed by more than 1.51 years (18.12 months), the BTL becomes better than the conventional delivery. In other words, when more than 1.51 years (18.12 months) of completion delay is expected in the conventional delivery, the BTL can be a more appropriate delivery option even if $M.VFM_{BTL}$ is negative without completion delay.

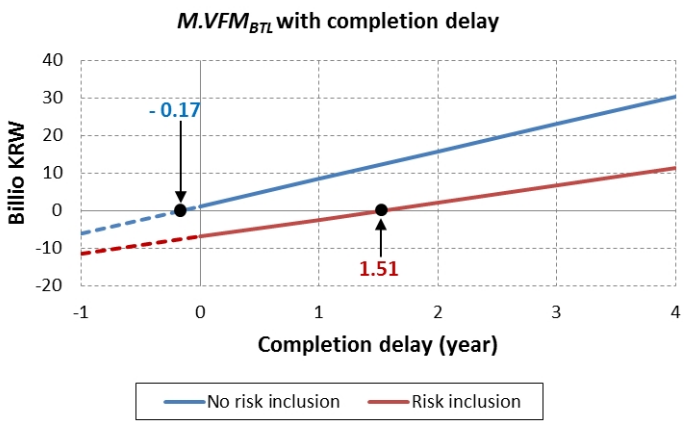


Figure 4-15: The Modified VFM result according to completion delay

4.4.4.3 Sensitivity analysis

$M.VFM_{BTL}$ results can be different depending on how large values are used as analysis factors. As in the Todang-Gwansan case, in order to examine the behaviour of $M.VFM_{BTL}$, according to the change of analysis factors, a sensitivity analysis is conducted. For this analysis, the following eight analysis factors are considered: 1) BTL construction cost; 2) BTL operation cost; 3) BTL finance interest rate; 4) discount rate; 5) BTL lease profitability; 6) construction deflator; 7) consumer price index; and 8) the size of social benefits.

The changes of $M.VFM_{BTL}$ with risk inclusion and a 2.74 year delay are shown in Figure 4-16, when the analysis factors vary by from -20 to 20 per cent on each factor's given value. A summary of the sensitivity analysis is shown in Table 4-12.

The sensitivity analysis results, shown in Figure 4-16, show that $M.VFM_{BTL}$ values with risk inclusion and a 2.74 year delay can be negative, which means the conventional delivery can be better than the BTL, when lease profitability goes up by about 9 per cent, the discount rate drops by about 14 per cent or the consumer price index drops by about 15 per cent. In the case of BTL construction cost, when it goes up by about 6 per cent, the Modified VFM becomes negative.

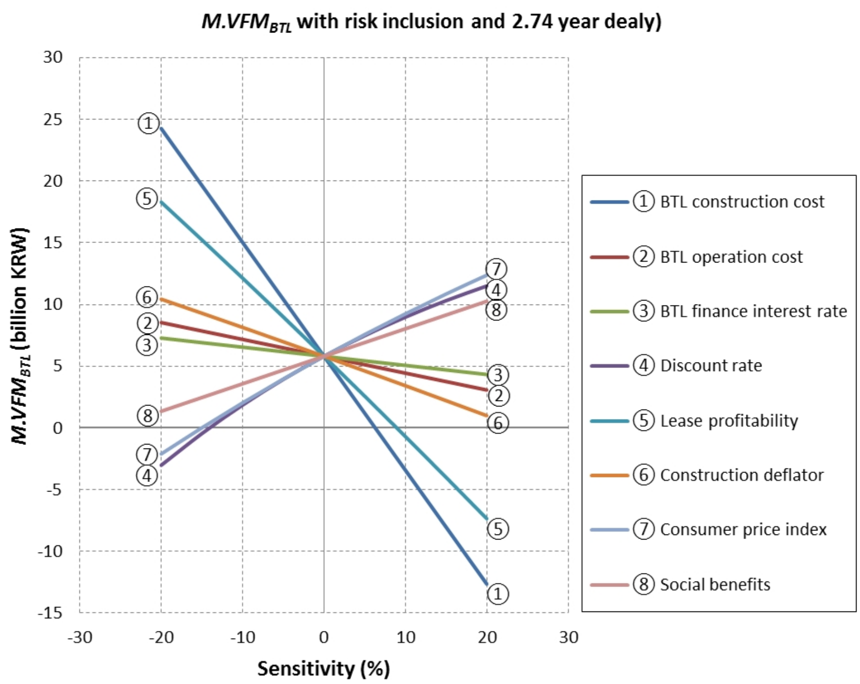


Figure 4-16: Sensitivity analysis of analysis factors (risk inclusion, 2.74 year delay)

Among the eight analysis factors, as seen in Table 4-12 and Figure 4-16, as discount rate, consumer price index or social benefits go up, $M.VFM_{BTL}$ rises with a positive slope, mainly because these factors make the lease fee drop. However, in the case of other factors, when they go up, $M.VFM_{BTL}$ falls with a negative slope because they make the lease fee rise or mean directly an increase in the public sector cost in the BTL (BTL operation cost).

In addition, the sensitivity results show that among the factors, BTL construction cost and lease profitability are most influential on the Modified VFM with the steepest slopes when they rise by from -20 to 20 per cent points based on each factor’s given value, which is the same result as found in the Todang-Gwansan case.

Accordingly, when the viability of the BTL is needed in terms of the government policy, it could be achieved by reducing BTL construction cost or lease profitability. For this reason, in reality, according to Kim (2011), when conducting the VFM analysis, many BTL projects adopt a lower BTL construction cost (93.8 per cent on average) than the PSC construction cost without sufficient support for this decision.

Table 4-12: Sensitivity of analysis factors on the Modified VFM

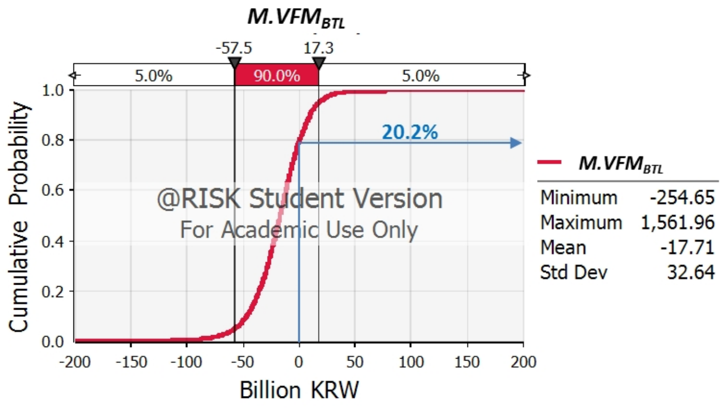
Analysis factors	$M.VFM_{BTL}$ changes due to the increase of analysis factors		
	Increase /decrease	Unit change (billion KRW)	Reasons
1. BTL construction cost	Decrease	-0.92	The increase of BTL construction cost makes private investment and lease fee rise, so $M.VFM_{BTL}$ decreases.
2. BTL operation cost	Decrease	-0.13	The increase of BTL operation cost naturally makes $M.VFM_{BTL}$ decrease.
3. BTL finance interest rate	Decrease	-0.07	The increase of BTL finance interest rate makes lease fee rise, so $M.VFM_{BTL}$ decreases
4. Discount rate	Increase	0.36	The increase of discount rate makes cost items fall. Among them, lease fee has a largest drop, so $M.VFM_{BTL}$ decreases.
5. Lease profitability	Decrease	-0.64	The rise of lease profitability makes lease fee rise, so $M.VFM_{BTL}$ decreases
6. Construction deflator	Decrease	-0.24	The rise of construction deflator makes private investment and lease fee increase, so $M.VFM_{BTL}$ decreases.
7. Consumer price index (CPI)	Increase	0.36	Nominal lease fee is converted to real term by consumer price index. The rise of CPI makes lease fee in real term drop, so $M.VFM_{BTL}$ increases.
8. Social benefits	Increase	0.22	The rise of social benefits makes the social benefit difference grow, so $M.VFM_{BTL}$ increases.

Note; Unit change means the change of $M.VFM_{BTL}$ when an analysis factor rises by 1 per cent on its given value.

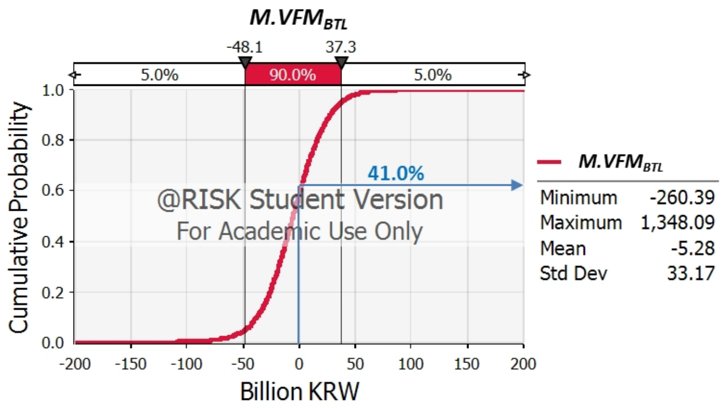
4.4.4.4 The Monte Carlo Simulations

The MCS is conducted to identify the impact of the following 11 risk variables, shown in Figure 4-1~Figure 4-7, from historical observations: WBR, construction cost overrun, traffic volume, three operation costs, construction deflator, consumer price index, five-year exchequer bond interest rate, and three-year non-guaranteed corporate bond interest rate. Figure 4-17 shows the MSC results with no completion delay and with a 2.74-year completion delay. In the case of no completion delay (Figure 4-17 (a)), $M.VFM_{BTL}$ is distributed between -57.5 and 17.3 (billion KRW) with a 90 per cent probability and the mean value is -17.7 (billion KRW). Additionally, the probability that $M.VFM_{BTL}$ is positive is 20.2 per cent, which shows that the BTL scheme would not be feasible for this project. In addition, in the case of a 2.74-year completion delay (Figure 4-17 (b)), $M.VFM_{BTL}$ is distributed between -48.1 and 37.3 (billion KRW) with a 90 per cent probability and the mean value is -5.3 (billion KRW). The probability that $M.VFM_{BTL}$ is positive is 41.0 per cent, meaning that the BTL scheme is not the best option for this project, even considering the average completion delay of the National Highways.

From the MCS results, as a completion delay goes up, the mean value $M.VFM_{BTL}$ and the probability that the BTL is better also go up. In addition, even when considering the average completion delay of the National Highway projects (2.74 years), the conventional delivery is more favourable for this project than the BTL scheme, which is a quite different result from single-value estimations.



(a) No delay



(b) 2.74 year completion delay

Figure 4-17: Probability distribution of the Modified VFM

This difference between single-value estimation and the MCS seems to occur because some analysis factors estimated by following Korea's BTL guidelines (MOSF, 2009a) are considerably different from the expected values (mean value) from historical observations. For examples, the five-year exchequer bond interest rate in the single-value estimation method is 3.77 per cent, while the historical observations produce 5.10 per cent as an expected value. As the five-year exchequer bond interest rate is closely related to BTL profitability, considering the sensitivity of BTL profitability shown in Figure 4-16, it can cause the MCS result of $M.VFM_{BTL}$ to drop considerably, compared with the use of the single-value estimation method.

Consequently, it seems reasonable that the MCS technique using historical observations should be used in PPP decisions because this can produce some different results to single-value estimation method by considering the potential for change of various analysis factors at the same time.

4.5 Findings

In order to determine the impact of transferable risks on the PPP decisions and which delivery option is the most appropriate in the National Highway programme, the Modified VFM analysis was applied to the Todang-Gwansan case and the Dongup-Hanlim case. Through two case studies, the application of the analysis revealed several common features.

1) Regarding construction cost risk, $M.VFM_{BTL}$ with an average WBR of turn-key/alternative bid based on Korea's BTL guidelines (MOSF, 2009a) can be exaggerated compared with that with the use of construction cost risk (winning bid ratio risk and construction cost overrun risk). This is because the average WBR of turn-key/alternative bids in the National Highway projects was 88.55 per cent between 2002 and 2011 (MLTM, 2012b), while the historical observations suggests an application ratio of 84.58 per cent, meaning construction cost risk.

Although it is true that some National Highway projects use turn-key/alternative bid, a typical bid system in the conventional delivery[64] in the National Highways seems to be design-bid-build, not a turn-key/alternative. Particularly, non-governmental organisations like CCEJ (2012), and the media, have criticised the turn-key/alternative bid for being inefficient and for wasting public funds. Considering that a PSC needs to be backed by a plausible and practical case (Grimsey and Lewis, 2005), it does not appear reasonable to use an average turn-key/alternative bid for the public sector cost calculation of a PSC.

As a result, for more accurate quantitative PPP decision-making in the National Highway projects, the Modified VFM considering historical observations reflecting all bid systems is recommended for the estimation of asset cost, instead of an average WBR of turn-key/alternative projects.

2) Traffic volume risk seems to affect PPP decisions in the National Highways. When including traffic volume risk (68.6 per cent), $M.VFM_{BTL}$ values decrease by 4.6 and 3.7 (billion KRW) in the Todang-Gwansan case and in the Dongup-Hanlim case, respectively, compared with those without traffic volume risk. This is due to the decrease of operation cost in the PSC by the VKT decrease in the projects from traffic volume reduction (from 100 to 68.6 per cent). In addition,

[64] According to (MLTM, 2012b), between 2002 and 2011, 33 National Highway projects were started by turnkey/alternative bidding. Considering that 20 to 40 projects are started every year, it seems that approximately 10–15 per cent of the National Highway projects start by turnkey/alternative bidding.

when considering traffic volume risk solely, the most favourable procurement option with no completion delay changes from conventional to BTL in the Dongup-Hanlim case.

3) A completion delay in the conventional delivery can make a critical impact on the PPP decisions. When including a completion delay (2.74 years) in the conventional delivery, $M.VFM_{BTL}$ values, with risk (construction cost risk and traffic volume risk) inclusion, soar by 36.7 and 13.1 (billion KRW) in the Todang-Gwansan case and in the Dongup-Hanlim case, respectively. As a result, the most favourable procurement option in two cases with risk (construction cost risk and traffic volume risk) inclusion changes from the conventional to the BTL option.

4) Case studies show that each project has its own critical completion delay, making $M.VFM_{BTL}$ zero. In no risk inclusion cases, critical completion delay is -0.35 and -0.17 years in the Todang-Gwansan case and in the Dongup-Hanlim case respectively. This means that, with no risk inclusion, even if the construction in the BTL starts up to 0.35 and 0.17 years, later, respectively, than the conventional delivery because of, for example, a negotiation delay or a financial problem, the BTL is more favourable than the conventional delivery.

Similarly, in the case of risk inclusion (construction cost risk and traffic volume risk), the critical completion delay is respectively 0.26 and 1.51 years in the Todang-Gwansan case and in the Dongup-Hanlim case. This means that, when more than 0.26 and 1.51 years of completion delay are respectively expected in the conventional delivery, the BTL can be a more appropriate delivery option even when the Modified VFM is negative without completion delay.

5) Sensitivity analysis shows that BTL construction cost and BTL lease profitability are the most influential among eight analysis factors in the calculation of $M.VFM_{BTL}$. In the Todang-Gwansan case, even when each analysis factor fluctuates from -20 to + 20 on its given value, the procurement decision does not change. However, in the Dongup-Hanlim case, the procurement decision could change in accordance with the fluctuation of some analysis factor, such as BTL construction cost, BTL lease profitability, discount rate and consumer price index.

6) The MCS results, with 11 risk variables from historical observations, show that as completion delay increases, the mean value of $M.VFM_{BTL}$ and the probability that the BTL is better increase. Considering a completion delay (2.74 years), the most favourable procurement option is the BTL scheme for the Todang-Gwansan case, which is the same as the result from the single-value method. However, in the Dongup-Hanlim case, the result is different from that obtained by single-value method. This appears to be the case because some analysis factors, estimated by following Korea's BTL guidelines (MOSF, 2009a), differ considerably from the expected values (mean value) derived from historical observations.

Summing up the results, considering all risk variables from historical observations, the BTL option is more favourable for the Todang-Gwansan case, while conventional delivery is more favourable for the Dongup-Hanlim case. In addition, it seems reasonable to say that the MCS technique should be used in PPP decisions because it might produce some different results by considering the potential for change of various analysis factors at the same time.

CHAPTER 5 The National Expressway Case Studies

5.1 Introduction

The objective of this chapter is to find out the impact of transferable risks on the Modified VFM and the PPP decisions in the National Expressway programme, using two case studies, covering the research objectives (2-1, 2-2 and 2-3). As case studies, the Suwon-Pyungtaek National Expressway case and the Bongdam-Songsan National Expressway case are considered in this chapter (as explained in Chapter 3 (see 3.6)). Therefore, this chapter is largely made up of three sections: 1) quantified risks for the National Expressways; 2) case study 1: the Suwon-Pyungtaek case; and 3) case study 2: the Bongdam-Songsan case.

To begin with, as in Chapter 4 (the National Highway case studies), risk quantification is conducted (in section 5.2) regarding not only transferable risks but also other risks like operation costs and inflation, based on historical observation and the literature. In terms of transferable risks, as with the National Highway programme, three risks are considered in this chapter: construction cost risk (consists of WBR risk and construction cost overrun), traffic volume risk and completion delay in the conventional delivery. Besides, three operation cost items are also quantified: general maintenance cost/VKT, re-pavement cost/VKT and road structure maintenance cost/VKT. The risk quantification is performed using the @ Risk 5.7 software package.

In the section of the Suwon–Pyungtaek case (5.3) and the Bongdam-Songsan case (5.4), the impacts of transferable risks on the Modified VFM and the PPP decisions are verified using impact analyses, such as single-value estimation, sensitivity analysis and the Monte Carlo Simulation, as explained in Chapter 3 (see 3.5).

As with the National Highway programme, for the calculation of the Modified VFM using single-value estimation and sensitivity analysis, analysis input data are estimated by following Korea's BTL guidelines (MOSF, 2009a) because these can provide the reference points for various analysis factors. When it comes to the Modified VFM using Monte Carlo Simulation, analysis factors are used as a form of the probability distribution, quantified from historical observations. By doing so, how the PPP or procurement decisions could be changed will be scrutinised, when they are reflected simultaneously in the Modified VFM.

5.2 Quantified risks for the National Expressways

5.2.1 Transferable risks

5.2.1.1 Construction cost risk

Construction cost risk in the National Expressways is estimated using historical observations collected from 66 National Expressway projects completed between 2006 and 2010. From equation (3-10), construction cost risk is composed of EP, WBR and construction cost overrun (α). Among these, estimated price (designed price in this research) is a constant for a project, so WBR and construction cost overrun are considered as risk factors.

Construction cost overrun

Construction cost overrun risk in real terms for the National Expressways can be estimated from equation (3-11) and the quantified PDF is shown in Figure 5-1. The mean value (expected value) is 10.21 per cent, which means that the construction cost of a National Expressway project is expected to increase on average by 10.21 per cent on the contract construction cost in real terms.

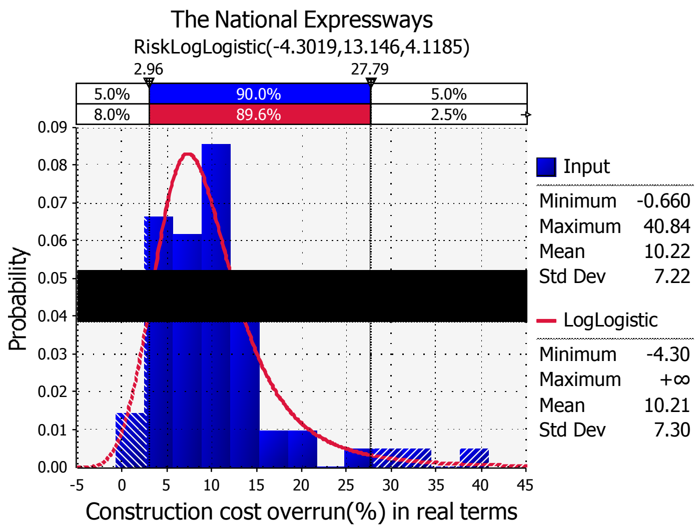


Figure 5-1: The PDF for construction cost overrun risk in the National Expressways

WBR

WBR means the proportion of bid winner's price (contract price) to EP for a project. WBR is directly obtained from the historical observations. In contrast to construction cost overrun risk, there are no PDFs passing the Chi square test (χ^2), so WBR risk is expressed as a form of frequency distribution, shown in Figure 5-2. From Figure 5-2, the mean value of winning bid ratio is 71.5 per cent, which means the expected value of winning bid ratio of a National Expressway project.

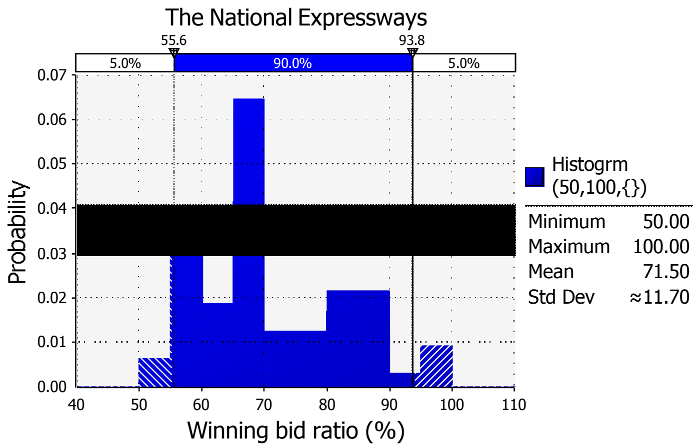


Figure 5-2: Frequency distribution for WBR in the National Expressway

Application ratio

Based on construction cost risk and WBR estimated above, the application ratio from equation (3-10), meaning construction cost risk, can be calculated. Therefore, the mean value of the application ratio becomes 78.80 (per cent),[65] which will be used in order to estimate the Modified VFM using single-value estimation and sensitivity analysis. For the MCS of the Modified VFM, the PDF of construction cost overrun and the frequency distribution of the WBR will be used, shown in Fig 5-1 and Figure 5-2 respectively.

5.2.1.2 Completion delay

From the historical observations, the probability distribution of the completion delays in the National Expressways is shown in Fig 5-3. As seen in Figure 5-3, completion delay in the conventional delivery is, on average, 6.30 years. Taking five years as the standard construction duration (KDI, 2008a, MLTM, 2010c), as discussed in Chapter 3, 1.30 years of completion delay are expected to occur when using conventional delivery for a National Expressway project.

[65] 78.80 (%) = $0.715 \times (1 + 0.1021)$

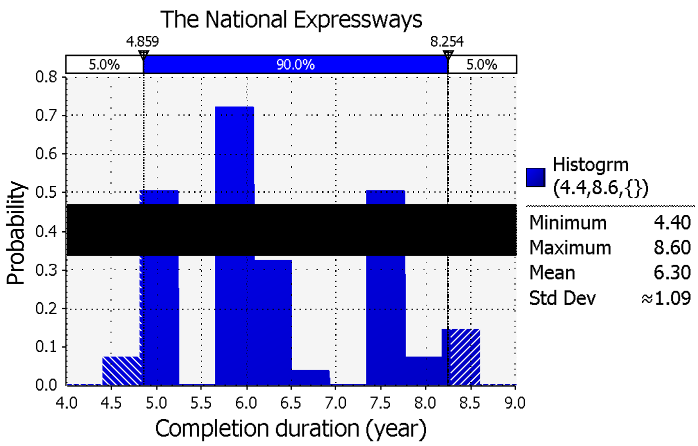


Figure 5-3: Construction duration probability distribution in the National Expressways

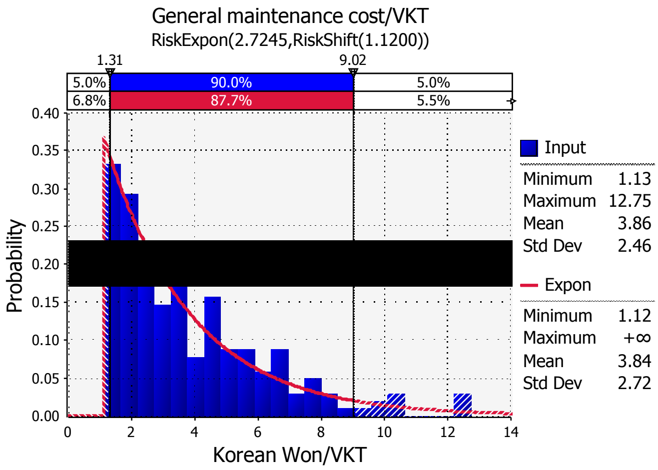
5.2.1.3 Traffic volume risk

Along with the National Highways, traffic volume risk in the road sector, shown in Figure 4-4, is also used for the National Expressway case because of the unavailability of the historical observations.

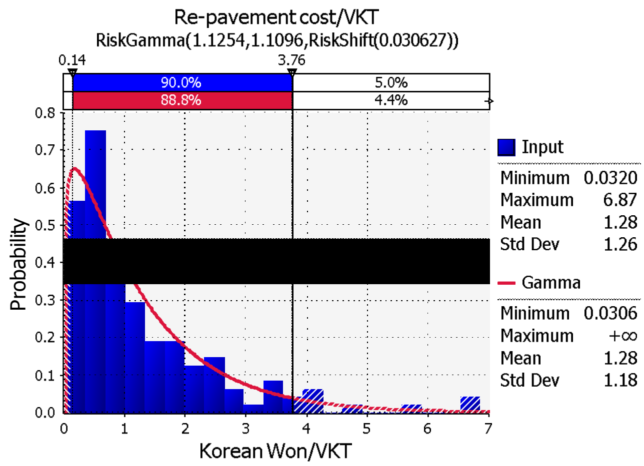
5.2.2 Other risk variables

5.2.2.1 Operation cost

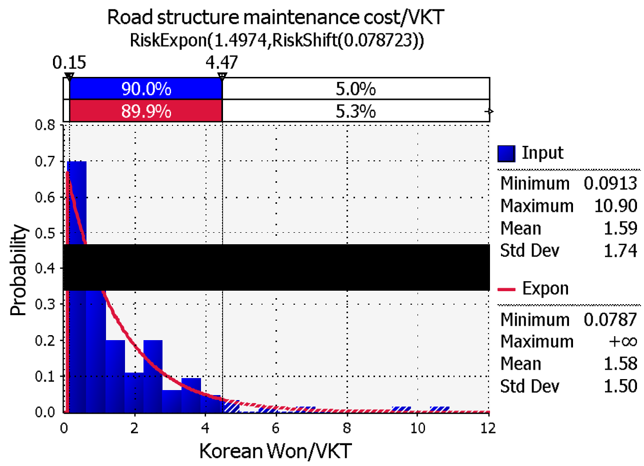
In this research, the historical observations on operation cost in the National Expressways come from 44 regional National Expressway Management Offices (NEMOs) under the KEC, not from individual projects. Therefore, the historical observation data concern the budget executed in the appropriate NEMO from 2006 to 2010. In the same way as for the National Highway, using VKT as a scale factor, three risk variables are considered for operation cost: 1) general maintenance cost/VKT; 2) re-pavement cost/VKT; and 3) road structure maintenance cost/VKT, which are shown in Figure 5-5. The risk variables are calculated based on the 2005 price.



(a) General maintenance cost/VKT



(b) Re-pavement cost/VKT



(c) Road structure maintenance cost/VKT

Figure 5-4: Operation cost risks in the National Expressways

5.2.2.2 Inflation

With respect to inflation, according to Korea's BTL guidelines (MOSF, 2009a), a construction deflator, shown in Figure 4-6 (a), is used for the calculation of the BTL lease fee. In addition, the yearly BTL lease fee in nominal terms is converted to real terms by the consumer price index, shown in Figure 4-6 (b).

5.2.2.3 Factors relating BTL viability

According to Korea's BTL guidelines (MOSF, 2009a), BTL lease profitability is expressed through "five-year exchequer bond interest rate + mark-up" and the mark-up is composed of a premium for long term investment and risk premium for construction and operation. In the same way, BTL finance interest rate for private sector is estimated by applying additional rate to a "three-year non-guaranteed corporate bond (AA-) interest rate", which is the base rate. These are shown in Figure 4-7.

5.3 Case 1: The Suwon-Pyungtaek case

5.3.1 Project overview

In 1998, the Suwon-Pyungtaek National Expressway was planned by the Korean government to supplement the main north-south transport corridors, which were experiencing daily congestion,[66] in the southern part of Gyeonggi Province, such as Expressway 1 (Seoul-Busan) and Expressway 15 (Seoul-Mokpo). New capacity would be provided by building a new main transport axis connecting several east-west transport axes, such as Expressway 40 (Pyungtaek-Jaechun) and Expressway 400 (the 2nd Seoul metropolitan orbital), as shown in Figure 5-5. However, The Suwon-Pyungtaek National Expressway was suggested to the Korean government from the private sector, specifically construction companies and finance firms, as a BTO project in 2000. As a result, it was decided to implement this project using BTO scheme in 2002 after the deliberation of the PPP board. After final design and negotiation, construction on this project started in 2005; the project was completed in 2009.

The overview of this project (as shown in the contract awarded in 2005) is as follows:

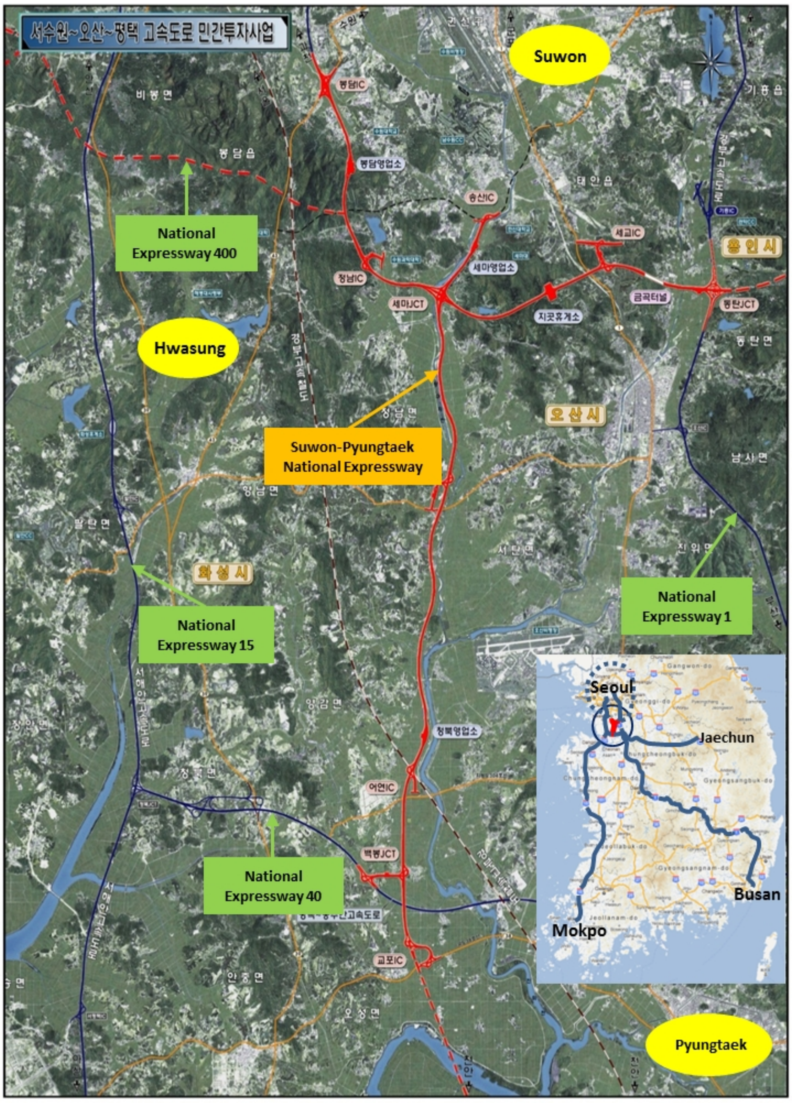
- Title: the Suwon-Pyungtaek National Expressway (171 & 400) Project
- Length and location: : 38.5km (4~6 lanes)
  (North-south) Anyung-ri, Hwasung ~ Suksung-ri, Pyungtaek, Gyeonggi province
  (East-west) Dongwha-ri, Hwasung ~ Bangkyo-ri, Hwasung, Gyeonggi Province
- PPP type: BTO
- Construction duration: 52 months
- Operation duration: 30 years
- Project cost:[67] 856.9 (billion KRW, 2002 price)
  (Private fund: 608.4, construction subsidy: 248.5)
- Inflation rate: 4 per cent
- Internal rate of return (IRR): 7.40 per cent in real terms
- MRG and redemption

[66] As of 2010, the neighbouring National Expressway 1 (ten lanes) had a traffic volume of 150,242 (level of service: E) and National Expressway 15 (six lanes) has 109,507 traffic volume, according to MLTM (2011d).

[67] The project cost in this project means asset cost excluding compensation cost (567.8 billion KRW) provided by the Korean Government.

- The Korean government guarantees up to 80 per cent, 70 per cent and 60 per cent of contract revenue every five years for 15 years after start of operation.
- The Korean government does not provide a guarantee when actual revenue is smaller than a half of contract revenue.
- The Korean government redeems revenue exceeding 120 per cent, 130 per cent and 140 per cent of contract revenue in first five years, second five years and third five years, respectively, after the start of operation.

- Concessionaire: Gyeonggi Expressway Corp.
  - Construction investor (90 per cent): Doosan heavy industry (25 per cent), Keumho corp. (25 per cent), Daelim corp. (16 per cent), Dongbu construction (13.33 per cent), Hanwha construction (10.67 per cent),
  - Financial investor (10 per cent): Shinhan bank (10 per cent).



Source: MLTM

Figure 5-5: The Suwon-Pyungtaek National Expressway project map

5.3.2 Analysis factors and assumptions for the Modified VFM

Although this project has already been implemented under the BTO scheme, in order to verify the impact of transferable risks on the PPP decisions and the appropriateness of PPP decision, this case study considers three alternative delivery procurement options: conventional, BTL and BTO.

Basic analysis factors for Modified VFM are as follows:

- PPP model: BTO and BTL
- Discount rate: 7.5 per cent (real)
- Decision-making time: 2002
- Price base year: 2002
- Five-year exchequer bond interest rate:[68] 6.9 per cent (nominal)
- Three-year non-guaranteed corporate bond (AA-) interest rate:[69] 7.01 per cent (nominal)
- Construction deflator:[70] 3.51 per cent (nominal, on average from 1999 to 2002)
- Consumer price index:[71] 3.50 per cent (nominal, on average from 1999 to 2002)
- BTL Lease profitability:[72] 8.9 per cent (nominal)
  (Five-year exchequer bond interest rate + 2 per cent)
- BTL finance interest rate:[73] 8.51 per cent (nominal)

---

[68] The five-year exchequer bond interest rate is calculated by a weighted average method, which applies 0.1, 0.2, 0.3 and 0.4 to the first, second, third and fourth quarter value (MOSF, 2009a). The quarterly five-year exchequer bond interest rate is provided by the Korea Bond Information Service (http://www.kofiabond.or.kr).

[69] The three-year non-guaranteed corporate bond interest rate is also provided by the Korea Bond Information Service (http://www.kofiabond.or.kr). It is estimated in the same way as the five-year exchequer bond interest rate, following Korea's BTL guidelines (MOSF, 2009a).

[70] Construction deflator means the construction investment deflator in Expenditure on Gross Domestic Product on National Accounts and it is provided by the Bank of Korea (http://www.bok.or.kr).

[71] Consumer price index is also provided by the Bank of Korea (http://www.bok.or.kr).

[72] BTL lease profitability is expressed as a "five-year exchequer bond interest rate + mark-up rate" and the mark-up is composed of a premium for long-term investment and risk premium for construction and operation (MOSF, 2009a). According to research (Jung et al., 2006) and newspaper reports (Jung, 2005, Lee, 2009), the mark-up rate is distributed from 0.5 per cent to 2.25 per cent. Considering that there is no advanced BTL projects for road programme and road projects usually takes 35 years for construction and operation, a mark-up rate of 2.0 per cent is considered for the National Expressways in this research.

(Three-year non-guaranteed corporate bond (AA-) interest rate + 1.5 per cent)

- BTL Finance terms: level debt service during operation period
- BTL finance structure: equity 15 per cent, debt 85 per cent
- Operation period: 30 years, construction duration: five years

In addition, the same assumptions (see 4.3.2) for the Modified VFM used in the National Highway cases are also used in the National Expressway cases.

5.3.3 Main calculation items for the Modified VFM

From equation (3-7), (3-8) and (3-9), the main calculation items for the Modified VFM are the asset cost of a PSC (AC_{PSC}), the operation cost of a PSC (OC_{PSC}) and a BTL (OC_{BTL}), the lease fee of a BTL ($Lease\ fee_{BTL}$), the revenue ($Revenue$) and subsidy ($Subsidy_{BTO}$) from the Korean government, the minimum revenue guarantee cost (MRG_{BTO}) and the benefit difference (ΔB).

***Asset cost of the PSC* (AC_{PSC})**

The basic asset cost data for this project is shown in Table 5-1. With respect to AC_{PSC}, the cost items are collected from the negotiation result report on the Suwon-Pyungtaek National Expressway (MLTM, 2005). The bracketed cost values mean the designed price, not including WBR. Therefore, design cost and construction cost in the PSC based on Korea's BTL guidelines (MOSF, 2009a) are calculated by multiplying each bracketed cost and 82.14 per cent, an average WBR[74] of turn-key/alternative bids in the National Expressways between 2002 and 2011 (MLTM, 2012b). The asset cost items of the PPP are collected from the agreement on the Suwon-Pyungtaek National Expressway (MLTM and Gyeonggi Expressway Corp., 2005).

In addition, in order to estimate the Modified VFM, according to Table 4-2, the yearly asset costs of the PSC are distributed. With respect to longer construction durations, considering

[73] BTL finance interest rate is expressed as "three- year non-guaranteed corporate bond interest rate + mark-up rate" (MOSF, 2009a) and, according to Kim et al. (2005), a mark-up rate seems to be distributed from 0.66 per cent to 2.00 per cent. Considering that there is no advanced BTL projects for roads and road projects usually takes 35 years for construction and operation, a mark-up rate of 1.5 per cent is used for the National Expressways.

[74] The details are given in Appendix D.

completion delay, new yearly distribution ratios based on interpolation methods and Table 4-2 will be applied to the calculation of the Modified VFM.

Table 5-1: Basic asset cost for the PSC and the PPP

(Unit: billion KRW, 2002 price)

<table>
<tr><th colspan="2">Asset cost items</th><th>PSC
[BTL guideline]</th><th>PPP
[Contract]</th></tr>
<tr><td rowspan="4">Building cost</td><td>Investigation</td><td>2.2</td><td>2.2</td></tr>
<tr><td>Design</td><td>16.2
(19.7)</td><td>15.5</td></tr>
<tr><td>Construction</td><td>712.7
(867.6)</td><td>770.0</td></tr>
<tr><td>Sub total</td><td>731.1</td><td>787.7</td></tr>
<tr><td colspan="2">Compensation cost</td><td>0</td><td>0</td></tr>
<tr><td colspan="2">Additional cost</td><td>27.0
Construction inspection 17.0
Environmental/traffic impact assessment 1.4
Cultural asset survey 4.6
Insurance 4.0</td><td>37.3
Construction inspection 17.0
Environmental/traffic impact assessment 1.40
Cultural asset survey 4.6
Insurance 5.0
Financial cost 9.3</td></tr>
<tr><td colspan="2">Operation facility cost</td><td>21.1
Toll collection 14.0
Traffic monitoring and control 5.7
Traffic safety 0.6
Facility maintenance 0.8</td><td>21.1
Toll collection 14.0
Traffic monitoring and control 5.7
Traffic safety 0.6
Facility maintenance 0.8</td></tr>
<tr><td colspan="2">Business reserve</td><td>0</td><td>9.7
Business commence cost 8.6
Stock issue cost 1.1</td></tr>
<tr><td colspan="2">Total</td><td>779.1</td><td>855.8</td></tr>
</table>

Note: 1. Compensation cost is provided by the Korean government, so it is not included in the Modified VFM assessment. 2. The bracketed values are from the negotiation result report on the Suwon-Pyungtaek National Expressway (MLTM, 2005). 3. Insurance cost for a PSC is contractor's all risk insurance(4.0), while insurance cost for a PPP is composed of contractor's all risk (4.0), advanced loss of profits (0.3), employer's liability (0.01) and performance guarantee (0.7)

Operation cost for the PSC and the BTL (OC_{PSC}, OC_{BTL})

As for the National Highway cases, yearly base operation costs for the PSC (OC_{PSC}) are calculated by multiplying the mean values of the operation costs[75] (KRW/VKT) from the historical observations and yearly VKT data of this project from the contract (MLTM and Gyeonggi Expressway Corp., 2005). In order to consider the variation of maintenance cost

[75] From the historical observations, the mean values of operation cost items are as follows: 1) management cost (personnel cost included)/VKT = 16.51 KRW/VKT; 2) general maintenance cost/VKT = 3.84 KRW/VKT; 3) re-pavement cost/VKT = 1.28 KRW/VKT; and 4) road structure maintenance cost/VKT = 1.58 KRW/VKT.

according to aging, yearly maintenance costs are estimated by considering the decrepitude of road with Table 4-3.

When it comes to the operation cost of the BTL (OC_{BTL}), since yearly operation costs are provided in the contract awarded in 2005, these values are used for the Modified VFM calculation.

Lease fee for the BTL (Lease fee_{BTL})

According to Korea's BTL guidelines (MOSF, 2009a), the yearly lease fee in nominal terms is calculated as in equation (4-1). The asset cost of the PPP (BTL) in real terms in Table 5-1 is delivered as a form of equity (15 per cent) and debt (85 per cent) according to the BTL finance structure. Considering construction deflator and BTL finance interest rate, the total investment of private sector, including principal and interest, becomes 1,150.1 (billion KRW, nominal term), which is the sum of (a), (b) and (C) in Table 5-2.

Table 5-2: Calculation of the private sector investment

(Unit: billion KRW)

Year	Equity (15%)		Debt (85%)		Interest (nominal)
	Real (2002 price)	Nominal	Real (2002 price)	Nominal	
2005	6.9	7.7	39.4	43.8	
2006	17.7	20.5	101.0	116.1	3.7
2007	41.8	49.8	237.5	282.3	13.6
2008	41.7	51.4	236.8	291.4	37.6
2009	19.9	25.4	113.1	144.1	62.4
Total	128.0	154.9 (a)	727.8	877.8 (b)	117.4 (c)
Private sector investment (P = a + b + c)			1150.1		

Consequently, in this case study, the yearly lease fee in nominal terms for the BTL is calculated as follows:

$$PVIFA_{(30,0.089)} = \sum_{i=1}^{30} \frac{1}{(1+0.089)^i} = 10.3654$$

$$Lease\ fee = \frac{1150.1}{PVIFA_{(30,0.089)}} = \frac{1150.1}{10.3654} = 110.951\ \text{(billion KRW, nominal)}$$

Considering the consumer price index and economic discount rate, the yearly lease fee in nominal terms will be transformed into real terms to be applied to the Modified VFM.

Revenue, subsidy and MRG for the BTO ($Revenue, Subsidy_{BTO}, MRG_{BTO}$)

As shown in equation (3-7), revenue, subsidy and MRG costs reduce the Modified VFM in the BTO scheme. Revenue and subsidy are collected from the contract awarded in 2005.

With respect to MRG, the MRG condition of this project is weaker than in previous projects, such as the Incheon International Airport Expressway and the Chunan-Nonsan Expressway, where up to 90 per cent of contract revenue is guaranteed for 20 years. In this project, the Korean government guarantees up to 80 per cent, 70 per cent and 60 per cent of the contract revenue every five years for 15 years after the project is opened. In addition, when actual revenue is less than half of contract revenue, the MRG condition is not applied.

Although the MRG cost is zero when forecast traffic volume is realised, in reality there is some discrepancy between forecast and actual traffic volumes. Using the traffic volume risk and the MRG condition, the MRG cost will be calculated in Modified VFM analysis.

Social benefit difference (ΔB)

The social benefits for the Modified VFM analysis are collected from the negotiation report on the Suwon-Pyungtaek National Expressway project (MLTM, 2005). For a simple calculation, the relationship between benefit cost ratio and volume/capacity in the National Expressway is assumed to follow equation (4-2) because of the unavailability of appropriate historical observations. Using equation (4-2) and social benefit data, the social benefit difference (ΔB) beween the PSC and the PPP (BTL and BTO) can be calculated.

Considering equation (4-3) and the BCR (=2.72) of this case, when the traffic volume drops to 68.6 per cent of the forecast one, the social benefits also drop to 74.0 per cent of the forecast one.

5.3.4 Analysis

5.3.4.1 The Modified VFM (with no completion delay)

In order to verify the impact of the inclusion of construction cost risk and traffic volume risk on the Modified VFM when there is no completion delay in the conventional delivery, four different Modified VFM (*M.VFM*) using the mean value of each risk are conducted: 1) *M.VFM* without risks; 2) *M.VFM* with construction cost risk; 3) *M.VFM* with traffic volume risk; and 4) *M.VFM* with both risks (construction cost risk and traffic volume risk). The results of *M.VFM* are shown in Table 5-3.

Table 5-3: The Modified VFM results according to risk inclusion

(Discounted value, billion KRW, price of 2002)

	PSC		*Revenue* (c)	BTL		BTO		ΔB (f)	$M.VFM_{BTL}$	$M.VFM_{BTO}$	$M.VFM_{BTL\text{-}BTO}$
	AC_{PSC} (a)	OC_{PSC} (b)		$Lease\ fee_{BTL}$ (d)	OC_{BTL} (e)	$Subsidy_{BTO}$ (f)	MRG_{BTO} (g)		(a+b)-(d+e)	(a+b-c) -(f+g)	(c+f+g) -(d+e)
1) *M.VFM* (+no risks)	437.5	129.6	519.5	447.7	85.5	135.5	0.0	0.0	33.8	-87.9	121.8
2) *M.VFM* (+const. risk)	420.8	129.6	519.5	447.7	85.5	135.5	0.0	0.0	17.2	-104.6	121.8
3) *M.VFM* (+volume risk)	437.5	120.6	356.6	447.7	85.5	135.5	15.9	0.0	24.8	50.1	-25.3
4) *M.VFM* (+both risks)	420.8	120.6	356.6	447.7	85.5	135.5	15.9	0.0	8.2	33.5	-25.3

Note: 1. M.VFM (+no risks) = the Modified VFM without considering risks, based on the BTL guidelines of Korea, M.VFM (+const. risk) = the Modified VFM considering the mean values of winning bid ratio risk and construction cost overrun risk, M.VFM (+volume risk) = the Modified VFM value considering the mean value of traffic volume risk, and M.VFM (+both risks) = the Modified VFM value considering the mean values of winning bid ratio risk, cost overrun risk and traffic volume risk.
2. AC_{PSC} = Asset cost in the PSC, OC_{PSC} = Operation cost in the PSC, *Revenue* = Revenue, $Lease\ fee_{BTL}$ = Lease fee in the BTL, OC_{BTL} = Operation cost in the BTL $Subsidy_{BTO}$ = Subsidy from the Korean government, MRG_{BTO} = MRG cost and *DB* = social benefit difference between the PSC and the PPP (BTL/BTO).

M.VFM with no risk inclusion

According to Korea's BTL guidelines (MOSF, 2009a), an average WBR of turn-key/alternative bids (82.14 per cent) in the National Expressway projects between 2002 and 2011 (MLTM, 2012b) is considered in calculating the asset cost of the PSC, as shown in the first row of Table 5-3.

The results of *M.VFM* with no risk inclusion show that the BTL is more favourable than the conventional delivery, indicating $M.VFM_{BTL}$ of 33.8 (billion KRW), while the BTO is not the best option indicating $M.VFM_{BTO}$ of -87.9 (billion KRW). Accordingly, the BTL option is much better than the BTO, indicating $M.VFM_{BTL\text{-}BTO}$ of 121.8 (billion KRW).

M.VFM with construction cost risk

From equation (3-10), an application ratio, indicating construction cost risk, consists of WBR risk and construction cost overrun risk. Using the mean values of the WBR risk (71.50 per cent, Fig 5-2) and construction cost overrun risk (10.21 per cent, Figure 5-1), the asset cost of the PSC can be freshly calculated.

The results (Table 5-3, the second row) show that $M.VFM_{BTL}$ and $M.VFM_{BTO}$ considering the construction cost risk are respectively 17.2 and -104.6 (billion KRW), which are 16.6 (billion KRW) lower than those with no risk inclusion. This is because the mean values of WBR and construction cost overrun make an application ratio of 78.80 per cent (0.715 × (1+0.1021)), which is 3.34 per cent lower than an average winning bid ratio (82.14 per cent) of turn-key/alternative bids used. This means that $M.VFM_{BTL}$ and $M.VFM_{BTO}$ with no risk inclusion based on Korea's BTL guidelines (MOSF, 2009a) could be exaggerated by as much as the difference of 3.34 per cent more than the situation in reality.

However, $M.VFM_{BTL\text{-}BTO}$ (the Modified VFM difference between the BTL and the BTO) is not changed because this is not related to the asset cost of the PSC, though affected by WBR and construction cost overrun, according to equation (3-10).

M.VFM with traffic volume risk

To verify the effect of traffic demand risk on *M.VFM*, the mean value of traffic volume risk (68.6 per cent) shown in Figure 4-4 is applied to the analysis. The result (Table 5-3, third row) shows that $M.VFM_{BTL}$ decreases by 9.0 (billion KRW), whereas $M.VFM_{BTO}$ increases by 138.0 (billion KRW), compared with those with no risk inclusion.

The decrease of $M.VFM_{BTL}$ is due to the decrease in operation cost in the PSC by VKT reduction following the traffic volume decrease. In addition, the main reason for the $M.VFM_{BTO}$ increase is that with the traffic volume decreasing, the decrease in revenue is much more than the MRG increase.

As a result, $M.VFM_{BTL\text{-}BTO}$ is changed to a negative value (-25.3) from a positive value (121.8). In other words, the BTO option becomes more favourable than the BTL for this project, when actual traffic volume drops to 68.6 per cent of forecast traffic volume.

M.VFM with both risks

When both construction cost risk and traffic volume risk are included in the analysis, Table 5-3 (the last row) shows that that $M.VFM_{BTL}$ and $M.VFM_{BTO}$ become respectively 8.2 and 33.5

(billion KRW), which means that the BTL and the BTO option are more favourable than the conventional delivery for this project. In addition, among PPP alternatives the BTO option is better than the BTL because $M.VFM_{BTL\text{-}BTO}$ shows a negative value (-25.3 billion KRW).

5.3.4.2 The Modified VFM (with completion delay)

Impact of a completion delay in the conventional delivery

To verify the impact of a completion delay in the conventional delivery on the PPP decision-making, the Modified VFM analyses ($M.VFM_{BTL}$, $M.VFM_{BTO}$, and $M.VFM_{BTL\text{-}BTO}$) with completion delay (zero to four years) are conducted. The Modified VFM values are calculated by considering a completion delay of conventional delivery, which affects not only yearly asset cost input but also the social benefit difference between the PSC and the PPP alternatives.

The results are shown in Table 5-4. In the no risk inclusion case, as completion is delayed from zero to four years, $M.VFM_{BTL}$ soars from 33.6 to 620.7 (billion KRW) and $M.VFM_{BTO}$ also jumps from -88.1 to 629.5 (billion KRW). Similarly, in the risk (construction cost risk and traffic volume risk) inclusion case, $M.VFM_{BTL}$ and $M.VFM_{BTO}$ respectively rise from 8.0 and 33.3 (billion KRW) to 420.0 and 534.9 (billion KRW) according to completion delay. This increasing trend is mainly because of the increase in the social benefit difference between the PSC and the PPP alternatives (BTL/BTO): a completion delay is much bigger than the decrease of the public sector cost in the PSC due to discounting. In consequence, as completion is delayed, the PPP alternatives seem to become more favourable than the conventional delivery.

Table 5-4: The Modified VFM result with completion delay

(Discounted value, 100 million KRW, price of 2002)

	Delay (year)	PSC		*Revenue* (c)	BTL		BTO		*ΔB* (f)	***M.VFM BTL***	***M.VFM BTO***	***M.VFM BTL-BTO***
		AC PSC (a)	*OC PSC* (b)		*Lease fee BTL* (d)	*OC BTL* (e)	*Subsidy BTO* (f)	*MRG BTO* (g)		(a+b)-(d+e)	(a+b-c) -(f+g)	(c+f+g) -(d+e)
No risk inclusion	0	437.3	129.6	519.5	447.7	85.5	135.4	0.0	0.0	33.6	-88.1	121.7
	1	420.3	120.6	483.3	447.7	85.5	135.4	0.0	189.9	197.5	112.1	85.5
	1.30	415.0	118.0	473.0	447.7	85.5	135.4	0.0	243.6	243.3	168.1	75.2
	2	404.0	112.2	449.6	447.7	85.5	135.4	0.0	366.6	349.5	297.7	51.7
	3	388.3	104.3	418.2	447.7	85.5	135.4	0.0	531.0	490.3	469.9	20.4
	4	373.1	97.0	389.0	447.7	85.5	135.4	0.0	683.8	620.7	629.5	-8.8
Risk inclusion	0	420.6	120.6	356.6	447.7	85.5	135.4	15.9	0.0	8.0	33.3	-25.3
	1	404.3	112.2	331.7	447.7	85.5	135.4	15.9	140.0	123.2	173.4	-50.2
	1.30	399.2	109.8	324.7	447.7	85.5	135.4	15.9	179.5	155.2	212.5	-57.2
	2	388.6	104.3	308.6	447.7	85.5	135.4	15.9	270.2	229.9	303.3	-73.4
	3	373.5	97.1	287.0	447.7	85.5	135.4	15.9	391.3	328.6	423.5	-94.9
	4	358.9	90.3	267.0	447.7	85.5	135.4	15.9	504.0	420.0	534.9	-114.9

Note: 1. No risk inclusion = the Modified VFM without considering risks, based on the BTL guidelines of Korea, Risk inclusion = the Modified VFM considering construction cost risk and traffic volume risk.
2. AC_{PSC} = Asset cost in the PSC, OC_{PSC} = Operation cost in the PSC, *Revenue* = Revenue, *Lease fee* $_{BTL}$ = Lease fee in the BTL, OC_{BTL} = Operation cost in the BTL *Subsidy* $_{BTO}$ = Subsidy from the Korean government, MRG_{BTO} = MRG cost and *DB* = social benefit difference between the PSC and the PPP (BTL/BTO).

On the other hand, $M.VFM_{BTL\text{-}BTO}$ decreases as completion is delayed from zero to four years regardless of risk inclusion mainly because the revenue stream is increasingly reduced due to the discounting effect. This implies that as completion is delayed, the BTO option becomes more favourable than the BTL option.

Additionally, as shown in Table 5-4, considering construction cost risk, traffic volume risk and completion delay (the mean value: 1.30 years, Figure 5-3) in the National Expressway projects, the BTO is better than any other procurement option.

Critical completion delay

In order to determine the critical completion delay in the conventional delivery which makes the *M.VFM* zero, linear regression analyses were conducted, using Table 5.4. As seen in Figure 5-6, depending on whether construction cost risk and traffic volume risk are included or not, the regression lines of *M.VFM* differ.

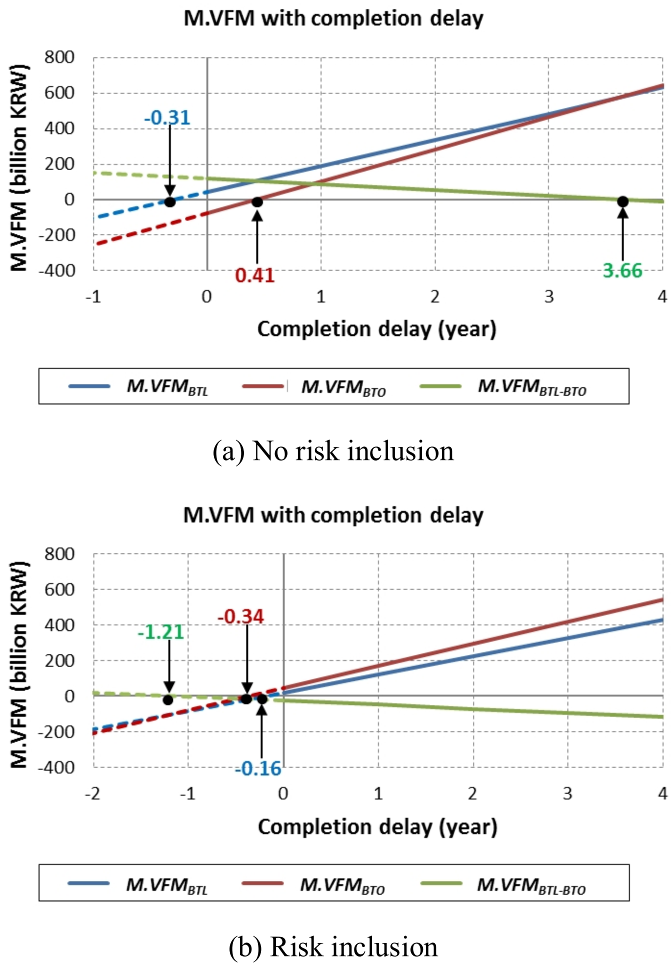


Figure 5-6: The Modified VFM result according to completion delay

In the case of no risk inclusion (Figure 5-6 (a)), with respect to $M.VFM_{BTL}$, when the linear regression line is extended, it meets the horizontal axis at -0.31 year (-3.72 months). This means that even when the conventional delivery is competed earlier than the BTL by up to 0.31 years (3.72 months), the BTL is more favourable than the conventional delivery. In other words, even if the construction in the BTL starts up to 0.31 years (3.72 months) later than the conventional delivery, perhaps because of negotiation delays or financial problems, the BTL is more favourable. Regarding $M.VFM_{BTO}$, when the conventional delivery is delayed more than 0.41 years (4.92 months), the BTO option becomes feasible. In addition, when a completion delay is longer than 3.66 years (43.92 months) the BTO option is the most appropriate procurement option.

In the same way, completion delays in the risk inclusion case are shown in Figure 5-6 (b). With respect to $M.VFM_{BTL}$, the intercept of the horizontal axis (the critical completion delay) becomes -0.16 years (1.92 months). This means that even when the conventional delivery is completed earlier than the BTL by up to 0.16 years (1.92 months), the BTL is more feasible than the conventional delivery. In other words, even if the construction in the BTL starts up to 0.16 years (1.92 months) later than the conventional delivery, perhaps because of negotiation delays or financial problems, the BTL is more favourable. Regarding $M.VFM_{BTO}$, even if the construction in the BTO starts 0.34 years (4.08 months) later than the conventional delivery, the BTO is more favourable than the conventional delivery. In addition, when a completion delay is expected in conventional delivery the BTO is better than the BTL. Besides, even if the conventional delivery completes this project 1.21 years (14.52 months) earlier than the PPP alternatives (BTO/BTL), the BTO option is more favourable than the BTL.

Furthermore, considering that critical completion delay in this project is less than the mean value (1.30 years, Figure 5-3) of the completion delay in the National Expressway projects, the BTO option seems to be more favourable for this project.

5.3.4.3 Sensitivity analysis

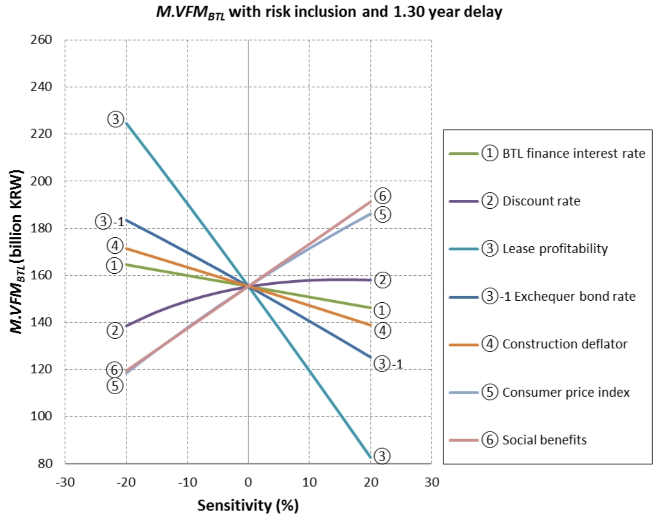
M.VFM results can differ depending on how large values are used as analysis factors. In order to examine the behaviour of *M.VFM* depending on the change of analysis factors, sensitivity analysis is conducted. To conduct a sensitivity analysis, the following seven analysis factors are considered: 1) BTL finance interest rate; 2) discount rate; 3) BTL lease profitability, 3-1) five-year exchequer bond interest rate; 4) construction deflator; and 5) consumer price index; and 6) the size of social benefits. BTL lease profitability is composed of a five-year exchequer bond interest rate and mark-up rate, so the five-year exchequer bond interest rate does not seem to be included as an analysis factor in $M.VFM_{BTL}$. However, in the calculation of $M.VFM_{BTO}$ and $M.VFM_{BTL\text{-}BTO}$, it needs to be considered, so inevitably both BTL lease profitability and the five-year exchequer bond interest rate are considered in the sensitivity analysis. In addition, this case study is analysed using fixed PPP construction cost and operation cost from the contract awarded in 2005, so these cost items are excluded in the sensitivity analysis factors.

The changes of *M.VFM* with risk inclusion and a 1.30-year delay are shown in Figure 5-7, where the analysis factors vary by from -20 to +20 per cent on each factor's given value. The summary of sensitivity analysis is shown in Table 5-5.

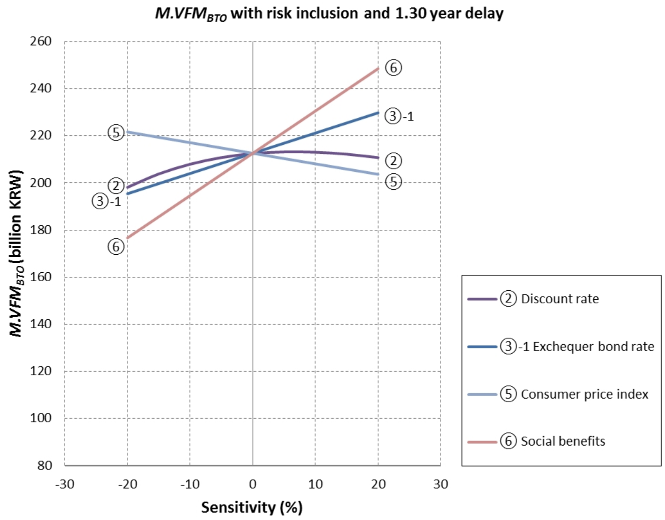
In the case of $M.VFM_{BTL}$ (Figure 5-7 (a), Table 5-5), the result is similar to those in the National Highway cases. Among the seven analysis factors, the BTL lease profitability is most influential. In addition, regardless of the change of the factors, the BTL is more favourable than the conventional delivery.

With respect to $M.VFM_{BTO}$ (Figure 5-7 (b), Table 5-5), social benefit size is the most influential among the four factors but the impact is not large compared with the BTL lease profitability in $M.VFM_{BTL}$. The BTO is more favourable than the conventional delivery regardless of the change of the factors.

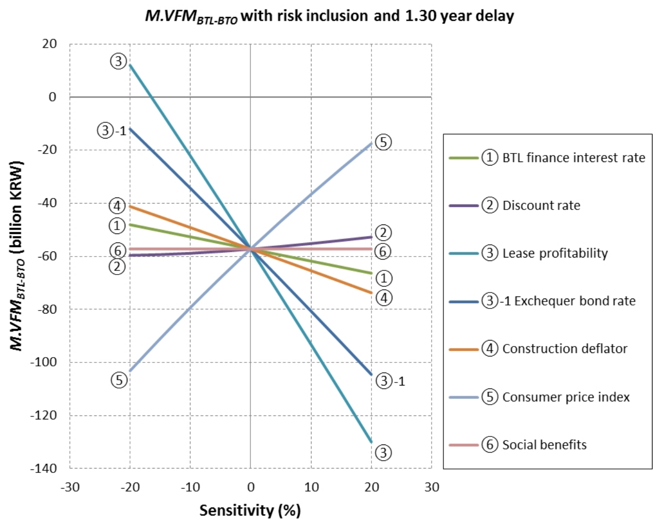
When it comes to $M.VFM_{BTL\text{-}BTO}$ (Figure 5-7 (c), Table 5-5), though it shows a negative value in most cases, meaning that the BTO is better than the BTL, it can show a positive value when BTL lease profitability drops more than approximately 17 per cent on the given value. In addition, BTL lease profitability is the most influential factor among the seven analysis factors in the calculation of $M.VFM_{BTL\text{-}BTO}$.



(a) $M.VFM_{BTL}$



(b) $M.VFM_{BTO}$



(c) $M.VFM_{BTL\text{-}BTO}$

Figure 5-7: Sensitivity analysis on the Modified VFM (risk inclusion, 1.30 year delay)

Table 5-5: Sensitivity of analysis factors on the Modified VFM

The Modified VFM	Analysis factors	M.VFM changes due to the increase of analysis factors		
		Increase /decrease	Unit change (Bill. KRW)	Reason
$M.VFM_{BTL}$	1. BTL finance interest rate	Decrease	-0.45	The increase of BTL finance interest rate makes lease fee rise, so $M.VFM_{BTL}$ decreases
	2. Discount rate	Increase	0.49	The increase of discount rate makes cost items fall. Among them, lease fee has largest drop, so $M.VFM_{BTL}$ decreases.
	3. Lease profitability	Decrease	-3.55	The rise of lease profitability makes lease fee rise, so $M.VFM_{BTL}$ decreases
	3-1. Exchequer bond interest rate	Decrease	-1.45	The rise of 5 year exchequer bond rate means the rise of lease profitability, making lease fee rise, so $M.VFM_{BTL}$ decreases.
	4. Construction deflator	Decrease	-0.81	The rise of construction deflator makes private investment and lease fee increase, so $M.VFM_{BTL}$ decreases.
	5. Consumer price index	Increase	1.69	Nominal lease fee is converted to real by CPI. The rise of CPI, making real lease fee drop, means $M.VFM_{BTL}$ increases.
	6. Social benefits	Increase	1.80	The rise of social benefits makes $M.VFM_{BTL}$ increase.
$M.VFM_{BTO}$	2. Discount rate	Increase	0.32	The increase of discount rate makes cost items fall. Among them, revenue has a largest drop, so $M.VFM_{BTO}$ decreases.
	3-1. Exchequer bond interest rate	Increase	0.86	The rise of 5 year exchequer bond rate means the rise of the asset cost in the PSC, so $M.VFM_{BTO}$ increases.
	5. Consumer price index	Decrease	-0.45	The rise of CPI makes the borrowing cost of the public sector in real term drop, so $M.VFM_{BTO}$ decreases.
	6. Social benefits	Increase	1.80	The rise of social benefits makes $M.VFM_{BTO}$ increases.
$M.VFM_{BTL\text{-}BTO}$	1. BTL finance interest rate	Decrease	-0.45	The increase of BTL finance interest rate makes lease fee rise, so $M.VFM_{BTL\text{-}BTO}$ decreases
	2. Discount rate	Increase	0.17	The lease fee reduction due to the discount rate increase is bigger than the revenue decrease, so $M.VFM_{BTL\text{-}BTO}$ increases.
	3. Lease profitability	Decrease	-3.55	The rise of lease profitability makes lease fee rise, so $M.VFM_{BTL\text{-}BTO}$ decreases
	3-1. Exchequer bond interest rate	Decrease	-2.31	The 5 year exchequer bond rate rise (the lease profitability rise) makes lease fee rise, so $M.VFM_{BTL\text{-}BTO}$ decreases.
	4. Construction deflator	Decrease	-0.81	The rise of construction deflator makes private investment and lease fee increase, so $M.VFM_{BTL\text{-}BTO}$ decreases.
	5. Consumer price index	Increase	2.14	The lease fee drop and the borrowing cost drop in the PSC make $M.VFM_{BTL\text{-}BTO}$ increase.
	6. Social benefits	-	0	The rise of social benefits does not make any changes in $M.VFM_{BTL\text{-}BTO}$.

Note: Unit change means the change of the Modified VFM when an analysis factor rises by from -20 to 20 per cent based on its given base value.

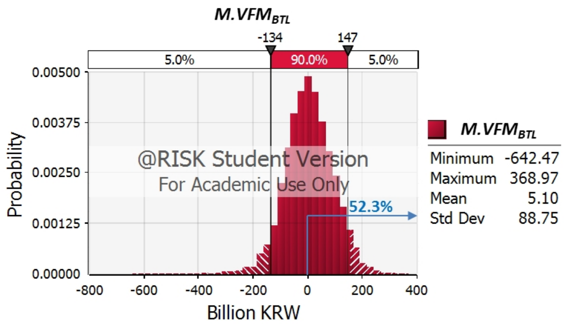
5.3.4.4 The Monte Carlo Simulations

The MCS is conducted to identify the impact of the following 11 risk variables (shown in Figure 5-1~Figure 5-4, Figure 4-4 and Figure 4-6~Figure 4-7) from historical observations: WBR, construction cost overrun, traffic volume, three operation costs, construction deflator, consumer price index, five-year exchequer bond interest rate, and three-year non-guaranteed corporate bond interest rate. Figure 5-8 shows the MSC results with no completion delay and with a 1.30-year completion delay, which is an average completion delay in the National Expressways from historical observations, as shown in Fig 5-3.

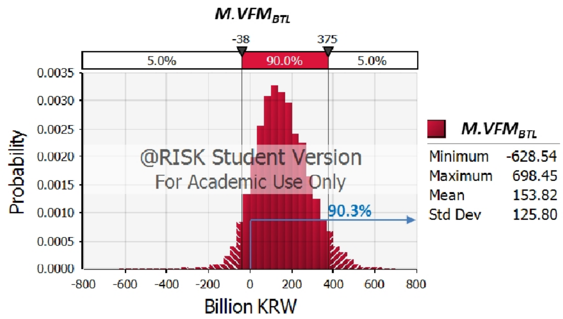
In the case of no completion delay (Figure 5-8 (a)), the mean value of $M.VFM_{BTL}$ is 5.1 (billion KRW) and the probability that $M.VFM_{BTL}$ is positive is 52.3 per cent. This implies that the BTL option is better than the conventional option. With respect to $M.VFM_{BTO}$, its mean value is 33.0 (billion KRW) and the probability that it is positive is 56.7 per cent, which implies the BTO option is more favourable than the conventional option. Additionally, $M.VFM_{BTL\text{-}BTO}$ has a mean value of -27.9 (billion KRW) and the probability that it is positive is 44.7 per cent, which implies the BTO option is better than the BTL option. Accordingly, assuming that there is no completion delay in the conventional delivery, the most appropriate delivery option for this project is the BTO, followed by the conventional and the BTL option.

Similarly, in the case of a 1.30-year completion delay (Figure 5-8 (b)), the mean value of $M.VFM_{BTL}$ is 153.8 (billion KRW) and the probability that it is positive is 90.3 per cent. This implies that the BTL option is better than the conventional delivery. With respect to $M.VFM_{BTO}$, its mean value is 213.6 (billion KRW) and the probability that it is positive is 99.6 per cent, which implies the BTO option is more favourable than the conventional option. Besides, $M.VFM_{BTL\text{-}BTO}$ has a mean value of -59.8 (billion KRW) and the probability that it is positive is 37.8 per cent, which implies that the BTO option is better than the BTL option. Accordingly, considering an average completion delay in the conventional delivery (1.30 years), the most appropriate delivery option is the BTO, followed by the BTL and the conventional option.

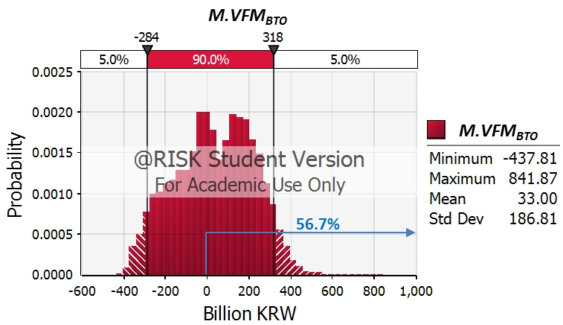
Consequently, as the completion delay increases, the mean values of *M.VFM* and the probabilities that the PPP options are better increase. The PPP decision for the Suwon-Pyungtaek National Expressway made in 2002 seems to be appropriate, considering construction cost risk, traffic volume risk and an average completion delay (1.30 years) in the conventional delivery.



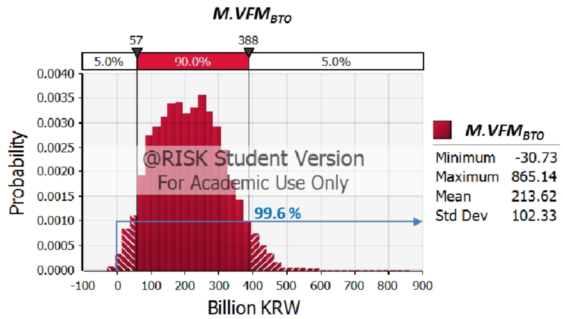
i) $M.VFM_{BTL}$



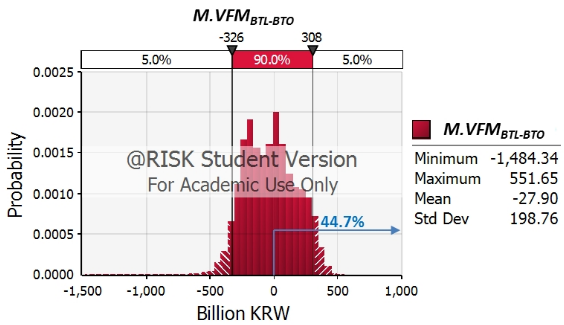
i) $M.VFM_{BTL}$



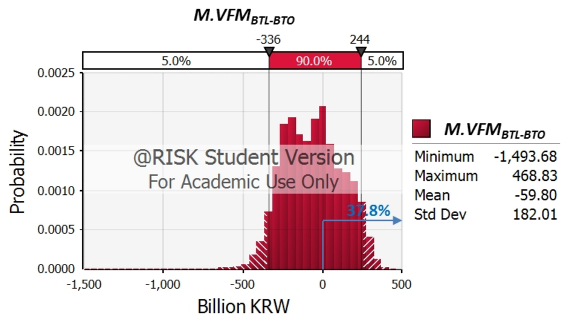
ii) $M.VFM_{BTO}$



ii) $M.VFM_{BTO}$



iii) $M.VFM_{BTL-BTO}$



iii) $M.VFM_{BTL-BTO}$

(a) No delay (b) 1.30 year completion delay

Figure 5-8: Probability distribution of the Modified VFM with a 1.30-year completion delay

5.4 Case 2: The Bongdam-Songsan case

5.4.1 Project overview

In order to solve daily traffic congestion in the Seoul metropolitan region, the Korean government established the Seoul metropolitan National Expressway Network Plan, including the second Seoul metropolitan orbital, in 2008. As part of this plan, the second Seoul metropolitan orbital is composed of 12 National Expressway sections, shown in Figure 5-9. Its total length is 259.2 km and the total project cost is approximately 10.1 trillion KRW (at 2007 prices). Among the 12 sections, the Bongdam-Dongtan is already in operation, the Gimpo-Incheon is under construction and the Pocheon-Hwado is under PPP negotiation with the private sector. In addition, another eight sections are also planned to be completed by 2020 using public or private funds.

The Bongdam-Songsan National Expressway project, a part of the second Seoul metropolitan orbital, is connected to the Bondam-Dongtan section, the Ansan-Songsan section and the National Expressway 15 (Seoul-Mokpo). This project was proposed as a BTO project from the private sector in 2007, so PPP pre-qualification test was conducted in 2009. Though the PPP pre-qualification result was affirmative, owing to the difficulty of financial agreement in private sector from the financial market crisis from 2008 (Song, 2011), the PPP decision-making was delayed to 2012 and construction has still not yet started.

The overview of the Bongdam-Songsan National Expressway project, proposed in 2007, is as follows:

- Title: Bongdam-Songsan National Expressway project
- PPP type: BTO
- Location: Mado ~ Bongdam, Hwasung city, Gyeonggi Province
- Length: 18.46 km (four lanes)
- Project cost:[76] 326.5 (billion KRW, 2006 price)
  - Private fund: 264.8, construction subsidy: 61.7
- Inflation: 4 per cent

[76] The project cost in this project means asset cost excluding compensation cost (259.9 billion KRW) provided by the Korean Government, so it is composed of construction subsidies and other cost needed for the duration of the construction, which is delivered by the private sector.

- IRR: 5.03 per cent (real)
- Construction period: 54 months
- Operation period: 30 years
- Support request

  - Construction subsidy 61.7 (billion KRW, at 2006 prices)

  - Compensation cost 259.9 (billion KRW, at 2006 prices)

  (No minimum revenue guarantee was requested in this project)
- Proposer: Gyeonggi Dongseo Expressway corp.

  - Construction investors (10 per cent): eight companies including Hanhwa construction (1.967 per cent)

  - Financial investors (80 per cent): Emerging infrastructure investment (20 per cent), Hankook infra2 (20 per cent), Daehan life insurance (12 per cent), Kyobo life insurance (12 per cent), Shinhan bank (8 per cent), IBK bank (8 per cent)

  - Operational investor (10 per cent): Korea Expressway Corp. (10 per cent)

Source: MLTM, maps.google.com

Figure 5-9: The Bongdam-Songsan National Expressway project map

5.4.2 Analysis factors and assumptions for the Modified VFM

Although this project was proposed as a BTO scheme, in order to verify the impact of transferable risks on the PPP decisions and the Modified VFM, this research considers three alternative options: the conventional delivery, the BTL and the BTO option.

Basic analysis factors for the Modified VFM are as follows:

- PPP model considered: BTO and BTL
- Decision-making time:[77] 2009 (with construction to start in 2012)
- Discount rate: 5.5 per cent (real); price base year: 2006
- Construction deflator:[78] 4.82 per cent (average between 2005 and 2009)
- Consumer price index:[79] 2.99 per cent (average between 2005 and 2009)
- Five-year exchequer bond interest rate:[80] 4.72 per cent (2009)
- BTL Lease profitability:[81] 6.72 per cent
  (Five-year exchequer bond interest rate + 2.0 per cent, nominal)

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[77] Following the financial market crisis triggered by the collapse of Lehman Brothers in 2008, the financial agreement in private sector became difficult (Song, 2011), so the PPP decision on this project was delayed to 2012 though PPP pre-qualification result in 2009 was affirmative. In this case study, the decision making time is assumed to be 2009, considering the time when PPP pre-qualification was conducted.

[78] Construction deflator means construction investment deflator in expenditure on Gross Domestic Product on National Accounts, which is provided by the Bank of Korea (http://ecos.bok.or.kr), and according to Korea's BTL guidelines (MOSF, 2009a), it is used in the calculation of the private sector investment for the lease fee calculation. For a more accurate private sector investment calculation, it is used instead of consumer price index.

[79] Consumer price index, which is used as inflation in operation period, is provided by the Bank of Korea (http://ecos.bok.or.kr).

[80] The five-year exchequer bond interest rate is calculated by a weighted average method, which applies 0.1, 0.2, 0.3 and 0.4 to the first, second, third and fourth quarter value (MOSF, 2009a). The quarterly five-year exchequer bond interest rate is provided by the Korea Bond Information Service (http://www.kofiabond.or.kr).

[81] BTL lease profitability is expressed as "five-year exchequer bond interest rate + mark-up" and mark-up rate is composed of a premium for long term investment and risk premium for construction and operation (MOSF, 2009a). According to research (Jung et al., 2006) and newspaper reports (Jung, 2005, Lee, 2009), the mark-up rate is distributed from 0.5 per cent to 2.25 per cent. Considering that there is no advanced BTL projects for road programme and road projects usually takes 35 years for construction and operation, a mark-up rate of 2.0 per cent is considered for the National Highways in this research.

- BTL finance interest rate:[82] 7.12 per cent
  (Three-year non-guaranteed corporate bond (AA-),[83] 5.62 per cent + 1.5 per cent, nominal)
- BTL finance structure: equity 15 per cent, debt 85 per cent
- BTL finance terms: level debt service during operation period
- Operation period: 30 years; standard construction duration: five years
- MRG condition: not included

In addition, the same assumptions (see 4.3.2) for the Modified VFM used in the National Highway cases are also used in the National Expressway cases.

5.4.3 Main calculation items for the Modified VFM

From equations (3-7), (3-8) and (3-9), it is clear that the main calculation items for the Modified VFM are the asset cost of a PSC (AC_{PSC}), the operation cost of a PSC (OC_{PSC}) and a BTL (OC_{BTL}), the lease fee of a BTL ($Lease\ fee_{BTL}$), revenue ($Revenue$), the subsidy ($Subsidy_{BTO}$) from the Korean government, the minimum revenue guarantee cost (MRG_{BTO}) and the benefit difference (ΔB).

Asset cost of the PSC (AC_{PSC})

Table 5-6 shows the basic asset cost of this project. With respect to the PSC column in Table 5-6, the cost data are collected from the PPP pre-qualification report on the Bongdam-Songsan National Expressway project (PIMAC, 2009b). Among cost data, the building costs of the PSC are calculated by multiplying designed prices (values not including winning bid ratio in the report) and an average turn-key/alternative WBR (82.14 per cent) in the National Expressway projects between 2002 and 2011(MLTM, 2012b). Other PSC cost items are collected from the

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[82] BTL finance interest rate is expressed as a "three-year non-guaranteed corporate bond interest rate + mark-up" (MOSF, 2009a) and, according to Kim et al. (2005), the mark-up rate seems to be distributed from 0.66 per cent to 2.00 per cent. Considering that there is no advanced BTL projects for road programme and road projects usually takes 35 years for construction and operation, this research uses 1.5 per cent for the mark-up rate.

[83] The three-year non-guaranteed corporate bond (AA-) interest rate is calculated by a weighted average method, which applies 0.1, 0.2, 0.3 and 0.4 to the first, second, third and fourth quarter value (MOSF, 2009a). The quarterly three-year non-guaranteed bond (AA-) interest rate is provided by the Korea Bond Information Service (http://www.kofiabond.or.kr).

PPP pre-qualification report on the Bongdam-Songsan National Expressway project (PIMAC, 2009b).

With respect to basic asset costs for the PPP, proposed asset costs are utilised in this case; these are also collected from the PPP pre-qualification report on the Bongdam-Songsan National Expressway project (PIMAC, 2009b).

In addition, in order to estimate the Modified VFM, according to Table 4-2 the yearly asset costs of the PSC are distributed. With respect to longer construction duration considering completion delay, new yearly distribution ratios using interpolation methods and Table 4-2 will be applied to the calculation of the Modified VFM.

Table 5-6: Basic asset cost for the PSC and the PPP

(Unit: billion KRW, 2006 price)

Asset cost items		PSC [BTL guideline]	PPP [Proposed]
Building cost	Investigation	**3.0** (3.6)	**1.7**
	Design	**13.8** (16.8)	**8.1**
	Construction	**341.0** (415.2)	**278.2**
	Sub total	**357.8**	**288.0**
Compensation cost		0	0
Additional cost		**16.6** Design inspection 1.4 Construction inspection 9.1 Environmental impact assessment 1.9 Traffic impact assessment 0.2 Disaster impact assessment 0.3 Cultural asset survey 1.8 Insurance 1.9	**18.4** Design inspection 0.2 Construction inspection 7.6 Environmental impact assessment 1.7 Traffic impact assessment 0.2 Disaster impact assessment 0.2 Cultural asset survey 1.8 Insurance 1.9 Financial cost 4.8
Operation facility cost		**16.5** Toll collection 9.8 Traffic monitoring and control 5.0 Traffic safety 0.6 Facility maintenance 1.3	**14.3** Toll collection 9.1 Traffic monitoring and control 3.7 Traffic safety 0.6 Facility maintenance 0.9
Business reserve		**0**	**5.8** Business commence cost 5.5 Stock issue cost 0.3
Total		**390.9**	**326.5**

Note: 1. Compensation cost is provided by the Korean government, so it is not included in the Modified VFM assessment. 2. All values in the Table comes from the PPP pre-qualification report on the Bongdam-Songsan National Expressway projects (PIMAC, 2009) and the bracketed values are designed prices not including winning bid ratios. 3. Insurance cost for a PSC is contractor's all risk insurance (1.9), while insurance cost for a PPP is composed of contractor's all risk (1.50), advanced loss of profits(0.3), employer's liability (0.01), and performance guarantee (0.13)

Operation cost for the PSC and the BTL $(\boldsymbol{OC_{PSC}}, \boldsymbol{OC_{BTL}})$

As with the National Highway cases, yearly base operation costs for the PSC (OC_{PSC}) are calculated by multiplying the mean values of the operation costs[84] (KRW/VKT) from the historical observations and yearly VKT data of this project from the PPP pre-qualification report on the Bongdam-Songsan National Expressway (PIMAC, 2009b). In order to consider the variation of maintenance cost according to aging, yearly maintenance costs are estimated by considering decrepitude of road by Table 4-3.

When it comes to the operation cost of the BTL (OC_{BTL}), proposed operation costs from private sector, collected from the PPP pre-qualification report on Bongdam-Songsan National Expressway (PIMAC, 2009b), are used for the Modified VFM calculation.

Lease fee for the BTL $(\boldsymbol{Lease\ fee_{BTL}})$

According to Korea's BTL guidelines (MOSF, 2009a), the yearly lease fee in nominal terms is calculated as equation (4-1). The asset cost of the PPP (BTL) in real terms in Table 5-6 is delivered as a form of equity (15 per cent) and debt (85 per cent) according to the BTL finance structure. Considering construction deflator and BTL finance interest rate, the total investment from the private sector, including principal and interest, becomes 460.9 (billion KRW, nominal term) at completion time, which is the sum of (a), (b) and (C) in Table 5-7.

Table 5-7: Calculation of private sector investment

(Unit: billion KRW)

Year	Equity (15%)		Debt (85%)		Interest (nominal)
	Real (2006 price)	Nominal	Real (2006 price)	Nominal	
2012	3.5	4.1	19.9	22.9	
2013	7.1	8.5	40.0	48.2	1.6
2014	13.6	17.2	77.2	97.7	5.1
2015	16.4	21.8	92.9	123.2	12.0
2016	8.4	11.7	47.5	66.1	20.8
Total	49.0	63.3 (a)	277.5	358.1 (b)	39.5 (c)
Private sector investment (P = a + b + c)			460.9		

Consequently, in this case study, the yearly lease fee in nominal terms for the BTL is calculated as follows:

[84] From the historical observations, the mean values of operation cost items are as follows: 1) management cost (personnel cost included)/VKT = 16.51 KRW/VKT; 2) general maintenance cost/VKT = 3.84 KRW/VKT; 3) re-pavement cost/VKT = 1.28 KRW/VKT; and 4) road structure maintenance cost/VKT = 1.58 KRW/VKT.

$$PVIFA_{(30,0.0672)} = \sum_{i=1}^{30} \frac{1}{(1+0.0672)^i} = 12.7662$$

$$Lease\ fee = \frac{460.9}{PVIFA_{(30,0.0674)}} = \frac{460.9}{12.7662} = 36.099 \text{ (billion KRW, nominal)}$$

Considering the consumer price index and the economic discount rate, the lease fee in nominal terms in each year will be transformed into real terms to be applied to the Modified VFM.

Revenue, subsidy and MRG for the BTO ($\boldsymbol{Revenue, Subsidy_{BTO}, MRG_{BTO}}$)

As shown in equation (3-7), revenue, subsidy and MRG cost reduce the Modified VFM in the BTO scheme. Along with other items, revenue and subsidy are collected from the PPP pre-qualification report on the Bongdam-Songsan National Expressway (PIMAC, 2009b).

With respect to MRG, the MRG system for an unsolicited project was abolished in 2006 because public opinion had it that the MRG system created an enormous economic burden to the public sector, so the private sector did not require an MRG condition. Accordingly, this case study does not include the MRG cost.

Social benefit difference ($\boldsymbol{\Delta B}$)

Information on social benefits for the Modified VFM analysis is collected from the PPP pre-qualification report on the Bongdam-Songsan National Expressway. As with the Suwon-Pyungtaek case, for a simple calculation, the relationship between benefit cost ratio and volume/capacity in the National Expressway is assumed to follow equation (4-2), because of the unavailability of appropriate historical observations. Using equation (4-2) and social benefit data, the social benefit difference (ΔB) beween the PSC and the PPP (BTL and BTO) can be calculated.

Considering equation (4-3) and the BCR of this case (= 1.17), when the traffic volume drops to 68.6 per cent of the forecast one, the social benefits also drop to 80.4 per cent of the forecast one.

5.4.4. Analysis

5.4.4.1 The Modified VFM (with no completion delay)

To verify the impact of risk inclusion (construction cost risk and traffic volume risk) on the Modified VFM analysis when there is no completion delay in the conventional delivery, four different types of Modified VFM (*M.VFM*) using the mean value of each risk are conducted: 1) *M.VFM* without risks; 2) *M.VFM* with construction cost risk; 3) *M.VFM* with traffic volume risk; and 4) *M.VFM* with both risks (construction cost risk and traffic volume risk). The results of *M.VFM* are shown in Table 5-8.

Table 5-8: The Modified VFM results according to risk inclusion

(Discounted value, billion KRW, 2006 price)

	PSC		*Revenue* (c)	BTL		BTO		ΔB (f)	$M.VFM_{BTL}$	$M.VFM_{BTO}$	$M.VFM_{BTL\text{-}BTO}$
	AC_{PSC} (a)	OC_{PSC} (b)		$Lease\ fee_{BTL}$ (d)	OC_{BTL} (e)	$Subsidy_{BTO}$ (f)	MRG_{BTO} (g)		(a+b)-(d+e)	(a+b-c) -(f+g)	(c+f+g) -(d+e)
1) *M.VFM* (+no risks)	245.3	67.7	322.4	214.0	86.3	38.1	0.0	0.0	12.7	-47.5	60.3
2) *M.VFM* (+const. risk)	236.2	67.7	322.4	214.0	86.3	38.1	0.0	0.0	3.6	-56.6	60.3
3) *M.VFM* (+volume risk)	245.3	62.6	221.3	214.0	86.3	38.1	0.0	0.0	7.7	48.6	-40.9
4) *M.VFM* (+both risks)	236.2	62.6	221.3	214.0	86.3	38.1	0.0	0.0	-1.4	39.4	-40.9

Note: 1. M.VFM (+no risks) = the Modified VFM without considering risks, based on the BTL guidelines of Korea, M.VFM (+const. risk) = the Modified VFM considering the mean values of winning bid ratio risk and construction cost overrun risk, M.VFM (+volume risk) = the Modified VFM value considering the mean value of traffic volume risk, and M.VFM (+both risks) = the Modified VFM value considering the mean values of winning bid ratio risk, cost overrun risk and traffic volume risk.
2. AC_{PSC} = Asset cost in the PSC, OC_{PSC} = Operation cost in the PSC, *Revenue* = Revenue, $Lease\ fee_{BTL}$ = Lease fee in the BTL, OC_{BTL} = Operation cost in the BTL $Subsidy_{BTO}$ = Subsidy from the Korean government, MRG_{BTO} = MRG cost and ΔB = social benefit difference between the PSC and the PPP (BTL/BTO).

M.VFM with no risk inclusion

According to Korea's BTL guidelines (MOSF, 2009a), an average WBR of turn-key/alternative bids (82.14 per cent) in the National Expressway projects between 2002 and 2011 (MLTM, 2012b) is considered in the calculating the asset cost of the PSC, as shown in the first row of Table 5-8.

The results of *M.VFM* with no risk inclusion show that the BTL is more favourable than the conventional delivery, indicating $M.VFM_{BTL}$ of 12.7 (billion KRW), while the BTO is not the best option, indicating $M.VFM_{BTO}$ of -47.5 (billion KRW). Accordingly, the BTL option is preferable by far to the BTO, indicating $M.VFM_{BTL\text{-}BTO}$ of 60.3 (billion KRW).

M.VFM with construction cost risk

From equation (3-10), an application ratio, indicating construction cost risk, consists of WBR risk and construction cost overrun risk. Using the mean values of the WBR risk (71.50 per cent, Fig 5-2) and construction cost overrun risk (10.21 per cent, Figure 5-1), the asset cost of the PSC can be freshly calculated.

The results (Table 5-8, the second row) show that $M.VFM_{BTL}$ and $M.VFM_{BTO}$ considering the construction cost risk are respectively 3.6 and -56.6 (billion KRW), which are 9.1 (billion KRW) lower than those with no risk inclusion. This is because the mean values of the WBR and construction cost overrun make an application ratio of 78.80 per cent (0.715 × (1+0.1021)), which is 3.34 per cent lower than an average winning bid ratio (82.14 per cent) of turn-key/alternative bids used. This means that $M.VFM_{BTL}$ and $M.VFM_{BTO}$ with no risk inclusion based on Korea's BTL guidelines (MOSF, 2009a) could be exaggerated by as much as the difference of 3.34 per cent more than the situation in reality.

However, $M.VFM_{BTL\text{-}BTO}$ (the Modified VFM difference between the BTL and the BTO) is not changed because this is not related to the asset cost of the PSC, affected by the WBR and construction cost overrun, according to equation (3-10).

M.VFM with traffic volume risk

To verify the effect of traffic demand risk on *M.VFM*, the mean value of traffic volume risk (68.6 per cent) shown in Figure 4-4 is applied to the analysis. The result (Table 5-8, third row) shows that $M.VFM_{BTL}$ decreases by 5.0 (billion KRW) whereas $M.VFM_{BTO}$ increases by 96.1 (billion KRW), compared with those with no risk inclusion.

The decrease of $M.VFM_{BTL}$ is due to the decrease in the operation cost by VKT reduction as traffic volume decreases. In addition, the main reason for $M.VFM_{BTO}$ increase is the decrease of revenue due to the reduction of traffic volume, which causes $M.VFM_{BTO}$ to rise according to equation (3-7).

As a result, $M.VFM_{BTL\text{-}BTO}$ is changed to a negative value (-40.9) from a positive value (60.3). In other words, the BTO option becomes more favourable than the BTL for this project when actual traffic volume is expected to reach 68.6 per cent of forecast traffic volume.

M.VFM with both risks

Table 5-8 (the last row) shows that that $M.VFM_{BTL}$ and $M.VFM_{BTO}$ show respectively -1.4 and 39.4 (billion KRW), which means that the most appropriate procurement option for this case is the BTO option, followed by the conventional and the BTL options, when construction cost risk and traffic volume risk are taken into account.

5.4.4.2 The Modified VFM (with completion delay)

Impact of a completion delay in the conventional delivery

To verify the impact of a completion delay in the conventional delivery on the PPP decision-making, Modified VFM analyses ($M.VFM_{BTL}$, $M.VFM_{BTO}$, and $M.VFM_{BTL\text{-}BTO}$) with completion delay (zero to four years) are conducted. The Modified VFM values are calculated by considering a completion delay of conventional delivery, which affects not only yearly asset cost input but also the social benefit difference between the PSC and the PPP alternatives.

The results are shown in Table 5-9. In the no risk inclusion case, as completion is delayed from zero to four years, $M.VFM_{BTL}$ soars from 12.7 to 103.0 (billion KRW) and $M.VFM_{BTO}$ also jumps from -47.5 to 104.9 (billion KRW). Similarly, in the risk (construction cost risk and traffic volume risk) inclusion case, $M.VFM_{BTL}$ and $M.VFM_{BTO}$ respectively rise from -1.4 and 39.4 (billion KRW) to 65.2 and 148.7 (billion KRW), according to completion delay. This increasing trend is mainly because of the increase of the social benefit difference between the PSC and the PPP alternatives (BTL/BTO) since the completion delay is much bigger than the decrease of the public sector cost in the PSC due to discounting. In consequence, as a completion is delayed, the PPP alternatives seem to become more favourable than the conventional delivery.

Table 5-9: The Modified VFM result with completion delay

(Discounted value, billion KRW, 2006 price)

	Delay (year)	PSC		*Revenue*	BTL		BTO		*ΔB*	***M.VFM BTL***	***M.VFM BTO***	***M.VFM BTL-BTO***
		AC PSC (a)	*OC PSC* (b)	(c)	*Lease fee BTL* (d)	*OC BTL* (e)	*Subsidy BTO* (f)	*MRG BTO* (g)	(f)	(a+b)-(d+e)	(a+b-c) -(f+g)	(c+f+g) -(d+e)
No risk inclusion	0	245.3	67.7	322.4	214.0	86.3	38.1	0.0	0.0	12.7	-47.5	60.3
	1	238.3	64.1	305.6	214.0	86.3	38.1	0.0	35.3	37.4	-6.0	43.4
	1.30	236.0	63.1	300.8	214.0	86.3	38.1	0.0	45.4	44.3	5.7	38.6
	2	231.4	60.8	289.6	214.0	86.3	38.1	0.0	68.8	60.7	33.2	27.5
	3	224.7	57.6	274.5	214.0	86.3	38.1	0.0	100.5	82.5	70.1	12.4
	4	218.1	54.6	260.2	214.0	86.3	38.1	0.0	130.5	103.0	104.9	-1.9
Risk inclusion	0	236.2	62.6	221.3	214.0	86.3	38.1	0.0	0.0	-1.4	39.4	-40.9
	1	229.4	59.4	209.7	214.0	86.3	38.1	0.0	28.4	16.9	69.3	-52.4
	1.30	227.2	58.4	206.4	214.0	86.3	38.1	0.0	36.5	21.9	77.6	-55.7
	2	222.7	56.3	198.8	214.0	86.3	38.1	0.0	55.3	34.0	97.4	-63.3
	3	216.3	53.3	188.4	214.0	86.3	38.1	0.0	80.8	50.1	123.8	-73.7
	4	210.0	50.6	178.6	214.0	86.3	38.1	0.0	105.0	65.2	148.7	-83.5

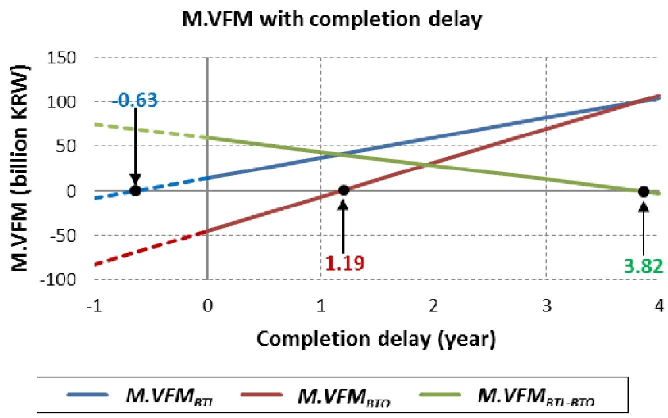
Note: 1. No risk inclusion = the Modified VFM without considering risks, based on the BTL guidelines of Korea, Risk inclusion = the Modified VFM considering construction cost risk and traffic volume risk.
2. AC_{PSC} = Asset cost in the PSC, OC_{PSC} = Operation cost in the PSC, *Revenue* = Revenue, *Lease fee* $_{BTL}$ = Lease fee in the BTL, OC_{BTL} = Operation cost in the BTL *Subsidy* $_{BTO}$ = Subsidy from the Korean government, MRG_{BTO} = MRG cost and *DB* = social benefit difference between the PSC and the PPP (BTL/BTO).

On the other hand, $M.VFM_{BTL\text{-}BTO}$ decreases as completion is delayed from zero to four years regardless of risk inclusion mainly because the revenue stream is reduced due to the discounting effect. This implies that as completion is delayed the BTO option become more and more preferable to the BTL option.

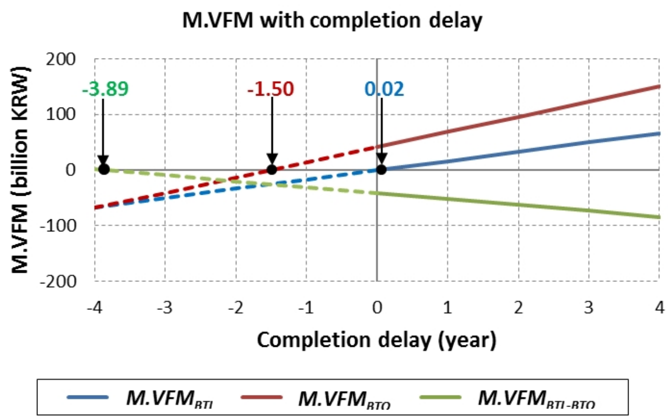
Additionally, as shown in Table 5-9, considering construction cost risk, traffic volume risk and completion delay (the mean value: 1.30 years; Figure 5-3) in the National Expressway projects, the BTO is better than any other procurement option.

Critical completion delay

In order to determine a critical completion delay in the conventional delivery, which makes the *M.VFM* zero, linear regression analyses were conducted, using Table 5-9. As seen in Figure 5-10, depending on whether construction cost risk and traffic volume risk are included or not, the regression lines of *M.VFM* differ.



(a) No risk inclusion



(b) Risk inclusion

Figure 5-10: The Modified VFM result according to completion delay

In the case of no risk inclusion (Figure 5-10 (a)), with respect to $M.VFM_{BTL}$, when the linear regression line is extended, it meets the horizontal axis at -0.63 years (-7.56 months). This means that even if the conventional delivery completes this project earlier than up to 0.63 years (7.56 months) than the BTL, the BTL option is better than the conventional option for this project. In other words, even if the construction in the BTL starts 0.63 years (7.56 months) later for a reason such as a negotiation delay or financial problem than the conventional delivery, the BTL is more favourable than the conventional delivery. In a similar way, regarding $M.VFM_{BTO}$, when a completion is delayed more than 1.19 years (14.28 months) in the conventional delivery, the BTO scheme becomes feasible. In addition, the completion delay of $M.VFM_{BTL\text{-}BTO}$ shows that, when a completion delay in the conventional delivery is expected to be longer than 3.82 years (45.84 months), the BTO becomes the most appropriate option.

However, when construction risk and traffic volume risk are included, the critical completion delay is changed, as shown in Figure 5-10 (b). With respect to $M.VFM_{BTL}$, the intercept of the horizontal axis (the critical completion delay) becomes 0.02 years (0.24 month). This means that when a completion in the conventional delivery is delayed more than 0.02 years (0.24 month), the BTL is better than the conventional delivery. With respect to $M.VFM_{BTO}$, the critical completion delay becomes -1.50 years (-18.00 months) when the linear regression line is extended. This means that even if the conventional delivery completes this project earlier by up to 1.50 years (18.00 months) than the BTO, the BTO is better than the conventional delivery for this project. In other words, even if the construction in the BTO starts 1.50 years (18.00 months) later for a reason such as a negotiation delay or financial problem than the conventional delivery, the BTO is preferable to the conventional delivery. In addition, the critical completion delay of $M.VFM_{BTL\text{-}BTO}$ becomes -3.89 years (-46.68 months) when the linear regression line is extended. This means that even if the conventional delivery completes this project within 3.89 years (46.68 months) earlier than the PPP (BTO/BTL), the BTO is better than the BTL for this project.

As stated above, owing to the problems surrounding financial agreements in the private sector caused by the financial crisis beginning in 2008 (Song, 2011), this project has been delayed in terms of PPP decision-making and construction start date. If it was decided that this project was to be implemented by the BTO scheme in 2009, as in this case study, it would have started in 2012. Considering the critical completion delay (-1.5 years) of $M.VFM_{BTO}$, this project needs to start construction at the latest by June 2013[85] in order that the PPP decision to use the BTO option is valid. Accordingly, if the Korean government made a PPP decision for the Bongdam-

[85] According to the Korean government, the Bongdam-Songsan project is going to start construction in 2015.

Songsan case and also knew this information (the critical completion delay), it would be possible that the BTO option for the project could be changed to other procurement option like the conventional delivery.

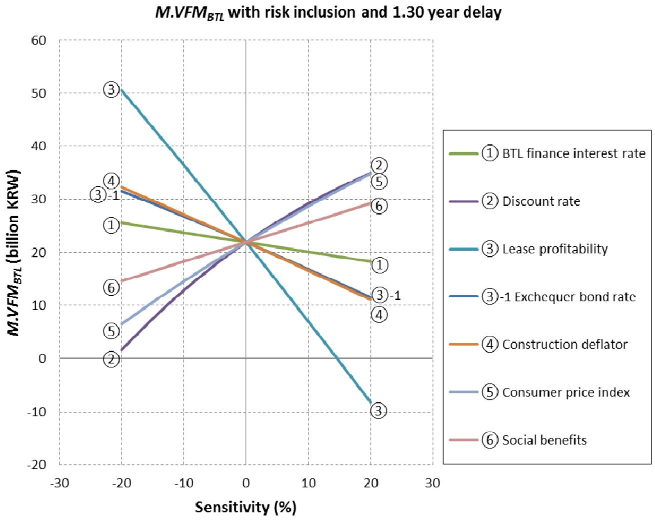
5.4.4.3 Sensitivity analysis

M.VFM results can differ depending on how large values are used as analysis factors. In order to examine the behaviour of *M.VFM* depending on the change of analysis factors, a sensitivity analysis is conducted. For this analysis, the following seven analysis factors are considered: 1) BTL finance interest rate; 2) discount rate; 3) BTL lease profitability; 3-1) five-year exchequer bond interest rate; 4) construction deflator; 5) consumer price index; and 6) the size of the social benefits. The BTL lease profitability is composed of a five-year exchequer bond interest rate and mark-up rate, so it does not seem necessary to include a five-year exchequer bond interest rate as an analysis factor in $M.VFM_{BTL}$. However, in the calculation of $M.VFM_{BTO}$ and $M.VFM_{BTL\text{-}BTO}$, this rate does need to be considered, so inevitably both BTL lease profitability and the five-year exchequer bond interest rate are considered in the sensitivity analysis. In addition, this case study is analysed using fixed PPP construction cost and operation cost, proposed by private sector in 2007, so these cost items are excluded from the sensitivity analysis factors.

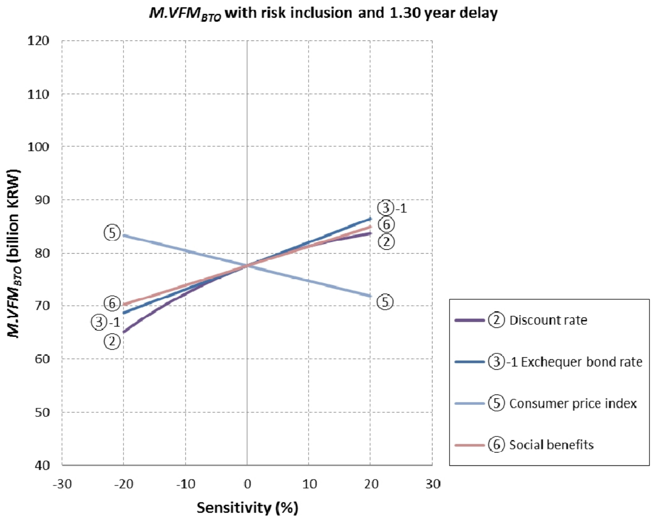
The changes in *M.VFM* with risk inclusion and a 1.30-year delay are shown in Figure 5-11 when the analysis factors vary by from -20 to +20 per cent on each factor's given value. The summary of sensitivity analysis is shown in Table 5-10.

In case of $M.VFM_{BTL}$ (Figure 5-11 (a), Table 5-10), the result is similar to those in the National Highway cases and in the Suwon-Pyungtaek case. Among the seven analysis factors, the BTL lease profitability is most influential, being the largest unit change value (-1.47) in terms of absolute value. When the BTL lease profitability grows by more than about 14 per cent, $M.VFM_{BTL}$ is changed from a positive value to a negative one. This means that in such a case the delivery option can be changed from the BTL to the conventional option.

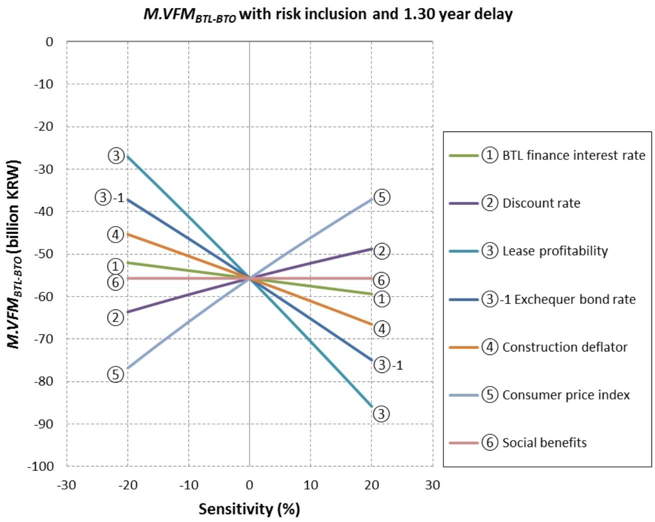
With respect to $M.VFM_{BTO}$ (Figure 5-11 (b), Table 5-10), the discount rate and a five-year exchequer bond interest rate are relatively influential but the impact is not big, compared with the BTL lease profitability in $M.VFM_{BTL}$. Besides, the BTO is more favourable than the conventional delivery regardless of the change of the factors with positive $M.VFM_{BTO}$ values.



(a) $M.VFM_{BTL}$



(b) $M.VFM_{BTO}$



(c) $M.VFM_{BTL\text{-}BTO}$

Figure 5-11: Sensitivity analysis on the Modified VFM (risk inclusion, 1.30-year delay)

When it comes to $M.VFM_{BTL\text{-}BTO}$ (Figure 5-11 (c), Table 5-10), a negative value in all cases regardless of the fluctuation of analysis factors is shown, implying that the BTO is better than the BTL. In addition, BTL lease profitability is the most influential factor among seven analysis factors in the calculation of $M.VFM_{BTL\text{-}BTO}$, being the largest unit change value (-1.47) in terms of absolute value, as shown in Table 5-10.

Table 5-10: Sensitivity of analysis factors on the Modified VFM

The Modified VFM	Analysis factors	M.VFM changes due to the increase of analysis factors		
		Increase /decrease	Unit change (Bill. KRW)	Reason
$M.VFM_{BTL}$	1. BTL finance interest rate	Decrease	-0.18	The increase of BTL finance interest rate makes lease fee rise, so $M.VFM_{BTL}$ decreases
	2. Discount rate	Increase	0.83	The increase of discount rate makes cost items fall. Among them, lease fee has largest drop, so $M.VFM_{BTL}$ decreases.
	3. Lease profitability	Decrease	-1.47	The rise of lease profitability makes lease fee rise, so $M.VFM_{BTL}$ decreases
	3-1. Exchequer bond interest rate	Decrease	-0.50	The rise of 5 year exchequer bond rate means the rise of lease profitability, making lease fee rise, so $M.VFM_{BTL}$ decreases.
	4. Construction deflator	Decrease	-0.53	The rise of construction deflator makes private investment and lease fee increase, so $M.VFM_{BTL}$ decreases.
	5. Consumer price index	Increase	0.71	Nominal lease fee is converted to real by CPI. The rise of CPI, making real lease fee drop, means $M.VFM_{BTL}$ increases.
	6. Social benefits	Increase	0.37	The rise of social benefits makes $M.VFM_{BTL}$ increase.
$M.VFM_{BTO}$	2. Discount rate	Increase	0.46	The increase of discount rate makes cost items fall. Among them, revenue has a largest drop, so $M.VFM_{BTO}$ decreases.
	3-1. Exchequer bond interest rate	Increase	0.44	The rise of 5 year exchequer bond rate means the rise of the asset cost in the PSC, so $M.VFM_{BTO}$ increases.
	5. Consumer price index	Decrease	-0.29	The rise of CPI makes the borrowing cost of the public sector in real term drop, so $M.VFM_{BTO}$ decreases.
	6. Social benefits	Increase	0.37	The rise of social benefits makes $M.VFM_{BTO}$ increases.
$M.VFM_{BTL\text{-}BTO}$	1. BTL finance interest rate	Decrease	-0.18	The increase of BTL finance interest rate makes lease fee rise, so $M.VFM_{BTL\text{-}BTO}$ decreases
	2. Discount rate	Increase	0.37	The lease fee reduction due to the discount rate increase is bigger than the revenue decrease, so $M.VFM_{BTL\text{-}BTO}$ increases.
	3. Lease profitability	Decrease	-1.47	The rise of lease profitability makes lease fee rise, so $M.VFM_{BTL\text{-}BTO}$ decreases
	3-1. Exchequer bond interest rate	Decrease	-0.94	The 5 year exchequer bond rate rise (the lease profitability rise) makes lease fee rise, so $M.VFM_{BTL\text{-}BTO}$ decreases.
	4. Construction deflator	Decrease	-0.53	The rise of construction deflator makes private investment and lease fee increase, so $M.VFM_{BTL\text{-}BTO}$ decreases.
	5. Consumer price index	Increase	0.99	The lease fee drop and the borrowing cost drop in the PSC make $M.VFM_{BTL\text{-}BTO}$ increase.
	6. Social benefits	-	0	The rise of social benefits does not make any changes in $M.VFM_{BTL\text{-}BTO}$.

Note: Unit change means the change of the Modified VFM when an analysis factor rises by from -20 to 20 per cent based on its given base value.

5.4.4.4 The Monte Carlo Simulations

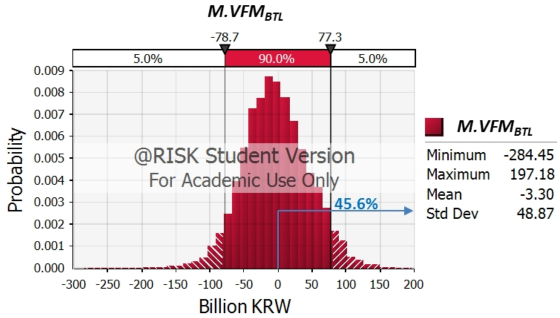
The MCS is conducted to identify the impact of the following 11 risk variables (shown in Figure 5-1~Figure 5-4, Figure 4-4 and Figure 4-6~Figure 4-7) from historical observations: WBR, construction cost overrun, traffic volume, three operation costs, construction deflator, consumer price index, five-year exchequer bond interest rate, and three-year non-guaranteed corporate bond interest rate.

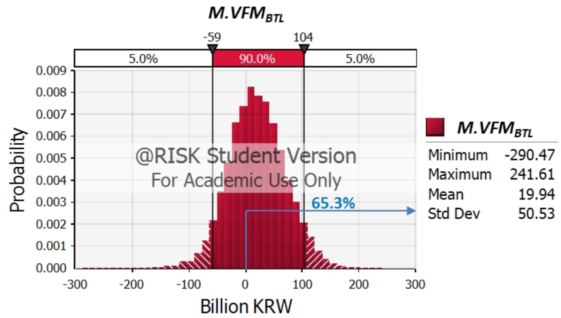
Figure 5-12 shows the MSC results with no completion delay and with a 1.30-year completion delay, which is an average completion delay in the National Expressways from the historical observations, as shown in Figure 5-3.

In the case of no completion delay (Figure 5-12 (a)), the mean value of $M.VFM_{BTL}$ is -3.3 (billion KRW) and the probability that $M.VFM_{BTL}$ is positive is 45.6 per cent. This implies that the conventional option is better than the BTL. With respect to $M.VFM_{BTO}$, its mean value is 41.5 (billion KRW) and the probability that it is positive is 66.5 per cent, which implies the BTO option is more favourable than the conventional option. Additionally, $M.VFM_{BTL\text{-}BTO}$ has a mean value of -44.8 (billion KRW) and the probability that it is positive is 33.6 per cent, which implies the BTO option is better than the BTL option. Accordingly, assuming that there is no completion delay in the conventional delivery, the most appropriate delivery option for this project is the BTO, followed by the conventional and the BTL option.

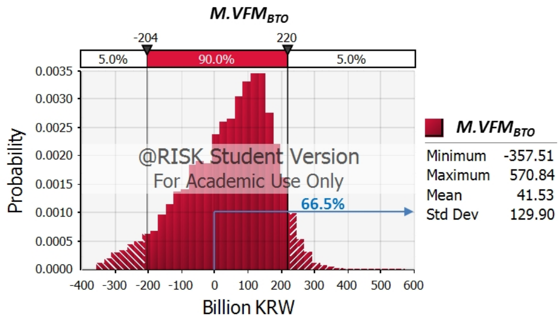
Similarly, in the case of a 1.30-year completion delay (Figure 5-12 (b)), the mean value of $M.VFM_{BTL}$ is 19.9 (billion KRW) and the probability that it is positive is 65.3 per cent. This implies that the BTL option is better than the conventional delivery. With respect to $M.VFM_{BTO}$, its mean value is 79.6 (billion KRW) and the probability that it is positive is 76.7 per cent, which implies the BTO option is more favourable than the conventional option. In addition, $M.VFM_{BTL\text{-}BTO}$ has a mean value of -59.7 (billion KRW) and the probability that it is positive is 29.4 per cent, which implies the BTO option is better than the BTL option. Accordingly, taking in account an average completion delay in the conventional delivery (1.30 years), the most appropriate delivery option is the BTO, followed by the BTL and the conventional option.

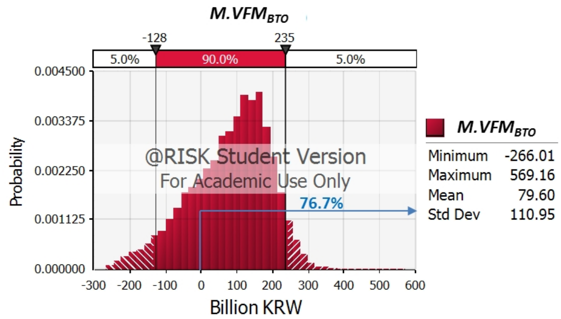
Consequently, as completion delay increases, the mean values of *M.VFM* and the probabilities that the PPP options are better also increase. Furthermore, considering all the risk factors, including the 1.30-year delay, it is reasonable to implement the Bongdam-Songsan section among the second Seoul metropolitan orbital using the BTO option.



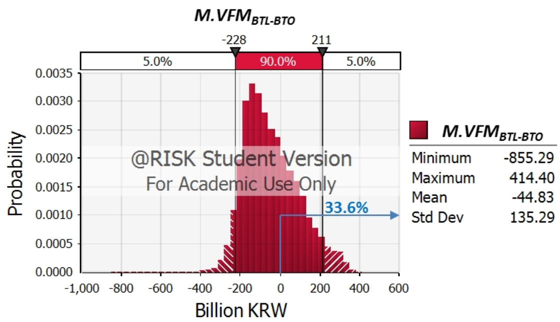


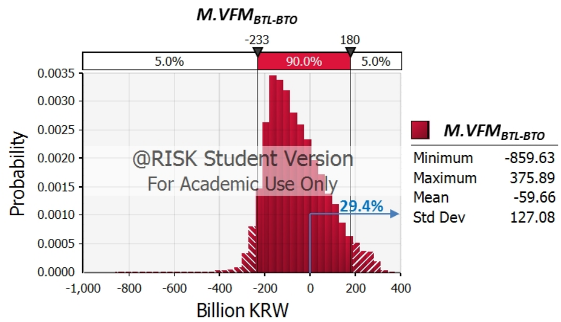
i) $M.VFM_{BTL}$ i) $M.VFM_{BTL}$





ii) $M.VFM_{BTO}$ ii) $M.VFM_{BTO}$





iii) $M.VFM_{BTL-BTO}$ iii) $M.VFM_{BTL-BTO}$

(a) No delay (b) 1.30 year completion delay

Figure 5-12: Probability distribution of the Modified VFM with 1.30-year completion delay

5.5 Findings

In order to find out the impact of transferable risks on the PPP decisions and which delivery option is the most appropriate in the National Expressway programme, the Modified VFM analysis on the Suwon-Pyungtaek case and the Bongdam-Songsan case were conducted. By examining two case studies, several characteristics are revealed.

1) Regarding construction cost risk, $M.VFM_{BTL}$ and $M.VFM_{BTO}$ using an average WBR of turn-key/alternative bids based on Korea's BTL guidelines (MOSF, 2009a) can be exaggerated, compared with those using construction cost risk (WBR risk and construction cost overrun risk) from the historical observations. This is because an average WBR of turn-key/alternative bids in the National Expressway projects was 82.14 per cent between 2002 and 2011 (MLTM, 2012b), while the historical observations from 66 National Expressway projects completed between 2006 and 2010 suggests an application ratio of 78.80 per cent, meaning construction cost risk.

It also appears, as with the National Highway programme, that this difference comes from the fact that the National Expressway projects are mainly delivered by design-bid-build in terms of conventional delivery.[86] In particular, non-governmental organisations like CCEJ (2012) and media (Lee, 2012, Sun, 2009) have criticised the turn-key/alternative bid for being inefficient and for wasting public funds from. Considering that a PSC needs to be built by a plausible and practical case (Grimsey and Lewis, 2005), it does not appear reasonable to use an average turn-key/alternative bid for the public sector cost calculation of a PSC.

As a result, for a more accurate quantitative PPP decision-making in the National Expressway projects, the Modified VFM considering historical observations and reflecting all bid systems is recommended to estimate the asset cost of the PSC instead of an average WBR of turn-key/alternative projects.

2) Traffic volume risk seems to affect PPP decisions in the National Expressway. When including traffic volume risk (68.6 per cent), $M.VFM_{BTL}$ values decrease respectively by 9.0 and 5.0 (billion KRW) in the Suwon-Pyungtaek case and in the Bongdam-Songsan case, comparing these without traffic volume risk. This is due to the decrease in the operation cost in the PSC by the VKT decrease in the projects from traffic volume reduction (from 100 to 68.6 per cent). On

[86] Only three projects used turn-key/alternative bid system among 66 National Expressway projects completed between 2006 and 2010.

the other hand, when including traffic volume risk (68.6 per cent), $M.VFM_{BTO}$ values increase respectively by 138.0 and 96.1 (billion KRW) in the Suwon-Pyungtaek case and in the Bongdam-Songsan case, compared to those without traffic volume risk. This is mainly because the decrease in revenue due to the traffic volume risk inclusion makes $M.VFM_{BTO}$ increase sharply. In addition, when considering traffic volume risk in the case of no completion delay, the most favourable procurement option changes to the BTO option from the BTL option in the two case studies.

3) A completion delay in the conventional delivery can make a critical impact on the PPP decisions. From the two case studies, according to the completion delay in the conventional delivery, the values of $M.VFM_{BTL}$ and $M.VFM_{BTO}$ increase mainly because the increase of the social benefit difference between the PSC and the PPP alternatives is much bigger than the decrease of the public sector cost in the PSC due to discounting. On the other hand, $M.VFM_{BTL\text{-}BTO}$ decreases as completion is delayed from zero to four years mainly because revenue stream drops due to the discounting effect. This implies that as completion is delayed, the BTO option become more and more preferable to the BTL option.

4) Considering risk inclusion (construction cost risk and traffic volume risk), the critical completion delays of $M.VFM_{BTL}$, $M.VFM_{BTO}$ and $M.VFM_{BTL\text{-}BTO}$ are respectively -0.16, -0.34 and -1.21 years in the Suwon-Pyungtaek case. This implies that even if the BTL or the BTO respectively start up to 0.16 or 0.34 year later than the conventional delivery, the BTL or the BTO is more favourable than the conventional delivery. Besides, even if the conventional delivery completes the project 1.21 years (14.52 months) earlier than the PPP alternatives (BTO/BTL), the BTO option is preferable to the BTL.

With respect to the Bongdam-Songsan case, the critical completion delays of $M.VFM_{BTL}$, $M.VFM_{BTO}$ and $M.VFM_{BTL\text{-}BTO}$ are respectively 0.02, -1.50 and -3.89 years. This means that when a completion in the conventional delivery is delayed more than 0.02 years (0.24 month), the BTL is better than the conventional delivery. Regarding $M.VFM_{BTO}$, even if the construction in the BTO starts 1.50 years (18.00 months) later for some reasons like a negotiation delay or financial problem than the conventional delivery, the BTO is preferable to the conventional delivery. In addition, regarding $M.VFM_{BTL\text{-}BTO}$, even if the conventional delivery completes this project within 3.89 years (46.68 months) earlier than the PPP (BTO/BTL), the BTO is better than the BTL for this project.

In addition, considering risk inclusion and an average completion delay (1.30 years) in the National Expressway projects, the BTO is the most favourable option in the two cases.

5) The sensitivity analysis results show that, when considering risk inclusion (construction and traffic volume risk) and an average completion delay (1.30 years) in the National Expressway projects, the procurement option selection could change depending on project and concerning procurement option. Among seven analysis factors, the BTL lease profitability is the most influential in the calculation $M.VFM_{BTL}$ and $M.VFM_{BTL\text{-}BTO}$ in the two cases. With respect to $M.VFM_{BTO}$, social benefit size is the most influential factor is the Suwon-Pyungtaek case, while discount rate is the most influential in the Bongdam-Songsan case. However, their impacts are very small, compared with that of BTL lease profitability in $M.VFM_{BTL}$ and $M.VFM_{BTL\text{-}BTO}$ in the two cases.

6) The MCS result, using 11 risk variables from historical observations, shows that as a completion delay rises, the probabilities that the PPP alternatives are better than the conventional delivery also increase. Considering an average completion delay of the National Expressway projects (1.30 years), the BTO scheme is the most appropriate option for the two projects.

Summing up all the results, considering the transferable risks (construction cost risk, traffic volume risk and completion delay), the BTO option is the most appropriate option for the Suwon-Pyungtaek case and the Bongdam-Songsan case. Therefore, the PPP decision made for the two projects seems to be appropriate. In addition, regarding the Bongdam-Songsan case, this project was delayed in terms of PPP decision-making and construction start due to the financial crisis beginning in 2008. If it has been decided to implement this project using the BTO scheme in 2009, as in this case study, it would have started in 2012. Considering the critical completion delay (-1.5 years), this project needs to start construction at the latest in June 2013 in order that the PPP decision to use the BTO option is valid. Accordingly, if the Korean government made a PPP decision for the Bongdam-Songsan case and also knew this information (the critical completion delay), it would be possible that the BTO option for the project could be changed to other procurement option like the conventional delivery.

CHAPTER 6 The National Railway Case Studies

6.1 Introduction

The objective of this chapter is to determine the impact of transferable risks on the Modified VFM and the PPP decisions in the National Railway programme, using two case studies covering the research objectives 2-1, 2-2 and 2-3. As case studies, the Sosa-Wonsi National Railway project and the Bujeon-Masan National Railway project are considered in this chapter, as explained in Chapter 3. Therefore, this chapter is largely made up of three sections: 1) quantified risks for the National Railways; 2) case 1: the Sosa-Wonsi case; and 3) case 2: the Bujeon-Masan case.

To begin with, as in Chapter 4, risk quantification is conducted in section 6.2 in terms of not only transferable risks but also maintenance, based on historical observation and the literature. As with the road programmes, three risks are considered in this chapter as transferable risks: construction cost risk, traffic volume risk and completion delay. The difference from road programmes is that construction cost risk in railways consists of six WBR risks and six construction cost overruns regarding six major work elements. In addition, maintenance cost is quantified, reflecting railway usage. The risk quantification is performed using the @ Risk 5.7 software package.

In the Sosa-Wonsi case (6.3) and in the Bujeon-Masan case (6.4), the impacts of transferable risks on the Modified VFM and the PPP decisions are verified, using impact analyses, such as single-value estimation, sensitivity analysis and the Monte Carlo Simulation, which are explained in Chapter 3.

Like the National Highway and the National Expressway programmes, for the calculation of the Modified VFM using single-value estimation and sensitivity analysis, analysis factors are estimated by following Korea's BTL guidelines (MOSF, 2009a) because these can provide reference points for various analysis factors. When it comes to the Modified VFM using the Monte Carlo Simulation, analysis factors are used as a form of probability distribution, quantified from historical observations. By doing so, how the PPP or procurement decisions could be changed will be scrutinised when they are reflected simultaneously in the Modified VFM.

6.2 Quantified risks for the National Railways

The risk variables used for the National Railway cases are largely divided into transferable risks and other risks. Transferable risks, as mentioned in Chapter 3, are construction cost risk, completion delay and traffic volume risk, which are the main risk variables in this research. Other risks include operation cost, construction deflator, consumer price index, the five-year exchequer bond interest rate and the three-year non-guaranteed corporate bond interest rate.

6.2.1 Transferable risks

6.2.1.1 Construction cost risk

In contrast to road projects, when it comes to the National Railway programme, a project is usually procured through six different major element work contracts: earth works/structures, track, buildings/equipment, electricity, communications and signalling due to relating laws.[87] For the National Railway programme, construction data sources include not only the National Railway but also the High Speed Railways and the Metropolitan Railways because there are a low number of railway projects in Korea. The total number of individual contracts, providing historical observations, is 339.[88] These come from 32 railways completed after 2000, including 26 National Railways, one High Speed Railway and five Metropolitan Railways.

From equation (3-10), construction cost risk is composed of EP, WBR and construction cost overrun (α). Among them, estimated price (designed price in this research) is a constant for a project, so winning bid ratio and construction cost overrun are considered as risk factors.

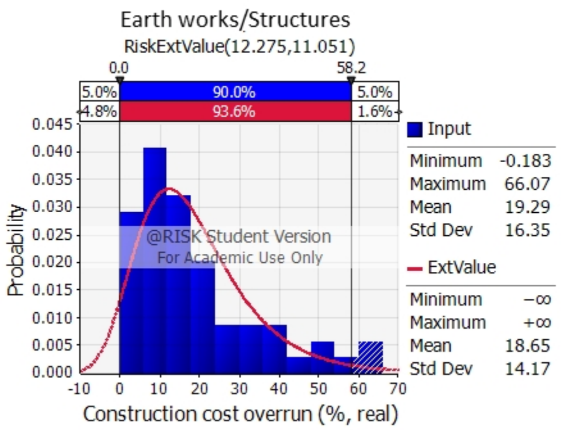
Construction cost overrun

Among the contracts of the six elements, usually earth works/structures is the largest, followed by buildings/equipment and electricity. Regarding the six major work elements, the probability

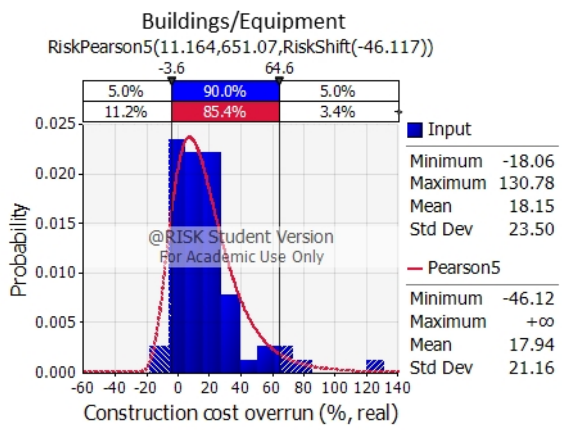
[87] Relating laws mean the Electricity Construction Business Act and the Information and Communications Construction Business Act. For example, according to the Electricity Construction Business Act (Article 1, Paragraph 11), the electricity construction work is to be contracted separately from other construction work.

[88] The total contract number is 339 (earth works/structures 55, buildings/equipment 67, track 21, electricity 80, communications 51, and signalling 65).

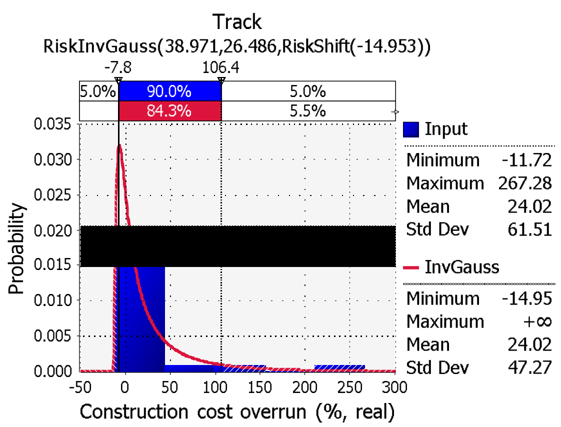
distributions of construction cost overrun risks (2005 price) in real terms from the historical observations are shown in Figure 6-1.



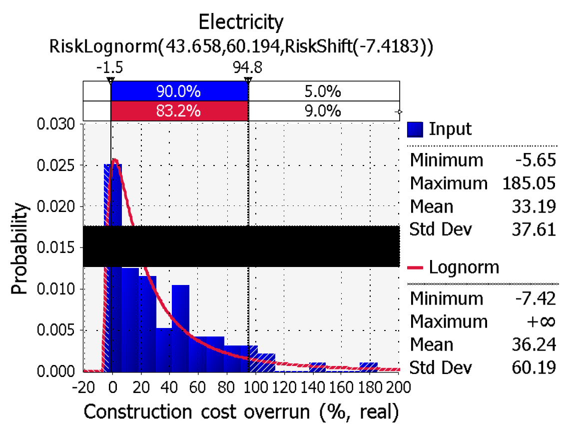
(a) Earth works/structures



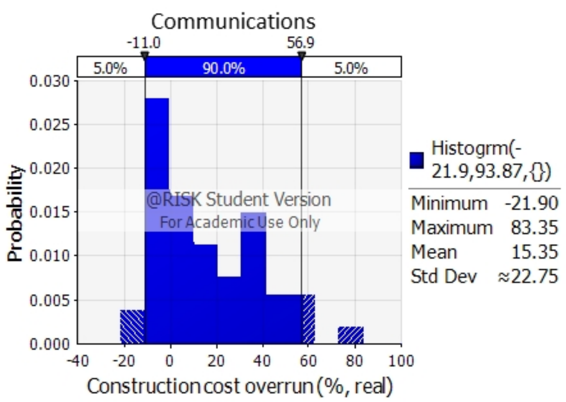
(b) Buildings/equipment



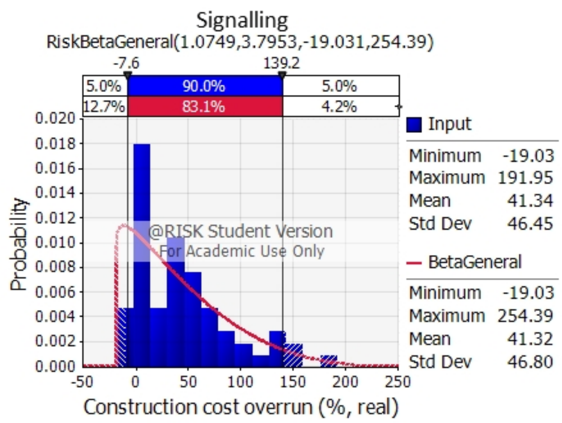
(c) Track



(d) Electricity



(e) Communications



(f) Signalling

Figure 6-1: The probability distributions for construction cost overrun risks in the National Railways

From Figure 6-1, the construction cost of earth work/structure, buildings/equipment and track is respectively expected to increase on average 18.65, 17.94 and 24.02 (per cent) in real terms on its contract cost. In addition, the construction cost of electricity, communications and signalling is respectively expected to increase on average 36.24, 15.35 and 41.32 (per cent) in real terms on its contract cost.

WBR

WBR means the proportion of bid winner's price (the contract price) to the EP for a project. The WBR is directly obtained from the historical observations. In contrast to construction cost overrun risk, there is no PDFs passing the Chi square test (χ^2), so WBR risk is expressed as a form of frequency distribution. Regarding the six major work elements, the frequency distribution graphs of WBRs are shown in Figure 6-2.

From Figure 6-2, the WBR of earth works/structures, buildings/equipment and track is respectively expected to be 74.45, 82.69 and 83.36 (per cent) on average. In addition, the WBR of electricity, communications and signalling is respectively expected to be 83.65, 85.67 and 86.03 (per cent) on average.

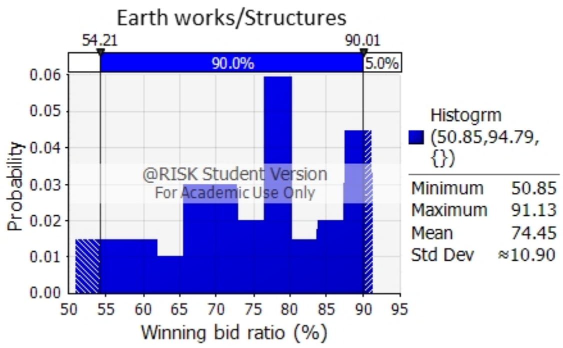
Application ratio

Based on construction cost risks (Figure 6-1) and WBRs (Figure 6-2) in the six major element works, each element's application ratio in equation (3-10), meaning construction cost risk, can be calculated. As seen in Table 6-1, the application ratio of earth works/structures, buildings/equipment and track is respectively 88.33, 97.52 and 103.38 (per cent) in real terms. In addition, the application ratio of electricity, communications and signalling is respectively 113.96, 102.63 and 121.58 (per cent) in real terms. The application ratio over 100 (per cent) means that construction cost at completion exceeds the estimated construction price in real terms.

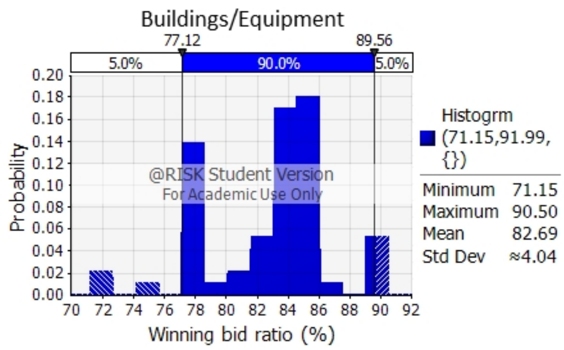
Table 6-1: The application ratios of six major work elements

	Winning bid ratio (%)	Construction cost overrun (%, real)	Application ratio (%, real)
Earth work/Structure	74.45	18.65	88.33
Building/Equipment	82.69	17.94	97.52
Track	83.36	24.02	103.38
Electricity	83.65	36.24	113.96
Communication	85.67	15.35	98.82
Signalling	86.03	41.32	121.58

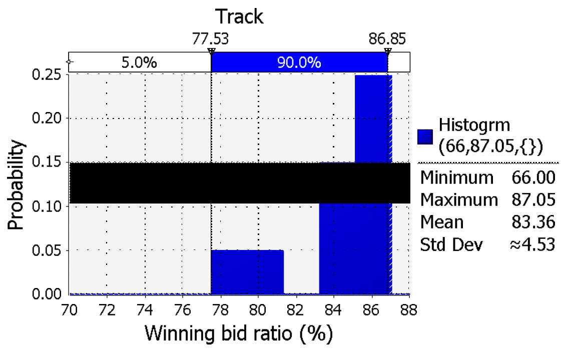
Note: Application ratio (%) = Winning bid ratio (%) × (1 + Construction cost overrun (%))



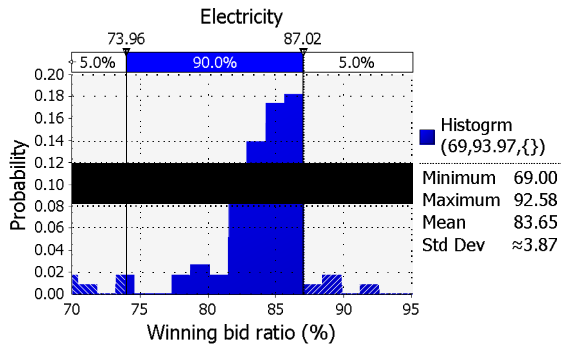
(a) Earth works/structures



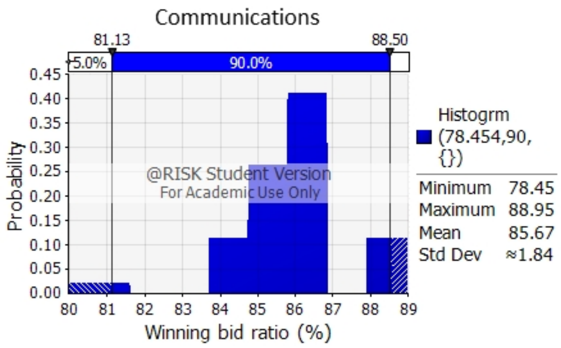
(b) Buildings/equipment



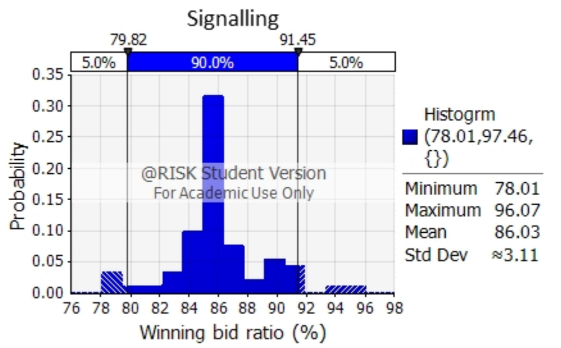
(c) Track



(d) Electricity



(e) Communications



(f) Signalling

Figure 6-2: Frequency distribution for WBR in the National Expressway

6.2.1.2 Completion delay

Regarding completion delay for the National Railway, historical observations are currently not available. However, it is appropriate to attempt to establish how long the National Railway projects can be expected to be delayed due to lack of budget.

According to a press release from Jingoo Lee, a member of the National Assembly, the KRNA expected that due to a lack of budget, railway projects under construction will be delayed by between two and seven years, with respect to the inspection of the KRNA conducted by the National Assembly in 2006 (Kwon, 2006). As seen in Table 5, a lack of budget means a delay of 3.36 years on average on the expected completion time.

Table 6-2: Completion delay expected in the National Railways

Railway projects	Completion year (planned)	Completion year (re-scheduled)	Completion delay (expected)
Suwon-Incheon (electrified double track rail)	2008	2015	7 years
Yongsan-Moonsan (electrified double track rail)	2008	2010	2 years
Ori-Suwon (electrified double track rail)	2008	2015	7 years
Wangsimri-Sunrung (electrified double track rail)	2008	2010	2 years
Busan-Ulsan (electrified double track rail)	2010	2015	5 years
Seoul-Choonchun (electrified double track rail)	2009	2013	4 years
Dukso-Wonju (electrified double track rail)	2008	2010	2 years
Youngdong line (relocation)	2007	2009	2 years
Dongsoonchun-kwangyang (double track rail)	2006	2009	3 years
Soonchun-Yeosu (improvement)	2008	2010	2 years
Jaechun-Dodam (electrified double track rail)	2007	2011	4 years
Junla line (double track rail)	2008	2010	2 years
Jaechun-Ssangyong (electrified double track rail)	2008	2011	3 years
Samrangjin-Jinju (electrified double track rail)	2011	2013	2 years
Average			3.36 years

Source: Jingoo Lee, recited from Kwon (2006)

6.2.1.3 Traffic volume risk

Railway traffic volume changes in Korea, shown in Table 4, are gathered from a literature review. Using equation (3-12) and this table, the probability distribution histogram of railway traffic volume can be drawn. As seen in Figure 6-3, the mean value of rail traffic volume risk is 0.507.

Table 6-3: The traffic volume changes in railways of Korea

Railway projects	Length (km)	Open	Passenger/day		B/A	Source
			Forecast (A)	Actual (B)		
Seoul metro line 1(Seoul station-Chungryangri)	7.8	1974	395,255	87,060	0.22	(a)
Seoul metro line 2 (Circulation)	60.2	1980	156,499	58,750	0.38	(a)
Seoul metro line 5 (Bangwha-Sangil, Macheon)	52.3	1995	1,725,000	524,714	0.3	(a)
Seoul metro line 6 (Ungam-Bongwhasan)	35.1	2000	1,319,276	246,803	0.19	(a)
Seoul metro line 7 (Jangam-Onsoo)	46.9	1996	897,220	380,464	0.42	(a)
Seoul metro line 8 (Amsa-Moran)	17.7	1996	241,229	150,963	0.63	(a)
Seoul metro line 9 (Gaewha-Nonhyun)	27	2009	312,438	260,452	0.83	(b)
Incheon metro 1 (Gyulhyun-Dongmak)	21.9	2000	1,890,000	218,551	0.12	(b)
Incheon metro 1 (Dongmak-Business Centre)	6.5	2009	81,783	11,376	0.14	(b)
Ilsan line (Daewha-Jichuk)	19.2	1996	110,266	44,104	0.4	(a)
Busan metro 2 (Jangsan-Yangsan)	45.2	1999	1,462,448	213,521	0.15	(a)
Busan metro 3 (Daejeo-Sooyoung)	18.1	2005	395,014	55,852	0.14	(a)
Busan metro line 4	12.7	2011	86,000	26,000	0.3	(c)
Busan-Kimhae light rail	23.9	2011	176,358	31,000	0.18	(c)
Daegu metro line 1 (Daegok-Anshim)	25.9	1997	1,128,055	137,705	0.12	(a)
Daegu metro line 2 (Moonyang-Sawol)	28	2005	912,468	124,595	0.14	(a)
Kwangjoo metro line 1 (Nokdong-Pyungdong)	20.5	2004	257,100	30,573	0.12	(a)
Daejeon metro line 1 (Panam-Banseok)	20.5	2006	420,096	93,483	0.22	(a)
Suseo line (Suseo-Ogum)	3	2009	16,610	16,813	1.01	(b)
Uijeongbu-Dongdoocheon line	23	2007	191,984	139,513	0.73	(b)
Suwon-cheonan line	55.6	2007	114,165	240,006	2.1	(b)
Janhhang line (renovation, 1st stage)	75.6	2009	39,234	19,693	0.5	(b)
Incheon airport railway	61.7	2010	421,592	47,791	0.11	(b)
Ori-Suwon line	19.5	2007	108,518	28,041	0.26	(b)
Cheongryangli-Deokso line	18	2010	96,916	155,921	1.61	(b)
Deokso-Wonju line	90.4	2009	55,511	38,326	0.69	(b)
Cheonan-Onyangoncheon line	16.5	2009	33,056	43,152	1.31	(b)
Kyungbu line (Seoul-Daegu, KTX 1st stage)	238.6	2004	226,155	195,363	0.86	(b)

Note: Data source is as follows; (a) Kim (2010b), (b) MLTM, recited from Gil (2012), (c) Park (2012)

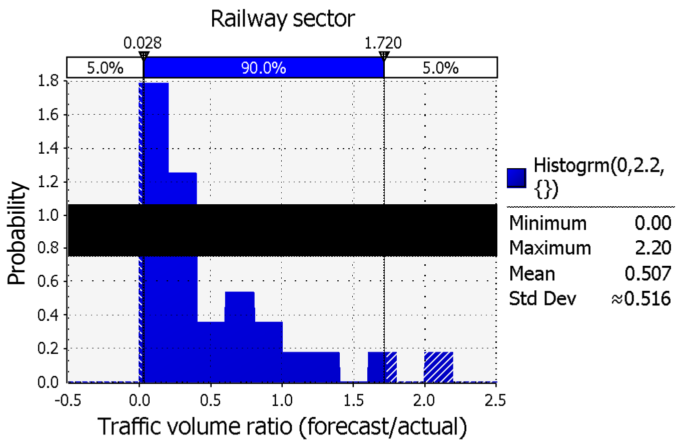


Figure 6-3: Probability distribution of railway traffic volume risk

6.2.2 Other risk variables

6.2.2.1 Operation cost

In this research, the historical observations on operation cost in the National Railways come from 18 National Railways between 2000 and 2010. The operation cost from the historical observations is largely composed of personnel cost, management cost and maintenance cost. In order to use the historical observations in the calculation of the Modified VFM on a specific project, these cost items need to be transformed by a scale factor because conditions such as length and traffic volume are different between a case studies and the projects providing the historical observations. As with road programmes, as a scale factor, passenger car kilometre travelled (PCKT) data from 18 National Railways between 2000 and 2010 are used because this measure can reflect the concept of length and traffic volume at the same time. However, personnel cost and management cost seems to be close to fixed cost, not varying according to project size or traffic volume. Therefore, only maintenance cost/PCKT is used as an operation cost risk variable in the National Railway programme. The PDF of maintenance cost/PCKT (2005 price) from the historical observations is shown in Figure 6-4.

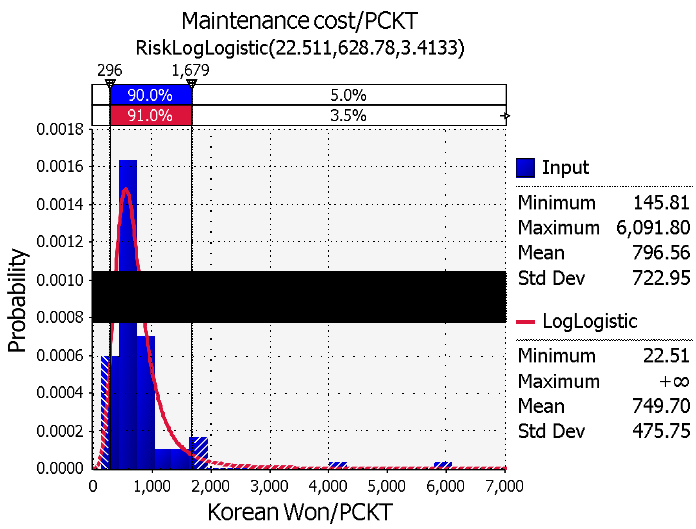


Figure 6-4: The PDF for maintenance cost/PCKT in National Railways

6.2.2.2 Inflation

With respect to inflation, according to Korea's BTL guidelines (MOSF, 2009a), a construction deflator is used for the calculation of the yearly BTL lease fee in nominal terms and it is converted to real terms by consumer price index. The construction deflator and consumer price index are shown in Figure 4-6.

6.2.2.3 Factors relating BTL viability

According to Korea's BTL guidelines (MOSF, 2009a), BTL lease profitability is expressed as a "five-year exchequer bond interest rate + mark-up" and the mark-up is composed of a premium for long term investment and risk premium for construction and operation. In a same way, the BTL finance interest rate for private sector is estimated by applying an additional rate to a "three-year non-guaranteed corporate bond (AA-) interest rate", which is the base rate. They are shown in Figure 4-7.

6.3 Case 1: The Sosa-Wonsi case

6.3.1 Project overview

The Sosa-Wonsi National Railway was planned with the aim of relieving traffic congestion due to large-scale housing and industrial development in the south-west of Gyeonggi Province, in particular in Ansan city and Sihung city. Connecting the Seoul-Incheon line and the Suwon-Incheon line, this project will provide not only a skeleton of urban circulation rail network in south-west Gyeonggi Province but also a new north-south rail corridor (Figure 6-5). In addition, this project is expected to support the balanced regional development and multi-centralisation[89] of Gyeonggi Province.

At first, this project was reviewed as a traditionally delivered project through a preliminary feasibility study in 2002. However, according to the introduction of the BTL system in 2005, this project was designated as a BTL project following PPP board deliberation in 2007 in order to activate the BTL system. After final design and negotiation, construction started in 2010 and is expected to be completed in 2015.

The overview of this project shown in the contract awarded in 2010 is as follows:

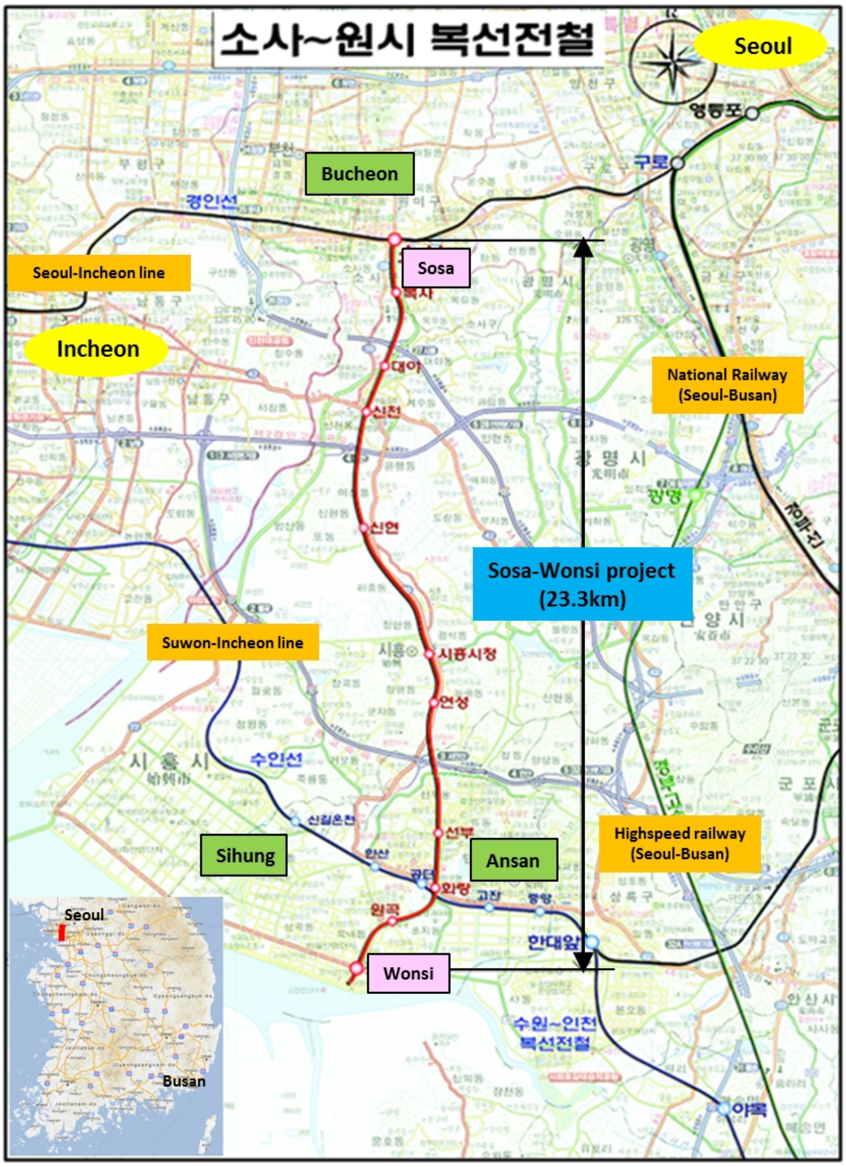
- Title: Sosa-Wonsi National Railway PPP Project
- Location: Sosa-dong, Bucheon city ~ Wonsi-dong, Ansan city, Gyeonggi Province
- Length: 23.3km (electrified double track)
- PPP type: BTL
- Construction duration:[90] 60 months, operation duration: 20 years
- Project cost:[91] 1,098 (billion KRW, 2006 price)

[89] For the sustainable development of Seoul metropolitan area including Seoul and Gyeonggi Province, Seoul metropolitan area readjustment plan was established in 2006, which includes the development of 10 growth centres in Gyeonggi Province in order to change the space structure of Seoul metropolitan area focused on Seoul in terms of population and functions.

[90] For the VFM and the Modified VFM analysis, the five-year construction duration will be used because these analyses are implemented at a decision-making stage (preliminary feasibility stage) earlier than the award of the contract.

[91] Project cost means asset cost excluding compensation cost (238.6 billion KRW) provided by the Korean government, so it is composed of all the costs that are necessary during the construction stage which are delivered by the private sector.

- Inflation rate: 3 per cent
- Lease profit rate: 5.7 per cent (nominal)
- BTL finance interest rate: 7.42 per cent (nominal)
- BTL finance structure: equity 10 per cent, debt 90 per cent
- Special project vehicle: E rail corp.
  - KB Sosa-Wonsi railway project investment trust (90 per cent), Daewoo construction (3.425 per cent), Hyundai construction (3.175 per cent), Hanwha construction (1.125 per cent), Taeyoung construction (0.6 per cent), Hanla construction (0.5 per cent), KCC construction (0.275 per cent), Bando construction (0.250 per cent), Wonha construction (0.125 per cent), Sampyo Enc. (0.1 per cent), Doohan construction (0.05 per cent)



Source: MLTM

Figure 6-5: The Sosa-Wonsi National Railway project map

6.3.2 Analysis factors and assumptions for the Modified VFM

Although this project has already being implemented by the BTL scheme, in order to verify the impact of transferable risks on the PPP decisions and the appropriateness of the PPP decision for this case in terms of the year 2007, this case study considers three alternative procurement options: the conventional delivery, the BTL and the BTO.

Basic analysis factors for Modified VFM are as follows:

- PPP model: BTO and BTL
- Discount rate: 6.5 per cent (real)
- Decision-making time: 2007; price base year: 2007
- Five-year exchequer bond interest rate:[92] 5.4 per cent (nominal)
- Three-year non-guaranteed corporate bond:[93] 5.85 per cent (nominal)
- Construction deflator:[94] 5.60 per cent (nominal, on average from 2002 to 2007)
- Consumer price index:[95] 2.92 per cent (nominal, on average from 2002 to 2007)
- BTL lease profitability:[96] 6.17 per cent (five-year exchequer bond interest rate + 0.77 per cent, nominal)
- BTL finance interest rate:[97] 6.85 per cent (three-year non-guaranteed corporate bond (AA-) + 1.0 per cent, nominal)

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[92] A five-year exchequer bond interest rate is calculated by a weighted average method, which applies 0.1, 0.2, 0.3 and 0.4 to the first, second, third and fourth quarter value (MOSF, 2009a). The quarterly five-year exchequer bond interest rate is provided by the Korea Bond Information Service (http://www.kofiabond.or.kr).

[93] A three-year non-guaranteed corporate bond interest rate is also provided by the Korea Bond Information Service (http://www.kofiabond.or.kr). It is estimated in the same way as the five-year exchequer bond interest rate, following Korea's BTL guidelines (MOSF, 2009a).

[94] Construction deflator means construction investment deflator in Expenditure on Gross Domestic Product on National Accounts and it is provided by the Bank of Korea (http://www.bok.or.kr).

[95] The consumer price index is also provided by the Bank of Korea (http://www.bok.or.kr).

[96] BTL lease profitability is expressed as a "five-year exchequer bond interest rate + mark-up rate" and mark-up is composed of a premium for long term investment and risk premium for construction and operation (MOSF, 2009a). Regarding the mark-up rate, 0.77 per cent, an average rate used in rail BTL project pre-qualification reports (Wonju-Gangrung: 0.77, Gyungjun/Junla line: 0.87, Bujeon-Masan: 0.74, Sosa-Wonsi: 0.77, Daegok-Sosa: 0.72), is considered in the National Railway cases.

[97] BTL finance interest rate is expressed as a "three-year non-guaranteed corporate bond interest rate + mark-up rate" (MOSF, 2009a) and, according to Kim et al. (2005), the mark-up rate seems to be distributed from 0.66 per cent to 2.00 per cent. As a mark-up rate, 1.0 per cent is used in the National

- BTL finance terms: level debt service during operation period
- BTL finance structure: equity 15 per cent, debt 85 per cent
- Operation period: 20 years; construction duration: five years

In addition, the same assumptions (see 4.3.2) for the Modified VFM used in the National Highway cases are also used in the National Railway cases.

6.3.3 Main cost items for the VFM and the Modified VFM analysis

From equation (3-7), (3-8) and (3-9), main calculation items for the Modified VFM are the asset cost of a PSC (AC_{PSC}), the operation cost of a PSC (OC_{PSC}) and a BTL (OC_{BTL}), the lease fee of a BTL ($Lease\ fee_{BTL}$), revenue ($Revenue$), the subsidy ($Subsidy_{BTO}$) from the Korean government, the minimum revenue guarantee cost (MRG_{BTO}) and the benefit difference (ΔB).

Asset cost of the PSC ($\boldsymbol{AC_{PSC}}$)

The basic asset cost data shown in Table 6-4 are collected from the BTL research report on the Sosa-Wonsi National Railway (KOTI, 2007). Among the building cost items, the bracketed values are the designed price of each item before each item's WBR is reflected. With respect to the design cost and construction cost of the PSC, these are calculated by multiplying each designed price and an average WBR (90.71 per cent) of the turn-key/alternative bids in the National Railway projects between 2000 and 2007 (Kim et al., 2008a). In addition, with respect to the design cost and construction cost of the PPP, the same values as in the PSC are used because the detailed cost of each work element is not available for this project.

In addition, in order to estimate the Modified VFM, the yearly asset costs of the PSC are distributed according to Table 4-3. With respect to longer construction duration considering completion delay, new yearly distribution ratios using interpolation method and Table 4-3 will be applied to the calculation of the Modified VFM.

Operation cost for the PSC and the BTL ($\boldsymbol{OC_{PSC}, OC_{BTL}}$)

In the same way as for road cases, the yearly base operation costs for the PSC (OC_{PSC}) are calculated by multiplying the mean values of the operation costs[98] (KRW/PCKT) from the

Railway cases, considering rail BTL project pre-qualification reports (Wonju-Gangrung: 1.0, Gyungjun/Junla line: 1.0, Bujeon-Masan: 1.0, Sosa-Wonsi: 1.0, Daegok-Sosa: 1.0).

[98] From the historical observations, the mean values of operation cost items (2005 price) are as follows: 1) personnel cost /PCKT = 4,898.1 KRW/PCKT; 2) management cost/VKT = 3,068.0 KRW/PCKT; and 3) maintenance cost/VKT = 749.7 KRW/PCKT.

historical observations and yearly PCKT data of this project from the feasibility and schematic design report on the Sosa-Wonsi National Railway (KORAIL, 2003).

Table 6-4: Basic asset cost for the PSC and the PPP (BTL/BTO)

(Unit: billion KRW, 2007 price)

Asset cost items		PSC [BTL guideline]	PPP
Building cost	Investigation	**0.7**	**0.7**
	Design	**23.6** (25.9) Earth work/Structure 15.1 (16.6) Building/Equipment 2.4 (2.6) Track 0.9 (1.0) Electricity 3.0 (3.3) Signal 1.2 (1.3) Communication 1.0 (1.1)	**23.6** (25.9) Earth work/Structure 15.1 (16.6) Building/Equipment 2.4 (2.6) Track 0.9 (1.0) Electricity 3.0 (3.3) Signal 1.2 (1.3) Communication 1.0 (1.1)
	Construction	**1,345.4** (1,483.2) Earth work/Structure 998.4 (1,089.6) Building/Equipment 135.0 (148.8) Track 36.0 (39.7) Electricity 107.5 (118.6) Signal 41.5 (45.8) Communication 37.0 (40.8)	**1,345.4** (1,483.2) Earth work/Structure 998.4 (1,089.6) Building/Equipment 135.0 (148.8) Track 36.0 (39.7) Electricity 107.5 (118.6) Signal 41.5 (45.8) Communication 37.0 (40.8)
	Sub total	**1,369.70**	**1,369.70**
Compensation cost		**0** (38.2)	**0** (38.2)
Additional cost		**30.8** **Design inspection** 2.8 Construction inspection 19.9 Traffic impact assessment 0.1 Environmental impact assessment 0.8 Disaster impact assessment 0.1 Energy use plan 0.1 Construction management 3.6 Waste disposal 3.4	**32.4** **Design inspection** 2.8 Construction inspection 19.9 Traffic impact assessment 0.1 Environmental impact assessment 0.8 Disaster impact assessment 0.1 Energy use plan 0.1 Construction management 3.6 Waste disposal 3.4 Insurance 1.1 financial cost 0.5
Operation facility cost		**80.0** Bedding measurement 0.1 Track management 0.5 Building equipment 0.1 Electricity facility 0.7 Signal/communication 1.8 Automatic fare collection system 0.2 Management information system 0.5 Train 76.1	**80.0** Bedding measurement 0.1 Track management 0.5 Building equipment 0.1 Electricity facility 0.7 Signal/communication 1.8 Automatic fare collection system 0.2 Management information system 0.5 Train 76.1
Business reserve		**0.6** Test drive cost 0.6	**4.5** Test drive cost 0.6 Organisation cost 0.2 Business commence cost 2.7 Stock issue cost 1.1
Total		**1,481.1**	**1,486.7**

Note: 1. Compensation cost is provided by the Korean government, so it is not included in the Modified VFM assessment. 2. All values in the Table come from the BTL research report on the Sosa-wonsi National Railway (KOTI, 2007) and the bracketed building cost values are designed prices before including winning bid ratios. 3. According to KOTI (2007), contractor's all risk insurance for the PSC is neglected and at the same time it is neglected in the PPP, which is possible in terms of competitive neutrality according to the BTL guidlelines of Korea (MOSF, 2009).

Maintenance cost tends to gradually increase over time because of the increasing decrepitude of the facility. However, there is currently no available way to consider the decrepitude of the railways. Thus, for a simple calculation, the assumption is made that the historical observations are collected from railways with a 10-year decrepitude[99]; yearly maintenance costs are converted using normalisation and the relative yearly ratios in roads from the preliminary feasibility guideline (KDI, 2008b). Yearly maintenance cost distribution ratios for the PSC in National Railway are given in Table 6-5. As reviewed in 4.3.3 regarding Table 4-3, though it seems to be oversimplified from the theoretical perspective, it seems that Table 6-5 can be carefully utilised in the calculation of maintenance costs, considering the impact of lack of maintenance funds, the superposition of various maintenance cost items with different maintenance periods and the unavailability of historical observations regarding railway maintenance. Moreover, train replacement costs during the operation period are also included in the PSC (OC_{PSC}).

Table 6-5: Yearly cost distribution ratios for maintenance costs of the PSC

Year	1	2	3	4	5	6	7	8	9	10
Maintenance cost ratio	0.93	1.11	1.31	1.55	1.82	2.13	2.49	2.88	3.32	3.8
Normalised ratio	0.24	0.29	0.34	0.41	0.48	0.56	0.66	0.76	0.87	1
Year	11	12	13	14	15	16	17	18	19	20
Maintenance cost ratio	4.32	4.87	5.45	6.04	6.63	7.23	7.81	8.36	8.89	9.37
Normalised ratio	1.14	1.28	1.43	1.59	1.74	1.9	2.06	2.2	2.34	2.47

Note: 1. Maintenance cost ratios regarding decrepitude is from road sectors in the preliminary feasibility guideline (KDI, 2008a) because those of railways are currently not available. 2. Normalised ratio in each year is calculated by dividing maintenance cost ratio value in each year by 3.8 (maintenance cost ratio of the 10th year).

In addition, when it comes to the operation cost of the BTL (OC_{BTL}), the same operation cost as the PSC will be applied in the Modified VFM.

Lease fee for the BTL ($\boldsymbol{Lease\ fee_{BTL}}$)

According to Korea's BTL guidelines (MOSF, 2009a), the yearly lease fee in nominal terms is calculated as equation (4-1). The asset cost of the PPP (BTL) in real terms in Table 6-4 is

[99] It is difficult to know the degree of decrepitude of the railway which produces the historical observations because the railway is always maintained. Therefore, considering operation period (20 years) in PPP railways in Korea, the historical observations are assumed to be obtained from the railways with a10-year decrepitude.

delivered as a form of equity (15 per cent) and debt (85 per cent) according to the BTL finance structure. Considering the construction deflator and BTL finance interest rate, the total investment of private sector, including principal and interest, becomes 2,177.1 (billion KRW, nominal term) at the completion time, which is the sum of (a), (b) and (C) in Table 6-6.

Table 6-6: Calculation of the private sector investment

Year	Equity (15%)		Debt (85%)		Interest (nominal)
	Real (2007 price)	Nominal	Real (2007 price)	Nominal	
2010	16.0	18.8	90.4	106.5	
2011	30.9	38.5	175.3	217.9	7.3
2012	51.7	67.9	293.1	384.8	22.2
2013	71.6	99.3	405.8	562.8	48.6
2014	52.8	77.3	299.1	438.0	87.1
Total	223.0	301.9 (a)	1,263.7	1,710.0 (b)	165.2 (c)
Private sector investment (P = a + b + c)			2,177.10		

Consequently, in this case study, the lease fee in nominal terms for the BTL is calculated as follows:

$$PVIFA_{(20,0.0617)} = \sum_{i=1}^{20} \frac{1}{(1+0.0617)^i} = 11.3096$$

$$Lease\ fee = \frac{2{,}177.1}{PVIFA_{(20,0.0617)}} = \frac{2{,}177.1}{11.3096} = 192.496\ (\text{billion KRW, nominal})$$

Considering the inflation index and the economic discount rate, the lease fee in nominal terms in each year will be transformed into real terms to be applied to the Modified VFM.

Revenue, subsidy and MRG for the BTO $(\boldsymbol{Revenue, Subsidy_{BTO}, MRG_{BTO}})$

As shown in equation (3-7), revenue, subsidy and MRG cost tends to reduce $M.VFM_{BTO}$ when comparing the PSC and the BTO. Revenue is calculated using distance matrix, origin-destination matrices from the BTL research report on the Sosa-Wonsi National Railway (KOTI, 2007) and the rail fare system.[100] In addition, the subsidy in the BTO can be calculated using the following equation when operation cost and IRR are known (MOSF, 2009b).

$$\sum_{i=0}^{n} \frac{CC_i}{(1+r)^i} = \sum_{i=n+1}^{N} \frac{OR_i - OC_i}{(1+r)^i} + \sum_{i=0}^{N} \frac{ANR_i}{(1+r)^i} \tag{6-1}$$

[100] As of 2007, the basic rate is 900 KRW within 10 km and 100 KRW is added every five kilometres.

where, n = completion time, N = the end of the operation term, CC_i = yearly asset cost excluding subsidy (purely construction costs), OR_i = the yearly revenue,[101] OC_i = the yearly operation cost (corporate tax excluded), ANR_i = the yearly net profit from subsidiary enterprise, r = IRR.

From equation (6-1), assuming no subsidiary enterprise, as construction cost, revenue stream and operation cost are already known, the subsidy can be calculated only if IRR is known.
As shown in Table 6-7, comparing the IRR of road and railway BTO projects between 1995 and 2005, railway BTO projects have a 0.95 per cent higher IRR than road BTO projects on average. Additionally, five road projects suggested from the private sector or contracted after 2006 have a 5.43 per cent IRR on average. As a result, rail BTO projects in 2007 could be assumed to have a 6.38 per cent IRR in real terms.

Table 6-7: IRRs of BTO projects

	IRR (real term)	
	1995 ~ 2005	**After 2006**
Road	Incheon international Airport Expressway (9.70%), Daegu-Busan (9.38%), Seoul beltway (9.52%), Daegu beltway (10.47%), Chunan-Nonsan (9.23%), Kwangju 2nd beltway (8.86%), Chunmasan tunnel (8.56%), Manwolsan tunnel (8.85%), Misiryung tunnel (9.52%), Suwon-Pyungtaek (7.40%)	Incheon-Gimpo (5.07%), Anyang-Sungnam (5.49%), Songsan-Bongdam (5.03%), Gimpo-Hwado (6.04%), Osan-Gwangju (5.54%)
	Average = 9.15%	**Average = 5.43%**
Rail	Choep light rail (10.48%), Seoul-Hannam 10.48%), Busan-Kimhae (10.24%), Incheon International Airport Railway (10.42%), Seoul metro (8.90%)	No project
	Average = 10.10%	

Source: Gil (2012), PIMAC (2009c), PIMAC (2009d) and PIMAC (2009b)

From equation (6-1), using the IRR (6.38 per cent), given operation cost and revenue stream, the subsidy can be calculated, assuming that there is no subsidiary enterprise. As seen in Table 6-8, considering the revenue stream, the Korean government needs to give as much as 84 per cent of PPP asset cost as a construction subsidy. This amount of subsidy is far beyond the governmental subsidy limitation[102] (50 per cent of BTO asset cost). In addition, considering the maximum

[101] Yearly revenue does not include operation subsidy (public service obligation) from the Korean government. According to the Framework Act on Rail Industry Development (Article 32, 33), when a rail operating company provides a public service not yielding profit by the request of the central or local government, the company can receive a public service subsidy from the request through agreement between the two parties. Therefore, the public service subsidy is not included in this case.

[102] According to MOSF (2010), the maximum subsidy is a half of the asset cost in the BTO in case of railways.

subsidy, the revenue stream needs to increase twice more than the given one, in order to attain real IRR of 6.38 per cent. Accordingly, it seems that, in practice, the BTO option cannot be selected as a procurement option with such a small revenue stream. However, this project still produces an IRR level (6.38 per cent, real) with the help of the governmental subsidy of 84 per cent on the BTO asset cost, so the BTO will be considered as a procurement option.

Table 6-8: The relationships among IRR, revenue stream and subsidy

Real IRR (%)	6.38						
Revenue stream (times)	1	1.2	1.4	1.6	1.8	2	2.06
Subsidy/asset cost	0.84	0.77	0.71	0.65	0.58	0.52	0.5

With respect to MRG cost for the BTO, the MRG condition for decision-making time in Korea is considered. As shown in Table 6-9, for a solicited project in 2007, as here, the Korean government guarantees up to 75 per cent (year 1 to 5) and 65 per cent (year 6 to 10) of the contract revenue for the first ten years after opening. However, it does not guarantee this when the actual revenue is lower than a half of contract revenue. In addition, the Korean government redeems the revenue exceeding 125 per cent (year 1 to 5) and 135 per cent (year 6 to 10) of the contract revenue for the first ten years in operation period.

Although the MRG cost is zero when forecast traffic volume is realised, in reality there is some discrepancy between forecast and actual volume. Using the traffic volume risk, the MRG cost will be calculated in the Modified VFM analysis.

Table 6-9: The change of MRG condition in BTO projects

<table>
<tr><th rowspan="2"></th><th rowspan="2">1999 ~ May 2003</th><th rowspan="2">Jun. 2003 ~ Dec. 2005</th><th colspan="2">Jan. 2006 ~ Sep. 2010</th><th rowspan="2">After Oct. 2010</th></tr>
<tr><th>Solicited</th><th>Unsolicited</th></tr>
<tr><td>Guarantee/ Redemption term</td><td>Throughout operation period</td><td>First 15 years of operation period</td><td>First 10 years of operation period</td><td rowspan="3">Abolition</td><td rowspan="3">Abolition</td></tr>
<tr><td>Guarantee level</td><td>▪ Solicited: 90%
▪ Unsolicited: 80%</td><td>▪ Solicited: 90/80/70% every 5 years
▪ Unsolicited: 80/70/60% every 5 years
▪ No guarantee when lower than 50 % of revenue</td><td>▪ 75/65% every 5 year
▪ No guarantee when lower than 50 % of revenue</td></tr>
<tr><td>Redemption level</td><td>▪ Solicited: 110%
▪ Unsolicited: 120%</td><td>▪ Solicited: 110/120/130% every 5 years
▪ Unsolicited: 120/130/140% every 5 years</td><td>▪ 125/135% every 5 year</td></tr>
</table>

Source: MOSF (2010)

Social benefit difference (ΔB)

Social benefits for the Modified VFM analysis are collected from the feasibility and schematic design report on the Sosa-Wonsi National Railway (KORAIL, 2003). The social benefit difference (ΔB) beween the PSC and the PPP alternatives, considering completion delay of the conventional delivery, can be calculated by using these data. In addition, with respect to the relationship of traffic volume and social benefit, it seems that social benefits could be different when actual traffic volume is different from forecast, because traffic volume could have an influence on above benefit factors directly or indirectly. In order to establish this relationship, it appears necessary to carry out a new traffic demand analysis for the project. However, if this is difficult in practice, using empirical method this relationship could be estimated roughly.

As with the research of Kim et al. (2011) regarding the National Highways, using the data of BCR, traffic volume and capacity regarding 24 National Railway projects[103] provided in the master plan research report on the 21st century National Railway network of Korea (KOTI, 2004), the relationship between BCR and volume-capacity ratio (V/C) can be estimated as shown in equation (6-2) and in Figure 6-6 as follows:

$$\boldsymbol{BCR = 0.615 \times \frac{V}{C} + 0.471\ (R^2 = 0.16)} \qquad (6\text{-}2)$$

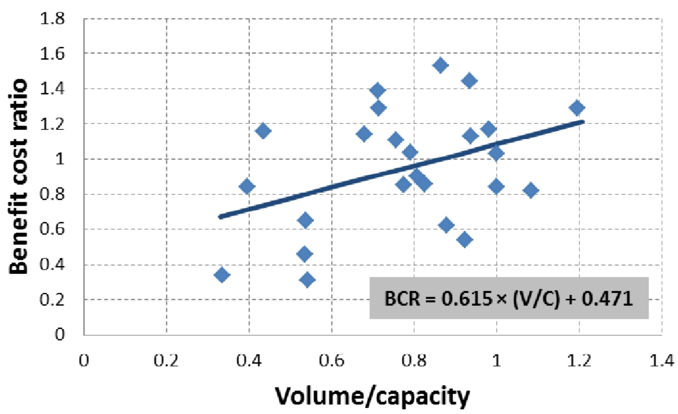

Figure 6-6: Relationship between BCR and V/C in the National Railways

Considering equation (4-4) and equation (6-2), as traffic volume becomes *k* times, social benefit changes to *b* times, as follows:

$$\boldsymbol{b = \frac{B + \Delta B}{B} = k + \frac{0.471(1-k)}{BCR}} \qquad (6\text{-}3)$$

[103] The details are given in Appendix E.

Where, B = social benefit with current traffic volume, ΔB = social benefit change when traffic volume changes to k times, BCR = benefit cost ratio.

Accordingly, in the Sosa-Wonsi case, with BCR of 1.12, when the traffic volume drops to 50.7 per cent of the forecast one, the social benefits also drop to 71.5 per cent of the forecast one.

6.3.4 Analysis

6.3.4.1 The Modified VFM (with no completion delay)

In order to verify the impact of the inclusion of construction cost risk and traffic volume risk on the Modified VFM when there is no completion delay in the conventional delivery, four different Modified VFM (*M.VFM*) using the mean value of each risk are conducted: 1) *M.VFM* without risks; 2) *M.VFM* with construction cost risk; 3) *M.VFM* with traffic volume risk; and 4) *M.VFM* with both risks (construction cost risk and traffic volume risk). The results of *M.VFM* are shown in Table 6-10.

Table 6-10: The Modified VFM results according to risk inclusion

(Discounted value, billion KRW, 2007 price)

	PSC		*Revenue*	BTL		BTO		ΔB	***M.VFM*** $_{BTL}$	***M.VFM*** $_{BTO}$	***M.VFM*** $_{BTL\text{-}BTO}$
	AC_{PSC} (a)	OC_{PSC} (b)	(c)	$Lease\ fee_{BTL}$ (d)	OC_{BTL} (e)	$Subsidy_{BTO}$ (f)	MRG_{BTO} (g)	(f)	(a+b)-(d+e)	(a+b-c) -(f+g)	(c+f+g) -(d+e)
1) *M.VFM* (+no risks)	870.9	161.8	331.1	885.6	161.8	732.7	0.0	0.0	-14.7	-31.1	16.3
2) *M.VFM* (+const. risk)	892.0	161.8	331.1	885.6	161.8	732.7	0.0	0.0	6.4	-10.0	16.3
3) *M.VFM* (+volume risk)	870.9	155.7	167.9	885.6	161.8	732.7	39.5	0.0	-20.8	86.5	-107.3
4) *M.VFM* (+both risks)	892.0	155.7	167.9	885.6	161.8	732.7	39.5	0.0	0.3	107.6	-107.3

Note: 1. M.VFM (+no risks) = the Modified VFM without considering risks, based on the BTL guidelines of Korea, M.VFM (+const. risk) = the Modified VFM considering the mean values of winning bid ratio risk and construction cost overrun risk, M.VFM (+volume risk) = the Modified VFM value considering the mean value of traffic volume risk, and M.VFM (+both risks) = the Modified VFM value considering the mean values of winning bid ratio risk, cost overrun risk and traffic volume risk.
2. AC_{PSC} = Asset cost in the PSC, OC_{PSC} = Operation cost in the PSC, *Revenue* = Revenue, $Lease\ fee_{BTL}$ = Lease fee in the BTL, OC_{BTL} = Operation cost in the BTL $Subsidy_{BTO}$ = Subsidy from the Korean government, MRG_{BTO} = MRG cost and ΔB = social benefit difference between the PSC and the PPP (BTL/BTO).

M.VFM with no risk inclusion

According to Korea's BTL guidelines (MOSF, 2009a), 90.71 per cent, an average WBR of turn-key/alternative bids in the National Railways between 2000 and 2007 (Kim et al., 2008a) is applied to calculate the asset cost of the PSC, as shown in the first row of Table 6-10.

The results of *M.VFM* with no risk inclusion (Table 6-10, the first row) show that it is not the best option to implement this project with the PPP alternatives, indicating negative values, $M.VFM_{BTL}$ of -14.7 (billion KRW) and $M.VFM_{BTL}$ of -31.1 (billion KRW). This appears to be because lease fee and subsidy are so excessive in the BTL and the BTO respectively, compared with the public sector cost in the conventional delivery. Therefore, with no risk inclusion, the conventional delivery is more favourable than any other PPP alternatives for this project.

***M.VFM* with construction cost risk**

From equation (3-10), an application ratio, indicating construction cost risk, consists of WBR risk and construction cost overrun risk. Using the mean values of the WBR risks (Fig 6-2) and construction cost overrun risks (Figure 6-1) of the six major work elements in the National Railways, the application ratios can be calculated as shown in Table 6-1. Using these application ratios the asset cost of the PSC can be freshly calculated. Considering each construction cost of the six major elements, the construction cost weighted application ratio can be calculated as 93.02 per cent.[104]

The results (Table 6-10, the second row) show that $M.VFM_{BTL}$ and $M.VFM_{BTO}$ considering the construction cost risk are respectively 6.4 and -10.0 (billion KRW), which are 21.1 (billion KRW) lower than those with no risk inclusion. This is because the mean values of WBR risks and construction cost overrun risk of the six elements make a new application ratio of 93.02 per cent, which is 2.31 per cent higher than an average winning bid ratio (90.71 per cent) of the turn-key/alternative bids used according to Korea's BTL guidelines (MOSF, 2009a). This means that $M.VFM_{BTL}$ and $M.VFM_{BTO}$ with no risk inclusion based on Korea's BTL guidelines (MOSF, 2009a) could be underestimated by as much as the difference of 2.31 per cent more than the situation in reality.

However, $M.VFM_{BTL\text{-}BTO}$ (the Modified VFM difference between the BTL and the BTO) is not changed because this is not related to the asset cost of the PSC, though it is affected by WBR and construction cost overrun, according to equation (3-10).

***M.VFM* with traffic volume risk**

To verify the effect of traffic volume risk on *M.VFM*, the mean value of traffic volume risk (50.7 per cent) shown in Figure 6-3 is applied to the analysis. The results (Table 6-10, the third row) show that $M.VFM_{BTL}$ decreases by 6.1 (billion KRW), whereas $M.VFM_{BTO}$ increases by 117.6 (billion KRW), as compared to those with no risk inclusion.

The decrease of $M.VFM_{BTL}$ is due to the decrease in the operation cost in the PSC by traffic volume reduction. In addition, the main reason for the $M.VFM_{BTO}$ increase is that with traffic volume decreasing the decrease of revenue is much greater than the MRG increase.

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[104] $93.02\ (\%) = \frac{\sum_{i=1}^{6} CC_i \times WBR_i \times (1+\alpha_i)}{\sum_{i=1}^{6} CC_i}$

Where, CC = construction cost, WBR = winning bid ratio and α= construction cost overrun, i = six major work elements in the National Railways.

As a result, $M.VFM_{BTL\text{-}BTO}$ is changed to a negative value (-107.3) from a positive value (16.3). In other words, the BTO option becomes more favourable than the BTL for this project when actual traffic volume is expected to be 50.7 per cent of forecast traffic volume.

M.VFM with both risks

When both risks are included in the analysis, Table 6-10 (the last row) shows that $M.VFM_{BTL}$ and $M.VFM_{BTO}$ become respectively 0.3 and 107.6 (billion KRW), which means that the BTL and the BTO option are more favourable than the conventional delivery for this project. In addition, among PPP alternatives the BTO option is better than the BTL because $M.VFM_{BTL\text{-}BTO}$ shows a negative value (-107.3 billion KRW).

All in all, from a viewpoint of *M.VFM* not considering completion delay in the conventional delivery, it seems that the BTO option is the most favourable for this project, followed by the BTL and the conventional delivery, when considering construction cost overrun risk and traffic volume risk.

6.3.4.2 The Modified VFM (with completion delay)

Impact of a completion delay in the conventional delivery

To verify the impact of a completion delay in the conventional delivery on the PPP decision-making, the Modified VFM analyses ($M.VFM_{BTL}$, $M.VFM_{BTO}$, and $M.VFM_{BTL\text{-}BTO}$) with completion delay (zero to four years) are conducted. The Modified VFM values are calculated by considering a completion delay of conventional delivery, which affects not only yearly asset cost input but also the social benefit difference between the PSC and the PPP alternatives.

The results are shown in Table 6-11. In the no risk inclusion case, as completion is delayed from zero to four years, $M.VFM_{BTL}$ soars from -14.7 to 246.9 (billion KRW) and $M.VFM_{BTO}$ also jumps from -31.1 to 304.3 (billion KRW). Similarly, in the risk (construction cost risk and traffic volume risk) inclusion case, $M.VFM_{BTL}$ and $M.VFM_{BTO}$ respectively rise from 0.3 and 107.6 (billion KRW) to 142.5 and 287.2 (billion KRW) according to the completion delay. This dramatic change is mainly because the increase of the social benefit difference between the PSC and the PPP alternatives (BTL/BTO) due to a completion delay is much bigger than the decrease of the public sector cost in the PSC due to discounting. In consequence, as completion is delayed, the PPP alternatives seem to become more favourable than the conventional delivery.

With respect to $M.VFM_{BTL\text{-}BTO}$, the BTL is more favourable than the BTO with no completion delay. However, if a completion delay occurs that is longer than one year, the BTO is more favourable than the BTL (Table 6-11, the last column). This means that completion delay in the conventional delivery has an influence on the selection of the PPP option between the BTL and the BTO.

In addition, considering the mean value of the completion delay (3.36 years), the PPP alternatives are better than the conventional delivery for this project, and between the PPP alternatives the BTO is better than the BTL.

Table 6-11: The Modified VFM result with completion delay

(Discounted value, billion KRW, 2007 price)

	Delay (year)	PSC		*Revenue* (c)	BTL		BTO		*ΔB* (f)	*M.VFM BTL*	*M.VFM BTO*	*M.VFM BTL-BTO*
		AC PSC (a)	*OC PSC* (b)		*Lease fee BTL* (d)	*OC BTL* (e)	*Subsidy BTO* (f)	*MRG BTO* (g)		(a+b)-(d+e)	(a+b-c) -(f+g)	(c+f+g) -(d+e)
No risk inclusion	0	870.9	161.8	331.1	885.6	161.8	732.7	0.0	0.0	-14.7	-31.1	16.3
	1	840.2	151.9	310.9	885.6	161.8	732.7	0.0	113.5	58.3	62.2	-3.9
	2	810.7	142.6	291.9	885.6	161.8	732.7	0.0	220.2	126.0	148.9	-22.9
	3	782.0	133.9	274.1	885.6	161.8	732.7	0.0	320.3	188.8	229.5	-40.7
	3.36	763.5	131.0	268.0	885.6	161.8	732.7	0.0	354.5	201.5	248.3	-46.8
	4	754.3	125.8	257.3	885.6	161.8	732.7	0.0	414.3	246.9	304.3	-57.4
Risk inclusion	0	892.0	155.7	167.9	885.6	161.8	732.7	39.5	0.0	0.3	107.6	-107.3
	1	860.6	146.2	157.6	885.6	161.8	732.7	39.5	81.2	40.6	158.2	-117.6
	2	830.4	137.3	148.0	885.6	161.8	732.7	39.5	157.4	77.6	204.9	-127.2
	3	801.1	128.9	139.0	885.6	161.8	732.7	39.5	229.0	111.5	247.8	-136.2
	3.36	782.1	126.0	135.9	885.6	161.8	732.7	39.5	253.5	114.1	253.5	-139.3
	4	772.7	121.0	130.5	885.6	161.8	732.7	39.5	296.2	142.5	287.2	-144.7

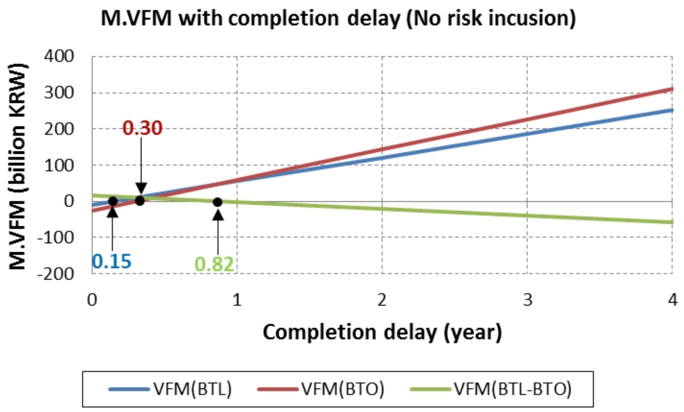
Note: 1. No risk inclusion = the Modified VFM without considering risks, based on the BTL guidelines of Korea, Risk inclusion = the Modified VFM considering construction cost risk and traffic volume risk.
2. AC_{PSC} = Asset cost in the PSC, OC_{PSC} = Operation cost in the PSC, *Revenue* = Revenue, *Lease fee* $_{BTL}$ = Lease fee in the BTL, OC_{BTL} = Operation cost in the BTL *Subsidy* $_{BTO}$ = Subsidy from the Korean government, MRG_{BTO} = MRG cost and *DB* = social benefit difference between the PSC and the PPP (BTL/BTO).

Critical completion delay

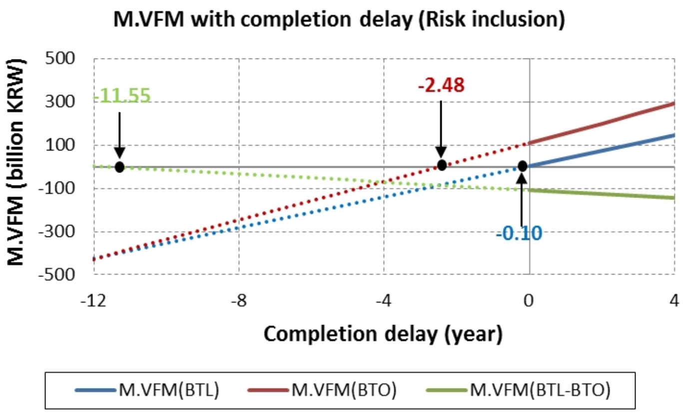
In order to determine the critical completion delay in the conventional delivery, which makes *M.VFM* zero, linear regression analyses were conducted using Table 6-11. As seen in Figure 6-7, depending on whether construction cost risk and traffic volume risk are included or not, the regression lines of *M.VFM* differ.

In the case of no risk inclusion (Figure 6-7 (a)), with respect to $M.VFM_{BTL}$, the regression line meets the horizontal axis at 0.15 years (1.80 months). This means that if the completion delay in conventional delivery occurs for a period longer than 0.15 years (1.80 months), the BTL option is better than the conventional delivery. In the same way, when the completion delay in the conventional delivery is longer than 0.30 years (3.60 months), the BTO scheme becomes feasible. In addition, when a completion delay in conventional delivery occurs for 0.82 years

(9.84 months), the BTL scheme is better than the BTO. In other words, the BTO scheme is more favourable than the BTL if the conventional delivery is expected to be delayed by more than 0.82 years (9.84 months). This is because the discounted revenue is diminished as completion is delayed.



(a) No risk inclusion



(b) Risk inclusion

Figure 6-7: The Modified VFM result according to completion delay

When it comes to risk inclusion case, regression lines and critical completion delays are shown in Figure 6-7 (b). With respect to $M.VFM_{BTL}$, when developing a linear regression line, the intercept of the horizontal axis (critical completion delay) becomes -0.10 years (-1.20 months). This means that even when the conventional delivery is completed earlier than the BTL by up to 0.10 years (1.20 months), the BTL is better than the conventional delivery for this project, to say nothing of positive completion delays. Regarding $M.VFM_{BTO}$, the critical completion delay becomes -2.48 years (29.76 months) when the linear regression line is extended. This means that even if the conventional delivery completes this project earlier than the BTO by 2.48 years (29.76 months), the BTO is better than the conventional delivery for this project. In other words, even if the construction in the BTO starts 2.48 years (29.76 months) later than the conventional delivery, the BTO is more favourable than the conventional delivery. Furthermore, if the conventional delivery is expected to complete this project 11.55 years (138.60 months) earlier than the PPP (BTO/BTL), the BTL is better than the BTO for this project. In reality, as construction duration is assumed to last five years for this project, it appears impossible to complete a project with the conventional delivery 11.55 years earlier than the PPP alternatives. Therefore, it is reasonable that the BTO is better than the BTL irrespective of the completion delay of the conventional delivery.

6.3.4.3 Sensitivity analysis

Analysis factors

M.VFM results can differ depending on how large values are used as analysis factors. In order to examine the behaviour of *M.VFM* depending on the change of analysis factors, a sensitivity analysis is conducted. For this sensitivity analysis, the following 11 analysis factors are considered: 1) PPP construction cost; 2) PPP operation cost; 3) BTL lease profitability; 3-1) five-year exchequer bond interest rate; 4) BTL finance interest rate; 5) discount rate; 6) construction deflator; 7) consumer price index; 8) social benefits; 9) revenue; and 10) BTO profitability (IRR).

Unlike in the Suwon-Pyungtaek case and the Bongdam-Songsan case, in this project the detailed cost of each work element from the private sector is not available, so some factors, such as PPP construction cost, PPP operation cost, revenue and BTO profitability (IRR), are used as analysis factors. Among 11 factors, BTL lease profitability is composed of the five-year exchequer bond interest rate and mark-up rate, so the five-year exchequer bond interest rate seems unnecessary to include as an analysis factor in $M.VFM_{BTL}$. However, in the calculation of $M.VFM_{BTO}$ and $M.VFM_{BTL\text{-}BTO}$, this rate needs to be considered, so inevitably both BTL lease profitability and the five-year exchequer bond interest rate are considered in the sensitivity analysis. In addition, some factors not related to $M.VFM_{BTL}$, $M.VFM_{BTO}$ and $M.VFM_{BTL\text{-}BTO}$ are neglected. For an example, revenue and BTO profitability do not affect the calculation of $M.VFM_{BTL}$, so they are not considered in the calculation of $M.VFM_{BTL}$. As a result, as seen in Figure 6-8 and in Table 6-12, the number of factors considered in $M.VFM_{BTL}$, $M.VFM_{BTO}$ and $M.VFM_{BTL\text{-}BTO}$ is nine, eight and ten respectively.

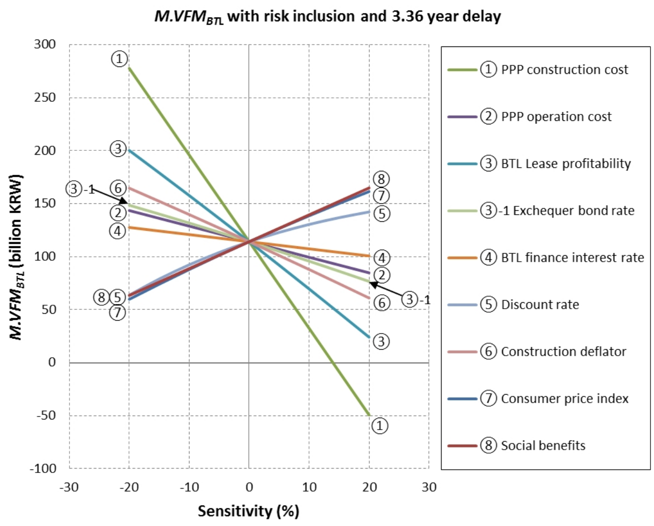
Analysis results

The changes of *M.VFM* with risk inclusion and a 3.36-year delay are shown in Figure 6-8 when the analysis factors vary from -20 to +20 per cent on each factor's given value, and the summary of sensitivity analysis is shown in Table 6-10.

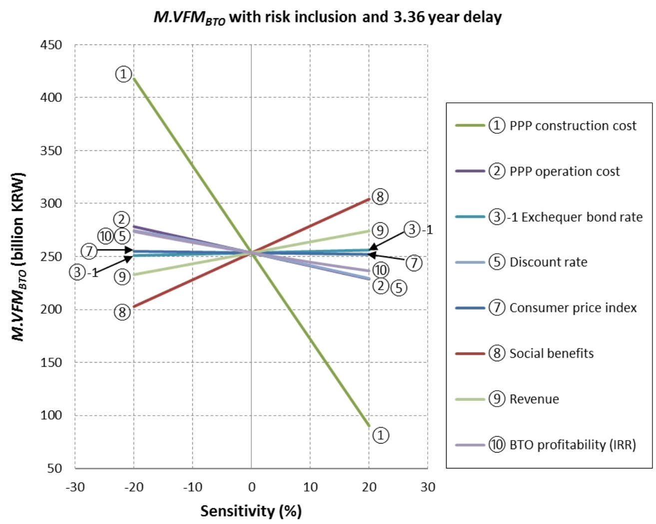
In the case of $M.VFM_{BTL}$ (Figure 6-8 (a), Table 6-12), the results are similar to those in the National Highway cases and in the National Expressway cases. Among nine analysis factors, PPP construction cost and BTL lease profitability are most influential, having unit change values of 8.17 and 4.40 respectively in terms of absolute value. The sensitivity analysis results (Figure 6-8 (a)) also show that $M.VFM_{BTL}$ values are always positive with the fluctuation of each factor, except PPP construction cost. Considering PPP construction cost does not seem to rise 12 per cent more than that of the PSC, regardless of the fluctuation of each factor, $M.VFM_{BTL}$ seems to be positive, which means that the BTL option is better than the conventional delivery.

With respect to $M.VFM_{BTO}$ (Figure 6-8 (b), Table 6-12), PPP construction cost and social benefit size is also strongly influential, having a unit value of 8.19 in terms of absolute value. Moreover, the BTO is more favourable than the conventional delivery regardless of the fluctuation of the analysis factors with positive $M.VFM_{BTO}$ values.

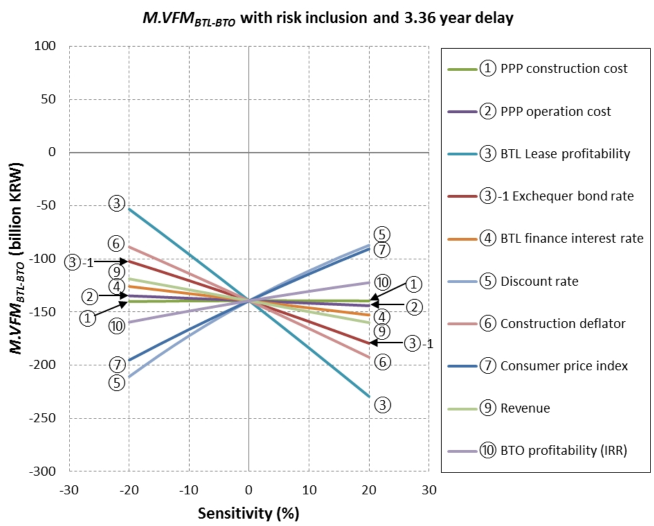
When it comes to $M.VFM_{BTL\text{-}BTO}$ (Figure 6-8 (c), Table 6-12), it shows a negative value in all cases regardless of the fluctuation of analysis factors, implying that the BTO is better than the BTL. In addition, BTL lease profitability is the most influential factor among ten analysis factors in the calculation of $M.VFM_{BTL\text{-}BTO}$, having the largest unit change value (-4.40) in terms of absolute value, as shown in Table 6-12.



(a) $M.VFM_{BTL}$



(b) $M.VFM_{BTO}$



(c) $M.VFM_{BTL\text{-}BTO}$

Figure 6-8: Sensitivity analysis on the Modified VFM (risk inclusion, 3.36 year delay)

Table 6-12: Sensitivity of analysis factors on the Modified VFM

The Modified VFM	Analysis factors	M.VFM changes due to the increase of analysis factors		
		Increase /decrease	Unit change (Bill. KRW)	Reason
$M.VFM_{BTL}$	1. PPP construciton cost	Decrease	-8.17	The increase of PPP (BTL) construction cost makes private investment and lease fee rise, so $M.VFM_{BTL}$ decreases.
	2. PPP operation cost	Decrease	-1.47	The increase of PPP (BTL) operation cost naturally makes $M.VFM_{BTL}$ decrease.
	3. Lease profitability	Decrease	-4.40	The rise of lease profitability makes lease fee rise, so $M.VFM_{BTL}$ decreases
	3-1. Exchequer bond interest rate	Decrease	-1.80	The rise of 5 year exchequer bond rate means the rise of lease profitability, making lease fee rise, so $M.VFM_{BTL}$ decreases.
	4. BTL finance interest rate	Decrease	-0.67	The increase of BTL finance interest rate makes lease fee rise, so $M.VFM_{BTL}$ decreases
	5. Discount rate	Increase	1.96	The increase of discount rate makes cost items fall. Among them, lease fee has largest drop, so $M.VFM_{BTL}$ decreases.
	6. Construction deflator	Decrease	-2.59	The rise of construction deflator makes private investment and lease fee increase, so $M.VFM_{BTL}$ decreases.
	7. Consumer price index	Increase	2.54	Nominal lease fee is converted to real by CPI. The rise of CPI, making real lease fee drop, means $M.VFM_{BTL}$ increases.
	8. Social benefits	Increase	2.53	The rise of social benefits makes $M.VFM_{BTL}$ increase.
$M.VFM_{BTO}$	1. PPP cosnstruction cost	Decrease	-8.19	The increase of PPP (BTO) construction cost causes subsidy to increase, so $M.VFM_{BTO}$ decreases
	2. PPP operatin cost	Decrease	-1.24	Considering constant IRR, the incrase of PPP (BTO) operation cost causes subsidy to increase, so $M.VFM_{BTO}$ decreases
	3-1. Exchequer bond interest rate	Increase	0.13	The rise of 5 year exchequer bond rate means the rise of the asset cost in the PSC, so $M.VFM_{BTO}$ increases.
	5. Discount rate	Increase	-1.13	The increase of discount rate makes cost items fall. Among them, revenue has a largest drop, so $M.VFM_{BTO}$ decreases.
	7. Consumer price index	Decrease	-0.07	The rise of CPI makes the borrowing cost of the public sector in real term drop, so $M.VFM_{BTO}$ decreases.
	6. Social benefits	Increase	2.53	The rise of social benefits makes $M.VFM_{BTO}$ increases.
	9. Revenue	Increase	1.03	Revenue rise makes subsidy drop considering constant IRR. Subsidy drop is bigger than revenue rise, so $M.VFM_{BTO}$ increases.
	10. BTO profitability (IRR)	Decrease	-0.93	IRR rise causes subsidy increase, so $M.VFM_{BTO}$ decreases
$M.VFM_{BTL\text{-}BTO}$	1. PPP construction cost	Increase	0.02	As a result of lease fee rise and subsidy rise due to PPP constuction cost rise, $M.VFM_{BTL\text{-}BTO}$ increases slightly
	2. PPP operation cost	Decrease	-0.23	$M.VFM_{BTL}$ reduction is bigger than $M.VFM_{BTO}$ reduction according to PPP operation cost rise, so $M.VFM_{BTL\text{-}BTO}$ drops
	3. Lease profitability	Decrease	-4.40	The rise of lease profitability makes lease fee rise, so $M.VFM_{BTL\text{-}BTO}$ decreases
	3-1. Exchequer bond interest rate	Decrease	-1.93	The 5 year exchequer bond rate rise (the lease profitability rise) makes lease fee rise, so $M.VFM_{BTL\text{-}BTO}$ decreases.
	4. BTL finance interest rate	Decrease	-0.67	The increase of BTL finance interest rate makes lease fee rise, so $M.VFM_{BTL\text{-}BTO}$ decreases
	5. Discount rate	Increase	3.09	The lease fee reduction due to the discount rate increase is bigger than the revenue decrease, so $M.VFM_{BTL\text{-}BTO}$ increases.
	6. Construction deflator	Decrease	-2.59	The rise of construction deflator makes private investment and lease fee increase, so $M.VFM_{BTL\text{-}BTO}$ decreases.
	7. Consumer price index	Increase	2.61	The lease fee drop and the borrowing cost drop in the PSC make $M.VFM_{BTL\text{-}BTO}$ increase.
	9. Revenue	Decrease	-1.03	Revenue rise makes subsidy drop considering constant IRR. Subsidy drop is bigger than revenue rise, so $M.VFM_{BTL\text{-}BTO}$ drops.
	10. BTO profitability (IRR)	Increase	0.93	IRR rise causes subsidy increase, so $M.VFM_{BTL\text{-}BTO}$ rises

Note: Unit change means the change of the Modified VFM when an analysis factor rises by from -20 to 20 per cent based on its given base value.

6.3.4.4 The Monte Carlo Simulations

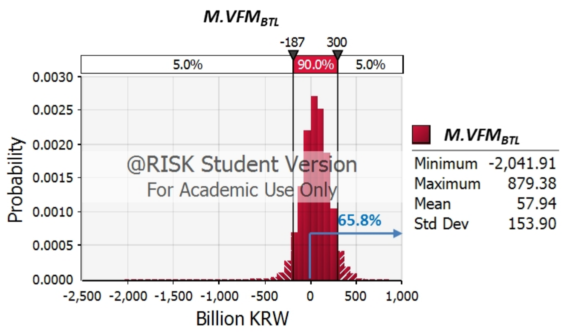
The MCS is conducted to identify the impact of the following 18 risk variables (shown in Figure 6-1~Figure 6-4, Figure 4-4 and Figure 4-6~Figure 4-7) from historical observations: six WBRs, six construction cost overruns, traffic volume, maintenance cost, construction deflator, consumer price index, five-year exchequer bond interest rate, and three-year non-guaranteed corporate bond interest rate.

Figure 6-9 shows the MSC results with no completion delay and with a 3.36-year completion delay, which is an average completion delay in the National Railways, as shown in Table 6-2.

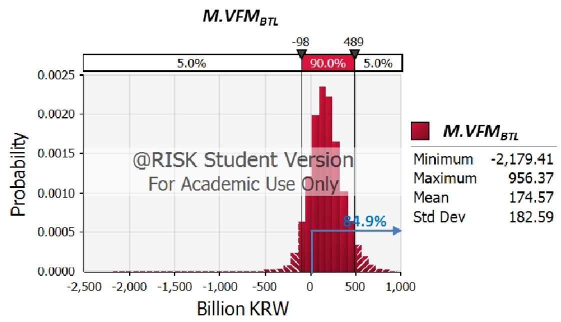
In case of no completion delay (Figure 6-9 (a)), the mean value of $M.VFM_{BTL}$ is 57.9 (billion KRW) and the probability that $M.VFM_{BTL}$ is positive is 65.8 per cent. This implies that the BTL option is more favourable than the conventional delivery. With respect to $M.VFM_{BTO}$, its mean value is 150.4 (billion KRW) and the probability that it is positive is 80.3 per cent, which implies the BTO option is more favourable than the conventional option. Additionally, $M.VFM_{BTL\text{-}BTO}$ has a mean value of -92.5 (billion KRW) and the probability that it is positive is 26.4 per cent, which implies the BTO option is better than the BTL option. Accordingly, assuming no completion delay in the conventional delivery, the most appropriate delivery option for this project is the BTO, followed by the BTL option and the conventional delivery.

Similarly, in the case of 3.36-year completion delay (Figure 6-9 (b)), the mean value of $M.VFM_{BTL}$ is 174.6 (billion KRW) and the probability that it is positive is 84.9 per cent. This implies that the BTL option is better than the conventional delivery. With respect to $M.VFM_{BTO}$, its mean value is 299.1 (billion KRW) and the probability that it is positive is 100 per cent, which implies the BTO option is more favourable than the conventional option. Furthermore, $M.VFM_{BTL\text{-}BTO}$ has a mean value of -124.5 (billion KRW) and the probability that it is positive is 20.3 per cent, which implies the BTO option is better than the BTL option. Accordingly, considering an average completion delay in the conventional delivery (3.36 years), the most appropriate delivery option is the BTO, followed by the BTL and the conventional option.

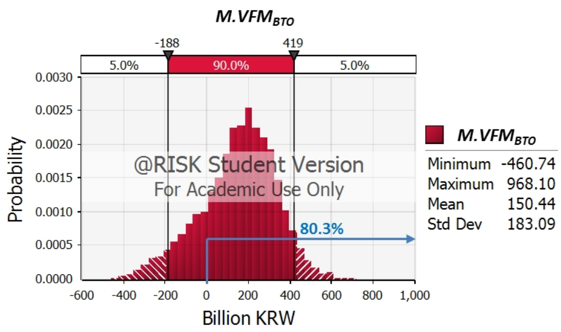
Consequently, as a completion delay increases, the mean values of $M.VFM$ and the probabilities that the PPP options are better increase. Considering all the risk factors, including the 3.36-year completion delay, it is ideal to implement the Sosa-Wonsi case with the BTO option, followed by the BTL. However, considering the limitation of governmental subsidy, as shown in Table 6-6, the BTL option seems to be a more practical procurement option for this project.



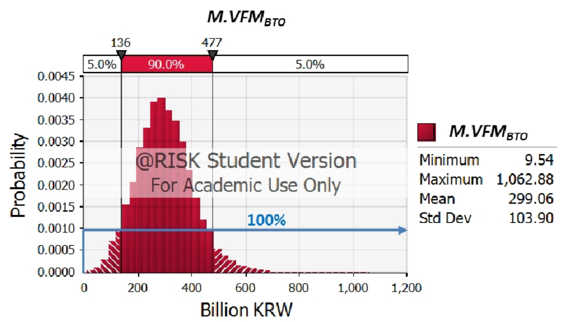
i) $M.VFM_{BTL}$



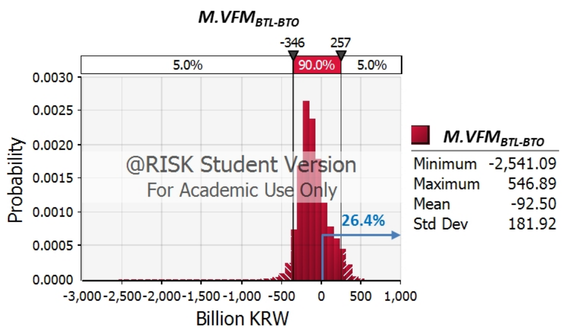
i) $M.VFM_{BTL}$



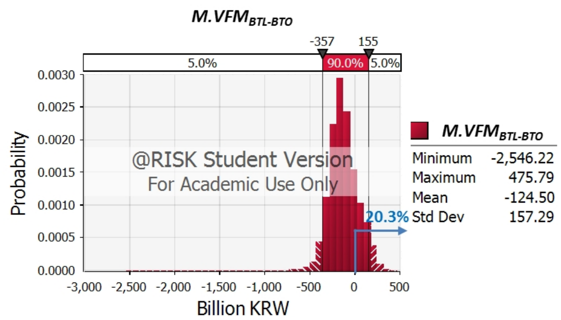
ii) $M.VFM_{BTO}$



ii) $M.VFM_{BTO}$



iii) $M.VFM_{BTL-BTO}$



iii) $M.VFM_{BTL-BTO}$

(a) No delay (b) 3.36 year completion delay

Figure 6-9: Probability distribution of the Modified VFM with a 3.36-year completion delay

6.4 Case 2: The Bujeon-Masan case

6.4.1. Project overview

The Bujeon-Masan National Railway was planned to go through Busan, Gimhae, Changwon and Masan, connecting the Seoul-Pusan line, the Busan-Ulsan line, the Samrangjin-Jinju line and the Busan New Port line (Figure 6-10). The distance from Busan to Masan using the current National Railway network, connecting the Seoul-Busan line and the Samrangjin-Jinju line, is approximately 78 kilometres; however, with this project completed this distance is reduced to 53 kilometres.

The construction master plan for this project was established in 2000. In 2008, notwithstanding low economic feasibility (BCR = 0.63), this project was selected as one of 30 leading projects for “Mega-city Region Development Strategy”, which was adopted by the Korean government in order to achieve the balanced national development with respect to a presidential election pledge in 2007. In the same year, the Bujeon-Masan project was also designated as a BTL project, and a negotiation process is in progress.

With respect to planning this project, in order to avoid overlapping investment, construction investment will be done on 51 per cent (green solid line in Figure 6-10) of total operation distance from Bujeon to Masan by sharing 49 per cent of total operation distance from the current National Railway network (the green dot line in Figure 6-10).

According to KOTI (2009), although this project shows a fairly low economic feasibility (BCR = 0.63), considering the necessity in the aspect of the governmental policy, it needs to be implemented. In addition, with regard to procurement option, the BTL scheme is more favourable than the conventional procurement for this project (KOTI, 2009). The overview of this project (KOTI, 2009, PIMAC, 2009a) is as follows:

- Title: Bujeon-Masan National Railway BTL project
- Location: Bujeon-dong, Jin-gu, Busan ~ Shinwol-ri, Jinrye-myon, Gimhae
- Length: 32.0 km (electrified double track)
- PPP type: BTL
- Construction duration: 72 months; operation duration: 20 years
- Five-year exchequer bond interest rate: 5.13 per cent (nominal)
- PSC Project cost: 1,312,4 (billion KRW, 2008 price)

- Benefit cost ratio: 0.63
- Construction deflator: 3 per cent (assumed); consumer price index: 3 per cent (assumed)
- Lease profit rate: 5.87 per cent (nominal)
- BTL finance interest rate: 6.87 per cent (nominal)
- BTL finance structure: equity 10 per cent, debt 90 per cent

Figure 6-10: The Bujeon-Masan National Railway project map

6.4.2 Analysis factors and assumptions for the Modified VFM

This project will be reviewed through two procurement options: the conventional and the BTL scheme, because the revenue stream of this project is so small that the BTO profit rate cannot be calculated. From equation (6-1), using revenue stream,[105] operation cost[106] for the BTO option, and assuming no subsidiary enterprise, the subsidy level can be obtained, shown in Table 6-13. As seen in Table 6-13, IRR cannot be obtained even if the Korean government gives a subsidy to match the BTO asset cost.[107] In the same way, even if the revenue stream increases 1.6 times and the Korean government supports 100 per cent of the BTL asset cost, the BTO cannot produce any profit rates.

Table 6-13: The relationships among IRR, revenue stream and subsidy

Real IRR (%)	N/A	N/A	6.38						
Revenue stream (times)	1	1.6	1.7	1.8	1.9	2	3	4	4.86
Subsidy/asset cost	1	1	0.96	0.95	0.93	0.92	0.77	0.63	0.50

In addition, in order to produce an IRR of 6.38 per cent in real terms, which is a notional BTO profit rate for rail projects after 2006 (see 6.3.3), if the revenue stream is doubled, the governmental subsidy should be larger than 92 per cent of the asset cost. In the same way, considering the subsidy limit for rail projects is 50 per cent of the BTO asset cost (MOSF, 2010), the revenue stream should rise to about 4.9 times. This means that the BTO scheme is, in practice, not appropriate for this project, so this case study considers only the conventional and BTL options.

Basic factors for the Modified VFM in this case are as follows:

- PPP model: BTL
- Discount rate: 5.5 per cent in real terms
- Decision-making time: 2009; price base year: 2008
- Construction deflator:[108] 4.82 per cent (average between 2005 and 2009)

[105] Revenue stream is calculated using distance matrix, origin-destination matrices (KOTI, 2009) and rail fare system. As of 2008, the basic rate is 900 KRW within 10 km and 100 KRW is added every 5 km.

[106] The BTO operation cost is assumed to be the same as the BTL operation cost.

[107] The BTO asset cost is assumed to be the same as the BTL asset cost.

[108] Construction deflator means construction investment deflator in Expenditure on Gross Domestic Product on National Accounts, which is provided by the Bank of Korea (http://ecos.bok.or.kr), and

- Consumer price index:[109] 2.99 per cent (average between 2005 and 2009)
- Five-year exchequer bond interest rate:[110] 4.72 per cent (2009)
- BTL Lease profitability:[111] 5.49 per cent

  (Five-year exchequer bond interest rate + 0.77 per cent, nominal)
- BTL finance interest rate:[112] 6.62 per cent

  (Three-year non-guaranteed corporate bond (AA-),[113] 5.62 per cent + 1.0 per cent, nominal)
- BTL finance structure: equity 15 per cent, debt 85 per cent
- BTL finance terms: level debt service during operation period
- Operation period: 30 years; construction duration: 5 years

In addition, the same assumptions (see 4.3.2) for the Modified VFM used in the National Highway cases are also used in the National Railway cases.

according to Korea's BTL guidelines (MOSF, 2009a), it is used in the calculation of the private sector investment for the lease fee calculation. For a more accurate private sector investment calculation, it is used instead of the consumer price index.

[109] Consumer price index, which is used as inflation in operation period, is provided by the Bank of Korea (http://ecos.bok.or.kr).

[110] The five-year exchequer bond interest rate is calculated by a weighted average method, which applies 0.1, 0.2, 0.3 and 0.4 to the first, second, third and fourth quarter value (MOSF, 2009a). The quarterly five-year exchequer bond interest rate is provided by the Korea Bond Information Service (http://www.kofiabond.or.kr).

[111] BTL lease profitability is expressed as a "five-year exchequer bond interest rate + mark-up" and the mark-up rate is composed of a premium for long term investment and risk premium for construction and operation (MOSF, 2009a). Regarding the mark-up rate, 0.77 per cent, an average rate used in rail BTL project pre-qualification reports (Wonju-Gangrung: 0.77, Gyungjun/Junla line: 0.87, Bujeon-Masan: 0.74, Sosa-Wonsi: 0.77, Daegok-Sosa: 0.72), is considered in the National Railway cases.

[112] BTL finance interest rate is expressed as a "three-year non-guaranteed corporate bond interest rate + mark-up" (MOSF, 2009a) and, according to Kim et al. (2005), the mark-up rate seems to be distributed from 0.66 per cent to 2.00 per cent. As a mark-up rate, 1.0 per cent is used in the National Railway cases, considering rail BTL project pre-qualification reports (Wonju-Gangrung: 1.0, Gyungjun/Junla line: 1.0, Bujeon-Masan: 1.0, Sosa-Wonsi: 1.0, Daegok-Sosa: 1.0).

[113] The three-year non-guaranteed corporate bond (AA-) interest rate is calculated by a weighted average method, which applies 0.1, 0.2, 0.3 and 0.4 to the first, second, third and fourth quarter value (MOSF, 2009a). The quarterly three-year non-guaranteed bond (AA-) interest rate is provided by the Korea Bond Information Service (http://www.kofiabond.or.kr).

6.4.3 Main calculation items for the Modified VFM

From equation (3-8), the main calculation items for the Modified VFM are the asset cost of a PSC (AC_{PSC}), the operation cost of a PSC (OC_{PSC}) and a BTL (OC_{BTL}), the lease fee of a BTL ($Lease\ fee_{BTL}$) and the benefit difference (ΔB).

Asset cost of the PSC (AC_{PSC})

The basic asset cost data, shown in Table 6-14, are collected from the BTL research report on the Bujeon-Masan National Railway (KOTI, 2009). Among building cost items, the bracketed values are the designed price of each item before reflecting each item's WBR. With respect to the design cost and construction cost of the PSC, they are calculated by multiplying each designed price and an average WBR (90.71 per cent) of turn-key/alternative bids in the National Railway projects between 2000 and 2007 (Kim et al., 2008a). In addition, with respect to the design cost and construction cost of the BTL, the same values as in the PSC are used because this case includes no contract cost or proposed cost from the private sector, differing in that from the Suwon-Pyungtaek case and the Bongdam-Songsan case.

In addition, in order to estimate the Modified VFM, according to Table 4-3, the yearly asset costs of the PSC are distributed. With respect to longer construction duration considering completion delay, new yearly distribution ratios using interpolation method and Table 4-3 will be applied to the calculation of the Modified VFM.

Operation cost for the PSC and the BTL (OC_{PSC}, OC_{BTL})

As with the road cases, the yearly base operation costs for the PSC (OC_{PSC}) are calculated by multiplying the mean values of the operation costs[114] (KRW/PCKT) from the historical observations and yearly PCKT data from the PPP pre-qualification report on the Bujeon-Masan National Railway (PIMAC, 2009a).

Maintenance costs tend to gradually increase over time because of the increasing decrepitude of the facility. However, there is currently no available way to consider the decrepitude of the railways. Thus, for a simple calculation, it is assumed that the historical observations are collected from railways with ten years of decrepitude in this case and yearly maintenance costs are converted using normalisation and the relative yearly ratios in roads (Table 6-5) from the

[114] From the historical observations, the mean values of operation cost items (2005 price) are as follows: 1) personnel cost /PCKT = 4,898.1 KRW/PCKT; 2) management cost/VKT = 3,068.0 KRW/PCKT; 3) maintenance cost/VKT = 749.7 KRW/PCKT.

preliminary feasibility guideline (KDI, 2008b). Train replacement costs during the operation period are also included in the PSC (OC_{PSC}).

When it comes to operation cost of the BTL (OC_{BTL}), the same operation cost as the PSC will be applied as in the Modified VFM.

Table 6-14: Basic asset cost for the PSC and the BTL

(Unit: billion KRW, 2008 price)

Asset cost items		PSC [BTL guideline]	BTL
Building cost	Investigation	**2.6**	**2.6**
	Design	**22.2** (24.5) Earth work/Structure 15.5 (17.1) Building/Equipment 1.2 (1.3) Track 1.2 (1.3) Electricity 1.5 (1.7) Signal 1.2 (1.3) Communication 1.7 (1.8)	**22.2** (24.5) Earth work/Structure 15.5 (17.1) Building/Equipment 1.2 (1.3) Track 1.2 (1.3) Electricity 1.5 (1.7) Signal 1.2 (1.3) Communication 1.7 (1.8)
	Construction	**1,293.6** (1,426.1) Earth work/Structure 1,054.8 (1,162.8) Building/Equipment 42.1 (46.5) Track 69.3 (76.4) Electricity 54.9 (60.5) Signal 42.3 (46.7) Communication 30.1 (33.2)	**1,293.6** (1,426.1) Earth work/Structure 1,054.8 (1,162.8) Building/Equipment 42.1 (46.5) Track 69.3 (76.4) Electricity 54.9 (60.5) Signal 42.3 (46.7) Communication 30.1 (33.2)
	Sub total	**1,369.70**	**1,369.70**
Compensation cost		**0** (129.4)	**0** (129.4)
Additional cost		**39.4** Design inspection 1.5 Construction inspection 31.5 Cultural asset survey 1.2 Traffic impact assessment 0.1 Environmental impact assessment 1.5 Disaster impact assessment 0.03 Energy use plan 0.1 Construction management 2.3 Waste disposal 1.2	**40.4** Design inspection 1.5 Construction inspection 31.5 Cultural asset survey 1.2 Traffic impact assessment 0.1 Environmental impact assessment 1.5 Disaster impact assessment 0.03 Energy use plan 0.1 Construction management 2.3 Waste disposal 1.2 Insurance 1.0
Operation facility cost		**66.1** Bedding measurement 0.04 Track management 0.6 Building equipment 0.1 Electricity facility 0.5 Signal/communication 0.8 Automatic fare collection system 0.2 Train 63.9	**66.6** Bedding measurement 0.04 Track management 0.6 Building equipment 0.1 Electricity facility 0.5 Signal/communication 0.8 Automatic fare collection system 0.2 Management information system 0.5 Train 63.9
Business reserve		**0.3** Test drive cost 0.3	**4.0** Test drive cost 0.3 Organisation cost 0.2 Business commence cost 0.7 Stock issue cost 2.8
Total		**1,424.2**	**1,429.3**

Note: 1. Compensation cost is provided by the Korean government, so it is not included in the Modified VFM assessment. 2. All values in the Table come from the BTL research report on the Bujeon-Masan National Railway (KOTI, 2009) and the bracketed building cost values are designed prices before including winning bid ratios. 3. According to KOTI (2009), contractor's all risk insurance for the PSC is neglected and at the same time it is neglected in the PPP, which is possible in terms of competitive neutrality according to the BTL guidlelines of Korea (MOSF, 2009). 4. The management information system (MIS) cost of operation facility cost in the PSC is neglected because there exists MIS in use for public sector. 5. According to KOTI (2009), the financial cost in BTL is not considered because the report regarded it was assumed to be included in the mark-up rates of BTL lease profitability and BTL finance rate.

Lease fee for the BTL $(Lease\ fee_{BTL})$

According to Korea's BTL guidelines (MOSF, 2009a), the yearly lease fee in nominal terms is calculated as equation (4-1). The asset cost of the BTL in real terms in Table 6-14 is delivered as a form of equity (15 per cent) and debt (85 per cent), according to the BTL finance structure. Considering construction deflator and BTL finance interest rate, the total investment of the private sector, including principal and interest, becomes 2,004.3 (billion KRW, nominal term) at the completion time, which is the sum of (a), (b) and (C) in Table 6-15.

Table 6-15: Calculation of the private sector investment

Year	Equity (15%)		Debt (85%)		Interest (nominal)
	Real (2008 price)	Nominal	Real (2008 price)	Nominal	
2011	16.0	18.4	90.7	104.5	
2012	29.9	36.1	169.6	204.7	6.9
2013	50.1	63.4	283.8	359.1	20.5
2014	69.1	91.7	391.8	519.7	44.2
2015	49.2	68.5	279.1	388.0	78.6
Total	214.3	278.1 (a)	1,215.0	1,576.0 (b)	150.2 (c)
Private sector investment (P = a + b + c)			2,004.3		

Consequently, in this case study, the lease fee in nominal terms for the BTL is calculated as follows:

$$PVIFA_{(20,0.0549)} = \sum_{i=1}^{20} \frac{1}{(1 + 0.0549)^i} = 11.9563$$

$$Lease\ fee = \frac{2{,}004.3}{PVIFA_{(20,0.0549)}} = \frac{2{,}177.1}{11.9563} = 167.636\ (\text{billion KRW, nominal})$$

Considering the inflation index and the economic discount rate, the lease fee in nominal terms in each year will be transformed into real terms to be applied to the Modified VFM.

Social benefit difference (ΔB)

Social benefits for the Modified VFM analysis is collected from the BTL research report on the Bujeon-Masan National Railway (KOTI, 2009). The social benefit difference (ΔB) between the PSC and the BTL alternative, considering the completion delay of the conventional delivery, can be calculated by using these data.

As with the Sosa-Wonsi case, using equation (6-3) and the BCR (=0.63) of the Bujeon-Masan case, when the traffic volume drops to 50.7 per cent of the forecast one, the social benefits also drop to 87.6 per cent of the forecast one.

6.4.4. Analysis

6.4.4.1 The VFM analysis results (with no completion delay)

To verify the impact of the inclusion of construction cost risk and traffic volume risk on the Modified VFM when there is no completion delay in the conventional delivery, four different Modified VFM ($M.VFM_{BTL}$) using the mean value of each risk are conducted: 1) $M.VFM_{BTL}$ without risks; 2) $M.VFM_{BTL}$ with construction cost risk; 3) $M.VFM_{BTL}$ with traffic volume risk; and 4) $M.VFM_{BTL}$ with both risks (construction cost risk and traffic volume risk). The results of $M.VFM_{BTL}$ are shown in Table 6-16.

Table 6-16: The VFM results according to risk inclusion

(Discounted value, billion KRW, 2008 price)

	PSC		BTL		ΔB	$M.VFM_{BTL}$
	AC_{PSC} (a)	OC_{PSC} (b)	$Lease\ fee_{BTL}$ (d)	OC_{BTL} (e)	(f)	(a+b)-(d+e)+f
1) $M.VFM_{BTL}$ (+no risks)	843.3	232.4	807.5	232.4	0.0	35.8
2) $M.VFM_{BTL}$ (+const. risk)	853.6	232.4	807.5	232.4	0.0	46.1
3) $M.VFM_{BTL}$ (+volume risk)	843.3	223.4	807.5	232.4	0.0	26.7
4) $M.VFM_{BTL}$ (+both risks)	853.6	223.4	807.5	232.4	0.0	37.0

Note: 1. $M.VFM_{BTL}$ (+no risks) = the Modified VFM value without considering risks based on the BTL guidelines of Korea, $M.VFM_{BTL}$ (+const. risk) = the Modified VFM value considering the mean values of winning bid ratio risk and construction cost overrun risk, $M.VFM_{BTL}$ (+volume risk) = the Modified VFM value considering the mean value of traffic volume risk, and $M.VFM_{BTL}$ (+both risks) = the Modified VFM value considering the mean values of winning bid ratio risk, cost overrun risk and traffic volume risk.
2. AC_{PSC} = Asset cost in the PSC, OC_{PSC} = Operation cost in the PSC, $Lease\ fee_{BTL}$ = Lease fee in the BTL, OC_{BTL} = Operation cost in the BTL and ΔB = social benefit difference between the PSC and the BTL.

$M.VFM_{BTL}$ with no risk inclusion

According to Korea's BTL guidelines (MOSF, 2009a), 90.71 per cent, an average WBR of turn-key/alternative bids in the National Railways between 2000 and 2007 (Kim et al., 2008a) is applied to calculate the asset cost of the PSC, shown in the first row of Table 6-16. The result of $M.VFM_{BTL}$ with no risk inclusion shows that the BTL is preferable to the conventional delivery with $M.VFM_{BTL}$ having a positive value of 35.8 (billion KRW).

$M.VFM_{BTL}$ with construction cost risk

From equation (3-10), an application ratio, indicating construction cost risk, consists of WBR risk and construction cost overrun risk. Using the mean values of the WBR risks (Figure 6-2) and construction cost overrun risks (Figure 6-1) of the six major work elements in the National Railways, application ratios can be calculated as shown in Table 6-1. Using these application ratios, the asset cost of the PSC can be freshly calculated. Considering each construction cost of the six major elements, the construction cost weighted application ratio can be calculated as 91.86 per cent.[115]

The results (Table 6-16, the second row) show that $M.VFM_{BTL}$ considering the construction cost risk are 46.1 (billion KRW), which are 10.3 (billion KRW) higher than those with no risk inclusion. This is because the mean values of WBR risks and construction cost overrun risk of the six elements make a new application ratio of 91.86 per cent, which is 1.15 per cent lower than an average winning bid ratio (90.71 per cent) of turn-key/alternative bids used, according to Korea's BTL guidelines (MOSF, 2009a). This means that $M.VFM_{BTL}$ with no risk inclusion based on Korea's BTL guidelines (MOSF, 2009a) could be underestimated by as much as the difference of 1.15 per cent more than the situation in reality.

$M.VFM_{BTL}$ with traffic volume risk

To verify the effect of traffic volume risk on $M.VFM$, the mean value of traffic volume risk (50.7 per cent) shown in Figure 6-3 is applied to the analysis. The results (Table 6-16, the third row) show that $M.VFM_{BTL}$ decreases by 9.1 (billion KRW). This is due to the decrease in the maintenance cost by traffic volume reduction.

$M.VFM_{BTL}$ with both risks

When both risks are included in the analysis, Table 6-16 (the last row) shows that $M.VFM_{BTL}$ becomes 37.0 (billion KRW), which means that the BTL is more favourable than the conventional delivery for this project.

All in all, from a viewpoint of $M.VFM_{BTL}$, and not considering completion delay in the conventional delivery, it seems that the BTL option is preferable to the conventional delivery regardless of whether the construction and traffic volume risks are included or not.

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[115] $91.86 = \frac{\sum_{i=1}^{6} CC_i \times WBR_i \times (1+\alpha_i)}{\sum_{i=1}^{6} CC_i}$

Where, CC = the construction cost, WB = the winning bid ratio, α = the construction cost overrun and i = six major work elements.

6.4.4.2 The Modified VFM (with completion delay)

Impact of a completion delay in the conventional delivery

To verify the impact of a completion delay in the conventional delivery on the PPP decision-making, $M.VFM_{BTL}$ with completion delay (zero to four years) is conducted. $M.VFM_{BTL}$ is calculated by considering a completion delay for conventional delivery, which affects not only yearly asset cost input but also the social benefit difference between the PSC and the BTL.

$M.VFM_{BTL}$ results are shown in Table 6-17. In the no risk inclusion case, $M.VFM_{BTL}$ slightly rises from 35.8 to 39.5 (billion KRW) as a completion is delayed from zero to four years. This is because the increase of the social benefit difference between the PSC and the BTL due to a completion delay is slightly bigger than the decrease of the public sector cost (asset cost and operation cost) in the PSC due to discounting. The slight rise of $M.VFM_{BTL}$ is due to the low BCR (0.63) of this project and the graph (blue line in Fig 6-11) of $M.VFM_{BTL}$ against completion delay is nearly flat, which differs from the Sosa-Wonsi case (blue line in Fig 6-7 (a)).

However, in the risk (construction cost risk and traffic volume risk) inclusion case, $M.VFM_{BTL}$ drops from 37.0 to 23.2 (billion KRW) according to completion delay. This is because the increase in the social benefit difference between the PSC and the BTL due to a completion delay is smaller than the decrease of the public sector cost in the PSC due to discounting: the social benefit difference between the PSC and the BTL is diminished due to traffic volume risk inclusion, compared to the figure without risk inclusion.

Looking at the risk inclusion rows in Table 6-17, when completion is delayed from 0 to 4 years, asset cost in the PSC decreases by 98.1 (billion KRW) and operation cost in the PSC also decreases by 43.1 (billion KRW), whereas social benefit difference between the PSC and the BTL increases by 127.4 (billion KRW). Consequently, due to completion delay (0 to 4 years), $M.VFM_{BTL}$ decreases by 13.8 (billion KRW) from 37.0 (billion KRW, no delay) to 23.2 (billion KRW, 4 year delay). In addition, comparing with Table 6-11 in the Sosa-Wonsi case, the biggest difference comes from the size of social benefit difference. With respect to the values of risk inclusion rows composing $M.VFM_{BTL}$ in Table 6-11 (Sosa-Wonsi case), according to completion delay (from 0 to 4 years) asset cost in the PSC decreases by 119.4 (billion KRW) and operation cost in the PSC also decreases by 34.8 (billion KRW), whereas social benefit difference between the PSC and the BTL increases by 296.4 (billion KRW). Accordingly, due to completion delay (0 to 4 years), $M.VFM_{BTL}$ increases by 142.2 (billion KRW) from 0.3 (billion KRW, no delay) to 142.5 (billion KRW, 4 year delay). Considering the sizes of asset cost, operation cost and social benefit difference in the two cases, the decrease in $M.VFM_{BTL}$ in

Bujeon-Masan case according to completion delay comes mainly from the relatively small social benefit difference between the PSC and the BTL, which has resulted from the small social benefit ratio (0.63) of the case.

Table 6-17: The Modified VFM result with completion delay

(Discounted value, billion KRW, 2008 price)

	Delay (year)	PSC		BTL		ΔB (f)	$M.VFM_{BTL}$
		AC_{PSC} (a)	OC_{PSC} (b)	$Lease\ fee_{BTL}$ (d)	OC_{BTL} (e)		(a+b)-(d+e)+f
No risk inclusion	0	843.3	232.4	807.5	232.4	0.0	35.8
	1	818.1	220.3	807.5	232.4	39.4	37.8
	2	793.5	208.8	807.5	232.4	76.7	39.1
	3	769.5	197.8	807.5	232.4	112.0	39.4
	3.36	761.1	194.2	807.5	232.4	124.2	39.5
	4	746.3	187.6	807.5	232.4	145.5	39.5
Risk inclusion	0	853.6	223.4	807.5	232.4	0.0	37.0
	1	828.1	211.8	807.5	232.4	34.5	34.3
	2	803.2	200.7	807.5	232.4	67.1	31.1
	3	779.0	190.3	807.5	232.4	98.1	27.4
	3.36	770.4	186.7	807.5	232.4	108.7	25.8
	4	755.5	180.3	807.5	232.4	127.4	23.2

Note: 1. AC_{PSC} = Asset cost in the PSC, OC_{PSC} = Operation cost in the PSC, $Lease\ fee_{BTL}$ = Lease fee in the BTL, OC_{BTL} = Operation cost in the BTL and ΔB = the social benefit difference between the PSC and the BTL. 2. Risk inclusion = construction cost risk (winning bid ratio and construction cost overrun) and traffic volume risk included

Additionally, regardless of how long the completion delay from zero to four years is, the BTL scheme is better than the conventional option for this project, to say nothing of considering the mean value of the completion delay (3.36 years, Table 6-2) in the National Railways.

Critical completion delay

In order to determine the critical completion delay in the conventional delivery, which makes the $M.VFM_{BTL}$ zero, a linear regression analysis was conducted, using Table 6-15. As seen in Figure 6-11, depending on whether construction cost risk and traffic volume risk are included or not, the regression line of $M.VFM_{BTL}$ differs.

In the no risk inclusion case, when the linear regression line is extended, it meets the horizontal axis at -39.58 years. This means that even if the conventional delivery completes this project earlier than the BTL by up to 39.58 years, the BTL is better than the conventional delivery. However, the earlier completion of 39.58 years in the conventional delivery cannot be realised in practice, considering the construction duration of five years in the BTL option. Consequently, the BTL option is more favourable than the conventional delivery in terms of a viable completion delay in the conventional delivery.

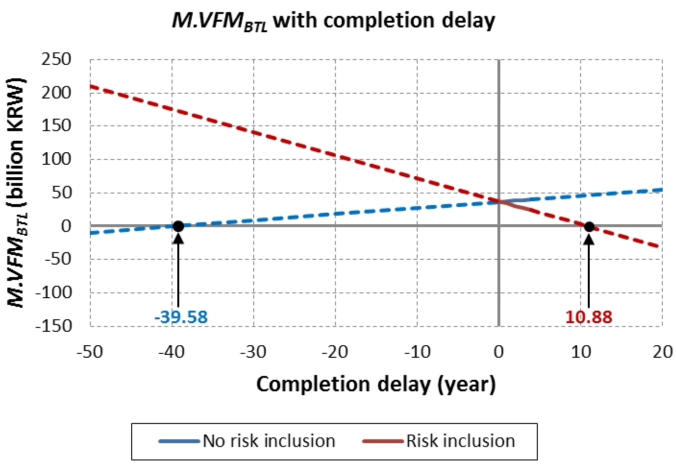


Figure 6-11: The Modified VFM result according to completion delay

In the same way, regarding $M.VFM_{BTL}$ with risk inclusion (construction cost risk and traffic volume risk), the intercept of the horizontal axis (the critical completion delay) becomes 10.88 years and the slope of the regression line is negative. This means that if the completion in the conventional delivery is delayed by up to 10.88 years, the BTL is better than the conventional delivery. In other words, when a completion delay of more than 10.88 year is expected in the conventional delivery, the conventional delivery can be a more appropriate delivery option than the BTL.

This result differs strongly from those in other cases. This difference comes from the fact that this project has such a small BCR that $M.VFM_{BTL}$ cannot increase according to completion delay. In other words, when including construction cost risk and traffic volume risk, the increase of the social benefit difference between the PSC and the BTL due to a completion delay is smaller than the decrease of the public sector cost in the PSC due to discounting.

6.4.4.3 Sensitivity analysis

$M.VFM_{BTL}$ results can differ depending on how large values are used as analysis factors. In the same way as with the Todang-Gwansan case, in order to examine the behaviour of $M.VFM_{BTL}$, according to the change of analysis factors, a sensitivity analysis is conducted. For a sensitivity analysis, the following eight analysis factors are considered: 1) BTL construction cost; 2) BTL operation cost; 3) BTL finance interest rate; 4) discount rate; 5) BTL lease profitability; 6) construction deflator; 7) consumer price index; and 8) the size of social benefits.

The changes of $M.VFM_{BTL}$ with risk inclusion and a 3.36-year delay are shown in Figure 6-12, when the analysis factors vary by from -20 to 20 per cent on each factor's given value. The summary of the sensitivity analysis is shown in Table 6-18.

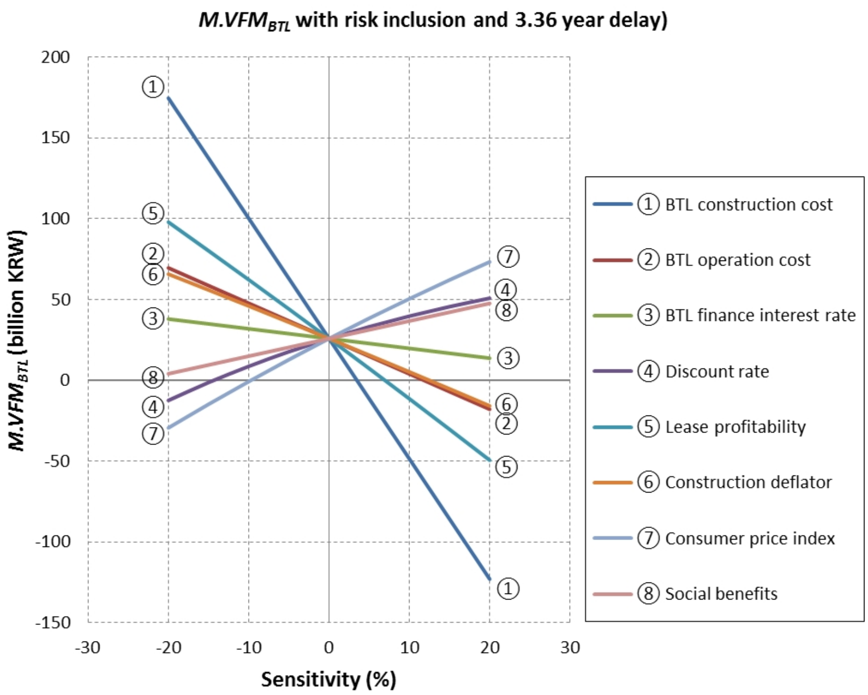


Figure 6-12: Sensitivity analysis of analysis factors (risk inclusion, 3.36-year delay)

The sensitivity analysis results, shown in Figure 6-12, show that $M.VFM_{BTL}$ values with risk inclusion and a 3.36-year delay can be negative, which means the conventional delivery can be better than the BTL, when lease profitability goes up by about 7 per cent, the discount rate drops by about 14 per cent or the consumer price index drops by about 9 per cent. In addition, when construction deflator or BTL operation cost rises by about 12 per cent, the conventional delivery is better than the BTL. In the case of BTL construction cost, though the Modified VFM becomes negative when it goes up by about 6 per cent, it is difficult to imagine that the construction cost of the BTL is likely to be bigger than that of the PSC.

Among the eight analysis factors, as seen in Table 6-18 and Figure 6-12, as discount rate, consumer price index or social benefits increase, $M.VFM_{BTL}$ rises with a positive slope mainly because these factors make the lease fee drop. However, when other factors increase, $M.VFM_{BTL}$ falls with a negative slope because they make the lease fees rise or lead to a direct increase in the public sector cost (BTL operation cost) in the BTL.

In addition, the sensitivity results show that among the factors, BTL construction cost and lease profitability are most influential on the Modified VFM: they have the steepest slopes when they rise by from -20 to 20 per cent point based on each factor's given value, which is the same result as found in the National Highway cases.

Table 6-18: Sensitivity of analysis factors on the Modified VFM

Analysis factors	$M.VFM_{BTL}$ changes due to the increase of analysis factors		
	Increase /decrease	Unit change (billion KRW)	Reasons
1. BTL construction cost	Decrease	-7.44	The increase of BTL construction cost makes private investment and lease fee rise, so $M.VFM_{BTL}$ decreases.
2. BTL operation cost	Decrease	-2.19	The increase of BTL operation cost naturally makes $M.VFM_{BTL}$ decrease.
3. BTL finance interest rate	Decrease	-0.61	The increase of BTL finance interest rate makes lease fee rise, so $M.VFM_{BTL}$ decreases
4. Discount rate	Increase	1.58	The increase of discount rate makes cost items fall. Among them, lease fee has a largest drop, so $M.VFM_{BTL}$ decreases.
5. Lease profitability	Decrease	-3.68	The rise of lease profitability makes lease fee rise, so $M.VFM_{BTL}$ decreases
6. Construction deflator	Decrease	-2.04	The rise of construction deflator makes private investment and lease fee increase, so $M.VFM_{BTL}$ decreases.
7. Consumer price index (CPI)	Increase	2.57	Nominal lease fee is converted to real term by consumer price index. The rise of CPI makes lease fee in real term drop, so $M.VFM_{BTL}$ increases.
8. Social benefits	Increase	1.09	The rise of social benefits makes the social benefit difference grow, so $M.VFM_{BTL}$ increases.

Note; Unit change means the change of $M.VFM_{BTL}$ when an analysis factor rises by 1 per cent on its given value.

Accordingly, when the viability of the BTL is needed in terms of the government policy, it could be achieved by reducing BTL construction cost or lease profitability. For this reason, in reality, according to Kim (2011), when conducting the VFM analysis, many BTL projects adopt a lower BTL construction cost (93.8 per cent on average) than PSC construction cost without any appropriate evidence to support this.

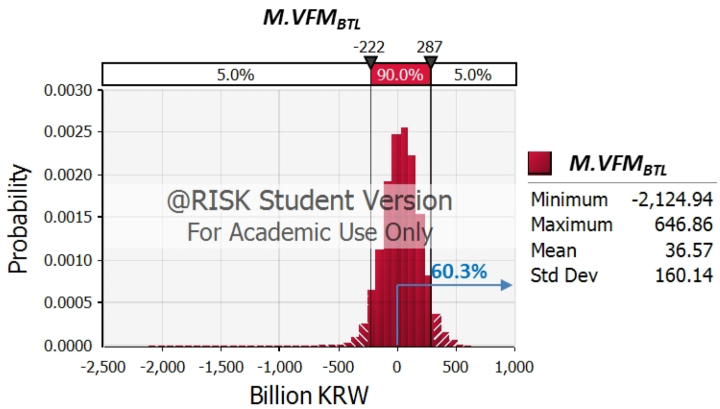
6.4.4.4 The Monte Carlo Simulations

The MCS is conducted to identify the impact of the following 18 risk variables when they are reflected at the same time, shown in Figure 6-1~Figure 6-4 and Figure 4-6~Figure 4-7, from historical observations: six WBRs, six construction cost overruns, traffic volume, maintenance cost/PCKT, construction deflator, consumer price index, the five-year exchequer bond interest rate, and the three-year non-guaranteed corporate bond interest rate.

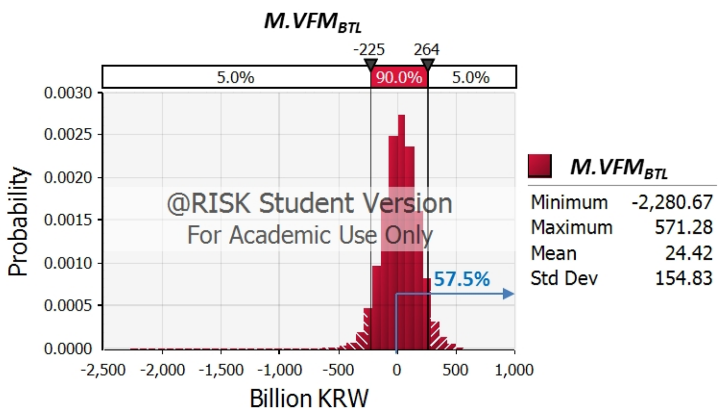
Figure 6-13 shows the MSC results with no completion delay and with a 3.36-year completion delay. In the case of no completion delay (Figure 6-13 (a)), $M.VFM_{BTL}$ is distributed between -222 and 287 (billion KRW) with 90 per cent probability and the mean value is 36.6 (billion KRW). Additionally, the probability that $M.VFM_{BTL}$ is positive is 60.3 per cent, which shows that the BTL scheme is unlikely to be feasible for this project.

With respect to the case of a 3.36-year completion delay (Figure 6-13 (b)), $M.VFM_{BTL}$ is distributed between -225 and 264 (billion KRW) with 90 per cent probability; the mean value is 24.4 (billion KRW). The probability that $M.VFM_{BTL}$ is positive is 57.5 per cent, meaning the BTL scheme is feasible for this project even considering the average completion delay of the National Railways.

The overall results from the MCS are similar to the single-value estimation result (6.4.4.1 & 6.4.4.2). Regardless of the completion delay in the conventional delivery, the BTL option is better than this option. In addition, as a completion delay goes up, and the mean value $M.VFM_{BTL}$ and the probability that the BTL is better also go down. This appears to be because this project has such a small BCR that $M.VFM_{BTL}$ cannot increase according to completion delay. In other words, the increase in the social benefit difference between the PSC and the BTL due to a completion delay is smaller than the decrease of the public sector cost in the PSC due to discounting. Finally, the PPP decision for the Bujeon-Masan National Railway project to use the BTL option in 2009 seems to be appropriate considering all the results.



(a) No delay



(b) 3.36-year completion delay

Figure 6-13: Probability distribution of the Modified VFM

6.5. Findings

In order to find out the impact of transferable risks on the PPP decisions and which delivery option is the most appropriate in the National Railway programme, the Modified VFM analysis on the Sosa-Wonsi case and the Bujeon-Masan case were conducted. Through these two case studies, several characteristics were found.

1) Regarding construction cost risk, $M.VFM_{BTL}$ and $M.VFM_{BTO}$ using an average WBR of turn-key/alternative bids based on Korea's BTL guidelines (MOSF, 2009a) can be underestimated, compared with those using winning bid ratio risks and construction cost overrun risks from the historical observations of six major work elements in railway projects.

According to Kim et al. (2008a), the average WBR of turn-key/alternative bid between 2000 and 2007 is 90.71 per cent, while a construction cost weighted application ratio from 339 contracts of 32 National Railway projects gives 93.02 and 91.86 per cent in the Sosa-Wonsi case and in the Bujeon-Masan case, respectively. Due to these differences (2.31 and 1.15 for respective project) the VFM results ($M.VFM_{BTL}$ and $M.VFM_{BTO}$) based on Korea's BTL guidelines are smaller than those using the historical observations. This is because the application ratio with construction cost weights from historical observations is higher than that based on Korea's BTL guidelines. In fact, the typical bid system for the National Railway is design-bid-build as with road programmes and WBRs of design-bid-build are usually lower than those of turn-key/alternative bid, which can be inferred from Table 6-1. However, the construction cost overrun ratios of six major work elements in the National Railways are much higher than that of road projects, as given in Table 6-1. Accordingly the application ratio with construction cost weights exceeds the average WBR of turn-key/alternative bids based on Korea's BTL guidelines. As a result, for a more accurate PPP decision in National Railway, an application ratio using the historical observations regarding six major work elements is recommended to estimate the asset cost in the PSC, instead of an average WBR of turn-key/alternative bids in the National Railways.

This result differs markedly from the result for the road programmes. The difference seems to come from whether a project is delivered separately or not. In other words, it seems that separate delivery with six different contracts for major elements in railways could cause more inefficiency than the combined delivery in roads. According to Lee (2002) and Yu (2001), the separate contract system in Korean construction industry could cause an inefficiency in terms of construction cost and duration because of the difficulties of collaboration and coordination among contractors. With respect to this, the National Bureau of Economic Research of the United States revealed that the compulsory multiple contractor system of the New York State could cause construction costs to increase by 8 percentage points (Ashenfelter et al., 1997).

2) Traffic volume risk seems to affect PPP decisions in the National Railway. When including traffic volume risk (50.7 per cent), $M.VFM_{BTL}$ values decrease by 6.1 and 9.1 (billion KRW) in the Sosa-Wonsi case and in the Bujeon-Masan case respectively, compared to those without traffic volume risk. This is due to the decrease in the operation cost in the PSC by the PCKT decrease in the projects from traffic volume reduction (from 100 to 50.7 per cent). On the other hand, when including traffic volume risk (50.7 per cent), $M.VFM_{BTO}$ value increases by 117.6 (billion KRW) in the Sosa-Wonsi case, compared to those without traffic volume risk. This is mainly because the decrease of revenue due to the traffic volume risk inclusion makes $M.VFM_{BTO}$ soar. In addition, when considering traffic volume risk in the no completion delay case, the most favourable procurement option is changed to the BTO option from the BTL option in the Sosa-Wonsi case.

3) A completion delay in the conventional delivery can also make a critical impact on the PPP decisions. In the Sosa-Wonsi case, according to the completion delay in the conventional delivery, the values of $M.VFM_{BTL}$ and $M.VFM_{BTO}$ increase, mainly because the increase of the social benefit difference between the PSC and the PPP alternatives is much bigger than the decrease of the public sector cost in the PSC due to discounting. On the other hand, $M.VFM_{BTL\text{-}BTO}$ decreases as completion is delayed from zero to four years mainly because revenue stream drops due to discounting effect. This implies that as completion is delayed the BTO option become more and more preferable to the BTL option.

However, with respect to the Bujeon-Masan case, when including construction cost risk and traffic volume risk, $M.VFM_{BTL}$ decreases because the increase of the social benefit difference between the PSC and the PPP alternatives is smaller than the decrease of the public sector cost in the PSC due to discounting. In other words, the Bujeon-Masan case has such a small BCR (0.63) that $M.VFM_{BTL}$ does not increase but decrease according to completion delay.

4) A critical completion delay in each project provides important information in PPP decisions. Considering risk inclusion (construction cost risk and traffic volume risk), the critical completion delays regarding $M.VFM_{BTL}$, $M.VFM_{BTO}$ and $M.VFM_{BTL\text{-}BTO}$ are respectively -0.10, -2.48 and -11.55 years in the Sosa-Wonsi case. This implies that even if the BTL or the BTO respectively start up to 0.10 or 2.48 years later than the conventional delivery, the BTL or the BTO is preferable to the conventional delivery. Moreover, even if the conventional delivery completes the project 11.55 years earlier than the PPP alternatives (BTO/BTL), the BTO option is more favourable than the BTL. Considering that earlier completion by 11.55 years in the conventional delivery is impractical, the BTO option always seems to be preferable to the BTL in reality.

With respect to the Bujeon-Masan case with risk inclusion, the critical completion delay regarding $M.VFM_{BTL}$ is 10.88 years. This means that if the completion in the conventional delivery is delayed by up to 10.88 years, the BTL is better than the conventional delivery because the regression line regarding $M.VFM_{BTL}$ has a negative slope, differing from the other cases. In other words, when a more than 10.88-year completion delay is expected in the conventional delivery, the conventional delivery can be a more appropriate delivery option than the BTL.

5) The sensitivity analysis results show that, when considering risk inclusion (construction and traffic volume risk) and an average completion delay (3.36 years) in the National Railway projects, the procurement option selection could change depending on the project and the procurement option. For the Sosa-Wonsi case, PPP construction cost is the most influential in the $M.VFM_{BTL}$ and $M.VFM_{BTO}$ calculation, whereas BTL lease profitability is the most influential in the $M.VFM_{BTL\text{-}BTO}$ calculation. With respect to the Bujeon-Masan case, $M.VFM_{BTO}$, BTL construction cost and BTL lease profitability are the most influential factors.

6) Regarding the MCS using 18 risk variables from historical observations, the results from the two cases are different. With respect to the Sosa-Wonsi case, as a completion delay goes up, the expected values (mean values) of the Modified VFM as well as the probabilities that the PPP alternatives are better than the conventional delivery all go up. In addition, the BTO option is the most favourable for this case, followed by the BTL.

On the contrary, with the Bujeon-Masan case, as a completion delay goes up, the expected value of Modified VFM and the probability that the BTL option is better than the conventional delivery go down. This is because the Bujeon-Masan case has such a small BCR (0.63) that $M.VFM_{BTL}$ does not increase but decrease according to completion delay. In other words, the increase in the social benefit difference between the PSC and the BTL due to a completion delay is smaller than the decrease of the public sector cost in the PSC due to discounting

7) Most significantly, the size of the revenue stream seems to be very important in PPP decisions in the National Railway cases. With respect to the Sosa-Wonsi case, considering the transferable risks (construction cost risk, traffic volume risk and completion delay), the BTO option seems to be the most appropriate option. However, considering the maximum governmental subsidy, the BTL can be a practical alternative for the Sosa-Wonsi case because the BTO scheme cannot produce an acceptable profit without a subsidy far beyond the subsidy limitation.

In addition, with respect to the Bujeon-Masan, the revenue stream is so small that the BTO option cannot produce acceptable profitability even when the Korean government supports all the BTO asset cost as a subsidy.

In conclusion, the PPP decisions for the Sosa-Wonsi case and the Bujeon-Masan case to use the BTL option seem to be totally appropriate.

CHAPTER 7 Analysis of Case studies

7.1 Introduction

Through the six case studies from three transport programmes (the National Highway, the National Expressway and the National Railway), it has been shown how the Modified VFM results and PPP decisions can be changed depending on whether the transferable risks, such as completion delay, construction cost risk and traffic volume risk, are included or not. The aim of this chapter is thus to extract some valuable conclusions and insights through analysis of the case studies, covering the research objectives 2-2 and 2-3. This chapter concentrates on a case or programme-specific analysis which is directly related to the impact of the transferable risks and the three transport programmes.

With respect to the case or programme-specific analysis, this chapter first examines the impact of completion delay (7.2), construction cost risk (7.3) and traffic volume risk (7.4) on the Modified VFM and PPP decisions in roads and railways in Korea, also providing a brief explanation of respective quantified transferable risk. Some detailed discussion on each risk's impact on PPP option selections, the Modified VFM and participants will also be given in this chapter. Specifically, regarding the impact of traffic volume risk on participants in BTO projects in Korea, a new BTO contract scheme considering traffic volume risk sharing will be suggested in order to minimise potential monetary damage that could happen in both the public and private sector in the near future, when actual revenue stays far below contract revenue.

Before suggesting the new traffic volume risk sharing scheme, the general principles for the success of a BTO project will also be briefly reviewed. In addition, considering the quantified risks and governmental subsidy limitations in Korea, the most favourable PPP option for each transport programme is also reviewed here (7.5).

7.2 The impact of completion delay

7.2.1 Completion delay in the conventional delivery in Korea

Completion delay in construction refers to the time overrun beyond what was initially planned, such as the completion time specified in a contract (Assaf and Al-Hejji, 2006), and it can occur due to various unexpected changes in circumstances: 1) contract management; 2) site conditions; 3) changes in requirements or design; 4) weather; 5) unavailability of labour, material, or equipment; 6) defective plans and specifications; and 7) owner's interference (Bramble and Callahan, 2011).

However, in Korea, completion delay is expected to occur more systematically due to the unusual national budget system, i.e. the LEC system (Kim et al., 2008b). According to the LEC system,[116] an infrastructure project starts by reflecting its first-year expenditure in the Budget Book settled by the National Assembly, even if the total expenditure of the project is not secured there. Using this system, too many infrastructure projects compared with the size of the budget tend to be implemented by reason of political necessity, such as the requirement to set a balanced regional development policy. As a result, each project under construction experiences project budget constraints and systematic completion delays occur.

In order to consider systematic completion delay in the conventional delivery in the calculation of the Modified VFM, the completion delay in transport programmes of Korea were quantified from the historical observations, as described in Chapters 4, 5 and 6. As shown in Table 7-1, completion delays are respectively 2.74, 1.30 and 3.36 years on average in the National Highways, the National Expressways and the National Railways.

Table 7-1: Completion delay in transport programmes of Korea

	National Highway	National Expressway	National Railway
Completion delay (conventional delivery)	2.74 years	1.30 years	3.36 years
Related Section	4.2.1.2 (Figure 4-3)	5.2.1.2 (Figure 5-3)	6.2.1.2 (Table 6-2)

[116] The LEC is outlined in Article 21 of the Act on Contracts, to which the State is a party. The inefficiency of the LEC is criticised by NGOs like the Citizen's Coalition for Economic Justice (CCEJ). The CCEJ (2010) criticised it for inducing too many projects to start without considering the budget available.

7.2.2 The impact of completion delay

The most important finding in this research is that a completion delay in the conventional delivery can make a critical impact on quantitative PPP decisions in roads and railways. This is because it generally leads to an increase in the Modified VFM by producing the social benefit difference between the conventional and the PPP alternatives, which is considered afresh here, along with other elements in the calculation of the Modified VFM.

This result was clearly revealed in five out of the six case studies. As the completion delay period in the conventional delivery becomes longer, the Modified VFM tends to increase, which means that the viability of the PPP option also increases. In addition, the Monte Carlo Simulation results reflecting all the risk variables quantified for this research support this finding. As shown in Table 7-2, the probability that the Modified VFM with an average completion delay is positive is clearly higher than that with no completion delay. This also proves therefore that completion delay could be a very important factor in PPP decisions.

Table 7-2: The Monte Carlo Simulation results for six cases

Delivery option selection	Completion delay	Probability: National Highway Todang-Gwansan	Probability: National Highway Dongup-Hanlim	Probability: National Expressway Suwon-Pyungtaek	Probability: National Expressway Bongdam-Songsan	Probability: National Railway Sosa-Wonsi	Probability: National Railway Bujeon-Masan
BTL > conventional	No delay	37.90%	20.20%	52.30%	45.60%	65.80%	60.30%
	Average delay*	84.90%	41.00%	90.30%	65.30%	84.90%	57.50%
BTO > conventional	No delay	-	-	56.70%	66.50%	80.30%	-
	Average delay*	-	-	99.60%	76.70%	100%	-
BTO > BTL	No delay	-	-	55.30%	66.40%	73.60%	-
	Average delay*	-	-	62.20%	70.60%	79.70%	-

Note: Average completion delay (years); 1) the National Highways = 2.74, 2) the National Expressways = 1.30, 3) the National Railways = 3.36

In contrast, in the case of the Bujeon-Masan project, the probability that the BTL option is better than the conventional delivery decreases when an average completion delay (3.36 years) is included. This is because the BCR of the Bujeon-Masan is so small (0.63[117]) that the Modified

[117] A BCR of 0.63 seems to be too small to be acceptable in investment decision. However, notwithstanding low economic feasibility (BCR = 0.63), the Bujeon-Masan project was selected as one of 30 leading projects for "Mega-city Region Development Strategy", which was adopted by the Korean government in order to achieve the balanced national development with respect to a presidential election pledge in 2007.

VFM value slightly decreases when the completion delay is considered. When a project has an acceptable BCR, the completion delay usually causes not only the asset cost of the PSC to drop by discounting but also the benefit difference between the PSC and the PPP option to rise. However, if a project has a small BCR, it could be the case that the decrease in the asset cost of the PSC is bigger than the increase in the social benefit difference when considering the completion delay. In this case, the Modified VFM could drop, even if a reasonable completion delay is considered.

In addition, the completion delay also affects the selection of PPP alternatives. As seen in Table 7-2 (the third row), the BTO option seems to be preferable to the BTL when including an average completion delay drawn from historical observations. This is because the Modified VFM difference between the BTL and the BTO options ($M.VFM_{BTL\text{-}BTO}$) decreases as completion is delayed, mainly because the revenue stream becomes reduced due to the discounting effect. This implies that as completion is delayed, the BTO option become more and more preferable to the BTL option.

In summary, considering the impact of completion delay, the public sector needs to include the completion delay factor in the quantitative PPP decisions in the transport sector in Korea. As completion delay in the conventional delivery lengthens, the PPP options become preferable to the conventional delivery. In addition, between the PPP options, the BTO becomes preferable to the BTL option when a project has an acceptable BCR. In addition, it seems important in PPP decisions to determine how long a completion delay should be for a certain project or a transport programme.

7.2.3 Critical completion delay

Introduction of critical completion delay

In this research, in order to identify the impact of a completion delay in the conventional delivery on the PPP decisions, the concept of a critical completion delay, making the Modified VFM zero, was introduced from the regression lines using completion delays (zero to four years) and the Modified VFM values in the six cases. Depending on whether the risk factors (construction cost risk or the traffic volume risk) are included or not, the critical completion delay for the conventional delivery is changed as in Table 7-3.

Five of the six cases, regardless of risk inclusion, the regression lines of the Modified VFM ($M.VFM_{BTL}$, $M.VFM_{BTO}$) have positive slopes, which mean that as a completion delay increases the Modified VFM increases. This is because a completion delay leads to an increase in the

Modified VFM by producing social benefit difference between the conventional and the PPP alternatives. However, in case of the Bujeon-Masan case, the regression line slope changes from a positive to a negative value according to risk inclusion. This is because the slope is so close to zero that risk inclusion makes it a negative value, which is very close to zero. Accordingly the critical completion delay changes drastically (from -39.57 to 10.88), shown in Table 7-3 (the last row)

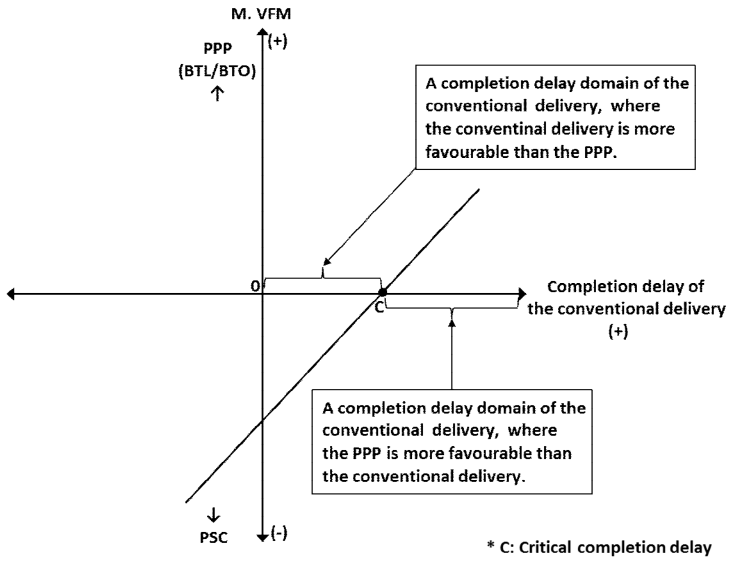
Table 7-3: The critical completion delay in six cases

<table>
<tr><th rowspan="2">Tranport programme</th><th rowspan="2">Case</th><th rowspan="2">Delivery method selection</th><th colspan="2">The critical completion delay of the conventional delivery</th><th rowspan="2">Average completion delay</th></tr>
<tr><th>No risk inclusion</th><th>Risk inclusion</th></tr>
<tr><td rowspan="2">National Highway</td><td>Todang-Gwansan (9.2km, BCR = 2.14)</td><td>PSC vs. BTL</td><td>-0.35 years</td><td>0.26 years</td><td rowspan="2">2.74 years</td></tr>
<tr><td>Dongup-Hanlim (7.3 km, BCR = 1.23)</td><td>PSC vs. BTL</td><td>-0.17 years</td><td>1.51 years</td></tr>
<tr><td rowspan="6">National Expressway</td><td rowspan="3">Suwon-Pyungtaek (38.5km, BCR = 2.72)</td><td>PSC vs. BTL</td><td>-0.31 years</td><td>-0.16 years</td><td rowspan="6">1.30 years</td></tr>
<tr><td>PSC vs. BTO</td><td>0.41 years</td><td>-0.34 years</td></tr>
<tr><td>BTL vs. BTO</td><td>3.66 years</td><td>-1.21 years</td></tr>
<tr><td rowspan="3">Bongdam-Songsan (18.5km, BCR = 1.17)</td><td>PSC vs. BTL</td><td>-0.63 years</td><td>0.02 years</td></tr>
<tr><td>PSC vs. BTO</td><td>1.19 years</td><td>-1.50 years</td></tr>
<tr><td>BTL vs. BTO</td><td>3.82 years</td><td>-3.89 years</td></tr>
<tr><td rowspan="4">National Railway</td><td rowspan="3">Sosa-Wonsi (23.3, BCR = 1.12)</td><td>PSC vs. BTL</td><td>0.15 years</td><td>-0.10 years</td><td rowspan="4">3.36 years</td></tr>
<tr><td>PSC vs. BTO</td><td>0.30 years</td><td>-2.48 years</td></tr>
<tr><td>BTL vs. BTO</td><td>0.82 years</td><td>-11.55 years</td></tr>
<tr><td>Bujeon-Masan (32.3km, BCR = 0.63)</td><td>PSC vs. BTL</td><td>-39.57 years</td><td>10.88 years</td></tr>
</table>

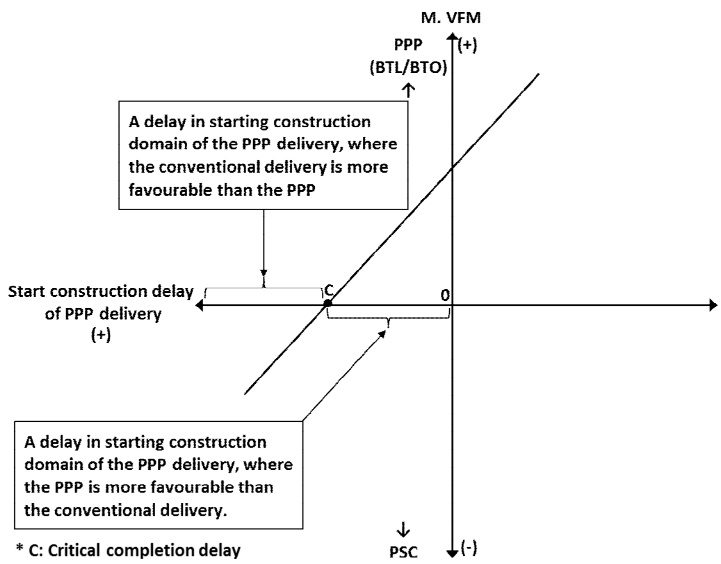
Interpretation of critical completion delay

When a regression line has a positive slope regardless of risk inclusion, it is clear from Table 7-3 that, if the expected completion delay of the conventional delivery for a project is larger than the critical delay, the right-side delivery method in the delivery selection column in Table 7-3 (excluding the Bujeon-Masan case) can be selected as a favourable delivery method.

In addition, the critical completion delay can be effectively used even after a comprehensive PPP decision including a quantitative method as well as a qualitative method. As shown in Figure 7-1 (a), the critical completion delay with a positive value in Table 7-3 (excluding the Bujeon-Masan case) means the lower boundary of the completion delay of the conventional delivery in which the right-side delivery method in the delivery selection column in Table 7-3 is preferable to the left-side one. As an example, as shown in Figure 7-1 (a), if the conventional delivery is used to implement the project in the first row of Table 7-3, the government needs to draw up a budget in order to complete the project within the lower boundary of the completion delay time (0.26 years, risk inclusion case).



(a) Critical completion delay with a positive value



(b) Critical completion delay with a negative value

Figure 7-1: Schematic diagram of the critical completion delay in PPP decisions

Conversely, as shown in Figure 7-1 (b), the critical completion delay with a negative value in Table 7-3 means the upper boundary of the delay in starting construction in the PPP delivery, compared with the conventional delivery. For example, from the first row in Table 7-3, even when a delay in starting construction in the BTL option, compared with the conventional delivery, is within 0.35 years (shown as -0.35 in Table 7-3), the BTL option (the right-side delivery method in the delivery method section column) is preferable to the PSC (the left-side one). A delay in starting construction can occur for various reasons, such as a delayed negotiation or a delay in private fund agreements. Therefore, if the BTL delivery is decided on to implement the case study project, the government seems to need to make a greater effort to break ground within the upper boundary (0.35 years) of the delay in starting construction delay in the BTL. In addition, when a delay in starting construction becomes longer than the upper boundary (0.35 years), it seems that the previous PPP decision becomes invalid and therefore that a new decision should be made for the project. According to the master plan of PPP (MOSF, 2009b) of Korea, a PPP option already decided for a project can be replaced with a conventional option and vice versa when it is difficult to conduct the already decided option. However, there are no examples that a PPP option is replaced with a conventional option seemingly because there are not clear criteria for the decision change. The concept of critical completion delay can be used as one of the decision change criteria when it is necessary (Park and Preston, 2013a).

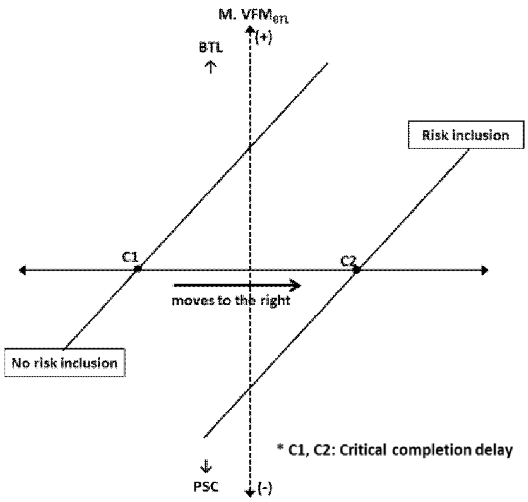
The behaviour of critical completion delays according to risk inclusion

Depending on whether the risks (construction cost risk and traffic volume risk) are included or not, the critical completion delay seems to show differing behaviours between roads and railways.

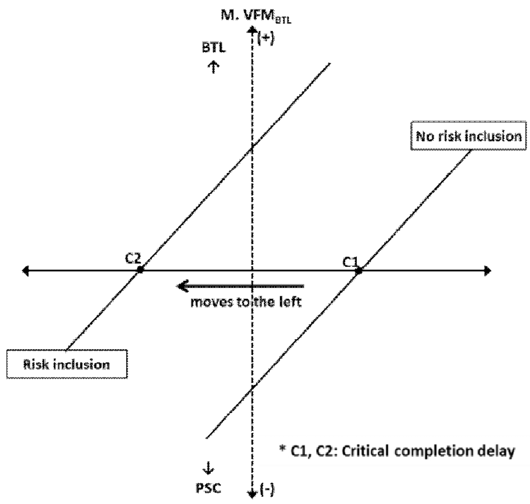
With respect to the comparison between the conventional delivery and the BTL (PSC vs. BTL rows in Table 7-3), for the road case studies the regression line moves to the right, which means the critical completion delay increases when construction cost risk and traffic volume risk are included (Figure 7-2 (a) roads). This is because the regression line has a positive slope with an acceptable BCR, and the intercept of the Modified VFM axis goes down according to risk inclusion. For roads, the reason for the decrease in the intercept of the Modified VFM is that construction cost risk reduces the asset cost of the PSC; also, the traffic volume risk causes the operation cost of the PSC to decrease. Accordingly, the Modified VFM goes down as these risks are included.

On the other hand, for railway case studies (Figure 7-2 (a) rail), when including construction cost risk and traffic volume risk, the regression line moves to the left, indicating that the critical completion delay decreases, as opposed to roads. This is because the regression line has a positive slope with an acceptable BCR, and the intercept of the Modified VFM axis increases according to risk inclusion. In railways, the reason for the increase in the intercept of the Modified VFM is that the increase of the asset cost of the PSC due to construction cost risk is bigger than the decrease in the operation cost of the PSC due to traffic volume risk. However, in the case of the Bujeon-Masan project, the slope of the regression line seems to be close to zero because it has such a small BCR (0.63). Accordingly, in contrast to the Sosa-Wonsi case, the critical completion delay varies markedly (from -39.57 to 10.88) according to the inclusion of the risks.

When it comes to a comparison between the conventional delivery and the BTO (PSC vs. BTO in Table 7-2), as shown in Figure 7-2 (b), the critical completion delay moves to the left when construction cost risk and traffic volume risk are included. This is because the regression line has a positive slope and the intercept of the Modified VFM axis goes up. The increase of the Modified VFM is mainly due to the decrease in the revenue stream, as shown in equation (3-7).

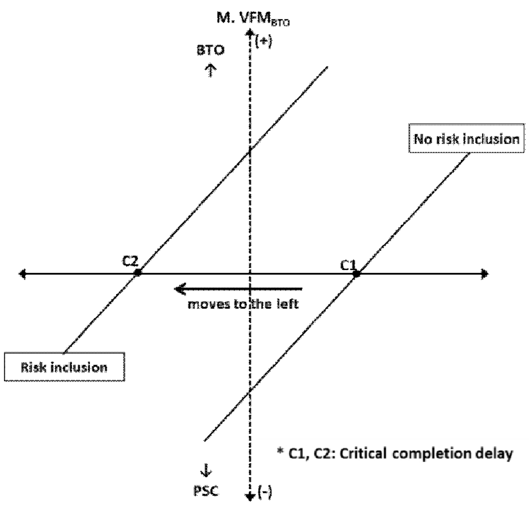


< Roads >



< Rail >

(a) $M.VFM_{BTL}$



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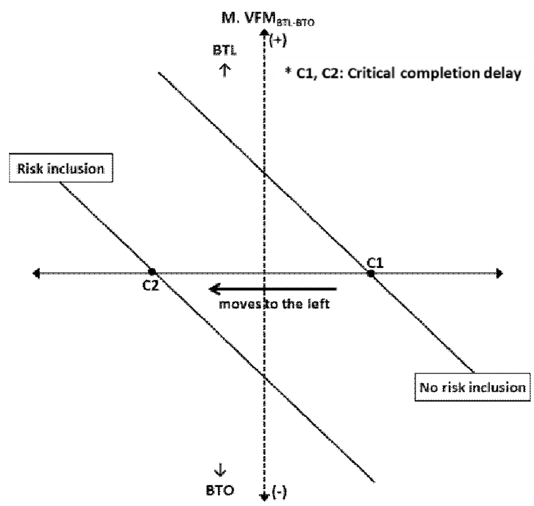

< Roads/Rail >

(b) $M.VFM_{BTO}$ (c) $M.VFM_{BTL\text{-}BTO}$

Figure 7-2: The behaviour of critical completion delay according to risk inclusion

In addition, in the comparison between the BTL and the BTO (BTL vs. BTO in Table 7-2), as show in Figure 7-2 (c), the critical completion delay moves to the left when the risks are included because the regression line has a negative slope and the intercept of the Modified VFM axis goes down mainly due to the decrease in the revenue stream.

These different behaviours are due to the components of the Modified VFM in the delivery option comparison (equations (3-7), (3-8) and (3-9)); they are also the result of the discounting effect due to the inclusion of a completion delay

7.3 The impact of construction cost risk

7.3.1 Application ratio for the asset cost of the PSC

According to Korea's BTL guidelines (MOSF, 2009a), the asset cost of the PSC is calculated by multiplying an average WBR (the ratio of winner's price to estimated price) of the turn-key/alternative bid[118] and the construction cost from the design stage. The reason for using an average WBR of turn-key/alternative bids is that these bid systems usually do not allow construction cost increases, except in the case of inflation and when the delivery authority is responsible for the increases. This means the public sector does not have to consider construction cost overruns when estimating the asset cost for the PSC.

However, although some projects use a turn-key/alternative bid, the typical bid system in terms of conventional delivery is not turn-key/alternative bid but design-bid-build. Additionally, it remains unclear how much the construction cost will rise between the start of construction and completion in each transport programme in Korea.

For this reason, in this research, a substitute for an average WBR of turn-key/alternative bid – which I call the application ratio (equation (3-10)) – is developed using historical observations.

[118] Public works in Korea are delivered using turn-key bid, alternative bid and design-bid-build. In turn-key and alternative bids, the designer selected through bidding process becomes the contractor for the project, whereas in design-bid-build bid the designer and the contractor are different each other. The difference between turn-key and alternative bid is a design scope. In turn-key bid, the design scope is all the parts of the project, whereas in alternative bid it is restricted to main part of the project which a delivery authority determines.

An application ratio is composed of the WBR risk and construction cost overrun risk quantified from historical observations, as mentioned in Chapter 3 (see 3.4.3.1). In addition, an average WBR of turn-key/alternative bids by Korea's BTL guidelines (MOSF, 2009a) can be a kind of application ratio with no construction cost overrun.[119] With respect to this, the impact of construction cost risk in each transport programme is shown in Table 7-4.

7.3.2 The impact on transport programmes

National Highways

As seen in Table 7-4, the impact of considering construction cost risk is different depending on the transport programmes. For the National Highways, the application ratio (construction cost risk) from historical observations is quantified as 84.58 per cent, which is 3.97 per cent lower than an average WBR of turn-key/alternative bid (88.55 per cent) based on Korea's BTL guidelines (MOSF, 2009a). This is because the representative bid system for the National Highways is not turn-key/alternative but design-bid-build and the WBRs of design-bid-build are usually lower than those of turn-key/alternative bid. In addition, even if construction cost overrun risk is included, the application ratio from historical observations is lower than that based on Korea's BTL guidelines, which means an average WBR of turn-key/alternative bid.

Due to this difference, when construction cost risk is included, namely when an application ratio from the historical observations is used instead of an average WBR of turn-key/alternative bids in the National Highway projects, the Modified VFM is reduced by 4.6 (billion KRW) in the Todang-Gwansan case, and by 4.3 (billion KRW) in the Dongup-Hanlim case. Accordingly, when estimating the Modified VFM of a National Highway project using Korea's BTL guidelines, the Modified VFM appears to be overestimated by 3.97 per cent on the construction cost of the PSC, compared with that using the historical observations.

National Expressways

As with the National Highways, when estimating the Modified VFM using Korea's BTL guidelines (MOSF, 2009a), the Modified VFM can also be exaggerated. The application ratio (construction cost risk) from the historical observations is quantified as 78.80 per cent, which is 3.34 per cent lower than an average WBR of turn-key/alternative bids (82.14 per cent) based on

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[119] From equation (3-10), an application ratio can be expressed as (winning bid ratio) × (1+construction cost overrun) when using historical observations. Considering an average turn-key/alternative winning bid ratio without construction cost overrun according to Korea's BTL guidelines, an application ratio in equation (3-10) becomes simply the average turn-key/alternative winning bid ratio.

Korea’s BTL guidelines (MOSF, 2009a). Due to this difference, when construction cost risk is included, the Modified VFM decreases by 16.6 (billion KRW) in the Suwon-Pyungtaek case and by 9.1 (billion KRW) in the Bongdam-Songsan case.

Table 7-4: Impact of construction cost risk in six cases

Transport Programme	Case project	Application ratio [1] for the asset cost of the PSC: BTL guidelines (a)	Historical observations (b)	Difference (a-b)	Impact on M.VFM (No completion delay) (billion KRW)
National Highway	Todang-Gwansan	88.55 %[2]	84.58%	3.97%	4.6 (Decrease) 4.2% on PSC asset cost
	Dongup-Hanlim				4.3 (Decrease) 4.2% on PSC asset cost
National Expressway	Suwon-Pyungtaek	82.14 %[3]	78.80%	3.34%	16.6 (Decrease) 3.8% on PSC asset cost
	Bongdam-Songsan				9.1 (Decrease) 3.7% on PSC asset cost
National Railway	Sosa-Wonsi	90.71 %[4]	93.02%[5]	-2.31%	21.1 (Increase) 2.4% on PSC asset cost
	Bujeon-Masan		91.86%[5]	-1.15%	10.3 (Increase) 1.2% on PSC asset cost

Note: 1) An application ratio is (WBR) × (1+construction cost overrun) when using historical observations. It also means the WBR of turn-key/alternative bids without construction cost overrun by Korea’s BTL guidelines. 2) and 3) are obtained from the status of WBRs of turn-key/alternative bids in National Highways and National Expressways (MLTM, 2012b), based on Korea’s BTL guidelines (MOSF, 2009a). 4) is obtained from Kim et al. (2008a). 5) The values are estimated considering construction cost weights because the National Railways are usually delivered by six different element contracts.

National Railways

On the other hand, with respect to the National Railways, the application ratio (construction cost risk) from historical observations considering construction cost weights are 93.02 and 91.86 per cent in the Sosa-Wonsi case and in the Bujeon-Masan case respectively, whereas the average WBR of turn-key/alternative bid is 90.71 per cent between 2000 and 2007, according to Kim et al. (2008a). This means that the application ratios from historical observations are respectively 2.31 and 1.15 per cent higher than an average WBR of turn-key/alternative bids, based on Korea’s BTL guidelines (MOSF, 2009a). In fact, the typical bid system for the National Railway is design-bid-build as with road programmes and WBRs of design-bid-build are usually lower than those of turn-key/alternative bid. However, the construction cost overrun ratios of six major work elements in the National Railways are much higher than that of road projects, as given in Table 6-1. Accordingly the application ratio with construction cost weights exceeds the average WBR of turn-key/alternative bids based on Korea’s BTL guidelines.

Due to these differences, when construction cost risk is included, the Modified VFM increases by 21.1 (billion KRW) in the Sosa-Wonsi case, and by 10.3 (billion KRW) in the Bujeon-Masan case. In other words, when estimating the Modified VFM of a National Railway project using Korea's BTL guidelines (MOSF, 2009a), it appears that the Modified VFM can be underestimated, compared with the estimation using the historical observations.

Reason for the difference

Compared with the results of the National Highways and the National Expressways, the results for the National Railways are quite different. When estimating the Modified VFM using Korea's BTL guidelines (MOSF, 2009a), the Modified VFM can be exaggerated in road projects, while it can be underestimated in railway projects, compared with the estimation using the historical observations. In other words, when using Korea's BTL guidelines (MOSF, 2009a), PPP options can have an advantage over the conventional option in roads. In contrast, with railways the conventional option has an advantage over the PPP options.

This difference between roads and railways seems to come from whether a project is delivered separately on the work element basis or not. It seems that a separate delivery with six different contracts for major elements in railways could cause more inefficiency than a single delivery in roads, showing bigger construction cost overruns. According to Lee (2002) and Yu (2001), the separate contract system in the Korean construction industry could cause inefficiency in terms of construction cost and duration because of the difficulties of collaboration and coordination among contractors. With respect to this, the National Bureau of Economic Research of the United States revealed that New York State's compulsory multiple contractor system could cause construction costs to increase by eight percentage points (Ashenfelter et al., 1997).

7.4 The impact of traffic volume risk

7.4.1 Impact on PPP option selection

The details of changes of traffic volume in individual projects are difficult to obtain, so traffic volume risk (actual traffic volume divided by forecast traffic volume) is quantified using the relevant literature. As shown in Table 7-4, the quantified traffic volume risk (mean value) of roads is estimated at 0.686, and that of railways is 0.507.

When considering traffic volume risk, the behaviour of the Modified VFM is different depending on the PPP option considered. In the BTL option, the Modified VFM drops relatively slightly. As seen in Table 7-5 (percentage on PSC asset cost columns), the Modified VFM drops by as much as from 0.7 to 4.2 per cent on the asset cost of the PSC depending on project and transport programme, because the maintenance cost in the PSC is reduced as the traffic volume ratio (actual/forecast) goes down, as is assumed in Chapters 4, 5 and 6.

Table 7-5: Impact of traffic volume risk on transport programmes

Transport Programme	Actual traffic volume/ forecast traffic volume		Case project	Impact on M.VFM (No completion delay)		Remark
	BTL guidelines	Literature		Billion KRW	Percentage on PSC asset cost	
National Highway	1.0[1)]	0.686[2)]	Todang-Gwansan	[BTL] 4.6 decrease	[BTL] 4.2%	-
			Dongup-Hanlim	[BTL] 3.7 decrease	[BTL] 3.6%	-
National Expressway			Suwon-Pyungtaek	[BTL] 9.0 decrease [BTO] 138.0 increase	[BTL] 2.1% [BTO] 31.5%	Most favourable option changes (BTL→BTO)
			Bongdam-Songsan	[BTL] 5.0 decrease [BTO] 96.1 increase	[BTL] 2.0% [BTO] 39.2%	Most favourable option changes (BTL→BTO)
National Railway		0.507[3)]	Sosa-Wonsi	[BTL] 6.1 increase [BTO] 117.6 increase	[BTL] 0.7% [BTO] 13.5%	Most favourable option changes (BTL→BTO)
			Bujeon-Masan	[BTL] 9.0 decrease	[BTL] 1.1%	-

Note: 1) There are no comments on traffic volume risk in Korea's BTL guidelines, so it is assumed that actual traffic is the same as forecast traffic in this research. 2) 0.686 is obtained by digitising the traffic volume inaccuracy graph in the road sector in the research of Kim (2007). 3) 0.507 is quantified using the following literature on railway traffic volume changes: i) Kim (2010b); ii) MLTM, quoted in Gil (2012); and iii) Park (2012). Detailed data for rail are shown in Table 6-3.

However, in the BTO option, when including the mean value of the traffic volume risk, the Modified VFM soars by as much as from 13.5 to 39.2 per cent of the asset cost of the PSC depending on project and transport programme, mainly because the revenue stream, which causes the Modified VFM to decrease according to equation (3-7), is reduced as the traffic volume ratio (actual/forecast) goes down. Following the considerable change in the Modified VFM by traffic volume risk, the most favourable delivery option changes from the BTL to the BTO option in all the cases with tariffs (the Suwon-Pyungtaek case, the Bongdam-Songsan case and the Sosa-Wonsi case).

7.4.2 Impact on participants in BTO projects

Cooperation between participants

Whether to initiate the BTO option for a project or not can depend on the participants, as shown in Figure 7-3 (the orange boxes). The public sector can decide to use the BTO option when the

BTO option can produce more VFM than any other options in terms of the Modified VFM. However, the private sector, especially financial investors, will only participate in the BTO project when they can gain acceptable profit above a certain level in terms of a return on investment (ROI), which is usually not open to the public because it is considered as confidential business. Apart from construction investors, who usually participate in the project to obtain the right to construct, financial investors participate in order to maximise financial profits by mixing equity, senior debt and subordinate debt. In addition, usually the private financial investors invest in the project when the IRR of the project is equal or greater than the minimum acceptable rate of return (Greer and Kolbe, 2003, Moyer et al., 2012), ROI is related to the IRR of the project, because IRR shows that the project is an attractive investment.

Therefore, in order to launch a BTO project, the project must show performances above an acceptable level in terms of the Modified VFM assessment, IRR and ROI. In this sense, participants should be aware that a BTO project can be launched only when it passes two different decision-making procedures in both sectors, regardless of which method it uses (i.e. solicited or unsolicited method), as seen in Figure7-3. As a result, mutual consideration and cooperation between participants in a BTO are a prerequisite for the success of a BTO project.

Why traffic volume risk sharing in Korea?

In Korea, the biggest threat to a BTO project after launch seems to be a shortfall of revenue due to traffic volume risk. A revenue shortfall causes the IRR of the project to decrease, which is related not only to the profit of the private sector but also to the provision of infrastructure services. Therefore, traffic volume risk sharing becomes important to both participants in terms of the mutual consideration and cooperation between participants in a BTO project.

There are two reasons why traffic volume risk needs to be shared in Korea. The first reason is that private sector does not seem to manage traffic volume risk sufficiently. According to some research (Ke et al., 2010, Roumboutsos and Anagnostopoulos, 2008, Li et al., 2005), operation revenue risk, which is directly related to traffic volume risk, should be taken on by the private sector, based on questionnaire surveys in several countries, such as the UK, China, Hong Kong and Greece. However, in some environments where traffic volumes are mainly dependent on economic development, fuel price and other macro-economic variables, it is difficult for the private sector to fully take on this risk (Mackie and Smith, 2005). Generally speaking, it is inadvisable to transfer too much risk to the private sector on the grounds that the private sector has better risk management ability than the public sector, because transferring excessive risk could make the total cost of the public sector increase instead of decrease (Sun et al., 2010, Cooper et al., 2005). Therefore, appropriate traffic volume risk sharing seems to be essential in a BTO.

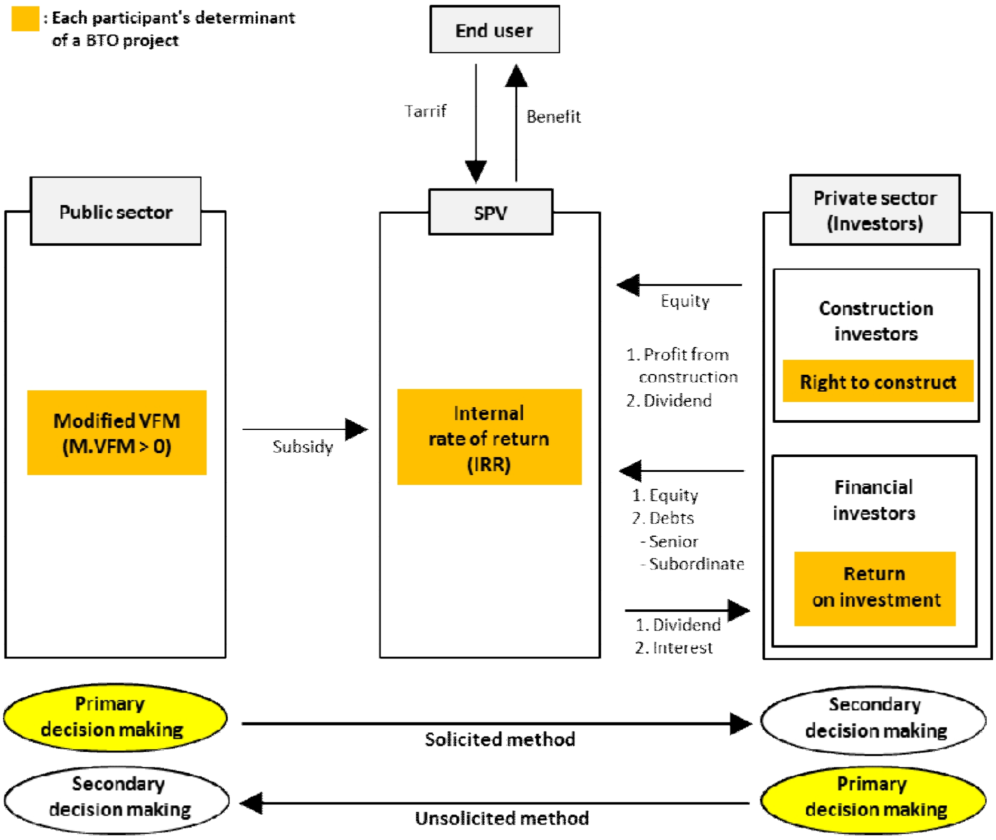


Figure 7-3: Decision-making determinants of participants in the BTO scheme

The second reason is related to the efficiency of private sector financing for a BTO project. In Korea, the operation revenue sharing system, MRG, was abolished in 2009. After that, BTO projects have experienced difficulties in delivering required capital from the finance market, because financial institutes tend to think BTO projects are very risky without MRG condition so they are reluctant to lend money to them (Park, 2010). As a result, after the abolition of MRG, the start of construction of many BTO projects has been delayed in Korea. Accordingly, appropriate traffic volume risk sharing seems to be a prerequisite for the smooth progress of BTO projects in Korea.

Impact of traffic volume risk on participants

Suppose there is a BTO contract without traffic volume risk sharing scheme contract 1 in Table 7-6. In this case, the private sector fully takes on the risk, which is actually beyond its ability, regardless of revenue ratio (R, actual revenue/contract revenue).

Table 7-6: Impact of traffic volume risk on participants and related suggestions

Revenue ratio (R) (Actual/contract)	Parties	Contract 1 (present) Revenue stream with traffic volume risk unknown (No traffic risk sharing scheme) Satisfaction level	Contract 1 (present) Remark	Contract 2 (suggestion) Reduced revenue considering traffic volume risk (IRR based risk share considering investment ratio) Satisfaction level	Contract 2 (suggestion) Remark
R>1	Public sector	Less than satisfactory	No excessive revenue sharing between two parties.	Satisfactory	Excessive revenue (or IRR) is shared between two parties considering investment ratio[1].
	Private sector	More than satisfactory (IRR, ROI increase)		Satisfactory (IRR, ROI increase)	
R=1	Public sector	Satisfactory		Satisfactory	
	Private sector	Satisfactory		Satisfactory	
R<1	Public sector	Satisfactory	SPV becomes unstable and it can go bankrupt. In this case, infrastructure service can be ceased and the government is not free from the resposibility	Less than satisfactory	Revenue (or IRR) deficiency is shared between two parties considering investment ratio[1].
	Private sector	**Unsatisfactory** (IRR, ROI decrease)		Less than satisfactory (IRR, ROI decrease)	
Pros		Small subsidy for public sector Good profitability for private sector		1. Risk sharing between parties and fair to two parties 2. Stable PSV and infrastructure service provision 3. Easy to get funded from private sector 4. Short negotiation expected	
Cons		1. Unfair and too risky to private sector 2. Unstable SPV and infrastructure service provision 3. Hard to get funded from private sector 4. Long negotiation expected		Larger subsidy but within governmental construction subsidy limit[2] Reduced profitability for private sector	

Note: 1) Investment ratio; i) public sector = all subsidy / (private sector investment + all subsidy), ii) private sector = private sector investment/(private sector investment + all subsidy); 2) Current governmental construction subsidy limit: i) roads = 30 per cent; and ii) railways = 50 per cent of the asset cost of the BTO (MOSF, 2010).

To begin with, the ideal situation is that contract revenue is realised in practice (R=1). In this case, each participant will be fully satisfied with the situation.

If actual revenue is above the contract revenue (R>1), the two parties will be overall satisfied with a stable infrastructure service provision for the public sector and more profit than expected for the private sector. However, if excessive revenues occur and are not shared between two parties, this situation, in fact, could be more than satisfactory for the private sector but less than satisfactory for the public sector.

In addition, when actual revenue is slightly below the contract revenue, the SPV becomes unstable because the cash inflow and the IRR of the project drop. At the same time, the ROI for financial investors also drop because dividends will be diminished. Although this situation is not fully satisfying from an investor's point of view, it still seems to be bearable because the profits are mainly from interest on debts. On the other hand, the public sector feels superficially satisfied regardless of how much actual revenue occurs because it does not have to pay any more. The contract seems ideal to the public sector in this aspect.

However, if actual revenue falls far below contract revenue (R<<1), the situation can be serious for the both sectors. In the event of a serious revenue shortfall, the SPV can go into bankruptcy, which can mean it cannot provide infrastructure services for the public and cannot pay dividends and interest to the private sector. Therefore, the bankruptcy of the SPV means a great loss to the both sectors. In this case, the project fails to obtain its ultimate objective: infrastructure service provision. The public sector is not free from the responsibility for the failure.

Consequently, a BTO contract without traffic volume risk sharing undermines the principle of mutual consideration and cooperation and is also unfair. In the end, it would be too risky for the both participants.

How to share traffic volume risk: a suggestion

According to Irwin (2005), various fiscal supports from the public sector are applied to share traffic volume risk in PPPs globally, considering each country's PPP environment. These include: shadow-toll (the UK and Portugal); annuity or availability payment (India and central Europe); debt guarantee (Poland); exchange rate guarantee (Chile and Colombia); and revenue guarantee (Korea).

However, the MRG system was abolished in 2009, so there is no traffic risk sharing system in Korea. In addition, considering the existing economic burden[120] from the previous BTO contracts with the MRG system that public sector should take in the future (BAI, 2012) and the public's unfavourable view of the MRG system and the traffic volume forecast (Jung, 2011, Kang, 2012), it seems impossible to re-introduce the MRG system in the BTO scheme. Thus, instead of the MRG system a new risk sharing method is suggested for Korea, as shown in Table 7-6 (contract 2).

The essence of this suggestion is to depreciate the value of a BTO project by reducing the contract revenue stream, considering the traffic volume risk, if the BTO project is viable in this case. In doing so, the public sector pays a higher subsidy and the private sector accepts reduced profitability (IRR), compared with the current contract scheme (contract 1 in Table 7-6). For the both participants to take some loss in terms of mutual consideration and cooperation, the project is expected to provide a good and stable infrastructure service. The suggestion in the BTO option has three advantages.

[120] The MRG burden in the future is expected to be 18.5 trillion KRW from the previous BTO projects, according to BAI (2012).

The first is that this method considers the reduced revenue stream as reflecting traffic volume risk instead of forecast revenue in order to avoid an extreme cost burden for each participant. This is shown in contract 2 in Table 7-6. Accordingly, this method means that the public sector takes some traffic volume risk beforehand by giving more construction subsidies to the SPV, compared with the existing contract method, which does not require risk to be taken on beforehand (contract 1 in Table 7-6).

The second is that this method considers governmental construction subsidy limitations with respect to fiscal support. Thus, if a total construction subsidy for an acceptable IRR and an acceptable toll level is beyond the government limitation, the BTO option should be discarded and other options will need to be considered.

The third, and most important, advantage relates to sharing the excessive or deficient revenue (or IRR) between participants. In other words, when actual revenue is beyond contract revenue, considering the reduced revenue stream, the excess more than the contract revenue is shared, being based on how much each party invests in the project (investment ratio). Similarly, when actual revenue is below contract revenue, the deficiency is also shared considering the investment ratio. In this case, the public sector will be able to consider the following ways to address its deficiency: 1) the provision of further fiscal support; 2) toll level adjustment; and 3) operation duration adjustment[121].

The bottom line of the suggestion is to make the two parties make a profit or loss according to how much they invest in the project. In addition, generally speaking, the public sector provides compensation cost as well as construction subsidy in the BTO option in Korea, so the case that the private sector takes all the revenue risk does not happen.

In addition, the suggestion is similar to the cap and collar mechanism[122] in the rail franchise bid in the UK, in that the excessive and deficient revenue is shared between the public sector and the private sector in order to protect taxpayers as well as the private sector exogenous revenue

[121] Operation duration adjustment is related to a variable length contract. In this respect, the suggestion has something in common with the Least-Present-Value-of-Revenue Auction scheme where the lowest bid in terms of revenue wins and the contract ends as soon as that amount has been collected (Engel et al., 2001).

[122] The cap-and-collar mechanism was introduced in the rail franchise in the UK in 2003 and abandoned with the change of government in 2010, when it was replaced by a GDP factor in some cases. The cap-and-collar mechanism shares revenue risk between participants, recognising that the private sector has not the ability to control a significant portion of revenue growth or decline, though revenues are intrinsically related not only to the general pattern of economy and employment, but also to the performance by the rail operator (Stokes and Demmer, 2012).

risk (DfT, 2010, Brown, 2013). However, it differs markedly from the cap-and-collar mechanism in that excessive or deficient revenue is shared based on how much each participant invests in the project (investment ratio), whereas revenue risk sharing is conducted based on the revenue sharing threshold parameters that the bidders propose in the bidding process (Competition Commission, 2006). In fact, the cap and collar mechanism has following typical revenue risk sharing features when the first four years have passed after the franchise contract (or earlier where negotiations have occurred): 1) Department for Transport (DfT) shares 50% of any fares revenues exceeding 102% of the train operation company (TOC)'s original forecasts; 2) DfT gives a support equivalent to 50% of any revenue shortfall below 98% of the TOC's original forecast; 3) For any shortfall below 96%, DfT's support increases to 80% (Preston, 2008).

Example calculation

Gil (2012) claimed that the appropriate MRG level for a BTO project can be determined using the difference of the saved public sector cost ($M.VFM_{BTL\text{-}BTO}$ in this research) by adopting the BTO scheme instead of the BTL scheme, meaning a saved public sector cost by transferring traffic volume risk to the private sector. With respect to the suggestion in this study, the saved public sector cost by transferring volume risk ($M.VFM_{BTL\text{-}BTO}$) can be used in designing a new restriction on the total governmental subsidy limitation.

With respect to the Suwon-Pyungtaek National Expressway case, an example calculation of the monetary loss of the two parties with various approaches to traffic volume risk sharing is shown in Table 7-7. It is assumed that contract 1 is awarded by using forecast revenue stream with traffic volume risk unknown, while contract 2 is awarded by using reduced revenue stream considering road traffic volume risk (0.686, see Figure 4-4) and an additional construction subsidy. As seen in Table 7-7, contract 1 includes three cases; no MRG condition, stepwise MRG condition (which is practically applied to the Suwon-Pyungtaek case), and Gil's approach. Following Gil's approach, the marginal traffic volume that makes $M.VFM_{BTL\text{-}BTO}$ zero is 75.5 per cent of forecast volume and the additional subsidy that can be given to the private sector is 25.3 billion KRW in the Suwon-Pyungtaek case, which is the difference between the BTO and the BTL in terms of the Modified VFM shown in Table 5-3 (the third row). Therefore, additional construction subsidy (25.3 billion KRW) is applied to contract 2. In addition, the IRR is estimated using equation (6-1) (see Section 6.3.3).

With respect to contract 1, when actual revenue decreases below the forecast, revenue shortage occurs and becomes a private sector monetary loss. The monetary loss of the public sector means the MRG cost that is given to the private sector, so this makes the private sector monetary loss reduced. Comparing the monetary loss of the two parties in contract 1, Gil's approach is most favourable to the private sector because the public sector gives the most monetary support to the private sector. For example, when actual revenue drops to half of the forecast one, the public sector gives an MRG support of 88.1 (billion KRW) according to Gil's approach, while MRG support is only 71.7 (billion KRW) in stepwise MRG condition. The total public sector loss in Gil's approach becomes 171.6 (billion KRW), while that in stepwise MRG condition becomes 188.0 (billion KRW).

When it comes to contract 2, revenue shortage starts to occur when actual revenue drops below 68.6 per cent of the forecast one because contract revenue considers road traffic volume risk (0.686) from the historical observations. In addition, additional construction subsidy (25.3 billion KRW) makes the private sector investment reduced, so it can help the contract profitability (IRR) of the SPV increase. The impact of traffic volume risk on BTO viability is addressed separately in the next section (7.4.3).

Table 7-7: Example calculation of the monetary loss for the two parties

(Unit: discounted billion KRW, 2002 price)

Revenue ratio (actual/forecast)	Contract 1 (contract revenue = forecast revenue)										Contract 2 (contract revenue = 0.686×forecast revenue)				
	Revenue shortage	No MRG			MRG						The suggestion				
					Stepwise			Gil's approach							
	$[a_1]$	Loss (G) $[b_1]$	Loss (P) $[a_1\text{-}b_1]$	(IRR %)	Loss (G) $[b_2]$	Loss (P) $[a_1\text{-}b_2]$	(IRR %)	Loss (G) $[b_3]$	Loss (P) $[a_1\text{-}b_3]$	(IRR %)	Revenue shortage $[a_2]$	Additional subsidy $[b_4]$	Loss (G) $[b_4+0.59\times a_2]$	Loss (P) $[0.41\times a_2]$	(IRR %)
1.2	-103.9	0.0	-103.9	(9.46)	0.0	-103.9	(9.46)	0.0	-103.9	(9.46)	-266.8	25.3	-132.3	-109.2	(7.09)
1.1	-52.0	0.0	-52.0	(8.64)	0.0	-52.0	(8.64)	0.0	-52.0	(8.64)	-214.9	25.3	-101.6	-87.9	(6.68)
1.0	0.0	0.0	0.0	(7.78)	0.0	0.0	(7.78)	0.0	0.0	(7.78)	-162.9	25.3	-70.9	-66.7	(6.25)
0.9	52.0	0.0	52.0	(6.83)	0.0	52.0	(6.83)	0.0	52.0	(6.83)	-111.0	25.3	-40.3	-45.4	(5.80)
0.8	103.9	0.0	103.9	(5.81)	0.0	103.9	(5.81)	0.0	103.9	(5.81)	-59.0	25.3	-9.6	-24.2	(5.34)
0.755	127.5	0.0	127.5	(5.31)	5.7	121.8	(5.41)	0.0	127.5	(5.31)	-35.4	25.3	4.4	-14.5	(5.12)
0.7	155.9	0.0	155.9	(4.68)	12.5	143.3	(4.90)	18.9	137.0	(5.06)	-7.1	25.3	21.1	-2.9	(4.85)
0.686	162.9	0.0	162.9	(4.52)	15.9	147.0	(4.80)	23.6	139.3	(4.99)	0.0	25.3	25.3	0.0	(4.78)
0.6	207.8	0.0	207.8	(3.40)	37.1	170.7	(4.12)	53.5	154.3	(4.54)	44.9	25.3	51.8	18.4	(4.34)
0.5	259.8	0.0	259.8	(1.92)	71.7	188.0	(3.47)	88.1	171.6	(3.95)	96.8	25.3	82.5	39.6	(3.80)

(Note) 1. Loss (G) = the loss of the public sector, Loss (P) = the loss of the private sector. 2. IRR = internal rate of return (real). 3. Above table was analysed based on $M.VFM_{BTL\text{-}BTO}$ (+volume risks) in Table 5-3 (Section 5.3.4.1). 4. Stepwise = the MRG condition of the Suwon-Pyungtaek case (the government guarantees up to 80% (1 to 5 years), 70% (6 to 10 years) and 60% (11 to 15 years) and redeems revenue exceeding 120% (1 to 5 years), 130% (6 to 10 years) and 140% (11 to 15 years) . 5. Gil's approach = MRG condition is determined to 75.5% (1 to 15 years) which makes $M.VFM_{BTL\text{-}BTO}$ zero. 6. For contract 2, the government investment includes compensation cost (567.8 billion KRW), construction subsidy (248.5 billion KRW) and additional construction subsidy (25.3 billion KRW), and the private sector investment is 583.1 (608.4-25.3) billion KRW. Therefore, the investment ratio for the public sector = 59.072% and the investment ratio for the private sector = 40.928%

Comparing contract 1 with contract 2, the monetary loss of the private sector is minimal in contract 2. For example, when actual revenue drops to half of the forecast one, the total public sector loss in Gil's approach (contract 1) becomes 171.6 (billion KRW), while that in contract 2 becomes 39.6 (billion KRW). In addition, contract 2 can also make money[123] for the private sector when actual revenue is greater than contract revenue (0.686× forecast revenue). However,

[123] The negative values in Loss (P) column in contract 2 means the cash inflow in the private sector

for the public sector, losses start to occur when actual revenue falls below approximately 76.9 per cent[124] of the forecast. These losses exceed the MRG Stepwise when actual revenue falls below 74.8 per cent[125] of the forecast and is higher than Gil's suggestion when actual revenue falls below 76.9 per cent[126] of the forecast. Other example calculations for the Bongdam-Songsan case and the Sosa-Wonsi case also show that contract 2 minimises the private sector monetary loss compared to contract 1 (see Appendix F).

In addition, with this new traffic volume risk sharing scheme, both sectors can avoid the worst case scenario (the bankruptcy of the SPV and the failure of service provision) that could happen to a BTO project in Korea in the near future. Also, the suggestion seems to help prevent unanticipated consequences, such as the moral hazard of the private sector, which can occur in the MRG system and cap-and-collar mechanism by directly linking the effort to make revenue increase of the private sector to their profits. In terms of moral hazard, the MRG system could inflate the revenue stream of the project which is proposed by the private sector because inflated revenue means more profits for the private sector (Song, 2011), and the private sector can make profits without the effort to make the revenue increase given MRG conditions. With respect to the cap-and-collar mechanism, it can almost inevitably cause the moral hazard behaviour of the private sector by sharing revenue risk, which leads bidders to submit and win based on the tactics that have the chance of winning, requiring more generous terms for the train operation company (Kain, 2007) though rogue bids with excessively high revenue forecasts can be detected.

Using this new contract scheme, it seems that a BTO contract will be fairer and more reasonable for the both participants, and the BTO option will then be more attractive in the PPP market in Korea.

[124] In contract 2 (Loss (G) column), the loss of the public sector is zero when revenue ratio (actual/forecast) becomes 76.9 per cent.

[125] When revenue ratio (actual/forecast) becomes 74.8 per cent, the loss of the public sector in the MRG stepwise condition in contract 1 becomes equal to that in contract 2, which is 6.58 (billion KRW).

[126] When revenue ratio (actual/forecast) becomes 76.9 per cent, the loss of the public sector in contract 2 becomes equal to that in Gil's approach contract 1, the value of which is zero (billion KRW).

7.4.3 Impact on BTO viability

Generally speaking, the concept of IRR[127], shown in equation (6-1), is used by private investors to estimate and compare the profitability of a project in a capital investment decision. In particular, if the IRR of a project is equal or greater than the minimum acceptable rate of return, the project can be invested in by the private financial investors (Greer and Kolbe, 2003, Moyer et al., 2012). However, it is difficult to know the minimum acceptable rate of return for financial investors because it is not open to the public and considered as a confidential.

With respect to this, in order to assess the BTO viability of the National Expressways in Seoul metropolitan region, the Korea Research Institute for Human Settlements (KRIHS, 2008) suggested 5.0 per cent (real) as a minimum acceptable IRR for the BTO viability, based on the six suggested BTO projects[128]. Using this information, the BTO viability of three projects (the Suwon-Pyungtaek case, the Bongdam-Songsan case and the Sosa-Wonsi case) considering contract 2 scheme can be reviewed.

To begin with, in case of the Suwon-Pyungtaek case, it seems possible to be implemented by BTO option when using contract 2 is applied, though the IRR is reduced from 7.78 (contract 1 in Table 7-7) to 4.78 per cent (real) (contract 2 in Table 7-7), which is lower than 5 per cent (real). This is because most of revenue risk is reduced for the private sector, so this project using BTO option can be attractive to the private sector.

In case of the Bongdam-Songsan case, the IRR is reduced from 5.77 (contract 1 in Appendix F) to 2.7 per cent (real) (contract 2 in Appendix F). It seems difficult for this project to get BTO funding from the private sector because the IRR is too low even if most of the revenue risk is reduced for the private sector. This implies that the BTL option without traffic volume risk could be better than the BTO option including traffic volume risk. In addition, this result indicates that contract 2 (the suggestion) can be meaningful only when revenue stream is so sufficient that the BTO can be viable even if traffic volume risk is considered in estimating the IRR.

When it comes to the Sosa-Wonsi case, the IRR drops to a negative value when including traffic volume risk regardless of contract 1 and contract 2 (Appendix F). This means that the BTO is not viable for this project, which is in agreement with Chapter 6 (section 6.5).

[127] As show in equation (6-1), the IRR means the discount rate that the net present value of cash inflows equals to that of cash outflows.

[128] The six projects include Seoul-Choonchun, Suwon-Pyungtaek, Pyungtaek-Sihung, Incheon-Gimpo, Anyang-Sungnam and Yongin-Seoul.

7.5 The most favourable delivery option

National Highways

In the National Highway cases, when considering the transferable risks (completion delay, construction cost risk and traffic volume risk), the BTL option is more favourable than the conventional delivery for both the Todang-Gwansan case and the Dongup-Hanlim case. However, some different results were revealed when the Monte Carlo Simulations were conducted, considering eight other risks (three maintenance cost risks, construction deflator, consumer price index (CPI), five-year exchequer bond interest rate and three-year non-guaranteed corporate bond interest rate), as well as three transferable risks. Although the BTL option is still favourable in the Todang-Gwansan case, this is no longer the case in the Dongup-Hanlim case. This difference seems to occur because some analysis factors estimated by following Korea's BTL guidelines (MOSF, 2009a) differ considerably from their expected values (mean value), as derived from historical observations. For example, the five-year exchequer bond interest rate in the single-value estimation method is 3.77 per cent, while the historical observations produce 5.10 per cent as an expected value. As the five-year exchequer bond interest rate is directly related to BTL profitability, it can cause the Monte Carlo Simulation result of $M.VFM_{BTL}$ to drop considerably.

Therefore, it is hard to definitively determine whether the BTL or the conventional option is more favourable in the National Highway programme. Nevertheless, it seems reasonable, if possible, to apply the Monte Carlo Simulation using historical risk observations.

National Expressways

With respect to the National Expressway cases, when considering the transferable risks (completion delay, construction cost risk and traffic volume risk), PPP alternatives are better than the conventional option in terms of the Modified VFM. Between PPP alternatives, the BTO option is the most favourable for the Suwon-Pyungtaek case as well as the Bongdam-Songsan case. In addition, this result is also supported by the Monte Carlo Simulation results. However, when estimating the IRR considering traffic volume risk, the BTO viability of the Bongdam-Songsan seems difficult to be achieved.

Accordingly, it is difficult to definitely determine whether the BTO or the BTL is more favourable for the National Expressway programme. Nevertheless, it is possible to draw a careful conclusion that the BTO option is the most favourable for the National Expressway programme, provided that the BTO viability can be achieved in terms of the IRR when traffic volume risk is included.

National Railways

When it comes to the National Railways, theoretically the BTO seems to be the most favourable option, as for the National Expressway, if the revenue stream is so large that the BTO option can be an affordable option within the limitations of governmental subsidy. Unfortunately, however, the BTO option cannot be considered in the Bujeon-Masan case because this project cannot produce the required level of profitability for the BTO option however much governmental support is given. Similarly, in the Sosa-Wonsi case, the BTO option can show acceptable profitability only when the governmental subsidy is far beyond a reasonable level. For this reason, the BTL option is, in practice, the most favourable option when considering the risk factors.

7.6 Conclusion

As stated above, based on the results of risk quantification and the six case studies, this chapter has examined the impact of the three transferable risks (completion delay, construction cost risk and traffic volume risk) on the Modified VFM and the procurement option selection. The main conclusions are outlined below.

First and most importantly, from the viewpoint of a quantitative PPP decision, it is reasonable to consider a completion delay in the conventional delivery regarding the respective transport programme when estimating the Modified VFM. As the completion delay in the conventional delivery lengthens, the PPP options become more favourable than the conventional delivery and between PPP options the BTO becomes more favourable than the BTL option when a project has an acceptable BCR. In addition, the critical completion delay, making the Modified VFM zero, also seems to be used effectively by the public sector in managing a project, as well as in making a procurement option selection. Other than that, according to the master plan of PPP (MOSF, 2009b) of Korea, a PPP option already decided for a project can be replaced with a conventional option and vice versa when it is difficult to conduct the already decided option. However, there are no examples that a PPP option is replaced with a conventional option seemingly because there are not clear criteria for the decision change. The concept of critical completion delay can be used as one of the decision change criteria when it is necessary.

In addition, with respect to construction cost risk, when using an average turn-key/alternative bid ratio, as is suggested by Korea's BTL guidelines (MOSF, 2009a), the viability of PPP options is exaggerated in roads but underestimated in railways, compared with when using an application ratio from the historical observations. Thus, for a more convincing PPP decision, it seems reasonable to use an application ratio reflecting the historical observations in estimating the Modified VFM.

Traffic volume risk also has a great influence on the choice of PPP options of transport programmes with tariffs such as the National Expressways and the National Railways. The most favourable delivery option changes from BTL to BTO in selecting PPP options when traffic volume risk is included. This is mainly because traffic volume risk directly means a shortfall of revenue, which, as a consequence, makes the BTO option more favourable. However, when including traffic volume risk, the BTO viability of the Bongdam-Songsan case does not seem to be achieved, implying that BTL could be better than the BTO for this project. In addition, in the railway cases, the BTL option can be a practical alternative because their revenue stream is so small that the BTO option is not affordable, even considering the maximum governmental subsidy condition.

Finally, it is also important that, considering that the private sector cannot, in practice, take on the traffic volume risk in its entirety, a new BTO contract scheme with traffic volume risk sharing is suggested for BTO projects in Korea, one using a reduced revenue stream considering traffic volume risk and sharing the revenue shortfall or excess according to the investment level of each participant. With this scheme, it seems that a BTO contract will be fairer and more reasonable for all the participants, and the BTO option can be more attractive in the PPP market in Korea.

CHAPTER 8 Meta-analysis

8.1 Introduction

To date, in Chapters 4, 5 and 6, through the six case studies from three transport programmes (the National Highway, the National Expressway and the National Railway), it has been shown how the Modified VFM results and PPP decisions can be changed depending on whether the transferable risks, such as completion delay, construction cost risk and traffic volume risk, are included or not. In addition, in Chapter 7, through a case or programme-specific analysis, the impact of the transferable risks on PPP decision in each transport programme has been scrutinised and the most favourable option for each transport programme has also been dealt with.

In this chapter, in order to draw a more generalised and transferable conclusion on the land transport programmes (including roads and railways), meta-analysis is used. There are three reasons for using meta-analysis: 1) to examine the impact of qualitative variables as well as quantitative variables on the Modified VFM, 2) to scrutinise the elasticity of the Modified VFM with respect to explanatory variables, and 3) to probe interaction effects on the Modified VFM among explanatory variables. A detailed literature review on meta-analysis is given in Section 3.7. This chapter is largely composed of five sections, covering the research objective 3-1; 1) meta-analysis (8.2), 2) data collection (8.3), 3) identification of the relevant variables (8.4), 4) regression model (8.5), and 5) estimation results (8.6).

Using meta-regression analysis, based on 216 Modified VFM values with various conditions from six cases, the impact of some quantitative and qualitative variables on the Modified VFM in the land transport programme (roads and railways) of Korea is examined, including the direction and magnitude of the impact. By estimating the relationship between quantitative/qualitative causes and effects through meta-regression models, some valuable insights and conclusions will be drawn in the later part of this chapter.

In order to verify the direction and size of causes on the Modified VFM values from the six case studies in the land transport programme, the STATA-based meta-regression algorithm (*metareg*) using the random-effects meta-regression model is employed.

8.2 Meta-analysis

The six case studies on the National Highways, the National Expressways and the National Railways, reveal many important findings on the different transport programmes. However, in spite of the importance of these findings, they are all restricted to the specific case studies or programmes. Thus, this chapter suppose an imaginary land transport programme, including roads and railways. Though the land transport programme does not exist in the budgetary investment programmes in Korea, sometimes the government needs to explain the relationship between the land transport and the PPPs with respect to the budget examination in the National Assembly.

Accordingly, this research needs to synthesise the results from the six case studies in order to extract some more generalised or transferable findings for land transport systems in Korea – in essence taking a specific to general approach. This is different from the more usual application of meta-analysis which is usually used to define key impact variables and to draw transferable conclusion from a mass of previous studies where the relationships between cause and effect are little known - which is akin to a general to specific approach.

This research adopts a specific to general methodology to achieve three objectives: 1) to examine influence factors of the Modified VFM and their impacts, 2) to scrutinise influence factor elasticity of the Modified VFM, and 3) to probe interaction effects on the Modified VFM among influence factors. The way of using meta-analysis in the thesis is different from the usual way, in that meta-analysis in the thesis uses the results of six case studies where the relationships of cause and effect are already known. However, the objectives to be obtained in this chapter cannot be achieved by specific case studies.

In this chapter, the research employs the random-effects meta-regression technique (see Section 3.7 for literature review). From the viewpoint of the land transport programme (roads and railways) of Korea, the quantitative and qualitative causes of the Modified VFM are reviewed. In addition, the relationship between the Modified VFM (effects) and the causes, such as direction, magnitude, elasticity and interaction effects will be scrutinised using meta-analysis.

8.3 Data collection

The effect value in this meta-analysis is the Modified VFM, so 216 Modified VFM values with various conditions are collected from the six case studies. As stated in the previous three chapters, the Modified VFM values with various analysis factors were calculated by taking into account whether construction cost risk or traffic volume risk are included or not and for how long a completion delay in the conventional delivery occurs. Regarding transferable risk inclusion and completion delay, the numbers of cases used in estimating the Modified VFM are respectively four and six for each project with a PPP option, so the number of the Modified VFM values becomes 24 in total in each project with a PPP option. The details and descriptive statistics of subgroups are shown in Table 8-1.

As can be seen from Table 8-1, total data collection is composed of nine subgroups with different projects and PPP options. In order to use the *metareg* (STATA-based meta-regression algorithm for the random-effects meta-regression), a standard error data set for each effect size (the Modified VFM value in this case) is needed, so it is assumed that each Modified VFM value has a standard error of the subgroup that it belongs to.

Table 8-1: Number of Modified VFM values in the meta-analysis

Programme	Project	PPP option	No. of M.VFM	Descriptive statistics (billion KRW)				
				Mean	Median	Max.	Min.	S.D.
National Highway	Todang-Gwansan	BTL	24	34.26	35.95	76.90	-4.40	22.88
	Dongup-Hanlim	BTL	24	9.83	9.31	30.01	-7.25	9.92
National Expressway	Suwon-Pyungtaek	BTL	24	266.74	236.60	620.70	8.00	177.38
		BTO	24	272.57	255.45	629.50	-104.60	208.54
	Bongdam-Songsan	BTL	24	43.95	40.05	103.00	-1.40	28.39
		BTO	24	59.72	69.70	156.90	-56.60	58.80
National Railway	Sosa-Wonsi	BTL	24	107.79	103.50	265.30	-20.80	82.90
		BTO	24	185.10	216.80	322.70	-31.10	95.85
	Bujeon-Masan	BTL	24	34.17	36.40	49.03	14.08	11.14
Total			216	112.68	52.20	629.50	-104.60	140.57
Remark	1. The cases regarding risk inclusion: 1) No risk inclusion, 2) Only construction cost risk inclusion, 3) Only traffic volume risk inclusion, and 4) Construction cost risk + traffic volume risk inclusion 2. The cases regarding completion delay: 1) No delay, 2) 1 year delay, 3) 2 year delay, 4) 3 year delay, 5) 4 year delay, and 6) The average delay from historical observations							

8.4 Identification of the relevant variables

8.4.1 Quantitative variables

Given the reason why a meta-analysis is used, the dependent variable in the random-effects regression model (equation (3-21)) should be the Modified VFM value (billion KRW). In order to examine the impact of the causes on the Modified VFM, both quantitative and qualitative independent variables are considered in the meta-regression.

The quantitative independent variables mean the quantified characteristics of a project or common elements in the calculation of the Modified VFM in the BTL and the BTO option. Therefore, the quantitative variables include project size, completion delay, BCR, discount rate, CPI, five-year exchequer bond interest rate, application ratio for the construction cost calculation of the PSC, and traffic volume ratio (actual traffic volume/forecast traffic volume). The descriptive statistics for the quantitative variables are shown in Table 8-2.

Table 8-2: Descriptive statistics for the quantitative variables

	Project size (km)	Completion delay (year)	BCR	Discount rate (%)
Number of data	216	216	216	216
Mean	23.23	2.05	1.57	6.39
Median	23.3	2	1.17	6.5
Maximum	38.5	4	2.72	7.5
Minimum	7.29	0	0.63	5.5
Standard deviation	10.77	1.35	0.72	0.88
	CPI (%)	**5 year exchequer bond interest (%)**	**Application ratio (%)**	**Traffic volume ratio (%)**
Number of data	216	216	216	216
Mean	3.23	5.45	85.56	81.33
Median	2.99	5.4	84.57	84.32
Maximum	3.77	6.9	93.03	100
Minimum	2.92	3.38	78.8	50.71
Standard deviation	0.31	1.17	5.18	19.65

8.4.2 Qualitative variables

Aside from various quantitative variables, several qualitative variables are examined in terms of their impact on the Modified VFM. Qualitative variables include transport mode, PPP option and region. Decision-making year can also be used as a qualitative variable, though it is not considered in this research because it is difficult to find a meaningful reference year that categorises decision-making times.[129] Descriptive statistics for qualitative variables are shown in Table 8-3.

Transport mode

This variable is introduced to make it possible to examine which transport mode between roads and railways has more influence on the Modified VFM. Thus, 216 data sets from six case studies are categorised into road (144 sets) and railway (72 sets). As seen in Table 8-3, road data sets have a Modified VFM of 114.5 (billion KRW) on average, which is slightly higher than the figure for the railway data sets. In addition, the standard deviation of the Modified VFM (158.7) in road data sets is much higher than that in railways data sets (95.4). In the meta-regression, dummy values of 0 and 1 are assigned to roads and railways respectively.

Table 8-3: Descriptive statistics for the quantitative variables

(Unit: billion KRW)

Variables		Number (Modified VFM)	Mean (Modified VFM)	S. D. (Modified VFM)
Transport mode	Road	144	114.51	158.69
	Railway	72	109.02	95.36
	Total	216	112.68	140.57
PPP option	BTL	144	82.79	118.9
	BTO	72	172.46	161.01
	Total	216	112.68	140.57
Region	Gyeonggi	168	138.59	149.42
	Gyungnam	48	22.00	16.13
	Total	216	112.68	140.57

PPP option

The PPP option can also have a different impact on the Modified VFM. Thus, 216 data sets from the six case studies are categorised into BTL (144 sets) and BTO (72 sets). As shown in Table 8-3, the Modified VFM using the BTL option has a Modified VFM of 82.8 (billion KRW) on average, which is lower than the figure obtained when using the BTO option (172.5). In

[129] On the one hand, the use of decision making time does not seem to need to be included as one of qualitative variables because some quantitative variables such as discount rate, consumer price index and five-year exchequer bond interest rate already consider the effect of decision-making time. In addition, considering the decision-making time in the six cases is the relatively short term (from 2002 to 2009), the detailed grouping using four different decision-making times (the Todang-Gwansan case: 2002, the Dongup-Hanlim case: 2011, The Suwon-Pyungtaek case: 2002, The Bongdam-Songsan case: 2009, The Sosa-Wonsi case: 2007, and the Bujeon-Masan case: 2009) does not seem to lead to meaningful insight.

addition, the standard deviation of the Modified VFM in BTL data sets (118.9) is also lower than that in BTO data sets (161.0). For the meta-regression, dummy values of 0 and 1 are assigned to BTL and BTO respectively.

Region

The locations of the six case studies are largely divided into two categories, as seen in Figure 3-4, with all being in either Gyeonggi Province or Gyungnam Province. As with other qualitative variables, using this variable the impact from regional difference on the Modified VFM can be estimated. Two hundred and sixteen data sets from six case studies are divided into Gyeonggi (168 sets) and Gyungnam (48 sets). As seen in Table 8-3, there is a very broad distinction between the two regions. The Modified VFM in Gyeonggi Province is 138.6 (billion KRW) on average, which is much higher than in Gyungnam Province (22.0). Additionally, the standard deviations in the two regions also show similar results. With respect to meta-regression, dummies of 0 and 1 are assigned to Gyeonggi and Gyungnam provinces respectively.

8.5 Regression model

Using eight quantitative variables and three qualitative variables, a multivariate regression model can be constructed. In this research, a basic regression model explaining the relationship between dependent variable and independent variables is selected by comparing the goodness of fit values (adjusted R-square values in this study) among five candidate models. Firstly, full transformation models are considered by taking various transformations between dependent variable and all independent variables: 1) linear-linear, 2) log[130]-linear, 3) linear-log and 4) log-log. In addition, a mixed transformation model is considered by examining the relationship between dependent variable and each independent variable based on the R-square table and scatter plots (Appendix H). Considering R-square value and scatter plots between dependent variable and each independent variable, for most independent variables linear-linear seems appropriate, however log-linear seems to appropriate for CPI and traffic volume ratio[131]. Using these results, a mixed transformation model with linear terms and exponential terms can be constructed. Adjusted R-square values in regard to the five candidate models are shown in Table

[130] Some Modified VFMs are negative values, so double of the absolute value of the lowest Modified VFM is added to all the Modified VFM before log-transformation.

[131] The transformation shows that the highest R-square or best fit between the Modified VFM and each explanatory variable (Appendix H).

8-4 (Appendix G). As the linear-linear model shows the highest adjust R-square (0.7509), this model is selected as a basic regression model.

Table 8-4: Adjust R-square values for five candidate regression models

	Full transformation				Mixed transformation
	Linear-Linear	Log-Linear	Linear-Log	Log-Log	
Adj-R^2	0.7509	0.7431	$<10^{-4}$	$<10^{-4}$	0.7508

However, when conducting meta-regression with 11 variables using the *metareg*, it is shown that among three variables (BCR, discount rate and CPI) there is a collinearity[132] problem (see Appendix I), which occurs when variance inflation factor (VIF[133]) is more than 10 (StataCorp, 2013). Accordingly, these three variables cannot be included simultaneously in a regression model because a regression result cannot be trusted when there is a collinearity problem (Kennedy, 2003). Inevitably, therefore, three different regression models, including one variable among BCR (model 1), discount rate (model 2) and CPI (model 3), are used for meta-regression.

Consequently, the regression model in this research can be expressed as follows:

M.VFM = f (length, completion delay, BCR or discount rate or CPI, five-year exchequer bond interest rate, application ratio, traffic volume ratio, transport mode, PPP option, region)$+\epsilon$

namely:

$$M.VFM = \beta_0 + \overbrace{\beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6}^{\text{Quantitative variables}} + \underbrace{\beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9}_{\text{Qualitative variables}} + \epsilon \qquad (8\text{-}1)$$

where $\beta_0, \beta_1 \ldots \beta_9$ = the regression coefficients composing the vector β, X_1= project size (km), X_2 = completion delay (year), X_3= BCR or discount rate (per cent) or CPI (per cent), X_4= five-

[132] Collinearity means that there is an exact or similar linear relationship between two independent variables. The reason for the existence of collinearity in this research seems to come from the fact that all data set is from only six cases, so each explanatory variable is categorised into less than or equal to six. In the *metareg* package, when there is a collinearity problem between variables, the variables causing this are automatically dropped. The results showing collinearity are included in Appendix I.

[133] VIF = 1 / (1-R_j^2), where R_j^2 is the coefficient of determination of a regression regarding independent variable j.

year exchequer bond interest rate (per cent), X_5= application ratio (per cent), X_6= traffic volume ratio (per cent), X_7 = dummy variable for transport mode (road = 0, railway =1), X_8= dummy variable for PPP option (BTL = 0, BTO =1), X_9= dummy variable for region (Gyeonggi Province = 0, Gyungnam Province =1), and ϵ = the error term.

The coefficient of each quantitative variable with linear relationship in equation (8-1) explains how much the Modified VFM changes according to the unit change of each independent variable. With respect to the coefficients of the qualitative variables, they show the direction and size of the impact of a variable on the Modified VFM, as compared with the reference group. In addition, this regression model can be extended in order to examine interaction effects between explanatory variables by adding interaction terms.

8.6 Estimation results

Using three regression models, meta-regression analysis was conducted and the results obtained are shown in Table 8-5. The adjusted R-square of the regression is equal to 0.75 in each regression analysis, which gives strong evidence of the satisfactory fit of the regression. From Table 8-5, it can be seen that six out of the nine variables in the regression model are statically significant at the 5 per cent significance level. Those are project size, completion delay, BCR of model 1 (discount rate of model 2, CPI of model 3), five-year exchequer bond interest rate, PPP option, and region. As shown in Table 8-5, the existence of between-study variance (τ^2) supports the finding that it is proper to use the random-effects model allowing for residual heterogeneity (Debrezion et al., 2007) .

8.6.1 Quantitative variables

With respect to quantitative variables, first of all the length of the project has a statistically significant impact on the Modified VFM in land transport projects. Table 8-5 shows that as project size increases by 1 km the Modified VFM increases by 5.2 to 8.5 (billion KRW), depending on the regression model being used.

Completion delay in the conventional delivery also has a statically significant impact on the Modified VFM in land transport projects, which can be expected from the six case studies. As the length of the completion delay lengthens, the Modified VFM increases 44.9 (billion KRW) per year, which is given by all the regression models.

When it comes to BCR, discount rate and CPI in models 1, 2 and 3 respectively, their unit increases produce positive change (or percentage change) of the Modified VFM in land transport projects, as shown in Table 8-5. The result on BCR and discount rate can be inferred from sensitivity analysis (e.g. Figure 4-11) on the six case studies. From Figure 4-11, the Modified VFM increases according to the increase of BCR or discount rate or CPI, indicating that the signs of each explanatory variable's coefficient are positive values. The signs of the coefficient of BCR is also known from the Modified VFM equations (3-7 ~ 3-9), showing that as BCR increases the Modified VFM increases. As BCR increases by 0.1, the Modified VFM goes up as much as 16.5 (billion KRW). In addition, a 1 per cent increase in the discount rate and CPI respectively means a 137.8 (billion KRW) increase and 255.9 (billion KRW) increase in the Modified VFM.

The five-year exchequer bond interest rate shows a statistically significant impact on the Modified VFM in land transport projects as well. The result can also be inferred from sensitivity analysis (e.g. Figure 4-11) on the six case studies. According to the Korea's BTL guideline (MOSF, 2009a), BTL lease profitability to the private sector is expressed as "five-year exchequer bond interest rate + mark-up rate" (see Section 4.3.2 and footnote 45), thus the increase of five-year exchequer bond interest rate means the increase of BTL lease profitability to the private sector. Accordingly, from Figure 4-11, the Modified VFM decreases according to the increase of BTL lease profitability, indicating that the sign of the coefficient of five-year exchequer bond interest rate is a negative value. A 1 per cent increase in the five-year exchequer bond interest rate causes the Modified VFM to decrease by between 38.0 and 104.6 (billion KRW) depending on the regression models.

Other than that, the traffic volume ratio and application ratio respectively have a positive influence on the Modified VFM in the land transport programme. The results show that a 1 per cent increase in the traffic volume ratio and application ratio for the calculation of the asset cost in the PSC respectively produce 0.3 and 3.2 (billion KRW) in the Modified VFM. However, they do not show a statically significant impact on the Modified VFM in land transport projects at the 5 per cent significance level.

8.6.2 Qualitative variables

With respect to the qualitative variables, first of all the coefficient for transport mode is positive or negative depending on the regression model, which means that the transport mode does not show a consistent direction or size regarding its impact on the Modified VFM. In other words, from a statistical viewpoint, it is impossible to say which transport mode – road or rail – has a greater impact on the Modified VFM.

Table 8-5: Estimation results using three regression models[134]

Variables		Model	Coefficients	Std. Err.	t statistics	p statistics
X_1	Project size (km)	1	5.240	1.059	4.950	0.000
		2	8.515	0.944	9.020	0.000
		3	8.515	0.944	9.020	0.000
X_2	Completion delay (year)	1	44.885	3.722	12.060	0.000
		2	44.885	3.722	12.060	0.000
		3	44.885	3.722	12.060	0.000
X_3	BCR	1	164.929	23.462	7.030	0.000
	Discount rate (%)	2	137.802	19.603	7.030	0.000
	CPI (%)	3	255.947	36.410	7.030	0.000
X_4	5 year exchequer bond interest rate (%)	1	-65.070	12.174	-5.340	0.000
		2	-104.559	16.645	-6.280	0.000
		3	-38.013	9.817	-3.870	0.000
X_5	Application ratio (%)	1	3.223	3.193	1.010	0.314
		2	3.223	3.193	1.010	0.314
		3	3.223	3.193	1.010	0.314
X_6	Traffic volume ratio (%)	1	0.297	0.260	1.150	0.253
		2	0.297	0.260	1.150	0.253
		3	0.297	0.260	1.150	0.253
X_7	Transport mode	1	63.844	44.352	1.440	0.152
		2	-63.121	34.677	-1.820	0.070
		3	47.346	42.788	1.110	0.270
X_8	PPP option	1	34.581	12.499	2.770	0.006
		2	34.581	12.499	2.770	0.006
		3	34.581	12.499	2.770	0.006
X_9	Region	1	-93.832	21.560	-4.350	0.000
		2	-100.272	21.599	-4.640	0.000
		3	-210.739	27.503	-7.660	0.000
	(Constant)	1	-316.816	260.031	-1.220	0.224
		2	-755.823	238.383	-3.170	0.002
		3	-1,077.293	232.105	-4.640	0.000

(Note) No. of data = 216, between study variance (τ^2) = 4470, Adjusted R^2 = 75.09%

[134] More detailed regression results are to be found in Appendix J.

In addition, the coefficient for the PPP option is positive, indicating that the impact of BTO on the Modified VFM is greater than BTL (the base group in the estimation). More specifically, the Modified VFM using a BTO option is expected to be 34.6 (billion KRW) larger than the figure obtained using a BTL option in the land transport projects, which is also statistically significant at the 1 per cent significance level.

The results also show that the Modified VFM in the land transport programme is clearly affected by the regional factor. The coefficient for region is negative, meaning that the impact of Gyeonggi Province as the project location on the Modified VFM is greater than that of Gyungnam Province. In other words, the Modified VFM of a project in Gyeonggi Province is expected to be from 93.8 to 210.7 (billion KRW) larger than in Gyungnam Province, depending on the regression model. The result seems to be related to the regional difference of population and car ownership though there could be various and complex causes. Gyeonggi Province and Seoul surrounding Gyeonggi Province are much larger than Gyungnam Province and neighbouring Busan in terms of population and car ownership.[135]

8.6.3 Elasticity

As a tool for measuring how the Modified VFM changes with respect to the change of an explanatory variable, elasticity can be used. Elasticity can usually be defined as the ratio of proportionate change (percentage change) in an independent variable to the proportionate change (percentage change) in an explanatory variables (Brons et al., 2008, Taylor, 2009). Accordingly, using mean values of each variables, the elasticity of the Modified VFM (E_i) with respect to explanatory variables (X_i) can be expressed as follows;

$$E_i = \frac{\frac{\partial M.VFM}{M.VFM}}{\frac{\partial X_i}{X_i}} = \frac{\partial M.VFM}{\partial X_i} \cdot \frac{X_i}{M.VFM} \tag{8-2}$$

[135] The population, population density and car ownership of Gyeonggi and Seoul are about three times greater than the figures for Gyungnam and Busan.

	Gyeonggi	Seoul	Gyungnam	Busan
Population (persons)	12,093,299	10,195,318	3,319,314	3,538,484
Population density (persons/km^2)	1,119	16,189	300	4,452
Car ownership (cars)	3,496,083	2,455,274	1,138,044	928,401

Source: http://kostat.go.kr (retrieved on 28 May 2013)

Considering the regression coefficients (β_i) in equation (8-2) and the mean values ($\bar{X}_i, \overline{M.VFM}$) of the variables from Table 8-1 to Table 8-3, point elasticity of Modified VFM with respect to explanatory variable can be defined as follows;

$$E_i = \beta_i \cdot \frac{\bar{X}_i}{\overline{M.VFM}} \tag{8-3}$$

Based on equation (8-3), the elasticity of the Modified VFM with respect to explanatory variables is calculated in Table 8-6 according to the models. In Table 8-6, the elasticity of dummy variables (transport mode, PPP option and region) is excluded because it is difficult to give it a special meaning when the variables are not continuous.

The regression coefficients in shaded cells mean that they are statistically significant at the 1 per cent significance level according to Table 8-5 and elasticities using them are also shaded. As seen in Table 8-6, considering shaded cells, project size, completion delay, BCR, discount rate and CPI have a positive elasticity, which means that the Modified VFM increases according to the rise of these variables. In addition, discount rate, CPI, BCR and project size have an elasticity of more than 1, which means that when these variables go up 1 per cent, the Modified VFM goes up more than 1 per cent. In particular, the impact of discount rate and CPI on the Modified VFM is most influential, showing an elasticity of 7.81 (discount rate) and 7.34 (CPI).

Table 8-6: Elasticity of the Modified VFM with respect to explanatory variables

Variables	Mean values	β_i			Elasticity		
		Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
X_1	23.23	5.24	8.52	8.52	1.08	1.76	1.76
X_2	2.05	44.89	44.89	44.89	0.82	0.82	0.82
X_3	1.57[1] (6.39[2] or 3.23[3])	164.93	137.80	255.95	2.30	7.81	7.34
X_4	5.45	-65.07	-104.56	-38.01	-3.15	-5.06	-1.84
X_5	85.56	3.22	3.22	3.22	2.45	2.45	2.45
X_6	81.33	0.30	0.30	0.30	0.21	0.21	0.21
X_7	0.33	63.84	-63.12	47.35	-	-	-
X_8	0.33	34.58	34.58	34.58	-	-	-
X_9	0.22	-93.83	-100.27	-210.74	-	-	-
$M.VFM$	112.68						

(Note) 1. Mean value of BCR in Model 1. 2. Mean value of discount rate in Model 2, 3. Mean value of CPI in Model 3.

On the contrary, five-year exchequer bond interest rate has a negative elasticity, meaning that the Modified VFM decreases according to the rise of this variable. The absolute value of elasticity of five-year exchequer bond interest rate is between 1.84 and 5.06 (more than 1) depending on models, which is very elastic. In addition, regarding dummy variables, as discussed earlier, PPP option has a positive impact on the Modified VFM whereas region has a negative impact on the Modified VFM when these variables go up from 0 to 1. On the other hand, it is difficult to say the direction of the impact of transport mode on the Modified VFM because the signs of the regression coefficient vary according to the models.

Consequently, the most influential factors on the Modified VFM in the imaginary land transport in Korea are discount rate, CPI and five-year exchequer bond interest rate. Therefore, when estimating the Modified VFM, the choice of discount rate, CPI and five-year exchequer bond interest rate seems to be critical in PPP decisions in the land transport.

8.6.4 Interaction effects

Two way interactions

Interaction effects were examined based on the model 1 using BCR, referring to the correlation matrix shown in Appendix H: BCR is selected among the variables (e.g. BCR, discount rate and CPI) that are collinear because it has the highest correlation with the Modified VFM.

Six variables (i.e. length, completion delay, BCR, five-year exchequer bond interest rate, PPP option and region) are selected for the meta-regression including interaction effects because they have high correlation coefficients with statistically significant p-values, which are shown in Table 8-5. All the possible two way interaction effects based on the six variables (in total 15 cases) were examined and the results are given in Appendix K. The results show that there are five cases that increase explanatory power (adjusted R-square) of the model as well as producing statistically significant estimates at the 1 per cent level: 1) length and completion delay, 2) completion delay and BCR, 3) completion delay and five-year exchequer bond interest rate, 4) completion delay and PPP option, and 5) completion delay and region.

The important implication is that the statistically significant interaction effects are all related to completion delay. Accordingly, it seems that completion delay is not only meaningful as a single explanatory variable, but also plays an important role in reducing information set of five other explanatory variables in regard to the Modified VFM. In particular, the interaction effects of completion delay are remarkable when it is combined with length, PPP option and region. In other words, regarding the three explanatory variables, their explanatory power on the Modified VFM related to completion delay is greater than their individual explanatory power on the Modified VFM.

The best interaction model can be composed by adding these five two way interaction terms to the basic regression model (equation (8-1)) as follows:

$$M.VFM = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_1 X_2 + \beta_{11} X_2 X_3 + \beta_{12} X_2 X_4 + \beta_{13} X_2 X_8 + \beta_{14} X_2 X_9 + \epsilon \quad (8\text{-}4)$$

The estimation results are given in Table 8-7. As seen in Table 8-7, by adding two way interaction terms to a basic regression model (equation (8-1)), the explanatory power is improved by approximately 26 per cent[136].

Table 8-7: Estimation results using two way interaction terms

Variables	Coefficients	Std. Err.	t statistics	p statistics
X_1	0.204	0.685	0.300	0.766
X_2	-4.310	13.886	-0.310	0.757
X_3	58.911	15.048	3.910	0.000
X_4	-29.882	9.115	-3.280	0.001
X_5	2.922	1.557	1.880	0.062
X_6	0.270	0.126	2.130	0.034
X_7	67.328	21.626	3.110	0.002
X_8	-4.348	11.513	-0.380	0.706
X_9	-29.545	16.496	-1.790	0.075
X_1X_2	2.569	0.219	11.710	0.000
X_2X_3	55.576	4.847	11.460	0.000
X_2X_4	-17.097	3.359	-5.090	0.000
X_2X_8	20.258	4.751	4.260	0.000
X_2X_9	-26.623	6.176	-4.310	0.000
(Constanct)	-205.840	129.851	-1.590	0.114

(Note) No. of data = 216, between study variance (τ^2) = 926.3, Adjusted R^2 = 94.84%

From Table 8-7, the Modified VFM changes according to the unit change of the six independent variables (e.g. project size, completion delay, BCR, five-year exchequer bond interest rate, PPP option and region), which show statistically significant p-values in Table 8-5, can be determined as follows:

136 (94.84-75.09)/75.09 = 0.263

$$\frac{\partial M.VFM}{\partial X_1} = 0.204 + 2.569X_2 \tag{8-5}$$

$$\frac{\partial M.VFM}{\partial X_2} = -4.310 + 2.569X_1 + 55.576X_3 - 17.097X_4 + 20.258X_8 - 26.623X_9 \tag{8-6}$$

$$\frac{\partial M.VFM}{\partial X_3} = 58.911 + 55.576X_2 \tag{8-7}$$

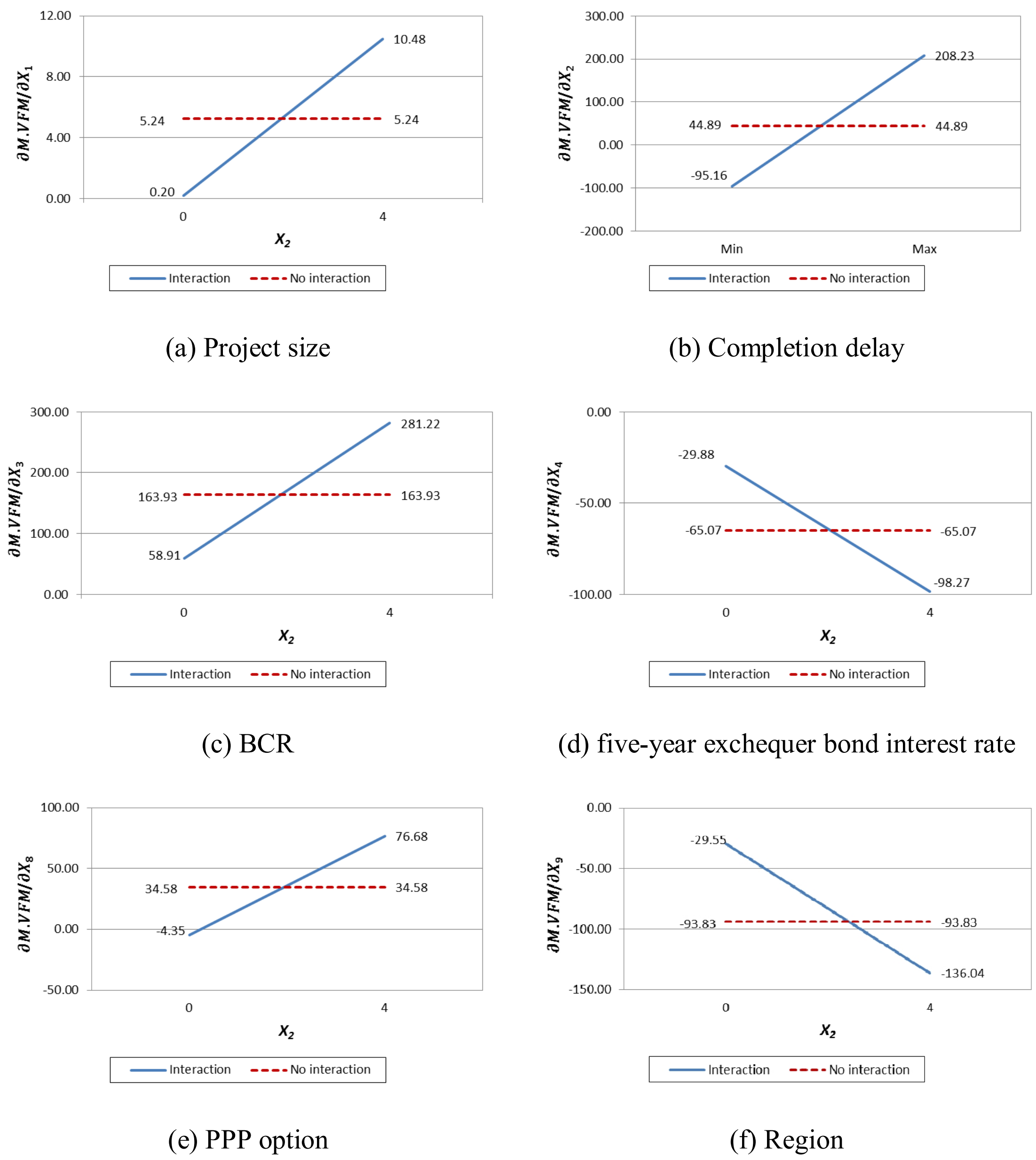
$$\frac{\partial M.VFM}{\partial X_4} = -29.882 - 17.097X_2 \tag{8-8}$$

$$\frac{\partial M.VFM}{\partial X_8} = -4.348 + 20.258X_2 \tag{8-9}$$

$$\frac{\partial M.VFM}{\partial X_9} = -29.545 - 26.623X_2 \tag{8-10}$$

Based on equation (8-5) ~ (8-10), using the minimum and maximum values of the independent variables shown in Table 8-2, the Modified VFM change according to the unit change of each variable is given in Figure 8-1. In Figure 8-1, dot lines mean the Modified VFM change according to the unit change of each variable without interaction effects as given in Table 8-5. In addition, solid lines indicate the Modified VFM change according to the unit change of each variable with interaction effects and the values by the line mean the minimum and maximum value respectively.

As seen from equation (8-5) to equation (8-10) and Figure 8-1, the Modified VFM changes according to the unit change of project size, BCR, five-year exchequer bond interest rate, PPP option and region are all affected by completion delay. In particular, as completion delay increases, the Modified VFM changes according to the unit change of project size, BCR and PPP option increase, whereas the Modified VFM changes according to the unit change of those are five-year exchequer bond interest rate and region decrease.



(a) Project size

(b) Completion delay

(c) BCR

(d) five-year exchequer bond interest rate

(e) PPP option

(f) Region

Figure 8-1: The Modified VFM change according to the unit change of each variable

With respect to project size (Figure 8-1 (a)), looking at project size and BCR in Table 7-3, two among three programmes (67 per cent) show that the bigger project size is, the higher is the BCR. This means that it is possible that a project with bigger size has a bigger social benefit difference according to completion delay. Therefore, the Modified VFM change with respect to the unit change of project size has a positive slope according to completion delay.

In addition, with respect to BCR (Figure 8-1 (b)), it seems natural that the Modified VFM change with respect to the unit change of BCR has a positive slope according to completion delay.

When it comes to five-year exchequer bond interest rate (Figure 8-1 (d)), it is shown that the Modified VFM changes with respect to the unit change of five-year exchequer bond interest rate decreases according to completion delay. Five-year exchequer bond interest rate can affect the Modified VFM by influencing three items in the Modified VFM: 1) the total interest composing asset cost in the PSC that government needs to pay to delivery construction cost by issuing five-year exchequer bond, 2) the government subsidy in the BTO, which is delivered by issuing the bond, and 3) the lease fee in the BTL (BTL lease profitability for private sector is composed of five-year exchequer bond interest rate and mark-up rate). Among these three items, the government subsidy in the BTO and the lease fee in the BTL do not change according to completion delay in the conventional delivery. However, the total interest in real terms that government needs to pay decreases according to completion delay due to the discounting effect, though the total interest in nominal terms does not change according to completion delay. Therefore, the Modified VFM change with respect to the unit change of the five-year exchequer bond interest rate has a negative slope according to completion delay.

Similarly, the signs of the slopes in Figure 8-1 (e) and (f) also can be explained using the change of social benefit difference according to completion delay. From Table 8-3, the values of Modified VFM in the BTO option is bigger than in the BTL option. In addition, a BTO project needs a bigger transport demand (or traffic volume), which is directly related to social benefit size according to the empirical relationship (equation (4-2) and (6-2)). Accordingly, the Modified VFM change with respect to the unit change of PPP option (from BTL to BTO) has a positive slope according to completion delay (Figure 8-1 (e)).

In addition, with respect to region (Figure 8-1 (f)), it is possible that a project in Gyeonggi province has a bigger social benefit that Gyungnam province according to Table 8-3. Therefore, the Modified VFM change with respect to the unit change of region (from Gyeonggi to Gyungnam) has a negative slope according to completion delay in the conventional delivery.

Consequently, completion delay in the conventional delivery can play an important role in making interaction effects with other variables in PPP decisions, by increasing social benefit difference between the PSC and PPP options and public sector cost in the PSC. Therefore, it is reasonable to include completion delay in the conventional delivery in the quantitative PPP decision in Korea.

Elasticity considering interaction effects

Using equation (8-5) ~ (8-10), point elasticity of the modified VFM with respect to some variables such as project size, completion delay, BCR, five-year exchequer bond interest rate, PPP option and region can be newly calculated, which is shown in Table 8-8.

Table 8-8: Elasticity of the Modified VFM considering two way interactions (Model 1)

Variables	$\bar{X}$	Elasticity $\left(\frac{\partial \mathrm{M.VFM}}{\partial \mathrm{X}_i}\frac{\bar{X}_1}{M.VFM}\right)$	
		Calculations	Results
X_1	23.23	$(0.204 + 2.569\bar{X}_2) \times \frac{\bar{X}_1}{M.VFM}$	1.13
X_2	2.05	$(-4.310 + 2.569\bar{X}_1 + 55.576\bar{X}_2 - 17.097\bar{X}_4 + 20.258\,\bar{X}_8 - 26.623\,\bar{X}_9) \times \frac{\bar{X}_2}{M.VFM}$	0.91
X_3	1.57	$(58.911 + 55.576\bar{X}_2) \times \frac{\bar{X}_3}{M.VFM}$	2.41
X_4	5.45	$(-29.882 - 17.097\bar{X}_2) \times \frac{\bar{X}_4}{M.VFM}$	-3.14
X_8	0.33	$(-4.348 + 20.258\bar{X}_2) \times \frac{\bar{X}_8}{M.VFM}$	0.11
X_9	0.22	$(-29.545 - 26.623\bar{X}_2) \times \frac{\bar{X}_9}{M.VFM}$	-0.17

As seen in Table 8-8, project size, completion delay, BCR and PPP option have a positive elasticity respectively, which means that the Modified VFM increases according to the rise of these variables. In addition, BCR and project size have an elasticity of more than 1, which means that when these variables go up 1 per cent, the Modified VFM goes up more than 1 per cent. On the contrary, the five-year exchequer bond interest rate and region have a negative elasticity, meaning that the Modified VFM decreases according to the rise of these variables. Comparing with elasticities (Model 1) in Table 8-6, the tendency (size and direction) of elasticity is almost same though there are some differences in size.

Three way and four way interaction effects

In the same manner as two way interaction effects, three way interaction effects and four way interaction effects can be estimated. Based on two way interaction effects, all the possible three way interaction effects (in total 10 cases) were examined and the results are given in Appendix K. The results show that there are six cases that increase explanatory power (adjusted R-square) of the model as well as producing statistically significant estimates at the 1 per cent level: 1) length, completion delay and BCR, 2) length, completion delay and five-year exchequer bond interest rate, 3) length, completion delay and region, 4) completion delay, BCR and five-year exchequer bond interest rate, 5) completion delay, BCR and region and 6) completion delay, five-year exchequer bond interest rate and region. However, no combinations of three way interaction terms produce more than a 2 per cent increase in explanatory power compared in two way interaction effects model (adjust R-square 94.84%).

In addition, with regard to four way interaction effects, all the possible case were examined (in total 4 cases, Appendix K) based on the three way interaction effects: 1) length, completion delay, BCR and five-year exchequer bond interest rate, 2) length, completion delay, BCR and region, 3) length, completion delay, five-year exchequer bond interest rate and region, and 4) completion delay, BCR, five-year exchequer bond interest rate and region. As with three way interaction models, no combinations of four way interaction terms produce by more than 2 per cent in explanatory power compared with the two way interaction effects model (adjust R-square 94.84%).

Accordingly, considering the difficulties of interpretation and the possibility of miss-specification, the introduction of three way or higher interaction terms does not seem to be of any practical use in this study. Therefore, this study dealt with a basic regression model and a two way interaction effects model.

8.7 Conclusion

In this chapter, using meta-regression model, based on 216 Modified VFM values with various conditions from the six cases, the impact of quantitative and qualitative variables on the Modified VFM in the land transport programme (roads and railways) of Korea was examined, including elasticity (direction and magnitude). In addition, interaction effects between explanatory variables were also scrutinised. The main conclusions are outlined below.

Considering the land transport programme (roads and railways) of Korea, in regard to quantitative variables, the Modified VFM is positively influenced by project size, completion delay, BCR, discount rate and CPI, whereas it is negatively influenced by five-year exchequer bond interest rate. The most influential factors on the Modified VFM in the land transport in Korea are discount rate, CPI and five-year exchequer bond interest rate. Therefore, when estimating the Modified VFM, the choice of discount rate, CPI and five-year exchequer bond interest rate seems to be critical in PPP decisions in the land transport.

In addition, with respect to qualitative variables, the BTO option and Gyeonggi Province have a stronger influence on the Modified VFM than the BTL option and Gyungnam Province respectively. In particular, the impact difference between the two regions on the Modified VFM seems to be related to the regional difference of population and car ownership though there could be various and complex causes.

With respect to interaction effects, it seems that completion delay is not only meaningful as a single explanatory variable, but also plays an important role in reducing information set of other explanatory variables in regard to the Modified VFM. In addition, completion delay in the conventional delivery can be important in making interaction effects with other variables in PPP decisions, by increasing social benefit difference between the PSC and PPP options and public sector cost in the PSC.

In conclusion, when estimating the Modified VFM, the choice of discount rate, CPI and five-year exchequer bond interest rate seems to be critical in PPP decisions in the land transport. In addition, considering interaction effects of completion delay, it is reasonable to include completion delay in the conventional delivery in the quantitative PPP decision in Korea. In some respects, these results are obtained because they were used as input factors to calculate the Modified VFM, which could raise circularity issue. However, the results are meaningful in that this research shows three critical variables among various variables of the Modified VFM calculation in the land transport.

CHAPTER 9 Conclusions

9.1 Introduction

This research was conducted with a view to achieving three main research objectives, as mentioned in Chapter 1. One is to develop a new quantitative PPP decision methodology, considering the reality of the conventional delivery system of Korea, in order to overcome the limitations of the current quantitative VFM assessment due to the assumption that there are no differences of completion and effectiveness between a PSC and a PPP alternative. Another is to establish the impact of transferable risks, such as completion delay, construction cost risk and traffic volume risk, on the PPP decisions in the transport sector of Korea using case studies and the new quantitative PPP decision methodology. The final objective is to scrutinise the influence factors on PPP decision in the land transport (roads and railways) based on case studies.

To this end, a Modified VFM was developed in order to consider the systematic completion delay in the conventional delivery of Korea and the difference of benefit occurring time between a PSC and a PPP option, using the current VFM assessment methodology and the net present value concept. Then, transferable risks were quantified through historical observations and related literature. With respect to the completion delay of conventional delivery and construction cost risk for each transport programme (the National Highway, the National Expressway and the National Railway), the risks were quantified using historical observations, whereas traffic volume risk was quantified using the literature. Based on the Modified VFM and quantified transferable risks, in total six case studies (two per each transport programme) were conducted to scrutinise the impact of transferable risks on PPP decisions in each transport programme. Besides, in order to draw a more generalised and transferable conclusion on the land transport programme including roads and railways, meta-regression analysis is conducted, using 216 Modified VFM values with various conditions from the six cases.

In this chapter, the main conclusions on the three main research objectives are summarised; these were set out more fully in Chapters 3, 7 and 8. In addition, this chapter also discusses the contribution of the thesis to knowledge as well as the PPP in transport in Korea. In the later part of this chapter, there is a consideration on the limitation of the thesis, and a discussion of possible further study in transport PPPs in Korea.

9.2 Main conclusions

This research has three research objectives, as stated in Chapter 1: 1) the development of a new quantitative VFM assessment considering systematic completion delay in the conventional delivery of Korea; 2) the impact of transferable risks on the PPP decisions of the three transport programmes; and 3) the influential factors on the PPP decision on the land transport programme (roads and railways) and their impact. These research objectives were achieved, as mentioned in the previous chapters, through the development of methodology, risk quantification, case studies and meta-analysis. The main conclusions on the three research objectives are as follows.

9.2.1 Development of the Modified VFM

As the most common PPP decision-making methodology, the VFM assessment is popular in many countries when using PPPs, assuming that there are no completion differences between procurement alternatives. However, quantitative VFM assessment can be problematic due to the assumption in some countries where public sector cannot deliver sufficient, or any, funds without the help of private sector. When using quantitative VFM for PPP decisions, these countries have to pretend that a PSC could be a possible alternative, despite these being impossible in reality.

Therefore, from the viewpoint of the Korean context, considering the systematic completion delay in the conventional delivery due to lack of budget, the Modified VFM was developed to overcome the limitation of the assumption of the VFM analysis, as seen in equation (3-5) in Chapter 3. The Modified VFM has an importance in quantitative PPP decision methodology in three ways.

Firstly, the Modified VFM is simple, easy to understand and practical to use in PPP decisions. According to Grimsey and Lewis (2005), reviewing PPP decision practices in the world, the PPP decision methodology can be divided into two categories; 1) full cost-benefit analysis, 2) VFM assessment. A full cost-benefit analysis is generally used to decide whether to implement a project or not in the aspect of traditional procurement. It seems surprising that this method is used for PPP decision in Germany because notwithstanding the powerfulness of this method considering all the costs and benefits it is expensive, complicated and low in accuracy due to many assumptions (Grimsey and Lewis, 2005, Grout, 2005, Pearce and Nash, 1981). When it comes to VFM assessment, though it is simple and easy to understand, it seems problematic due to an assumption that there is no difference in completion time and effectiveness between the PSC and the PPP options and it can also be meaningless for low income developing countries when the PSC is not available as a delivery alternative (Leigland and Shugart, 2006). However, with respect to the Modified VFM, on the one hand, it connects public sector cost (characteristics of VFM assessment) and social benefit (characteristics of full cost-benefit analysis), comparing the PSC and the PPP options. On the other hand, it is simple, easy to understand and practical, which are the characteristics of VFM assessment. In other words, the Modified VFM is the product of negotiation between full cost-benefit analysis and VFM assessment.

Another reason that the Modified VFM can be used universally, though it is developed in order to solve the distinctive Korean problem (systematic completion delay in the conventional delivery), is that any other duration delay in the PPP as well as the PSC can be analysed in the Modified VFM calculation depending on countries. For example, the Modified VFM can embrace duration delays such as gestation, negotiation and financial closure delay in the PSC or PPP options, which are not rare in Korea. In Korea, due to lack of public funds, the Korean government tends to delay the start of the final design of transport projects, so gestation periods can be elongated in public delivery. Similarly, PPPs can also be delayed when negotiations or financial closure are delayed like the Bongdam-Songsan case in Korea.

The last importance in the Modified VFM is related to the viewpoint on project implementation. The current quantitative VFM methodology seems to represent the finance authority which wants to spend less of its budget, if possible. However, for the transport decision makers or transport service consumers, the time when the transport service is available can also be as important as spending less. Accordingly, the Modified VFM methodology considers the viewpoint of transport decision makers and transport service consumers as well as that of the finance authority, in terms of quantitative assessment. Consequently, in that the Modified VFM considers the differences of public sector cost and social benefit between procurement alternatives, the Modified VFM is more reasonable and more general than the current VFM in terms of quantitative assessment.

9.2.2 Impact of transferable risks

Impact of completion delay

One of the most important conclusions in this research is that a completion delay in the conventional delivery can make a critical impact on the PPP decisions in roads and railways in two ways.

One is that a completion delay in the conventional delivery has an influence on which procurement option to choose: the conventional or a PPP (BTL/BTO) alternative. As the completion delay in the conventional delivery lengthens, the Modified VFM tends to increase, which means that the viability of PPP (BTL/BTO) option increases, which was found in five case studies. This is because of the impact of the social benefit difference between the conventional and the PPP alternatives due to the completion delay in the calculation of the Modified VFM. However, in the case of the Bujeon-Masan project, the probability that the BTL option is better than the conventional delivery decreases as the completion delay becomes longer. This is because the BCR of the Bujeon-Masan is so small (0.63) that the Modified VFM value decreases slightly when the completion delay is considered. In contrast to the projects with an acceptable BCR, if a project has a small BCR, the decrease of the asset cost of the PSC due to discounting effect may be bigger than the increase by the social benefit difference as the completion delay lengthens.

Another is that the completion delay also affects the selection of PPP alternatives. As seen in Table 7-2, the BTO option seems to be more favourable than the BTL according to the inclusion of an average completion delay from the historical observations. This is because the Modified VFM comparing PPP options ($M.VFM_{BTL\text{-}BTO}$) decreases as completion is delayed mainly because the government revenue stream becomes reduced due to discounting effect. This implies that as completion is delayed, the BTO option become increasingly preferable to the BTL option.

In addition, in this research, in order to identify the impact of a completion delay in the conventional delivery on the PPP decisions for a project, the concept of the critical completion delay, making the Modified VFM zero, was introduced. Using a critical completion delay in the conventional delivery, a favourable delivery option can be selected for a certain project. An important implication of critical completion delay is that critical completion delay can be effectively used in PPP decisions and related management decisions such as budget invest planning in the conventional delivery and negotiation duration planning in PPP projects.

For example, as shown in Figure 7-1 (a), if the government decided to use conventional delivery for a project and critical completion delay is 0.26 years, the government needs to draw up a budget in order to complete the project within 0.26 years. In addition, as shown in Figure 7-1 (b), if the government decided to use a PPP option for a project and critical completion delay is -0.35 years, the government needs to make a greater effort to break ground within 0.35 years because negotiation and financial closure can be delayed in PPP procurements. In addition, when a delay in starting construction in a PPP option becomes longer than 0.35 years, it seems that the previous PPP decision becomes invalid and therefore that a new decision should be made for the project. According to the master plan of PPP (MOSF, 2009b) of Korea, a PPP option already decided for a project can be replaced with a conventional option and vice versa when it is difficult to conduct the already decided option. However, there are no examples that a PPP option is replaced with a conventional option seemingly because there are not clear criteria for the decision change. The concept of critical completion delay can be used as one of the decision criteria when it is necessary (Park and Preston, 2013a).

Consequently, it is crucial to include completion delay in the conventional delivery in PPP decisions in Korea and for a more reasonable PPP decision, it is essential to quantify the completion delay in specific infrastructure programme and to include the completion delay in calculating the quantitative assessment such as the Modified VFM.

Impact of construction cost risk

In this study, the construction cost risk from historical observations is composed of WBR risk and construction cost overrun risk that consider various bid systems like turn-key/alternative bid and design-bid-build. However, when following Korea's BTL guidelines, instead of including construction cost risk, only the turn-key/alternative bid is considered, ignoring construction cost overrun risk.

With respect to the National Highways and the National Expressways, the Modified VFM considering construction cost risk from historical observations is lower than the figure calculated according to Korea's BTL guidelines. This is because the representative bid system for roads is not turn-key but design-bid-build and the WBRs of design-bid-build are usually lower than that of turn-key/alternative bid. Therefore, this result implies that when estimating the Modified VFM using Korea's BTL guidelines, the Modified VFM values in roads can be exaggerated, compared with those considering historical observations.

On the contrary, with respect to the National Railways, usually separately delivered by six different major work element contracts, the Modified VFM considering construction cost risk from historical observations is higher than the figure calculated according to Korea's BTL guidelines. In other words, this result implies that when estimating the Modified VFM using

Korea's BTL guidelines, the Modified VFM values in railways can be underestimated, compared with those considering historical observations. This is mainly because construction cost overrun risk of each work element is much higher than that of roads.

In particular, this difference between roads and railways seems to come from whether a project is delivered separately on the work element basis or not. It seems that a separate delivery with six different contracts for major elements in railways could cause more inefficiency than a single delivery in roads, suggesting that there may be economies of scope.

Consequently, for a more convincing PPP decision, it seems reasonable to use an application ratio reflecting the historical observations in estimating the Modified VFM and in order to avoid distortion of PPP decisions in Korea, Korea's BTL guidelines seem to be corrected to use historical observations instead of an average turn-key/alternative bid ratio of similar projects.

Impact of traffic volume risk

Traffic volume risk can make an impact not only on PPP option selections in transport programme with tariffs (e.g. the National Expressways and the National Railways) but also on the participants of BTO projects.

With respect to the impact on PPP option selections, when including the mean value of the traffic volume risk (actual/forecast traffic volume ratio), the most favourable delivery option changes from the BTL to the BTO option in all the cases considering both PPP options (the Suwon-Pyungtaek case, the Bongdam-Songsan case and the Sosa-Wonsi case). This is mainly because revenue stream, which is the public sector cost in the BTO option, is reduced as the traffic volume ratio (actual/forecast) goes down.

In addition, traffic volume risk can make a serious impact on the participants of BTO projects. When including the mean value of traffic volume risks (roads: 0.687; railways: 0.507), actual revenue falls far below contract revenue and the situation could be very serious for the public sector and the private sector. According to the serious revenue shortfall, a SPV can go into bankruptcy, which can stop the provision of the infrastructure service, causing a great loss to the private sector. In addition, in this case, the project fails to achieve the ultimate objective, infrastructure service provision. The public sector is not free from the responsibility for the failure. Therefore, a BTO contract without traffic volume risk sharing is not favourable and is too risky for both participants.

In the case of Korea, the MRG system for traffic volume risk sharing was abolished in 2009, so there is no longer a traffic risk sharing system. In addition, considering the existing economic burden that public sector should take in the future by MRG and traffic volume risk, it seems impossible to re-introduce MRG in the BTO scheme. Thus, instead of MRG system this research has suggested a new traffic volume risk sharing system.

The essence of the new risk sharing method is to depreciate the value of a BTO project by reducing contract revenue stream, considering traffic volume risk. By doing so, the public sector needs to pay some more subsidies and the private sector to take some less profitability, compared with the current contract scheme. For both participants to take some loss in terms of mutual consideration and cooperation, the project is expected to provide a good and stable infrastructure service. According to the suggested method, the excessive or deficient revenue compared to contract one is shared between participants based on investment ratio between parties. Using this method, it seems that a BTO contract will be fairer and more reasonable between participants, and the BTO option can be more attractive in PPP markets in Korea.

Most favourable procurement option

When considering the transferable risks (completion delay, construction cost risk and traffic volume risk), it is hard determine which between the BTL and the conventional delivery option is more favourable in the National Highway programme because the most favourable procurement option is different depending on impact analysis methods: single-value estimation and the Monte Carlo Simulation.

With respect to the National Expressway cases, PPP alternatives are better than the conventional option in terms of the Modified VFM. Between PPP alternatives, the BTO option is the most favourable for the Suwon-Pyungtaek case and the Bongdam-Songsan case. This finding is also supported by the Monte Carlo Simulation results. However, when estimating the IRR considering traffic volume risk, the BTO viability of the Bongdam-Songsan seems difficult to be achieved. Therefore, it is difficult to definitely determine whether the BTO or the BTL is more favourable for the National Expressway programme. Nevertheless, it is possible to draw a careful conclusion that the BTO option is the most favourable for the National Expressway programme, provided that the BTO viability can be achieved when traffic volume risk is included.

When it comes to the National Railways, theoretically the BTO seems to be the most favourable option if the revenue stream is so large that the BTO option can be an affordable option within the limitation of governmental subsidy. Unfortunately, however, the BTO option cannot be considered in both the Bujeon-Masan case and the Sosa-Wonsi case because they have such a small revenue stream. For this reason, the BTL option is in practice the most favourable option when considering the risk factors and the size of revenue stream for the National Railways.

This result implies that, as a matter of fact, the revenue stream size is a decisive factor in deciding which type of PPPs is most favourable in the National Expressways and National Railways in Korea. In addition, the result also implies that the PPP types being used in Korea are reasonable considering revenue stream size and the governmental subsidy limitation.

9.2.3 Influential factors on the PPP decisions in the land transport programme

In order to draw a more generalised and transferable conclusion on the land transport programme including roads and railways, meta-regression analysis is conducted, using 216 Modified VFM values with various conditions from the six cases. By estimating the relationship between quantitative/qualitative causes and the effect (the Modified VFM) through meta-regression models, some valuable insights and conclusions have been reached.

With regard to quantitative variables, the Modified VFM is positively influenced by project size, completion delay, BCR, discount rate and CPI, whereas it is negatively influenced by five-year exchequer bond interest rate. The most influential factors on the Modified VFM in the land transport in Korea are discount rate, CPI and five-year exchequer bond interest rate. This implies that when estimating the Modified VFM, the choice of discount rate, CPI and five-year exchequer bond interest rate can be critical in PPP decisions in the land transport.

In particular, being different with CPI and five-year exchequer bond interest rate, discount rate cannot be acquired by historical observations but estimated considering socio-economic condition in Korea. Therefore, it seems that the government need to provide more detailed guidelines for the application of discount rate. The guidelines need to include the following: 1) sensitivity analysis range, 2) whether to use the same discount rate (with a different approach to risk assessment) or not for different risk band programmes (e.g. transport programme vs. environment programme), 3) whether to use the same discount rate or not between feasibility study and bidding process.

In addition, in regard to qualitative variables, the BTO option and Gyeonggi Province have a stronger influence on the Modified VFM than the BTL option and Gyungnam Province respectively. In particular, this result implies that the impact difference between the two regions on the Modified VFM seems to be related to the regional difference of population and car ownership though there could be various and complex causes.

With respect to interaction effects, it seems that completion delay is not only meaningful as a single explanatory variable, but also plays an important role in reducing information set of other explanatory variables in regard to the Modified VFM. In addition, completion delay in the conventional delivery can be important in making interaction effects with other variables (such as project size, BCR, five-year exchequer bond interest rate, PPP option and region) in PPP decisions, seemingly it is because completion delay increases social benefit difference between the PSC and PPP options and decrease public sector cost in the PSC, combined with other variables. This implies that it is essential to include completion delay in the conventional delivery in the quantitative PPP decision in Korea.

9.3 Contribution of the thesis

This thesis has developed the Modified VFM in order to consider systematic completion delay in the conventional delivery in Korea in terms of quantitative assessment, and has analysed the impact of transferable risks on the PPP decision using the six case studies and the Modified VFM. In addition, the thesis has dealt with the most favourable PPP option for the National Expressways and the National Railways, considering transferable risks and the revenue stream size of each transport programme. Other than that, the influence factors on the Modified VFM in the land transport (roads and railways) has also been scrutinised in the thesis. The thesis makes several contributions not only to knowledge but also to the PPP in transport in Korea.

The first and most important contribution is that it suggests a new quantitative PPP decision methodology, the Modified VFM, in order to consider public sector cost as well as completion delay. The methodology can be adopted in some countries like Korea where completion delay is expected to occur in the conventional delivery due to a lack of budget, as compared with PPP procurement. According to Mott MacDonald (2002), even the UK experiences works duration or gestation period delay, though the reasons of the delay can be different from the completion delay in Korea. Therefore, if the completion time difference between a PSC and a PPP is known or able to be quantified when procurement option decision for a project is made, the Modified VFM methodology can also be utilised in other countries as well as in Korea. In doing so, this methodology is expected to make it possible to take more reasonable PPP decisions in the transport sector with completion delay in the conventional delivery.

The second is that the thesis is the first study in which completion delay and construction cost risks are quantified and considered in the PPP decisions in the Korean transport. In particular, in doing so, construction cost risk is defined using WBR risk and construction cost overrun risk, which is also the first example in the PPP research.

In addition, the thesis first introduces the concept of critical completion delay in the conventional delivery where the most favourable procurement option changes in a certain project. Thus, using completion delay, the most favourable delivery option can be selected. In addition, critical completion delay also means the boundary value where a PPP decision already made in the past is valid, so it can be effectively used to decide whether a new PPP decision should be made or not, even after a PPP decision has already been made. According to the master plan of PPP (MOSF, 2009b) of Korea, a PPP option already decided for a project can be replaced with a conventional option and vice versa when it is difficult to conduct the already decided option. However, there are no examples that a PPP option is replaced with a conventional option seemingly because there are not clear criteria for the decision change. The concept of critical completion delay can be used as one of the decision change criteria when it is necessary.

Another important contribution is that this thesis suggests a new traffic volume risk (revenue shortfall risk) sharing system using reduced revenue stream, where the excessive or deficient revenue compared to contract one is shared between participants based on the investment ratio between parties. Using this method, a BTO contract can be fairer and more reasonable between participants and the BTO option can be more attractive in PPP markets in Korea.

Finally, the thesis provides some evidence that the PPP types being used for each transport programme seem appropriate in Korea, albeit with one caveat. In the Korean PPP practice, the BTO option is predominantly used for the National Expressways and the BTL option is usually used for the National Railways. The thesis suggests that, considering all the risk quantified and the revenue stream size of each transport programme, the BTL option is favourable in the National Railways, while the BTO option is the most favourable alternative for the National Expressways, provided (this is the caveat) that the BTO viability can be achieved in terms of the IRR.

9.4 Limitation of the thesis and future research

In spite of the contributions it makes, this thesis also has some limitations with respect to the assumption used in this research. This section discusses the limitation of the thesis as well as future research.

Limitation

Firstly, although social benefits could be different depending on procurement alternatives for various reasons, such as level of tariffs or traffic volume, this research assumes that the alternatives produce the same social benefits. In addition, for a simple calculation, social benefits from the literature are assumed to vary depending on traffic volume risk, though social benefits need to be estimated again through a traffic demand analysis. Besides, this research also ignores the social costs that could be induced by each procurement alternatives because of the difficulty of assessment. Therefore, if the social benefits and costs are included more properly, the PPP decision will be more persuasive.

Secondly, the delay in construction start in PPPs can also occur due to delayed negotiation or delayed private finance delivery and it could make a different result on the PPP decisions. However, this research assumes that there are no delays in construction start date because the historical observations regarding the delay in construction start are currently not available. Therefore, if the historical data on the delay in construction start in PPPs are accumulated and available, a more reasonable PPP decision can be made by using them.

Thirdly, completion delay is assumed to occur only in the conventional delivery due to a lack of budget and the long term expenditure contract system in Korea. However, even excluding a lack of budget, there are various causes that lead to a completion delay, such as unexpected changes in contract management, site condition and available resources. In addition, a completion delay can occur even in PPP options though there seems to be no evidence of this in Korea to date. Thus, the considerations of the causes of completion delay between the conventional and PPP options will make for a more robust PPP decision.

Future research

Firstly, it is needed to research on the difference in effectiveness between a conventionally procured project and a PPP project, ignoring completion delay effects in the conventional delivery, because it is important to know how different effectiveness can be produced by procurement alternatives in PPP decisions. The effectiveness produced by a PPP project could be related to different taxation effects, private finance effects and innovation and creativity, to say nothing of general social benefit items in a conventionally procured project. In addition, it is recommended to consider the distortion of completion regarding tax exemption (or reduction) in PPPs, when comparing the difference in effectiveness between alternatives.

Secondly, there is much room for further research in time delay in the conventional delivery or PPP delivery for PPP decisions. Completion delay in construction practice can be different depending on project size, project difficulties and environments like geological condition and weather. In addition, gestation and negotiation periods in conventional and PPP delivery can be different depending on infrastructure programme. In particular, PPPs can also have elongated negotiations (and re-negotiation) which leads to delays in construction start and completion and makes costs (such as transaction cost) increase. Therefore, the quantification of time duration (or delay) considering detailed conditions can make a contribution to reasonable PPP decisions.

Thirdly, it is recommended to do research on risk identification and allocation in PPPs in Korea. Although much research on risk identification and allocation in PPPs have been conducted globally such as Li et al. (2005), Roumboutsos and Anagnostopoulos (2008) and Ke et al. (2010), it is very difficult to find some research on this field in Korea. As this field is a fundamental of risk management process in PPP projects and risk allocation is little bit different depending countries, the research on risk identification and allocation in PPPs in Korea seems very important not only in PPP decisions but also PPP management.

Fourthly, although discount rate is very important in investment decisions and PPP decisions, the research on discount rate is very rare in Korea practically and academically. In particular, the public sector in Korea tends to use discount rate provided by KDI without critical thinking that it is appropriate for a specific project or a specific project stage. Therefore, it is recommended to develop detailed guidelines for the application of discount rate, in order that the public sector can conduct an appropriate decision depending on project risk band and project stage.

Fifthly, it is needed to carry out PPP research using the meta-analysis. To date the meta-analysis research on PPPs are very rare. In this research, the meta-analysis is restricted to a specific country (Korea) with two PPP types. Therefore, it is recommended to extend the meta-analysis with respect to PPPs by including more types of PPP schemes, more transport modes and international comparisons. It is expected that the meta-analysis will make PPP research bountiful. Finally, qualitative assessment for the PPP decisions seems to become more important recently, looking at the evolution of the PPP guidelines in some countries like the UK (KDI, 2012). Nevertheless, in this research, a qualitative approach was not included, focusing on quantitative VFM, because it could be vulnerable to a government policy and an appraiser's will. However, there exist many other qualitative factors affecting PPP decisions, such as flexible fiscal management and employment opportunities, depending on countries. In addition, the research methodology on systematic qualitative assessment does not seem to be established yet in spite of recent research using interview technique and analytic hierarchy process technique. Therefore, for better PPP decision-making, along with the research on quantitative approaches, it is recommended that future research on the selection of qualitative factors and systematic qualitative assessment methodology should be carried out.

Appendix A Turn-key/alternative winning bid ratio between 2002 and 2011(The National Highway projects)

(Price unit: 1,000KRW ≈0.58 GBP)

	Projects	Bid method	Start year	Estimated price (designed price)	Successful price tendered	Winning bid ratio (%)
Total	**33**			**5,602,328,018**	**4,960,861,892**	**88.55**
Seoul office	**3**			**531,392,505**	**505,387,000**	**95.11**
	Sungnam-Janghowon2	Turnkey	2002	302,900,000	285,318,000	94.2
	Pangsung-Osung	Alternative	2009	169,085,722	162,060,000	95.84
	Jucksung-Junkok2	Alternative	2009	59,406,783	58,009,000	97.65
Wonju office	**3**			**339,609,000**	**306,122,000**	**90.14**
	Shinbook-booksan	Turnkey	2004	172,500,000	163,496,000	94.78
	Taebak-Dogae	Alternative	2007	126,309,000	104,078,000	82.4
	Donggangbridge	Turnkey	2007	40,800,000	38,548,000	94.48
Deajun office	**3**			**668,201,000**	**631,007,700**	**94.43**
	Yongdoo-Gumga	Alternative	2002	165,765,000	159,001,000	95.92
	Boryung-Taeahn1	Turnkey	2010	396,810,000	373,802,000	94.2
	Boryung-Taeahn2	Turnkey	2010	105,626,000	98,204,700	92.97
Iksan office	**19**			**3,143,716,276**	**2,749,456,760**	**87.46**
	Sorok-Guguem	Turnkey	2002	233,340,000	208,372,000	89.3
	Jukguem-Youngnam	Turnkey	2002	203,000,000	192,730,000	94.94
	Aphae-Woonam	Alternative	2003	122,412,456	100,015,688	81.7
	Goonoe-Namchang	Alternative	2004	137,655,000	110,369,000	80.18
	Soonchang-Woonam4	Alternative	2004	93,234,000	78,836,000	84.56
	Dongsan-Whatae	Turnkey	2004	127,200,000	101,124,000	79.5
	Chungho-Samho	Alternative	2004	195,191,000	156,242,000	80.05
	Goha-Juckgyo	Turnkey	2004	274,000,000	258,654,000	94.4
	Woodoo-Jongwha	Turnkey	2005	79,952,554	70,700,000	88.43
	Saepoong-Joonggoon	Turnkey	2006	234,358,406	215,514,772	91.96
	Yongjung-Yongjin	Alternative	2006	238,622,000	190,547,000	79.85
	Goonjang bridge	Turnkey	2008	155,320,000	150,815,000	97.1
	Hongnong-Baeksoo	Turnkey	2008	59,499,000	55,802,300	93.79
	Gogoonsam2	Turnkey	2009	111,000,000	104,573,000	94.21
	Shinji-Gogeum	Turnkey	2010	68,039,000	67,970,000	99.9
	Aphae-Amtae1	Turnkey	2010	240,863,000	227,912,000	94.62
	Aphe-Amtae2	Turnkey	2010	308,834,000	248,877,000	80.59
	Whayang-Juckgeum2	Turnkey	2011	131,487,000	87,439,000	66.5
	Whayang-Juckgeum3	Turnkey	2011	129,708,860	122,964,000	94.8
Busan office	**5**			**919,409,237**	**768,888,432**	**83.63**
	Gyungjoo-Gampo2	Alternative	2003	175,683,350	140,546,680	80
	Namchun-Chungdo1	Alternative	2003	154,486,000	123,588,800	80
	Woongdong-Jangyu	Alternative	2006	220,957,990	176,766,392	80
	Gyori-Soosang	Alternative	2007	149,219,836	118,667,560	79.53
	Gohyun-HadongIC2	Alternative	2009	219,062,061	209,319,000	95.55

Source: MLTM (2012b)

Appendix B **Present value interest factor of an annuity (PVIFA)**

The equation of PVIFA used in calculating the lease fee has other form. Considering annuity a, rate of return k and duration n, the present value of total annuity P can be expressed as follows;

$$P = PVIFA\ \times a = \sum_{1}^{n} \frac{a}{(1+k)^i} = \frac{a}{(1+k)} + \frac{a}{(1+k)^2} + \frac{a}{(1+k)^3} + \cdots + \frac{a}{(1+k)^n} \qquad \text{(B-1)}$$

Multiplying both sides in equation (1) by (1+k),

$$(1+k)P = a + \frac{a}{(1+k)} + \frac{a}{(1+k)^2} + \frac{a}{(1+k)^3} + \cdots + \frac{a}{(1+k)^{n-1}} \qquad \text{(B-2)}$$

Subtracting equation (B-1) from equation (B-2) and dividing by k, P can be arranged as follows;

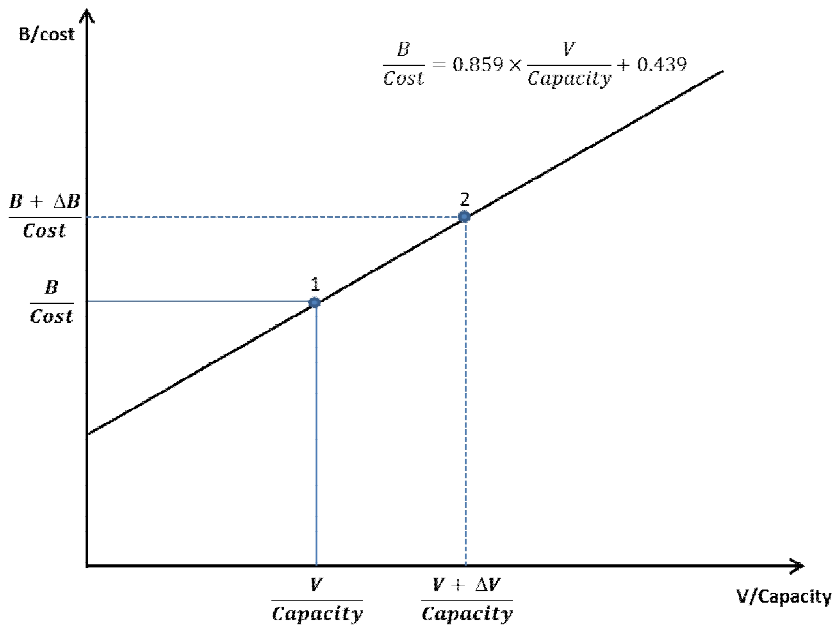
$$P = \frac{a}{k}\left[1 - \frac{1}{(1+k)^n}\right] = a\left[\frac{(1+k)^n - 1}{k(1+k)^n}\right] \qquad \text{(B-3)}$$

Finally comparing equation (B-1) and equation (B-3), PVIFA is summarised as follows;

$$PVIFA = \sum_{1}^{n} \frac{1}{(1+k)^i} = \left[\frac{(1+k)^n - 1}{k(1+k)^n}\right] \qquad \text{(B-4)}$$

Appendix C Detailed derivation of equation (4-3)

For a certain infrastructure project with a constant cost and a constant capacity, assuming that the relationship between BCR (benefit cost ratio) and volume capacity ratio follows the linear equation shown in below figure, change of social benefit can be supposed by change of traffic volume as following derivation.



From above figure, considering point 1 changes to point 2 according as V changes by ΔV, following two equations can be obtained.

$$BCR = \frac{B}{Cost} = 0.859 \times \frac{V}{Capacity} + 0.439 \qquad \text{(C-1)}$$

$$\frac{B + \Delta B}{Cost} = 0.859 \times \frac{V + \Delta V}{Capacity} + 0.439 \qquad \text{(C-2)}$$

If the traffic volume changes from V to $V + \Delta V$ $(=kV)$, equation (C-2) can be arranged as follows;

$$\frac{B + \Delta B}{Cost} = 0.859 \times \frac{kV}{Capacity} + 0.439 \qquad \text{(C-3)}$$

Dividing equation (C-3) by equation (C-1) and considering $\frac{V}{Capacity} = \frac{BCR-0.439}{0.859}$ from equation (C-1), social benefit change is as follows;

$$\frac{B + \Delta B}{B} = \frac{0.859 \times \frac{kV}{Capacity} + 0.439}{0.859 \times \frac{V}{Capacity} + 0.439} \qquad \text{(C-4)}$$

$$= \frac{0.859 \times \frac{k\,(BCR - 0.439)}{0.859} + 0.439}{0.859 \times \frac{BCR - 0.439}{0.859} + 0.439} \qquad \text{(C-5)}$$

$$= \frac{k\,(BCR - 0.439) + 0.439}{BCR} \qquad \text{(C-6)}$$

$$= k + \frac{0.439\,(1 - k)}{BCR} \qquad \text{(C-7)}$$

Therefore, if social benefit changes b times from the initial social benefit according as traffic volume changes k time, b can be expressed as follows;

$$\boldsymbol{b = \frac{B + \Delta B}{B} = k + \frac{0.439\,(1 - k)}{BCR}} \qquad \text{(C-8)}$$

Appendix D Turn-key/alternative winning bid ratios between 2002 and 2011 (The National Expressway projects)

(Price unit: 1,000KRW ≈0.58 GBP)

Projects	Bid method	Start year	Estimated price (designed price)	Successful price tendered	Winning bid ratio (%)
Total (26)			**4,622,315,674**	**3,796,643,039**	**82.14**
National Expressway 14 (Gochang-Jangsung 2)	Alternative	2002	95,234,168	82,507,700	86.64
National Expressway 40 (Umsung-Pyungtaek 6)	Turnkey	2002	154,200,000	146,451,700	94.98
National Expressway 40 (Umsung-Pyungtaek 7)	Turnkey	2002	128,300,000	121,243,000	94.50
National Expressway detour ITS 1	Turnkey	2003	44,638,000	37,400,000	83.79
National Expressway 45 (Yeojoo-Yangpyung 3)	Alternative	2003	168,913,706	143,069,300	84.70
Incheon Grand Bridge Connecting road 1	Turnkey	2005	90,700,000	85,838,500	94.64
Incheon Grand Bridge Connecting road 2	Turnkey	2005	183,600,000	172,480,000	93.94
Incheon Grand Bridge Connecting road 3	Turnkey	2005	179,100,000	165,300,000	92.29
Incheon Grand Bridge Connecting road 4	Turnkey	2005	162,300,000	153,795,400	94.76
Incheon Grand Bridge Connecting road 5	Turnkey	2005	87,100,000	82,396,600	94.60
National Expressway 10 (Janghung-Gwangyang 8)	Alternative	2006	191,015,220	154,045,000	80.65
National Expressway 10 (Janghung-Gwangyang 9)	Alternative	2006	197,546,302	156,847,000	79.40
National Expressway 12 (Damyang-Sungsan 4)	Alternative	2008	225,609,232	121,825,000	54.00
National Expressway 12 (Damyang-Sungsan 5)	Alternative	2008	186,106,072	126,500,000	67.97
National Expressway 12 (Damyang-Sungsan 6)	Alternative	2008	182,649,192	163,680,000	89.61
National Expressway 12 (Damyang-Sungsan 12)	Alternative	2008	231,866,963	216,409,200	93.33
National Expressway 104 (Nangjung-Busan 4)	Alternative	2009	221,443,968	201,080,000	90.80
National Expressway 551 (Nangjung-Busan 5)	Alternative	2009	163,638,038	103,700,000	63.37
National Expressway 551 (Nangjung-Busan 6)	Alternative	2009	129,373,480	78,160,000	60.41
National Expressway 551 (Nangjung-Busan 7)	Alternative	2009	129,899,350	120,185,879	92.52
National Expressway 12 (Damyang-Sungsan 10)	Turnkey	2009	153,234,918	79,640,000	51.97
National Expressway 60 (Donghongchun-Yangyang 11)	Alternative	2009	190,646,705	177,277,000	92.99
National Expressway 60 (Donghongchun-Yangyang 14)	Alternative	2009	543,943,279	500,751,000	92.06
National Expressway 600 (Busan outer beltway 6)	Alternative	2011	114,738,475	102,183,400	89.06
National Expressway 600 (Busan outer beltway 8)	Alternative	2011	209,696,034	131,450,000	62.69
National Expressway 600 (Busan outer beltway 9)	Alternative	2011	256,822,572	172,427,360	67.14

Appendix E **Details for the relationship between BCR and V/C in the National Railways**

Railway Name	Section	BCR	Capacity (C)	Traffic volume (V)	V/C
Kyungbu line	Seoul-Sihung (3 double track)	1.13	171	160	0.936
Janghang line	Cheonan-Onyang (doble track)	1.39	38	27	0.711
	Onyang-Shinjanghang (single track)	1.29	35	25	0.714
Junla line	Iksan-Dongsoonchun (double track)	1.44	45	42	0.933
	Dongsooncheon-Yeosoo (double track)	1.04	38	30	0.789
Joongang line	Chungyangri-Wonju (double track)	1.53	52	45	0.865
	Wonju-Jaechun (double track)	0.85	53	41	0.774
	Jaechun-Dodam (double track)	1.29	41	49	1.195
Kyungjeon line	Nakdongang-Jinju (double track)	1.11	41	31	0.756
	Jinju-Gwangyang (double track)	0.84	22	22	1.000
	Gwangyang-Soonchun (double track)	1.03	22	22	1.000
	Soonchun-Bosung (double track)	0.31	24	13	0.542
	Bosung-Songjungri (double track)	0.65	28	15	0.536
Kyungchoon line	Chungyangri-Choonchun (double track)	1.14	31	21	0.677
Taebaek line	Jaechun-Ssangyong (double track)	1.17	49	48	0.980
	Ssangyong-Baeksan (double track)	0.62	33	29	0.879
Yeongdong line	Youngju-Baeksan (double track)	0.46	30	16	0.533
	Baeksan-Donghae (double track)	0.82	36	39	1.083
	Donghae-Kangrung (double track)	0.84	33	13	0.394
Gyoei line	Nunggok-Uijungbu (double track)	0.34	15	5	0.333
Donghaenambu line	Busanjin-Ulsan (double track)	0.9	36	29	0.806
	Ulsan-Pohang (double track)	0.86	40	33	0.825
Gunsan line	Iksan-Daeya (double track)	1.16	23	10	0.435
Taegu line	Dongtaegu-Youngchun (double track)	0.54	39	36	0.923

Note: 1. These data are collected from the master-plan research report on the 21st century National Railway network of Korea (MLTM, 2004); BCR (425-427 page), capacity & traffic volume (239 page). 2. Capacity, meaning line capacity, is defined as the maximum throughput in trains per day in Korea. The calculation method for capacity is not officially established in Korea, so Yamakishi's formula, developed in Janpan in 1945, is usually used. 3. Traffic volume means available throughput in trains per day in 2005.

Source: MLTM (2004)

Appendix F Example calculations for the private sector monetary loss for the Bongdam-Songsan and the Sosa-Wonsi

1. The Bongdam-Songsan case

(Unit: discounted billion KRW, 2006 price)

Revenue ratio (actual/forecast)	Contract 1 (contract revenue = forecast revenue)							Contract 2 (contract revenue = 0.686×forecast revenue)				
	Revenue shortage [a_1]	No MRG			MRG: Gil's approach			The suggestion				
		Loss (G) [b_1]	Loss (P) [a_1-b_1]	(IRR %)	Loss (G) [b_2]	Loss (P) [a_1-b_2]	(IRR %)	Revenue shortage [a_2]	Additional subsidy [b_4]	Loss (G) [b_4+0.62×a_2]	Loss (P) [0.38×a_2]	(IRR %)
1.2	-64.5	0.0	-64.5	7.78	0.0	-64.5	7.78	-165.6	40.9	-61.4	-63.2	5.51
1.1	-32.2	0.0	-32.2	6.81	0.0	-32.2	6.81	-133.3	40.9	-41.5	-50.9	5.01
1.0	0.0	0.0	0.0	5.77	0.0	0.0	5.77	-101.1	40.9	-21.6	-38.6	4.50
0.9	32.2	0.0	32.2	4.63	0.0	32.2	4.63	-68.9	40.9	-1.7	-26.3	3.96
0.813	60.3	0.0	60.3	3.56	0.0	60.3	3.56	-40.8	40.9	15.7	-15.6	3.46
0.8	64.5	0.0	64.5	3.39	2.8	61.7	3.49	-36.6	40.9	18.3	-14.0	3.39
0.7	96.7	0.0	96.7	1.97	24.5	72.2	2.93	-4.4	40.9	38.2	-1.7	2.79
0.686	101.1	0.0	101.1	1.76	27.4	73.7	2.85	0.0	40.9	40.9	0.0	2.70
0.6	129.0	0.0	129.0	0.3	46.2	82.8	2.27	27.9	40.9	58.1	10.6	2.15
0.5	161.2	0.0	161.2	-1.81	67.8	93.4	1.46	60.1	40.9	78.0	23.0	1.47

(Note) 1. Loss (G) = the loss of the public sector, Loss (P) = the loss of the private sector. 2. IRR = internal rate of return (real). 3. Above table was analysed based on M.VFM $_{BTL-BTO}$ (+volume risks) in Table 5-8 (Section 5.4.4.1). 4. Gil's approach = MRG condition is determined to 81.3% (1 to 15 years) which makes M.VFM$_{BTL-BTO}$ zero. 5. For contract 2, the government investment includes compensation cost (259.9 billion KRW), construction subsidy (61.7 billion KRW) and additional construction subsidy (40.9 billion KRW), and the private sector investment is 223.9 (264.8-40.9) billion KRW. Therefore, the investment ratio for the public sector = 61.8% and the investment ratio for the private sector = 38.2%

2. The Sosa-Wonsi case

(Unit: discounted billion KRW, 2007 price)

Revenue ratio (actual/forecast)	Contract 1 (contract revenue = forecast revenue)										Contract 2 (contract revenue = 0.507×forecast revenue)				
	Revenue shortage [a_1]	No MRG			MRG: Stepwise			MRG: Gil's approach			The suggestion				
		Loss (G) [b_1]	Loss (P) [a_1-b_1]	(IRR %)	Loss (G) [b_2]	Loss (P) [a_1-b_2]	(IRR %)	Loss (G) [b_3]	Loss (P) [a_1-b_3]	(IRR %)	Revenue shortage [a_2]	Additional subsidy [b_4]	Loss (G) [b_4+0.92×a_2]	Loss (P) [0.08×a_2]	(IRR %)
1.2	-66.2	0.0	-66.2	9.84	0.0	-66.2	9.84	0.0	-66.2	9.84	-229.4	107.3	-104.2	-17.9	-5.08
1.1	-33.1	0.0	-33.1	8.2	0.0	-33.1	8.2	0.0	-33.1	8.2	-196.3	107.3	-73.7	-15.3	-6.02
1.0	0.0	0.0	0.0	6.38	0.0	0.0	6.38	0.0	0.0	6.38	-163.2	107.3	-43.1	-12.7	-7.12
0.951	16.2	0.0	16.2	5.4	0.0	16.2	5.4	0.0	16.2	5.4	-146.8	107.3	-28.1	-11.5	-7.77
0.9	33.1	0.0	33.1	4.31	0.0	33.1	4.31	10.1	23.0	4.94	-130.1	107.3	-12.6	-10.1	-8.53
0.8	66.2	0.0	66.2	1.86	0.0	66.2	1.86	30.2	36.1	3.91	-97.0	107.3	17.9	-7.6	-10.69
0.7	99.3	0.0	99.3	-1.27	10.0	89.3	-0.5	50.2	49.1	2.63	-63.8	107.3	48.4	-5.0	N.A.
0.6	132.4	0.0	132.4	-6.08	30.0	102.4	-3.02	70.2	62.2	0.89	-30.7	107.3	79.0	-2.4	N.A.
0.507	163.2	0.0	163.2	N.A.	48.6	114.5	-8.66	88.8	74.4	-1.67	0.0	107.3	107.3	0.0	N.A.
0.5	165.5	0.0	165.5	N.A.	50.1	115.5	-10.16	90.2	75.3	-1.96	2.4	107.3	109.5	0.2	N.A.

(Note) 1. Loss (G) = the loss of the public sector, Loss (P) = the loss of the private sector. 2. IRR = internal rate of return (real). 3. Above table was analysed based on M.VFM $_{BTL-BTO}$ (+volume risks) in Table 6-10 (Section 6.3.4.1). 4. Stepwise = the MRG condition of the Sosa-Wonsi case (the government guarantees up to 75% (1 to 5 years) and 65% (6 to 10 years) and redeems revenue exceeding 125% (1 to 5 years) and 135% (6 to 10 years). 5. Gil's approach = MRG condition is determined to 95.1% (1 to 10 years) which makes M.VFM$_{BTL-BTO}$ zero. 6. For contract 2, the government investment includes compensation cost (238.6 billion KRW), construction subsidy (1,245 billion KRW) and additional constructin subsidy (107.3 billion KRW), and the private sector investment is 134.4 (241.7-107.3) billion KRW. Therefore, the investment ratio for the public sector = 92.2% and the investment ratio for the private sector = 7.8%

Appendix G Regression model selection

1. Linear-Linear (full transformation)

```
. metareg m_vfm length completion_delay bcr discount_rate cpi exchequer_bond application_ratio tra
> ffic_vol model_d ppp_d region_d,wsse( SE_prj_ppp)
note: discount_rate dropped because of collinearity
note: cpi dropped because of collinearity

Meta-regression                                    Number of obs  =      216
REML estimate of between-study variance            tau2           =     4470
% residual variation due to heterogeneity          I-squared_res  =   94.33%
Proportion of between-study variance explained     Adj R-squared  =   75.09%
Joint test for all covariates                      Model F(9,206) =    53.68
With Knapp-Hartung modification                    Prob > F       =   0.0000

-----------------------------------------------------------------------------------
            m_vfm |     Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
------------------+----------------------------------------------------------------
           length |  5.240107   1.059075     4.95   0.000     3.152091    7.328124
 completion_delay |  44.88508   3.721983    12.06   0.000     37.54702    52.22314
              bcr |  164.9296    23.4619     7.03   0.000     118.6733    211.1858
   exchequer_bond | -65.06962   12.17439    -5.34   0.000      -89.072   -41.06723
application_ratio |   3.22274   3.193012     1.01   0.314    -3.072432    9.517911
      traffic_vol |  .6843516   .5975856     1.15   0.253    -.4938163     1.86252
          model_d |  63.84427   44.35139     1.44   0.152    -23.59656    151.2851
            ppp_d |  34.58096   12.49946     2.77   0.006     9.937693    59.22422
         region_d | -93.83192   21.56017    -4.35   0.000    -136.3388   -51.32505
            _cons | -316.8129   260.0296    -1.22   0.224    -829.4733    195.8475
-----------------------------------------------------------------------------------
```

2. Linear-Log (full transformation)

```
. metareg m_vfm length completion_delay bcr discount_rate cpi exchequer_bond application_ratio tra
> ffic_vol model_d ppp_d region_d,wsse( SE_prj_ppp)
note: discount_rate dropped because of collinearity
note: cpi dropped because of collinearity

Meta-regression                                    Number of obs  =      216
REML estimate of between-study variance            tau2           =     4609
% residual variation due to heterogeneity          I-squared_res  =   94.33%
Proportion of between-study variance explained     Adj R-squared  =   74.31%
Joint test for all covariates                      Model F(9,206) =    51.67
With Knapp-Hartung modification                    Prob > F       =   0.0000

-----------------------------------------------------------------------------------
            m_vfm |     Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
------------------+----------------------------------------------------------------
           length |  305.1624   45.26281     6.74   0.000     215.9247    394.4002
 completion_delay |  254.5009   21.79237    11.68   0.000     211.5363    297.4656
              bcr |  556.3857   62.51099     8.90   0.000     433.1424    679.6291
   exchequer_bond | -501.5248   120.3258    -4.17   0.000    -738.7528   -264.2969
application_ratio |  617.9551   627.7413     0.98   0.326    -619.6662    1855.576
      traffic_vol |  54.12252   46.55435     1.16   0.246    -37.66156    145.9066
          model_d |   49.1219   42.09443     1.17   0.245    -33.86924     132.113
            ppp_d |  34.54514   12.68224     2.72   0.007     9.541518    59.54876
         region_d | -15.09173   20.59426    -0.73   0.465    -55.69428    25.51081
            _cons | -1416.935   1224.154    -1.16   0.248    -3830.411    996.5417
-----------------------------------------------------------------------------------
```

3. Log-Linear (full transformation)

```
. metareg log_mvfm length completion_delay bcr discount_rate cpi exchequer_bond application_ratio
> traffic_vol model_d ppp_d region_d,wsse( SE_prj_ppp)
note: discount_rate dropped because of collinearity
note: cpi dropped because of collinearity

Meta-regression                                          Number of obs  =     216
REML estimate of between-study variance                  tau2           =       0
% residual variation due to heterogeneity                I-squared_res  =   0.00%
Proportion of between-study variance explained           Adj R-squared  =      .%
Joint test for all covariates                            Model F(9,206) =    0.00
With Knapp-Hartung modification                          Prob > F       =  1.0000
```

log_mvfm	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
length	.0054179	.1466004	0.04	0.971	-.2836116	.2944474
completion_delay	.010187	.2089013	0.05	0.961	-.4016716	.4220456
bcr	.1794373	4.09966	0.04	0.965	-7.903234	8.262108
exchequer_bond	-.0720714	1.562711	-0.05	0.963	-3.153029	3.008886
application_ratio	.0029059	.1774196	0.02	0.987	-.3468851	.3526969
traffic_vol	.0014576	.0330708	0.04	0.965	-.063743	.0666582
model_d	.1070101	4.400458	0.02	0.981	-8.568697	8.782717
ppp_d	.0317527	2.366001	0.01	0.989	-4.63293	4.696435
region_d	-.125053	2.432838	-0.05	0.959	-4.921507	4.671401
_cons	2.121987	15.01799	0.14	0.888	-27.48667	31.73065

4. Log-Log (full transformation)

```
. metareg log_mvfm length completion_delay bcr discount_rate cpi exchequer_bond application_ratio
> traffic_vol model_d ppp_d region_d,wsse( SE_prj_ppp)
note: discount_rate dropped because of collinearity
note: cpi dropped because of collinearity

Meta-regression                                          Number of obs  =     216
REML estimate of between-study variance                  tau2           =       0
% residual variation due to heterogeneity                I-squared_res  =   0.00%
Proportion of between-study variance explained           Adj R-squared  =      .%
Joint test for all covariates                            Model F(9,206) =    0.00
With Knapp-Hartung modification                          Prob > F       =  1.0000
```

log_mvfm	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
length	.3232022	7.661316	0.04	0.966	-14.78144	15.42784
completion_delay	.0587686	1.195031	0.05	0.961	-2.297291	2.414829
bcr	.598213	13.33831	0.04	0.964	-25.69888	26.89531
exchequer_bond	-.5640481	12.97083	-0.04	0.965	-26.13665	25.00855
application_ratio	.5722402	35.23398	0.02	0.987	-68.89319	70.03767
traffic_vol	.1115176	2.525296	0.04	0.965	-4.867222	5.090257
model_d	.0871497	4.107588	0.02	0.983	-8.011151	8.185451
ppp_d	.0317527	2.366001	0.01	0.989	-4.63293	4.696435
region_d	-.0426523	2.863943	-0.01	0.988	-5.68905	5.603745
_cons	1.040396	69.27511	0.02	0.988	-135.5387	137.6195

5. Mixed transformation

```
. metareg M_VFM length completion_delay BCR Discount_rate EXP_cpi exchequer_bond model_D ppp_D region_D
> application_ratio EXP_traffic_volume,wsse( SE_prj_ppp)
note: Discount_rate dropped because of collinearity
note: EXP_cpi dropped because of collinearity

Meta-regression                                          Number of obs  =     216
REML estimate of between-study variance                  tau2           =    4471
% residual variation due to heterogeneity                I-squared_res  =  94.33%
Proportion of between-study variance explained           Adj R-squared  =  75.08%
Joint test for all covariates                            Model F(9,206) =   53.67
With Knapp-Hartung modification                          Prob > F       =  0.0000
```

M_VFM	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
length	5.240135	1.059147	4.95	0.000	3.151978	7.328293
completion_delay	44.88589	3.722234	12.06	0.000	37.54734	52.22445
BCR	164.9293	23.46353	7.03	0.000	118.6699	211.1888
exchequer_bond	-65.06974	12.17526	-5.34	0.000	-89.07384	-41.06564
model_D	63.60076	44.34469	1.43	0.153	-23.82686	151.0284
ppp_D	34.58073	12.50025	2.77	0.006	9.935897	59.22557
region_D	-93.83251	21.56167	-4.35	0.000	-136.3423	-51.32268
application_ratio	3.222761	3.193226	1.01	0.314	-3.072834	9.518356
EXP_traffic_volume	47.98287	42.28439	1.13	0.258	-35.38278	131.3485
_cons	-361.1183	266.2367	-1.36	0.176	-886.0163	163.7796

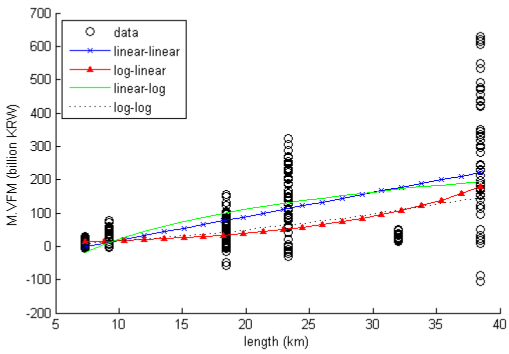
Appendix H R-square Table, Scatter plots and Correlation matrix

1. R-square between M.VFM and independent variables with various transformations

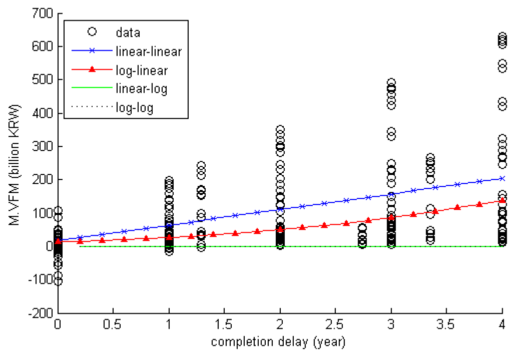
	R-squre between M.VFM and each independet variables			
	linear-linear	log-linear	linear-log	log-log
Length (km)	0.30007	0.16115	0.25612	0.14035
Completion delay (year)	0.20203	0.09285	$<10^{-5}$	$<10^{-5}$
BCR	0.24479	0.12624	0.20863	0.10929
Discount rate (%)	0.23788	0.14136	0.24098	0.14564
CPI (%)	0.00798	0.02102	0.00943	0.02185
5 year exchequer bond interest rate (%)	0.22516	0.11797	0.22063	0.11624
Application ratio (%)	0.02898	0.01469	0.03050	0.01479
Traffic volume ratio (%)	0.00207	0.00234	0.00220	0.00273

(Note) 1. The shaded cell means selected relationship because of the highest R-square in each row or showing best fit in scatter plots. 2. Dummy variables are not included in the table

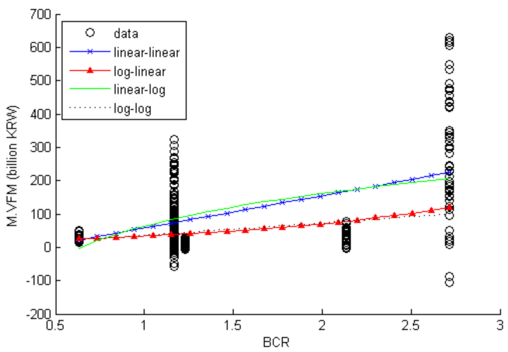
2. Scatter plots



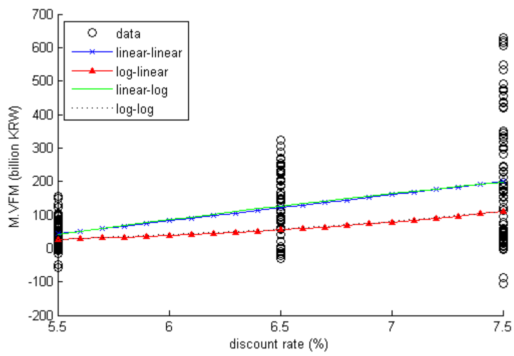
(1) M.VFM vs. length



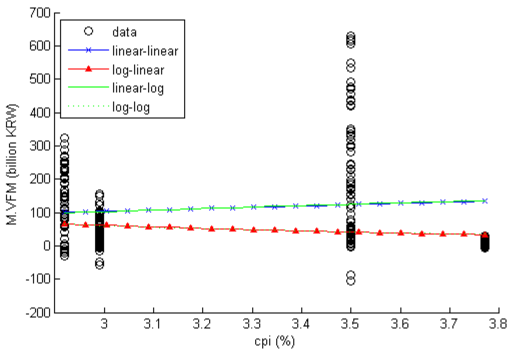
(2) M.VFM vs. completion delay



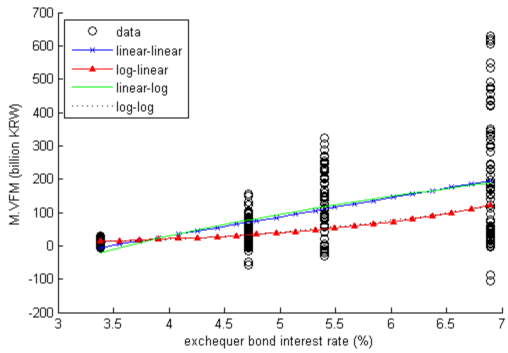
(3) M.VFM vs. BCR



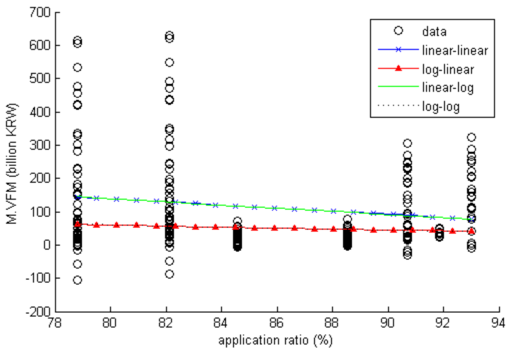
(4) M.VFM vs. discount rate



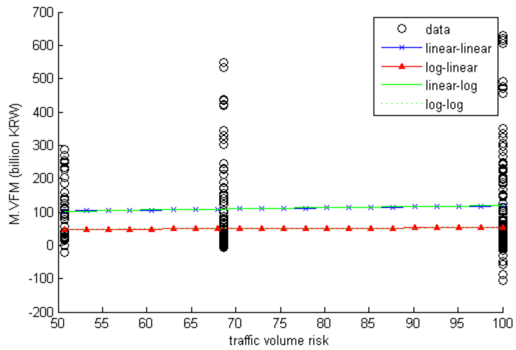
(5) M.VFM vs. CPI



(6) M.VFM vs. 5 year exchequer bond



(7) M.VFM vs. application ratio



(8) M.VFM vs. traffic volume ratio

3. Correlation matrix

	M.VFM	Length	Completion delay	BCR	Discount rate	CPI	exchequer bond rate	Transport mode	PPP option	Region	Application ratio	traffic volume ratio
M.VFM	1	0.542	0.441	0.484	0.479	0.033	0.466	0.003	0.305	-0.346	-0.151	0.038
Length		1	-0.028	0.361	0.357	-0.230	0.483	0.238	0.224	-0.161	-0.136	0.000
Completion delay			1	-0.059	-0.013	-0.018	-0.027	0.091	-0.028	0.049	0.108	0.000
BCR				1	0.873	0.546	0.814	-0.565	0.102	-0.476	-0.517	0.000
Discount rate					1	0.318	0.936	-0.161	0.076	-0.540	-0.110	0.000
CPI						1	0.072	-0.614	-0.242	0.325	-0.265	0.000
exchequer bond rate							1	-0.146	0.125	-0.642	-0.208	0.000
Transport mode								1	0.007	0.186	0.834	0.000
PPP option									1	-0.379	-0.173	0.000
Region										1	0.346	0.000
Application ratio											1	0.000
traffic volume												1

Appendix I The collinearity problem in the regression model

1) When all (11) independent variables are included in the regression model, collinearity problems occur, CPI and discount rate being dropped.

```
metareg M_VFM length completion_delay BCR discount_rate cpi exchequer_bond application_ratio traffic_v
> olume model_D ppp_D region_D,wsse( SE_prj_ppp)
note: discount_rate dropped because of collinearity
note: cpi dropped because of collinearity

Meta-regression                                      Number of obs  =      216
REML estimate of between-study variance              tau2           =     4470
% residual variation due to heterogeneity            I-squared_res  =   94.33%
Proportion of between-study variance explained       Adj R-squared  =   75.09%
Joint test for all covariates                        Model F(9,206) =    53.68
With Knapp-Hartung modification                      Prob > F       =   0.0000
------------------------------------------------------------------------------
           M_VFM |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-----------------+------------------------------------------------------------
          length |   5.240117    1.05908     4.95   0.000     3.152092    7.328142
completion_delay |   44.88508   3.721983    12.06   0.000     37.54702    52.22314
             BCR |   164.9294   23.46195     7.03   0.000     118.6731    211.1857
  exchequer_bond |  -65.06958   12.17439    -5.34   0.000    -89.07196   -41.06721
application_ratio|   3.222775   3.193032     1.01   0.314    -3.072438    9.517988
  traffic_volume |   .2972101   .2595281     1.15   0.253    -.2144617    .8088819
         model_D |   63.84379   44.35165     1.44   0.152    -23.59755    151.2851
           ppp_D |   34.58096   12.49946     2.77   0.006     9.937693    59.22422
        region_D |  -93.83194   21.56015    -4.35   0.000    -136.3388    -51.3251
           _cons |   -316.816   260.0314    -1.22   0.224    -829.4801    195.8481
------------------------------------------------------------------------------
```

2) When ten independent variables (without BCR or discount rate or CPI) are included in the regression model, a collinearity problim occurs. As an example, discount rate is dropped.

```
. metareg M_VFM length completion_delay BCR discount_rate exchequer_bond application_ratio traffic_volum
> e model_D ppp_D region_D,wsse( SE_prj_ppp)
note: discount_rate dropped because of collinearity

Meta-regression                                      Number of obs  =      216
REML estimate of between-study variance              tau2           =     4470
% residual variation due to heterogeneity            I-squared_res  =   94.33%
Proportion of between-study variance explained       Adj R-squared  =   75.09%
Joint test for all covariates                        Model F(9,206) =    53.68
With Knapp-Hartung modification                      Prob > F       =   0.0000
------------------------------------------------------------------------------
           M_VFM |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-----------------+------------------------------------------------------------
          length |   5.240117    1.05908     4.95   0.000     3.152092    7.328142
completion_delay |   44.88508   3.721983    12.06   0.000     37.54702    52.22314
             BCR |   164.9294   23.46195     7.03   0.000     118.6731    211.1857
  exchequer_bond |  -65.06958   12.17439    -5.34   0.000    -89.07196   -41.06721
application_ratio|   3.222775   3.193032     1.01   0.314    -3.072438    9.517988
  traffic_volume |   .2972101   .2595281     1.15   0.253    -.2144617    .8088819
         model_D |   63.84379   44.35165     1.44   0.152    -23.59755    151.2851
           ppp_D |   34.58096   12.49946     2.77   0.006     9.937693    59.22422
        region_D |  -93.83194   21.56015    -4.35   0.000    -136.3388    -51.3251
           _cons |   -316.816   260.0314    -1.22   0.224    -829.4801    195.8481
------------------------------------------------------------------------------
```

3) When nine independent variables (excluding BCR and discount rate, discount rate and CPI or CPI and BCR), no collinearity problem occurs.

```
Meta-regression                                      Number of obs  =      216
REML estimate of between-study variance              tau2           =     4470
% residual variation due to heterogeneity            I-squared_res  =   94.33%
Proportion of between-study variance explained       Adj R-squared  =   75.09%
Joint test for all covariates                        Model F(9,206) =    53.68
With Knapp-Hartung modification                      Prob > F       =   0.0000
------------------------------------------------------------------------------
           M_VFM |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-----------------+------------------------------------------------------------
          length |   5.240117    1.05908     4.95   0.000     3.152092    7.328142
completion_delay |   44.88508   3.721983    12.06   0.000     37.54702    52.22314
             BCR |   164.9294   23.46195     7.03   0.000     118.6731    211.1857
  exchequer_bond |  -65.06958   12.17439    -5.34   0.000    -89.07196   -41.06721
application_ratio|   3.222775   3.193032     1.01   0.314    -3.072438    9.517988
  traffic_volume |   .2972101   .2595281     1.15   0.253    -.2144617    .8088819
         model_D |   63.84379   44.35165     1.44   0.152    -23.59755    151.2851
           ppp_D |   34.58096   12.49946     2.77   0.006     9.937693    59.22422
        region_D |  -93.83194   21.56015    -4.35   0.000    -136.3388    -51.3251
           _cons |   -316.816   260.0314    -1.22   0.224    -829.4801    195.8481
------------------------------------------------------------------------------
```

➔ It is possible to know that there is a collinearity problem among BCR, discount rate and CPI.

Appendix J Meta-regression result using *metareg* package

1. Model 1

Meta-regression		Number of obs =	216
REML estimate of between-study variance		tau2 =	4470
% residual variation due to heterogeneity		I-squared_res =	94.33%
Proportion of between-study variance explained		Adj R-squared =	75.09%
Joint test for all covariates		Model F(9,206) =	53.68
With Knapp-Hartung modification		Prob > F =	0.0000

M_VFM	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
length	5.240117	1.05908	4.95	0.000	3.152092	7.328142
completion_delay	44.88508	3.721983	12.06	0.000	37.54702	52.22314
BCR	164.9294	23.46195	7.03	0.000	118.6731	211.1857
exchequer_bond	-65.06958	12.17439	-5.34	0.000	-89.07196	-41.06721
application_ratio	3.222775	3.193032	1.01	0.314	-3.072438	9.517988
traffic_volume	.2972101	.2595281	1.15	0.253	-.2144617	.8088819
model_D	63.84379	44.35165	1.44	0.152	-23.59755	151.2851
ppp_D	34.58096	12.49946	2.77	0.006	9.937693	59.22422
region_D	-93.83194	21.56015	-4.35	0.000	-136.3388	-51.3251
_cons	-316.816	260.0314	-1.22	0.224	-829.4801	195.8481

2. Model 2

Meta-regression		Number of obs =	216
REML estimate of between-study variance		tau2 =	4470
% residual variation due to heterogeneity		I-squared_res =	94.33%
Proportion of between-study variance explained		Adj R-squared =	75.09%
Joint test for all covariates		Model F(9,206) =	53.68
With Knapp-Hartung modification		Prob > F =	0.0000

M_VFM	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
length	8.515031	.9439123	9.02	0.000	6.654064	10.376
completion_delay	44.88508	3.721983	12.06	0.000	37.54702	52.22314
discount_rate	137.8021	19.60297	7.03	0.000	99.1539	176.4502
exchequer_bond	-104.5593	16.64508	-6.28	0.000	-137.3759	-71.74278
application_ratio	3.222775	3.193033	1.01	0.314	-3.072438	9.517988
traffic_volume	.2972101	.2595281	1.15	0.253	-.2144617	.8088819
model_D	-63.12074	34.67695	-1.82	0.070	-131.488	5.246481
ppp_D	34.58096	12.49946	2.77	0.006	9.937693	59.22422
region_D	-100.2716	21.59875	-4.64	0.000	-142.8546	-57.68867
_cons	-755.8233	238.383	-3.17	0.002	-1225.807	-285.8401

3. Model 3

Meta-regression		Number of obs =	216
REML estimate of between-study variance		tau2 =	4470
% residual variation due to heterogeneity		I-squared_res =	94.33%
Proportion of between-study variance explained		Adj R-squared =	75.09%
Joint test for all covariates		Model F(9,206) =	53.68
With Knapp-Hartung modification		Prob > F =	0.0000

M_VFM	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
length	8.515031	.9439123	9.02	0.000	6.654064	10.376
completion_delay	44.88508	3.721983	12.06	0.000	37.54702	52.22314
cpi	255.9473	36.40966	7.03	0.000	184.164	327.7307
exchequer_bond	-38.013	9.817042	-3.87	0.000	-57.36775	-18.65824
application_ratio	3.222775	3.193033	1.01	0.314	-3.072438	9.517988
traffic_volume	.2972101	.2595281	1.15	0.253	-.2144617	.8088819
model_D	47.3461	42.78832	1.11	0.270	-37.01307	131.7053
ppp_D	34.58096	12.49946	2.77	0.006	9.937693	59.22422
region_D	-210.7385	27.50318	-7.66	0.000	-264.9623	-156.5147
_cons	-1077.293	232.1047	-4.64	0.000	-1534.898	-619.6877

Appendix K Meta-regression results (interaction effects)

1. Two way interaction effects

1) length and completion delay

Meta-regression	Number of obs	=	216
REML estimate of between-study variance	tau2	=	2904
% residual variation due to heterogeneity	I-squared_res	=	93.99%
Proportion of between-study variance explained	Adj R-squared	=	83.81%
Joint test for all covariates	Model F(10,205)	=	83.68
With Knapp-Hartung modification	Prob > F	=	0.0000

m_vfm	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
X1	-.9644134	1.024577	-0.94	0.348	-2.984472	1.055645
X2	-23.24835	6.994023	-3.32	0.001	-37.03779	-9.458906
X3	176.5387	18.46274	9.56	0.000	140.1375	212.9399
X4	-67.92442	9.513602	-7.14	0.000	-86.68148	-49.16737
X5	3.165922	2.520953	1.26	0.211	-1.804398	8.136242
X6	.2912803	.2045987	1.42	0.156	-.1121072	.6946678
X7	68.50603	34.98175	1.96	0.052	-.4641149	137.4762
X8	35.12247	9.963139	3.53	0.001	15.47911	54.76583
X9	-93.0848	16.92678	-5.50	0.000	-126.4577	-59.7119
interaction_X1_X2	2.988783	.2872078	10.41	0.000	2.422523	3.555042
_cons	-173.1192	205.6571	-0.84	0.401	-578.5934	232.355

2) length and BCR

Meta-regression	Number of obs	=	216
REML estimate of between-study variance	tau2	=	4470
% residual variation due to heterogeneity	I-squared_res	=	94.33%
Proportion of between-study variance explained	Adj R-squared	=	75.09%
Joint test for all covariates	Model F(9,206)	=	53.68
With Knapp-Hartung modification	Prob > F	=	0.0000

m_vfm	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
X1	-2.249826	1.811302	-1.24	0.216	-5.820892	1.32124
X2	44.88508	3.721983	12.06	0.000	37.54702	52.22315
X4	-20.49441	8.866259	-2.31	0.022	-37.97465	-3.014167
X5	3.22274	3.193012	1.01	0.314	-3.072432	9.517911
X6	.2972103	.2595281	1.15	0.253	-.2144616	.8088821
X7	48.68885	42.9126	1.13	0.258	-35.91534	133.293
X8	34.58095	12.49946	2.77	0.006	9.937687	59.22422
X9	-60.98698	21.96482	-2.78	0.006	-104.2916	-17.68231
interaction_X1_X3	3.711432	.5279664	7.03	0.000	2.670521	4.752342
_cons	-276.1364	262.6974	-1.05	0.294	-794.0567	241.7838

3) length and exchequer bond interest rate

Meta-regression	Number of obs	=	216
REML estimate of between-study variance	tau2	=	4470
% residual variation due to heterogeneity	I-squared_res	=	94.33%
Proportion of between-study variance explained	Adj R-squared	=	75.09%
Joint test for all covariates	Model F(9,206)	=	53.68
With Knapp-Hartung modification	Prob > F	=	0.0000

m_vfm	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
X1	-16.27678	3.66498	-4.44	0.000	-23.50246	-9.051098
X2	44.88508	3.721983	12.06	0.000	37.54702	52.22315
X4	-44.4624	10.29768	-4.32	0.000	-64.76476	-24.16004
X5	3.22274	3.193012	1.01	0.314	-3.072432	9.517911
X6	.2972103	.2595281	1.15	0.253	-.2144616	.8088821
X7	14.79873	39.92949	0.37	0.711	-63.92413	93.52159
X8	34.58095	12.49946	2.77	0.006	9.937687	59.22422
X9	-72.13495	21.71591	-3.32	0.001	-114.9489	-29.32102
interaction_X1_X4	3.593015	.5111211	7.03	0.000	2.585316	4.600714
_cons	-136.9735	272.5573	-0.50	0.616	-674.333	400.386

4) length and PPP option

Meta-regression		Number of obs =	216
REML estimate of between-study variance		tau2 =	4481
% residual variation due to heterogeneity		I-squared_res =	94.34%
Proportion of between-study variance explained		Adj R-squared =	75.02%
Joint test for all covariates		Model F(10,205)=	48.33
With Knapp-Hartung modification		Prob > F =	0.0000

m_vfm	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
X1	5.355105	1.068191	5.01	0.000	3.249055	7.461155
X2	44.89606	3.724793	12.05	0.000	37.55224	52.23987
X3	172.9884	25.26882	6.85	0.000	123.1683	222.8085
X4	-65.97811	12.22953	-5.39	0.000	-90.08989	-41.86632
X5	3.223029	3.195417	1.01	0.314	-3.077067	9.523125
X6	.2972407	.2597262	1.14	0.254	-.2148363	.8093177
X7	67.05316	44.54108	1.51	0.134	-20.76419	154.8705
X8	68.50836	41.24954	1.66	0.098	-12.81938	149.8361
X9	-89.50422	22.15319	-4.04	0.000	-133.1815	-45.82692
interaction_X1_X8	-1.317161	1.52589	-0.86	0.389	-4.325611	1.69129
_cons	-328.8716	260.598	-1.26	0.208	-842.6675	184.9242

5) length and region

Meta-regression		Number of obs =	216
REML estimate of between-study variance		tau2 =	4470
% residual variation due to heterogeneity		I-squared_res =	94.33%
Proportion of between-study variance explained		Adj R-squared =	75.09%
Joint test for all covariates		Model F(9,206) =	53.68
With Knapp-Hartung modification		Prob > F =	0.0000

m_vfm	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
X1	6.586463	1.247261	5.28	0.000	4.127429	9.045497
X2	44.88508	3.721983	12.06	0.000	37.54702	52.22315
X3	97.12517	27.89054	3.48	0.001	42.13767	152.1127
X4	-29.32998	10.11931	-2.90	0.004	-49.28067	-9.379281
X5	3.22274	3.193012	1.01	0.314	-3.072432	9.517911
X6	.2972103	.2595281	1.15	0.253	-.2144616	.8088821
X7	32.95714	47.44129	0.69	0.488	-60.57558	126.4899
X8	34.58095	12.49946	2.77	0.006	9.937686	59.22422
interaction_X1_X9	-3.680901	.8457764	-4.35	0.000	-5.348388	-2.013413
_cons	-431.0266	271.8893	-1.59	0.114	-967.069	105.0157

6) completion delay and BCR

Meta-regression		Number of obs =	216
REML estimate of between-study variance		tau2 =	2496
% residual variation due to heterogeneity		I-squared_res =	92.45%
Proportion of between-study variance explained		Adj R-squared =	86.09%
Joint test for all covariates		Model F(10,205)=	96.95
With Knapp-Hartung modification		Prob > F =	0.0000

m_vfm	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
X1	5.515748	.7775167	7.09	0.000	3.982794	7.048703
X2	-31.87853	6.635899	-4.80	0.000	-44.96189	-18.79517
X3	67.64121	18.88678	3.58	0.000	30.40396	104.8785
X4	-66.31644	8.806149	-7.53	0.000	-83.67868	-48.95421
X5	3.14175	2.344152	1.34	0.182	-1.479988	7.763488
X6	.2888194	.190173	1.52	0.130	-.0861264	.6637653
X7	69.94058	32.51856	2.15	0.033	5.826875	134.0543
X8	35.32236	9.303305	3.80	0.000	16.97994	53.66479
X9	-88.10932	15.71029	-5.61	0.000	-119.0838	-57.13485
interaction_X2_X3	50.78745	4.159826	12.21	0.000	42.58592	58.98897
_cons	-162.5901	191.1877	-0.85	0.396	-539.5364	214.3561

7) completion delay and exchequer bond interest rate

Meta-regression		Number of obs	= 216
REML estimate of between-study variance		tau2	= 2951
% residual variation due to heterogeneity		I-squared_res	= 94.09%
Proportion of between-study variance explained		Adj R-squared	= 83.55%
Joint test for all covariates		Model F(10,205)	= 80.05
With Knapp-Hartung modification		Prob > F	= 0.0000

m_vfm	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
X1	5.385147	.8519002	6.32	0.000	3.705537	7.064756
X2	-96.37946	14.4319	-6.68	0.000	-124.8334	-67.92547
X3	173.2499	18.80517	9.21	0.000	136.1735	210.3262
X4	-121.4842	11.26743	-10.78	0.000	-143.6992	-99.26933
X5	3.168348	2.5693	1.23	0.219	-1.897294	8.233989
X6	.2915299	.2085325	1.40	0.164	-.1196135	.7026733
X7	68.43947	35.65402	1.92	0.056	-1.856119	138.7351
X8	35.1014	10.14999	3.46	0.001	15.08965	55.11315
X9	-89.04856	17.25972	-5.16	0.000	-123.0779	-55.01922
interaction_X2_X4	26.15837	2.651763	9.86	0.000	20.93014	31.38659
_cons	-24.78487	211.1579	-0.12	0.907	-441.1045	391.5347

8) completion delay and PPP option

Meta-regression		Number of obs	= 216
REML estimate of between-study variance		tau2	= 3593
% residual variation due to heterogeneity		I-squared_res	= 92.91%
Proportion of between-study variance explained		Adj R-squared	= 79.97%
Joint test for all covariates		Model F(10,205)	= 60.23
With Knapp-Hartung modification		Prob > F	= 0.0000

m_vfm	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
X1	5.265435	.9646641	5.46	0.000	3.3635	7.16737
X2	30.14625	4.074407	7.40	0.000	22.11313	38.17936
X3	161.6305	21.33034	7.58	0.000	119.5755	203.6854
X4	-62.96662	11.04015	-5.70	0.000	-84.73341	-41.19983
X5	3.196089	2.909388	1.10	0.273	-2.540071	8.932249
X6	.2944108	.2362877	1.25	0.214	-.1714548	.7602764
X7	60.03255	40.39652	1.49	0.139	-19.61337	139.6785
X8	-54.10056	18.56205	-2.91	0.004	-90.69757	-17.50355
X9	-89.36897	19.60226	-4.56	0.000	-128.0169	-50.72108
interaction_X2_X8	44.383	7.294038	6.08	0.000	30.00205	58.76395
_cons	-290.6675	236.9295	-1.23	0.221	-757.7986	176.4636

9) completion delay and region

Meta-regression		Number of obs	= 216
REML estimate of between-study variance		tau2	= 3270
% residual variation due to heterogeneity		I-squared_res	= 91.62%
Proportion of between-study variance explained		Adj R-squared	= 81.77%
Joint test for all covariates		Model F(10,205)	= 65.60
With Knapp-Hartung modification		Prob > F	= 0.0000

m_vfm	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
X1	5.438082	.9282555	5.86	0.000	3.60793	7.268234
X2	57.20561	3.767391	15.18	0.000	49.77781	64.63341
X3	159.5958	20.50119	7.78	0.000	119.1756	200.016
X4	-63.05204	10.59214	-5.95	0.000	-83.93554	-42.16854
X5	3.183271	2.798471	1.14	0.257	-2.334204	8.700746
X6	.2930741	.2272065	1.29	0.199	-.154887	.7410352
X7	57.57671	38.85362	1.48	0.140	-19.02722	134.1806
X8	34.96775	11.02726	3.17	0.002	13.22637	56.70913
X9	25.7093	24.87215	1.03	0.303	-23.32871	74.74732
interaction_X2_X9	-55.03956	7.528268	-7.31	0.000	-69.88232	-40.1968
_cons	-343.5702	227.899	-1.51	0.133	-792.8966	105.7562

10) BCR and exchequer bond interest rate

Meta-regression	Number of obs	=	216
REML estimate of between-study variance	tau2	=	4470
% residual variation due to heterogeneity	I-squared_res	=	94.33%
Proportion of between-study variance explained	Adj R-squared	=	75.09%
Joint test for all covariates	Model F(9,206)	=	53.68
With Knapp-Hartung modification	Prob > F	=	0.0000

m_vfm	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
X1	4.662908	1.098768	4.24	0.000	2.496636	6.82918
X2	44.88508	3.721983	12.06	0.000	37.54702	52.22315
X4	-113.2871	17.72146	-6.39	0.000	-148.2257	-78.34838
X5	3.22274	3.193012	1.01	0.314	-3.072432	9.517911
X6	.2972103	.2595281	1.15	0.253	-.2144616	.8088821
X7	77.04384	45.65054	1.69	0.093	-12.95833	167.046
X8	34.58095	12.49946	2.77	0.006	9.937687	59.22422
X9	-116.6169	21.86945	-5.33	0.000	-159.7335	-73.50027
interaction_X3_X4	28.11569	3.999572	7.03	0.000	20.23035	36.00103
_cons	-40.87005	279.9815	-0.15	0.884	-592.8666	511.1265

11) BCR and PPP option

Meta-regression	Number of obs	=	216
REML estimate of between-study variance	tau2	=	4440
% residual variation due to heterogeneity	I-squared_res	=	94.35%
Proportion of between-study variance explained	Adj R-squared	=	75.25%
Joint test for all covariates	Model F(10,205)	=	48.76
With Knapp-Hartung modification	Prob > F	=	0.0000

m_vfm	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
X1	5.528573	1.074933	5.14	0.000	3.409232	7.647914
X2	44.85634	3.711076	12.09	0.000	37.53957	52.17311
X3	174.1189	24.24893	7.18	0.000	126.3097	221.9282
X4	-65.39206	12.13902	-5.39	0.000	-89.3254	-41.45872
X5	3.221981	3.183666	1.01	0.313	-3.054947	9.498909
X6	.2971304	.2587621	1.15	0.252	-.2130459	.8073067
X7	62.6678	44.22864	1.42	0.158	-24.53354	149.8691
X8	75.91605	31.34119	2.42	0.016	14.12365	137.7084
X9	-86.07882	22.15973	-3.88	0.000	-129.769	-42.38862
interaction_X3_X8	-25.80512	17.95554	-1.44	0.152	-61.20633	9.596083
_cons	-336.7487	259.6424	-1.30	0.196	-848.6605	175.1632

12) BCR and region

Meta-regression	Number of obs	=	216
REML estimate of between-study variance	tau2	=	4470
% residual variation due to heterogeneity	I-squared_res	=	94.33%
Proportion of between-study variance explained	Adj R-squared	=	75.09%
Joint test for all covariates	Model F(9,206)	=	53.68
With Knapp-Hartung modification	Prob > F	=	0.0000

m_vfm	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
X1	5.240108	1.059075	4.95	0.000	3.152091	7.328124
X2	44.88508	3.721983	12.06	0.000	37.54702	52.22315
X3	164.9296	23.46191	7.03	0.000	118.6733	211.1858
X4	-65.06962	12.17439	-5.34	0.000	-89.072	-41.06723
X5	3.22274	3.193012	1.01	0.314	-3.072432	9.517911
X6	.2972103	.2595281	1.15	0.253	-.2144616	.8088821
X7	63.84426	44.35139	1.44	0.152	-23.59658	151.2851
X8	34.58095	12.49946	2.77	0.006	9.937686	59.22422
X9	-93.83193	21.56017	-4.35	0.000	-136.3388	-51.32505
_cons	-316.813	260.0296	-1.22	0.224	-829.4734	195.8475

13) exchequer bond interest rate and PPP option

```
Meta-regression                                    Number of obs  =      216
REML estimate of between-study variance            tau2           =     4490
% residual variation due to heterogeneity          I-squared_res  =   94.33%
Proportion of between-study variance explained     Adj R-squared  =   74.97%
Joint test for all covariates                      Model F(10,205)=    48.23
With Knapp-Hartung modification                    Prob > F       =   0.0000
```

m_vfm	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
X1	5.313109	1.06635	4.98	0.000	3.21069	7.415527
X2	44.90404	3.727886	12.05	0.000	37.55413	52.25396
X3	171.7033	25.6045	6.71	0.000	121.2213	222.1852
X4	-65.94145	12.26451	-5.38	0.000	-90.12219	-41.76071
X5	3.223239	3.198068	1.01	0.315	-3.082082	9.528561
X6	.2972629	.2599434	1.14	0.254	-.2152424	.8097682
X7	67.26905	44.72004	1.50	0.134	-20.90114	155.4392
X8	87.46422	80.32167	1.09	0.277	-70.89827	245.8267
X9	-90.62146	22.12881	-4.10	0.000	-134.2507	-46.99222
interaction_X4_X8	-9.498399	14.24894	-0.67	0.506	-37.59166	18.59486
_cons	-326.0284	260.8029	-1.25	0.213	-840.2284	188.1715

14) exchequer bon interest rate and region

```
Meta-regression                                    Number of obs  =      216
REML estimate of between-study variance            tau2           =     4470
% residual variation due to heterogeneity          I-squared_res  =   94.33%
Proportion of between-study variance explained     Adj R-squared  =   75.09%
Joint test for all covariates                      Model F(9,206) =    53.68
With Knapp-Hartung modification                    Prob > F       =   0.0000
```

m_vfm	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
X1	5.666294	1.1128	5.09	0.000	3.472357	7.860232
X2	44.88508	3.721983	12.06	0.000	37.54702	52.22315
X3	143.4662	23.87337	6.01	0.000	96.39873	190.5337
X4	-53.75629	10.91436	-4.93	0.000	-75.27446	-32.23813
X5	3.22274	3.193012	1.01	0.314	-3.072432	9.517911
X6	.2972103	.2595281	1.15	0.253	-.2144616	.8088821
X7	54.06699	45.23197	1.20	0.233	-35.10996	143.2439
X8	34.58095	12.49946	2.77	0.006	9.937687	59.22422
interaction_X4_X9	-21.48632	4.937005	-4.35	0.000	-31.21986	-11.75279
_cons	-352.9671	263.5589	-1.34	0.182	-872.5858	166.6515

15) PPP option and region

```
Meta-regression                                    Number of obs  =      216
REML estimate of between-study variance            tau2           =     4470
% residual variation due to heterogeneity          I-squared_res  =   94.33%
Proportion of between-study variance explained     Adj R-squared  =   75.09%
Joint test for all covariates                      Model F(9,206) =    53.68
With Knapp-Hartung modification                    Prob > F       =   0.0000
```

m_vfm	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
X1	5.240108	1.059075	4.95	0.000	3.152091	7.328124
X2	44.88508	3.721983	12.06	0.000	37.54702	52.22315
X3	164.9296	23.46191	7.03	0.000	118.6733	211.1858
X4	-65.06962	12.17439	-5.34	0.000	-89.072	-41.06723
X5	3.22274	3.193012	1.01	0.314	-3.072432	9.517911
X6	.2972103	.2595281	1.15	0.253	-.2144616	.8088821
X7	63.84426	44.35139	1.44	0.152	-23.59658	151.2851
X8	34.58095	12.49946	2.77	0.006	9.937686	59.22422
X9	-93.83193	21.56017	-4.35	0.000	-136.3388	-51.32505
_cons	-316.813	260.0296	-1.22	0.224	-829.4734	195.8475

2. Three way interaction effects

1) length, completion delay and BCR

Meta-regression	Number of obs = 216
REML estimate of between-study variance	tau2 = 580.8
% residual variation due to heterogeneity	I-squared_res = 80.20%
Proportion of between-study variance explained	Adj R-squared = 96.76%
Joint test for all covariates	Model F(15,200)= 153.39
With Knapp-Hartung modification	Prob > F = 0.0000

m_vfm	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
X1	1.412562	.6120434	2.31	0.022	.2056762	2.619448
X2	150.5194	23.36747	6.44	0.000	104.4411	196.5976
X3	-24.35352	16.88834	-1.44	0.151	-57.65556	8.94853
X4	6.389032	8.932571	0.72	0.475	-11.22507	24.00314
X5	2.783104	1.320373	2.11	0.036	.179466	5.386741
X6	.2626289	.107901	2.43	0.016	.0498594	.4753984
X7	-29.05981	22.43241	-1.30	0.197	-73.2942	15.17458
X8	1.27187	10.08662	0.13	0.900	-18.6179	21.16164
X9	-1.132372	14.36859	-0.08	0.937	-29.46575	27.201
interaction_X1_X2	-20.92042	3.093905	-6.76	0.000	-27.02127	-14.81956
interaction_X2_X3	-408.8327	61.34315	-6.66	0.000	-529.7951	-287.8704
interaction_X2_X4	102.5385	16.03731	6.39	0.000	70.91454	134.1624
interaction_X2_X8	17.45156	4.169618	4.19	0.000	9.229503	25.67361
interaction_X2_X9	62.47813	12.76175	4.90	0.000	37.31329	87.64297
interaction_X1_X2_X3	11.34767	1.491974	7.61	0.000	8.405656	14.28969
_cons	-266.6751	110.3909	-2.42	0.017	-484.3545	-48.99578

2) length, completion delay and five-year exchequer bond

Meta-regression	Number of obs = 216
REML estimate of between-study variance	tau2 = 580.8
% residual variation due to heterogeneity	I-squared_res = 80.20%
Proportion of between-study variance explained	Adj R-squared = 96.76%
Joint test for all covariates	Model F(15,200)= 153.39
With Knapp-Hartung modification	Prob > F = 0.0000

m_vfm	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
X1	1.41257	.6120436	2.31	0.022	.2056832	2.619456
X2	196.0599	28.7182	6.83	0.000	139.4305	252.6892
X3	-24.35365	16.88834	-1.44	0.151	-57.6557	8.948409
X4	6.389144	8.932576	0.72	0.475	-11.22497	24.00326
X5	2.783103	1.320372	2.11	0.036	.1794663	5.386741
X6	.2626289	.1079009	2.43	0.016	.0498595	.4753983
X7	-29.05996	22.43242	-1.30	0.197	-73.29436	15.17444
X8	1.271873	10.08662	0.13	0.900	-18.61789	21.16164
X9	-1.132115	14.3686	-0.08	0.937	-29.4655	27.20127
interaction_X1_X2	-18.34884	2.756529	-6.66	0.000	-23.78443	-12.91325
interaction_X2_X3	-60.38218	15.97376	-3.78	0.000	-91.88078	-28.88357
interaction_X2_X4	-14.2813	2.850782	-5.01	0.000	-19.90274	-8.659849
interaction_X2_X8	17.45156	4.169617	4.19	0.000	9.229503	25.67361
interaction_X2_X9	-17.44617	5.306656	-3.29	0.001	-27.91035	-6.981995
interaction_X1_X2_X4	3.394645	.4463224	7.61	0.000	2.514544	4.274747
_cons	-266.6757	110.3909	-2.42	0.017	-484.355	-48.99632

3) length, completion delay and PPP option

Meta-regression	Number of obs = 216
REML estimate of between-study variance	tau2 = 914.3
% residual variation due to heterogeneity	I-squared_res = 83.95%
Proportion of between-study variance explained	Adj R-squared = 94.90%
Joint test for all covariates	Model F(15,200)= 126.17
With Knapp-Hartung modification	Prob > F = 0.0000

m_vfm	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
X1	.226797	.6856296	0.33	0.741	-1.125193	1.578787
X2	-1.653057	14.21207	-0.12	0.908	-29.67779	26.37168
X3	57.37703	15.14988	3.79	0.000	27.50304	87.25102
X4	-29.22146	9.138594	-3.20	0.002	-47.24182	-11.2011
X5	2.918711	1.556776	1.87	0.062	-.1510894	5.988512
X6	.2698141	.1265503	2.13	0.034	.0202701	.5193582
X7	65.61699	21.71526	3.02	0.003	22.79675	108.4372
X8	-4.288251	11.51789	-0.37	0.710	-27.00034	18.42384
X9	-29.08809	16.49471	-1.76	0.079	-61.61396	3.437773
interaction_X1_X2	2.524528	.2257923	11.18	0.000	2.079289	2.969767
interaction_X2_X3	54.312	5.078	10.70	0.000	44.29871	64.32529
interaction_X2_X4	-17.04437	3.358391	-5.08	0.000	-23.66677	-10.42198
interaction_X2_X8	12.37413	10.32118	1.20	0.232	-7.978164	32.72642
interaction_X2_X9	-27.42228	6.243188	-4.39	0.000	-39.7332	-15.11136
interaction_X1_X2_X8	.3293101	.3830892	0.86	0.391	-.426102	1.084722
_cons	-206.8009	129.8127	-1.59	0.113	-462.778	49.17633

4) length, completion delay and region

Meta-regression	Number of obs = 216
REML estimate of between-study variance	tau2 = 580.8
% residual variation due to heterogeneity	I-squared_res = 80.20%
Proportion of between-study variance explained	Adj R-squared = 96.76%
Joint test for all covariates	Model F(15,200)= 153.39
With Knapp-Hartung modification	Prob > F = 0.0000

m_vfm	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
X1	1.412567	.6120432	2.31	0.022	.2056809	2.619452
X2	-145.1973	21.92719	-6.62	0.000	-188.4354	-101.9591
X3	-24.35342	16.88831	-1.44	0.151	-57.65541	8.948574
X4	6.389134	8.932569	0.72	0.475	-11.22497	24.00323
X5	2.783103	1.320372	2.11	0.036	.179467	5.386739
X6	.2626289	.1079009	2.43	0.016	.0498595	.4753982
X7	-29.05976	22.43239	-1.30	0.197	-73.2941	15.17457
X8	1.27188	10.08662	0.13	0.900	-18.61788	21.16164
X9	-1.131976	14.3686	-0.08	0.937	-29.46536	27.20141
interaction_X1_X2	3.999949	.2693085	14.85	0.000	3.4689	4.530997
interaction_X2_X3	-6.280425	9.327607	-0.67	0.502	-24.6735	12.11265
interaction_X2_X4	19.86683	5.668492	3.50	0.001	8.689148	31.0445
interaction_X2_X8	17.45155	4.169616	4.19	0.000	9.229502	25.6736
interaction_X2_X9	102.824	17.74091	5.80	0.000	67.84076	137.8072
interaction_X1_X2_X9	-5.522187	.726047	-7.61	0.000	-6.953876	-4.090497
_cons	-266.676	110.3908	-2.42	0.017	-484.3553	-48.99677

5) completion delay, BCR and five-year exchequer bond

Meta-regression	Number of obs = 216
REML estimate of between-study variance	tau2 = 580.8
% residual variation due to heterogeneity	I-squared_res = 80.20%
Proportion of between-study variance explained	Adj R-squared = 96.76%
Joint test for all covariates	Model F(15,200)= 153.39
With Knapp-Hartung modification	Prob > F = 0.0000

m_vfm	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
X1	1.412574	.612043	2.31	0.022	.2056887	2.619459
X2	-942.5652	123.9823	-7.60	0.000	-1187.045	-698.085
X3	-24.35322	16.88827	-1.44	0.151	-57.65514	8.948707
X4	6.389091	8.932557	0.72	0.475	-11.22498	24.00317
X5	2.783102	1.320371	2.11	0.036	.179468	5.386737
X6	.2626289	.1079008	2.43	0.016	.0498596	.4753981
X7	-29.05998	22.43238	-1.30	0.197	-73.29431	15.17435
X8	1.271891	10.08661	0.13	0.900	-18.61786	21.16164
X9	-1.132002	14.36859	-0.08	0.937	-29.46536	27.20136
interaction_X1_X2	4.006404	.2699032	14.84	0.000	3.474183	4.538625
interaction_X2_X3	674.4365	81.35098	8.29	0.000	514.0208	834.8522
interaction_X2_X4	135.5195	20.32034	6.67	0.000	95.44994	175.5892
interaction_X2_X8	17.45155	4.169614	4.19	0.000	9.2295	25.67359
interaction_X2_X9	42.04302	10.36369	4.06	0.000	21.60689	62.47915
interaction_X2_X3_X4	-98.70181	12.97711	-7.61	0.000	-124.2913	-73.1123
_cons	-266.6761	110.3908	-2.42	0.017	-484.3552	-48.99699

6) completion delay, BCR and PPP option

Meta-regression	Number of obs = 216
REML estimate of between-study variance	tau2 = 925.6
% residual variation due to heterogeneity	I-squared_res = 84.42%
Proportion of between-study variance explained	Adj R-squared = 94.84%
Joint test for all covariates	Model F(15,200)= 127.08
With Knapp-Hartung modification	Prob > F = 0.0000

m_vfm	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
X1	.2037727	.6839802	0.30	0.766	-1.144965	1.552511
X2	-7.245783	14.04956	-0.52	0.607	-34.95006	20.45849
X3	58.55946	15.02596	3.90	0.000	28.92983	88.18909
X4	-29.66333	9.101373	-3.26	0.001	-47.6103	-11.71637
X5	2.922121	1.554674	1.88	0.062	-.1435345	5.987777
X6	.2700413	.1263669	2.14	0.034	.0208589	.5192237
X7	66.95316	21.59205	3.10	0.002	24.37587	109.5304
X8	-3.927864	11.49872	-0.34	0.733	-26.60214	18.74642
X9	-29.18591	16.47055	-1.77	0.078	-61.66413	3.292304
interaction_X1_X2	2.644868	.226731	11.67	0.000	2.197778	3.091958
interaction_X2_X3	57.8785	5.159283	11.22	0.000	47.70493	68.05207
interaction_X2_X4	-17.48782	3.367746	-5.19	0.000	-24.12867	-10.84698
interaction_X2_X8	28.58946	8.024947	3.56	0.000	12.7651	44.41383
interaction_X2_X9	-25.72035	6.205477	-4.14	0.000	-37.9569	-13.48379
interaction_X2_X3_X8	-5.942972	4.617325	-1.29	0.200	-15.04786	3.161913
_cons	-206.5437	129.6344	-1.59	0.113	-462.1692	49.08191

7) completion delay, BCR and region

Meta-regression	Number of obs	=	216
REML estimate of between-study variance	tau2	=	580.8
% residual variation due to heterogeneity	I-squared_res	=	80.20%
Proportion of between-study variance explained	Adj R-squared	=	96.76%
Joint test for all covariates	Model F(15,200)	=	153.39
With Knapp-Hartung modification	Prob > F	=	0.0000

m_vfm	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
X1	1.412566	.6120432	2.31	0.022	.2056809	2.619452
X2	-145.1973	21.92719	-6.62	0.000	-188.4354	-101.9591
X3	-24.35342	16.88831	-1.44	0.151	-57.65541	8.948577
X4	6.389132	8.932569	0.72	0.475	-11.22497	24.00323
X5	2.783103	1.320372	2.11	0.036	.179467	5.386739
X6	.2626289	.1079009	2.43	0.016	.0498595	.4753982
X7	-29.05976	22.43239	-1.30	0.197	-73.2941	15.17458
X8	1.27188	10.08662	0.13	0.900	-18.61788	21.16164
X9	-1.131977	14.3686	-0.08	0.937	-29.46536	27.20141
interaction_X1_X2	3.999949	.2693085	14.85	0.000	3.4689	4.530997
interaction_X2_X3	-6.280425	9.327607	-0.67	0.502	-24.6735	12.11265
interaction_X2_X4	19.86683	5.668492	3.50	0.001	8.689148	31.0445
interaction_X2_X8	17.45155	4.169616	4.19	0.000	9.229502	25.6736
interaction_X2_X9	-217.1619	25.63189	-8.47	0.000	-267.7053	-166.6184
interaction_X2_X3_X9	227.4221	29.90104	7.61	0.000	168.4603	286.3838
_cons	-266.676	110.3908	-2.42	0.017	-484.3553	-48.99676

8) completion delay, five-year exchequer bond and PPP option

Meta-regression	Number of obs	=	216
REML estimate of between-study variance	tau2	=	892.8
% residual variation due to heterogeneity	I-squared_res	=	83.67%
Proportion of between-study variance explained	Adj R-squared	=	95.02%
Joint test for all covariates	Model F(15,200)	=	126.76
With Knapp-Hartung modification	Prob > F	=	0.0000

m_vfm	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
X1	.2545251	.6824432	0.37	0.710	-1.091182	1.600232
X2	.6364219	14.15605	0.04	0.964	-27.27783	28.55068
X3	55.2772	15.15322	3.65	0.000	25.39662	85.15778
X4	-28.28633	9.105119	-3.11	0.002	-46.24068	-10.33198
X5	2.912101	1.547864	1.88	0.061	-.1401267	5.964329
X6	.26938	.1258507	2.14	0.034	.0212155	.5175445
X7	63.32145	21.66619	2.92	0.004	20.59798	106.0449
X8	-4.041069	11.46879	-0.35	0.725	-26.65633	18.57419
X9	-28.36984	16.40175	-1.73	0.085	-60.71239	3.972723
interaction_X1_X2	2.494212	.2241182	11.13	0.000	2.052274	2.93615
interaction_X2_X3	53.5614	5.023935	10.66	0.000	43.65473	63.46808
interaction_X2_X4	-17.12208	3.336206	-5.13	0.000	-23.70074	-10.54343
interaction_X2_X8	-8.47643	19.42064	-0.44	0.663	-46.77192	29.81906
interaction_X2_X9	-28.09358	6.21091	-4.52	0.000	-40.34084	-15.84631
interaction_X2_X4_X8	5.327971	3.495509	1.52	0.129	-1.564809	12.22075
_cons	-208.1391	129.0706	-1.61	0.108	-462.6528	46.37465

9) completion delay, five-year exchequer bond and region

Meta-regression	Number of obs	=	216
REML estimate of between-study variance	tau2	=	580.8
% residual variation due to heterogeneity	I-squared_res	=	80.20%
Proportion of between-study variance explained	Adj R-squared	=	96.76%
Joint test for all covariates	Model F(15,200)	=	153.39
With Knapp-Hartung modification	Prob > F	=	0.0000

m_vfm	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
X1	1.412567	.6120432	2.31	0.022	.205681	2.619452
X2	-145.1973	21.92719	-6.62	0.000	-188.4354	-101.9591
X3	-24.35342	16.88831	-1.44	0.151	-57.65542	8.948573
X4	6.389135	8.932569	0.72	0.475	-11.22496	24.00323
X5	2.783103	1.320372	2.11	0.036	.179467	5.386739
X6	.2626289	.1079009	2.43	0.016	.0498595	.4753982
X7	-29.05977	22.43239	-1.30	0.197	-73.2941	15.17457
X8	1.27188	10.08662	0.13	0.900	-18.61788	21.16164
X9	-1.131979	14.3686	-0.08	0.937	-29.46536	27.2014
interaction_X1_X2	3.999949	.2693085	14.85	0.000	3.4689	4.530997
interaction_X2_X3	-6.280425	9.327607	-0.67	0.502	-24.6735	12.11265
interaction_X2_X4	19.86683	5.668492	3.50	0.001	8.689148	31.0445
interaction_X2_X8	17.45155	4.169616	4.19	0.000	9.229502	25.6736
interaction_X2_X9	406.7553	57.16348	7.12	0.000	294.0349	519.4758
interaction_X2_X4_X9	-101.8308	13.38853	-7.61	0.000	-128.2316	-75.43
_cons	-266.676	110.3908	-2.42	0.017	-484.3553	-48.99677

10) completion delay, PPP option and region

```
Meta-regression                                    Number of obs   =       216
REML estimate of between-study variance            tau2            =     926.3
% residual variation due to heterogeneity          I-squared_res   =    84.35%
Proportion of between-study variance explained     Adj R-squared   =    94.84%
Joint test for all covariates                      Model F(14,201) =    135.61
With Knapp-Hartung modification                    Prob > F        =    0.0000
```

m_vfm	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
X1	.2044851	.6851195	0.30	0.766	-1.146459	1.555429
X2	-4.309936	13.88667	-0.31	0.757	-31.69217	23.0723
X3	58.91068	15.04843	3.91	0.000	29.23764	88.58372
X4	-29.88247	9.115287	-3.28	0.001	-47.85632	-11.90861
X5	2.922305	1.557289	1.88	0.062	-.1484147	5.993025
X6	.2700536	.1265788	2.13	0.034	.0204609	.5196464
X7	67.32831	21.62633	3.11	0.002	24.68472	109.9719
X8	-4.348246	11.513	-0.38	0.706	-27.05001	18.35351
X9	-29.54544	16.49612	-1.79	0.075	-62.07309	2.982205
interaction_X1_X2	2.569897	.2194815	11.71	0.000	2.137116	3.002679
interaction_X2_X3	55.57667	4.847615	11.46	0.000	46.01796	65.13537
interaction_X2_X4	-17.09793	3.359838	-5.09	0.000	-23.72298	-10.47288
interaction_X2_X8	20.25868	4.751386	4.26	0.000	10.88972	29.62764
interaction_X2_X9	-26.623	6.176235	-4.31	0.000	-38.80152	-14.44447
_cons	-205.8408	129.8515	-1.59	0.114	-461.8867	50.20503

3. Four way interaction effects

1) length, compeltion delay, BCR and five-year exchequer bond

```
Meta-regression                                    Number of obs   =       216
REML estimate of between-study variance            tau2            =     580.8
% residual variation due to heterogeneity          I-squared_res   =    80.20%
Proportion of between-study variance explained     Adj R-squared   =    96.76%
Joint test for all covariates                      Model F(15,200) =    153.39
With Knapp-Hartung modification                    Prob > F        =    0.0000
```

m_vfm	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
X1	1.412568	.6120433	2.31	0.022	.205682	2.619454
X3	-24.35349	16.88832	-1.44	0.151	-57.65549	8.948518
X4	6.389151	8.932571	0.72	0.475	-11.22495	24.00325
X5	2.783103	1.320372	2.11	0.036	.1794668	5.386739
X6	.2626289	.1079009	2.43	0.016	.0498595	.4753983
X7	-29.05982	22.43239	-1.30	0.197	-73.29417	15.17453
X8	1.27188	10.08662	0.13	0.900	-18.61788	21.16164
X9	-1.131973	14.3686	-0.08	0.937	-29.46536	27.20141
interaction_X2_X8	17.45155	4.169616	4.19	0.000	9.229501	25.6736
interaction_X1_X2_X3	-5.882889	1.364224	-4.31	0.000	-8.572997	-3.192781
interaction_X1_X2_X4	.8521081	.1512075	5.64	0.000	.5539425	1.150274
interaction_X1_X2_X9	-5.024241	.7770185	-6.47	0.000	-6.556441	-3.492041
interaction_X2_X3_X4	-1.829633	.417084	-4.39	0.000	-2.652079	-1.007186
interaction_X2_X4_X9	17.38388	3.422688	5.08	0.000	10.63469	24.13306
interaction_X1_X2_X3_X4	.7649694	.1496875	5.11	0.000	.4698012	1.060138
_cons	-266.676	110.3908	-2.42	0.017	-484.3553	-48.99674

2) length, compeltion delay, BCR and PPP option

```
Meta-regression                                    Number of obs   =       216
REML estimate of between-study variance            tau2            =     580.8
% residual variation due to heterogeneity          I-squared_res   =    80.20%
Proportion of between-study variance explained     Adj R-squared   =    96.76%
Joint test for all covariates                      Model F(15,200) =    153.39
With Knapp-Hartung modification                    Prob > F        =    0.0000
```

m_vfm	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
X1	1.412569	.6120434	2.31	0.022	.2056825	2.619455
X3	-24.35354	16.88832	-1.44	0.151	-57.65555	8.948483
X4	6.389152	8.932572	0.72	0.475	-11.22495	24.00326
X5	2.783103	1.320372	2.11	0.036	.1794667	5.38674
X6	.2626289	.1079009	2.43	0.016	.0498595	.4753983
X7	-29.05988	22.4324	-1.30	0.197	-73.29425	15.17449
X8	1.271883	10.08662	0.13	0.900	-18.61788	21.16165
X9	-1.132013	14.3686	-0.08	0.937	-29.4654	27.20138
interaction_X1_X2	-6.180451	1.209377	-5.11	0.000	-8.565217	-3.795684
interaction_X2_X8	17.45155	4.169617	4.19	0.000	9.229499	25.6736
interaction_X1_X2_X3	-.6067696	.370508	-1.64	0.103	-1.337373	.1238337
interaction_X1_X2_X4	1.74876	.31771	5.50	0.000	1.122269	2.375251
interaction_X1_X2_X9	-6.220744	1.095762	-5.68	0.000	-8.381474	-4.060014
interaction_X2_X3_X4	-1.83077	.4171551	-4.39	0.000	-2.653357	-1.008184
interaction_X1_X2_X3_X9	7.396415	1.536958	4.81	0.000	4.365694	10.42714
_cons	-266.6759	110.3908	-2.42	0.017	-484.3552	-48.99663

3) length, compeltion delay, BCR and region

```
Meta-regression                                    Number of obs   =       216
REML estimate of between-study variance            tau2            =     580.8
% residual variation due to heterogeneity          I-squared_res   =    80.20%
Proportion of between-study variance explained     Adj R-squared   =    96.76%
Joint test for all covariates                      Model F(15,200) =    153.39
With Knapp-Hartung modification                    Prob > F        =    0.0000
```

m_vfm	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
X1	1.412569	.6120434	2.31	0.022	.2056825	2.619455
X3	-24.35354	16.88832	-1.44	0.151	-57.65555	8.948483
X4	6.389152	8.932572	0.72	0.475	-11.22495	24.00326
X5	2.783103	1.320372	2.11	0.036	.1794667	5.38674
X6	.2626289	.1079009	2.43	0.016	.0498595	.4753983
X7	-29.05988	22.4324	-1.30	0.197	-73.29425	15.17449
X8	1.271883	10.08662	0.13	0.900	-18.61788	21.16164
X9	-1.132012	14.3686	-0.08	0.937	-29.4654	27.20138
interaction_X1_X2	-6.18045	1.209377	-5.11	0.000	-8.565217	-3.795684
interaction_X2_X8	17.45155	4.169617	4.19	0.000	9.229499	25.6736
interaction_X1_X2_X3	-.6067696	.370508	-1.64	0.103	-1.337373	.1238337
interaction_X1_X2_X4	1.74876	.31771	5.50	0.000	1.122269	2.375251
interaction_X2_X3_X4	-1.83077	.4171551	-4.39	0.000	-2.653357	-1.008184
interaction_X2_X4_X9	11.15759	2.499586	4.46	0.000	6.228666	16.08651
interaction_X1_X2_X4_X9	-.6793956	.1084809	-6.26	0.000	-.8933085	-.4654826
_cons	-266.6759	110.3908	-2.42	0.017	-484.3552	-48.99663

4) completion delay, BCR, five-year exchequer bond and region

```
Meta-regression                                    Number of obs   =       216
REML estimate of between-study variance            tau2            =     580.8
% residual variation due to heterogeneity          I-squared_res   =    80.20%
Proportion of between-study variance explained     Adj R-squared   =    96.76%
Joint test for all covariates                      Model F(15,200) =    153.39
With Knapp-Hartung modification                    Prob > F        =    0.0000
```

m_vfm	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
X1	1.412569	.6120434	2.31	0.022	.2056826	2.619455
X3	-24.35354	16.88832	-1.44	0.151	-57.65555	8.948482
X4	6.389153	8.932572	0.72	0.475	-11.22495	24.00326
X5	2.783103	1.320372	2.11	0.036	.1794667	5.38674
X6	.2626289	.1079009	2.43	0.016	.0498595	.4753983
X7	-29.05988	22.4324	-1.30	0.197	-73.29425	15.17449
X8	1.271883	10.08662	0.13	0.900	-18.61788	21.16165
X9	-1.132011	14.3686	-0.08	0.937	-29.4654	27.20138
interaction_X1_X2	-6.180451	1.209377	-5.11	0.000	-8.565217	-3.795684
interaction_X2_X8	17.45155	4.169617	4.19	0.000	9.229499	25.6736
interaction_X1_X2_X3	-.6067696	.370508	-1.64	0.103	-1.337373	.1238337
interaction_X1_X2_X4	1.74876	.31771	5.50	0.000	1.122269	2.375251
interaction_X1_X2_X9	-2.424888	.3621418	-6.70	0.000	-3.138994	-1.710782
interaction_X2_X3_X4	-1.83077	.4171551	-4.39	0.000	-2.653357	-1.008184
interaction_X2_X3_X4_X9	9.296591	1.93181	4.81	0.000	5.487262	13.10592
_cons	-266.6759	110.3908	-2.42	0.017	-484.3552	-48.99664

Appendix L Historical observations

1. National Highway

(Construction)

Regional Construction Management Office	Project	Length (km)	Construction start	Completion	Construction cost (contract) (million KRW)	Construction cost (completion) (million KRW)	Winning bid ratio (%)
Seoul	Hyunri-Shinpal	9.18	01/07/2002	01/12/2010	116,363	139,568	76.02
Wonju	Gimwha detour	4.7	24/12/2004	29/09/2010	43,665	47,238	79.69
Wonju	Murung-Sabuk	4.1	30/12/2000	29/01/2010	93,524	126,285	75.80
Wonju	Bukmyun-Yongdae 2	10.9	24/06/2004	11/09/2010	78,663	96,514	54.85
Iksan	Doam-Ganjin	9.94	01/11/2002	01/06/2010	46,442	58,564	79.67
Iksan	Junghung-Wangji	13.60	01/12/1997	01/09/2010	124,389	170,335	68.67
Iksan	Taein-Wonpyung2	7.11	01/11/2002	01/07/2010	55,750	69,354	79.73
Iksan	Mujuansung dutour	6.80	01/12/2004	01/12/2010	44,146	58,229	79.87
Iksan	Yongjung-Chunpo	7.60	01/12/2002	01/12/2010	75,997	91,755	54.64
Iksan	Eyang-Nungju1	8.50	01/11/2002	01/11/2010	81,490	98,083	79.71
Iksan	Eyang-Nungju2	8.0	02/11/2002	10/10/2010	63,597	83,936	79.75
Iksan	Haksan-Jusanri	8.7	01/12/2004	01/12/2010	76,231	81,133	79.82
Daejeon	Eonhaeng-Okchun	6.1	01/10/2002	01/09/2010	65,198	90,077	79.69
Daejeon	Buyeoeonsan detour	2.8	01/09/2002	01/11/2010	26,470	32,473	83.92
Daejeon	Hangmok-Jungbang	6.6	01/12/2002	01/12/2010	86,100	115,282	58.86
Daejeon	Boeon-Naebuk	16.4	01/12/1996	01/12/2010	151,320	183,086	86.11
Busan	Sannae-Sanoe	4.1	01/11/2002	01/04/2010	54,679	69,517	79.60
Busan	Gisung-Wonnam	11.9	01/10/2003	01/12/2010	94,460	145,464	50.90
Busan	Daeryung-Sunggok	4.1	01/02/2004	01/12/2010	70,104	124,670	79.60
Busan	Mari-Songjung	6.1	01/05/1999	01/12/2010	80,529	92,732	69.30
Busan	Samchunpo-Sachun1	7.9	01/11/2004	01/12/2010	71,712	99,129	57.50
Busan	Samchunpo-Sachun2	10.1	01/10/2002	01/12/2010	88,638	118,343	80.10
Busan	Seohoo-Pyungeon	9.9	01/11/2002	01/12/2010	87,332	104,894	79.70
Busan	Anyui-Mari	12.3	01/12/2000	01/12/2010	82,836	114,359	79.90
Busan	Jindong detour	5.9	01/03/2000	01/12/2010	96,497	158,820	73.00
Busan	Chungam-Sanjang	7.5	01/09/2003	01/12/2010	27,844	37,446	83.80
Busan	Chilgok-Garae	4.3	01/11/2004	01/12/2010	38,976	50,426	79.80
Wonju	Munkok-Munung	6.5	30/12/2000	30/12/2009	103,252	126,285	75.10
Wonju	wongjinri	7.5	30/08/2001	31/12/2009	67,200	79,392	80.00
Wonju	Bukmyun-Wonduk	9.7	13/06/2003	31/12/2009	68,261	87,586	52.12
Wonju	Wonduk-Gunduck	10.3	19/06/2001	31/12/2009	79,339	117,802	60.29
Wonju	Bukmyung-Yongdae1	7.4	28/10/2003	31/12/2009	64,551	74,233	50.62
Iksan	Taein-Wonpyung1	3.75	01/11/2002	01/05/2009	44,461	49,870	79.72
Iksan	Buanbaeksan detour	2.48	01/12/2004	31/12/2009	11,152	22,346	83.98
Iksan	Buanbyunsan detour	2.87	01/11/2002	31/12/2009	20,479	25,096	83.74
Iksan	Hampyung IC-Suhori	0.80	01/12/2008	01/05/2009	2,086	2,806	86.75
Iksan	Wando-Gunoe	9.12	01/05/1999	01/07/2009	62,137	82,335	69.26
Iksan	Bosung-Eyang	3.51	01/12/2002	01/07/2009	105,609	114,183	60.78
Daejeon	Buyeo-Tanchun	11.9	01/12/2000	31/12/2009	65,577	89,657	79.57
Daejeon	Seosangobuk detour	4.2	01/09/2002	31/12/2009	26,280	39,135	88.65
Daejeon	Suanbo IC-Suan	6.6	01/01/2004	31/12/2009	53,984	69,744	79.61
Daejeon	Buyeo-Nonsan	17.4	01/10/1996	31/12/2009	80,147	159,746	70.34
Daejeon	Whasan-Okdong	6.2	01/02/2002	31/12/2009	77,037	92,857	79.64
Daejeon	Goesan-Yungpung 2	8.6	01/02/2003	01/01/2009	92,624	114,397	53.37
Busan	Gamchun-Yechun	13.1	01/11/2002	31/12/2009	98,002	115,056	80.30
Busan	Munduk-Woobok	6.5	01/11/2002	31/12/2009	79,288	112,064	60.00
Busan	Bunggok-Pyunghae	14.0	01/09/2003	31/12/2009	94,794	120,181	75.50
Busan	Sunsan-Dogae	4.6	01/07/2001	31/12/2009	80,567	107,442	86.40
Busan	Sinsuk-Yongsan	6.5	01/12/2001	31/12/2009	57,977	85,137	80.20
Busan	Ssangbaek-Hapchun	12.3	01/10/2002	31/12/2009	110,061	124,013	75.50
Busan	Andong-Seohoo	6.1	01/11/2002	31/12/2009	52,976	62,622	79.70
Busan	Jiphun-Sangbiryang	7.8	01/12/2002	31/12/2009	82,690	102,150	52.10
Busan	Hapchun-Ssangrim	13.0	01/03/1997	31/12/2009	87,431	116,957	70.20
Busan	Pyunghae-Gisung	10.1	01/09/2003	31/12/2009	66,580	76,182	54.84
Seoul	Woojung-Jangan	8.1	01/12/2000	01/06/2008	65,406	63,600	79.67
Seoul	Jangan-Balan	8.1	01/07/2002	01/06/2008	90,806	103,932	79.68
Seoul	Doopo-Chunchun	10.64	01/05/1999	01/06/2008	67,119	100,645	70.33
Wonju	Hungup-Gwansul	11.7	28/04/1999	01/01/2008	136,949	152,450	73.42
Wonju	Sindong-Gasa	5.2	17/10/2003	01/12/2008	69,527	76,748	79.6
Wonju	Gasa-Monkok	5.8	13/10/2003	01/12/2008	70228	75104	79.62
Iksan	Wongpyung-Gumgu	10.16	01/12/2000	01/08/2008	89,686	100,650	76.36
Iksan	Gui-Eseo	10.50	01/05/1999	01/01/2009	108,569	214,185	85.30
Iksan	Eseo-Yongjung	7.00	01/12/2001	01/12/2008	58,107	73,837	79.97
Iksan	Juksang-Muju IC	7.7	01/11/2002	01/12/2008	78,770	86,257	79.60

Iksan	Sumoon detour	4.28	01/12/2002	01/03/2008	23,088	24,771	83.86
Iksan	Gwangju-Jangsung	13.62	01/11/2002	01/12/2008	110,324	138,322	58.80
Iksan	Jangsung-Yaeon	5.40	01/09/2003	01/12/2008	37,438	44,572	79.72
Daejeon	Yesan-Sinyang	7.1	01/10/2002	01/12/2008	42,649	48,449	79.71
Daejeon	Hongsung Detour (south)	8.7	01/11/1999	01/12/2008	87,821	100,031	74.63
Daejeon	Hapduk-Sinraewon 1	6.6	01/10/2001	01/12/2008	75,340	100,229	79.58
Daejeon	Hapduk-Sinraewon 2	6.6	01/10/2001	01/04/2008	70,553	67,765	79.51
Daejeon	Guryong-Buyeo	8.4	01/12/1997	01/12/2008	154,500	179,339	94.79
Busan	Gimchun-Nammyun	9.2	01/11/2002	01/12/2008	80,804	87,241	79.60
Busan	Nammyun-Yakmok	10.0	01/11/2002	01/12/2008	75,595	82,745	79.70
Seoul	Sanung-Hopyung	6.134	01/02/1998	01/06/2007	100,417	128,564	94.00
Seoul	Yeoju detour	9.816	01/01/2000	01/12/2007	137,883	167,907	73.01
Wonju	Guirae detour	6.3	29/12/1999	20/07/2007	69,700	83,926	77.88
Wonju	Gusungpo-Doochun	10.6	30/12/2000	20/12/2007	95,917	134,495	75.30
Wonju	Miro-Samchuk	7.9	09/04/1999	24/12/2007	149,808	177,809	69.81
Wonju	Ero-Songjung	7.9	14/08/1998	31/08/2007	72,625	86,145	69.00
Iksan	Haseo-Buan	13.95	01/02/1998	01/05/2007	142,162	139,329	94.69
Iksan	Sungduk-Daeya	17.36	01/08/1998	01/04/2007	189,464	214,185	91.68
Iksan	Samsan-Haebo	11.4	01/06/1999	01/08/2007	74,439	86,257	69.03
Iksan	Younggwang-Haebo	21	01/12/1996	01/12/2007	192,554	213,440	91.17
Iksan	Daejeon-Damyang	16.9	01/05/1999	01/12/2007	105,548	135,057	68.96
Iksan	Nokdong-Doduk	9.8	01/07/2001	01/12/2007	63,124	72,253	79.59
Iksan	Doduk-Gohung	9.07	01/06/2001	01/10/2007	60,938	74,306	79.61
Iksan	Sunwoonsa-Hungduk	10.27	01/12/2000	01/07/2007	85,289	96,040	80.14
Iksan	Bosung detour	3.7	01/01/2000	01/12/2007	49,790	43,669	79.66
Iksan	Joosang-Gwangchi	6.4	01/05/1999	01/12/2007	51,975	68,264	68.97
Iksan	Munnae-Whangsan	17.5	01/12/1997	01/12/2007	120,530	140,195	94.73
Iksan	Gunsan-Daejeon	18.66	01/12/2000	01/12/2007	102,102	122,336	79.58
Daejeon	Asan-Umbong	7.6	01/02/1999	01/12/2007	70,215	69,271	69.20
Daejeon	Bungchun-Yongduri	3.2	01/05/2003	01/12/2007	34,279	34,686	79.66
Daejeon	Chungyangmokmyun detour	3.6	01/05/2003	01/12/2007	24,346	25,643	83.81
Daejeon	Haksan-Youngdong	20.3	01/12/1996	01/12/2007	187,663	224,222	71.16
Daejeon	Duksan-Yesan	22.8	01/12/1997	01/12/2007	204,494	244,627	94.75
Daejeon	Okchun-Sojung	11.0	01/12/1997	01/12/2007	93,711	136,655	69.70
Busan	Bongwha-Bubjeon	17.0	01/02/1997	01/12/2007	144,198	186,099	93.70
Busan	Sungjoo-Oegwan	10.9	01/02/1997	01/12/2007	95,826	118,198	69.70
Busan	Jundo IC-Shinwol	4.0	01/05/2001	01/12/2007	59,144	76,923	79.50
Busan	Toerae-Nongso	10.5	01/03/1998	01/12/2007	238,000	257,990	94.10
Busan	Woolsan-Gangdong	13.1	01/09/1998	01/12/2007	214,999	251,753	84.10
Busan	Sanoe-Sangbuk	8.7	01/06/2000	01/12/2007	237,260	270,200	-
Busan	Hamchang-Buljung	8.7	01/04/1999	01/08/2007	85,446	93,339	69.00
Seoul	Ildong-Youngjoong	7.11	01/06/1999	01/09/2006	88,495	95,518	71.63
Seoul	Ildong-Edong	16.96	01/05/1999	01/09/2006	153,880	185,032	83.62
Seoul	Gimpo detour	8.02	01/01/2000	01/12/2006	122,637	132,324	72.97
Wonju	Jigyung-Gimwha	7.4	19/04/1999	01/11/2006	47,650	49,127	69.06
Wonju	Munhae-Jigyung	5	30/12/2000	01/12/2006	40,162	48,634	79.68
Wonju	Eoron-Namjung	12.6	12/08/1998	01/12/2006	118,485	168,846	93.86
Wonju	Sabuk-Gohan	8.2	15/04/1997	01/12/2006	232,246	317,058	92.91
Wonju	Duchon-Eoron	10.7	30/12/2000	01/12/2006	95,917	111,891	79.50
Iksan	Iksan-Seosu	7.16	01/12/1998	01/03/2006	53,258	57,261	69.77
Iksan	the 2nd Jindo bridge	0.7	01/12/1998	01/03/2006	48,362	54,247	97.60
Iksan	Wando-Sinji	2.36	01/10/1997	01/03/2006	36,439	39,301	94.98
Iksan	Samseo-Jangsung	21.6	01/09/1995	01/03/2006	149,248	152,321	89.14
Iksan	Muan detour	8.9	01/10/1997	01/09/2006	64,937	76,696	92.68
Iksan	Mangwoon-Hyungyung	4.33	01/12/2002	01/08/2006	37,077	47,537	79.85
Iksan	Bongdong-Whasan	10.32	01/02/1998	01/10/2006	148,568	143,003	94.61
Iksan	Hampyung-Hampyung IC	10.03	01/12/2000	01/12/2006	56,092	59,265	79.55
Iksan	Susoo-Gunsan	11.21	01/08/1998	01/12/2006	98,590	108,394	69.72
Daejeon	Jinchungewol detour	4.0	01/09/2002	01/12/2006	32,771	34,619	79.75
Daejeon	Eomsung-Sangguk	18.7	01/02/1999	01/12/2006	132,339	159,713	69.99
Daejeon	Chobu-Daejeon	10.2	01/02/2001	01/12/2006	107,068	139,553	75.99
Daejeon	Haemi-Duksan1	6.9	01/10/2001	01/12/2006	58,556	63,481	79.51
Daejeon	Haemi-Duksan2	5.0	01/10/2001	01/12/2006	57,535	57,760	79.57
Daejeon	Danyang IC-Daegang	1.6	01/05/2003	01/11/2006	9,642	9,946	85.67
Daejeon	Gongju-Ein	15.9	01/12/1996	01/08/2006	87,690	106,640	69.08
Daejeon	Dooma-Banpo	10.1	01/11/1998	01/12/2006	158,559	208,469	72.10
Daejeon	Namdong-Hangmok	12.7	01/03/1998	01/07/2006	93,160	109,525	94.45
Busan	Dogye-Gyungjoo	11.2	01/05/1999	01/12/2006	52,161	62,645	69.90
Busan	Sangrim-Haepyung	17.7	01/02/1997	01/08/2006	176,632	194,312	94.10
Busan	Jinju-Jiphung	10.2	01/12/1996	01/12/2006	106,555	145,872	85.30
Busan	Hyungdong-Naeseo	6.4	01/03/1997	01/12/2006	125,229	170,763	96.90
Busan	Naeseo-Jungri	8.2	01/02/1997	01/12/2006	104,952	126,081	94.40
Busan	Jinju-Wansan	10.1	01/12/1997	01/12/2006	146,647	156,294	92.70
Busan	Doowang-Moogue	6.2	01/02/2001	01/12/2006	72,975	89,354	80.10
Busan	Moonduk-Yugang	5.6	01/03/1998	01/12/2006	120,760	127,968	94.80
Busan	Milyang-Sanoe	8.2	01/08/1998	01/12/2006	63,826	72,215	70.10

(Operation)

Region	Year	Length (km)	AADT (vehicles)	Management cost (billion KRW)	General maintenance cost (billion KRW)	Re-pavement cost (billion KRW)	Road structure maintenance cost (billion KRW)
Suwon	2010	440.9	27207	4004	11794	3626	8896
Suwon	2009	470.8	28378	4508	17002	1247	9431
Suwon	2008	470.8	27738	3607	16086	776	4083
Suwon	2007	459.3	29329	3533	11020	10340	2925
Suwon	2006	469.8	27083	3611	16210	7625	2438
Uijungbu	2010	452.6	20958	3627	9158	5823	13907
Uijungbu	2009	579.3	20425	3434	18901	9242	16090
Uijungbu	2008	579.3	20445	3985	16123	6016	5839
Uijungbu	2007	579.3	20601	3580	18524	7214	5494
Uijungbu	2006	579.3	21773	3213	17194	6744	4097
Hongchun	2010	494.6	11877	4112	26097	4865	12864
Hongchun	2009	815.1	10063	4756	43380	3629	14822
Hongchun	2008	823.9	9583	3874	33235	2913	9621
Hongchun	2007	823.2	10223	3823	30497	2324	9663
Hongchun	2006	827.9	10176	3899	31879	2467	9889
Gangnung	2010	419.3	11464	2588	27044	82	14177
Gangnung	2009	539.9	10968	2490	47508	731	14873
Gangnung	2008	546.7	10727	2723	26510	411	9331
Gangnung	2007	546.7	11379	2473	23558	422	21288
Gangnung	2006	546.7	11277	2556	22953	2034	13538
Jungsun	2010	343.3	8855	2594	33527	2258	1963
Jungsun	2009	343.3	8468	2716	41127	1869	5386
Jungsun	2008	387.9	8553	2554	33889	1427	3412
Jungsun	2007	388.8	8883	2683	24729	1099	11409
Jungsun	2006	388.8	8628	2223	16162	4136	12481
Nonsan	2010	324	15007	2661	7996	686	6728
Nonsan	2009	408	13237	2436	11561	1286	10428
Nonsan	2008	410	13744	2350	11037	240	5480
Nonsan	2007	408	14807	2474	9946	1912	4346
Nonsan	2006	400	14793	2272	12448	2359	5869
Choongju	2010	365.4	12202	3444	8964	2533	7085
Choongju	2009	479.9	10849	3223	10091	5545	11129
Choongju	2008	479.9	10176	2791	6172	4833	8474
Choongju	2007	479.9	10400	3003	6587	4859	9573
Choongju	2006	480.9	10408	2924	7192	3667	7218
Boeon	2010	413.4	14702	2491	7289	3090	10919
Boeon	2009	413.8	12390	2324	13548	2361	10919
Boeon	2008	413.8	12320	2163	8174	1596	3743
Boeon	2007	419	13682	2497	9909	818	1724
Boeon	2006	420.5	13575	2433	8690	2872	2983
Yesan	2010	605.9	17826	2942	11022	4170	15411
Yesan	2009	759.8	16543	2911	12347	5993	11585
Yesan	2008	758.3	17007	3016	11271	855	4107
Yesan	2007	753.6	18499	2976	19044	2783	2522
Yesan	2006	753.4	17790	2330	6446	3547	5724
Gwangju	2010	706.1	10147	4561	9849	13607	14938
Gwangju	2009	1031.8	9700	4730	15125	3658	22494
Gwangju	2008	1031.9	9737	4756	12708	8001	28017
Gwangju	2007	1031.8	10752	4418	9705	5922	16465
Gwangju	2006	1040	11175	3951	14270	5435	13725
Namwon	2010	428.5	6603	2342	12210	5583	5794

Namwon	2009	588.9	6043	2483	12152	2203	8526
Namwon	2008	590	5439	2572	11997	1123	13183
Namwon	2007	588.9	6712	2716	15753	4831	8842
Namwon	2006	588.9	6933	2318	16514	3696	7366
Soonchun	2010	523.7	10377	3307	9498	1763	10744
Soonchun	2009	765.2	9115	3523	16028	2815	14511
Soonchun	2008	765	8954	3785	8953	1745	11968
Soonchun	2007	763.9	9119	3569	7614	2133	25620
Soonchun	2006	763.1	9650	3049	11575	1750	19594
Junju	2010	534.3	12056	1607	9466	3194	6831
Junju	2009	503.7	11322	1695	16477	2417	8839
Junju	2008	572.2	10827	1738	15484	5164	5020
Junju	2007	573	11382	1686	10772	4438	999
Junju	2006	579	12672	1269	15507	4348	1747
Daegu	2010	538	11492	3627	19235	658	8455
Daegu	2009	573.8	10524	3059	18426	3319	8495
Daegu	2008	724.7	10643	3210	11942	219	9029
Daegu	2007	724.7	11424	3067	15614	489	14565
Daegu	2006	710.3	11354	3067	4344	9842	10772
Jinju	2010	730.2	11306	3380	7658	2494	7135
Jinju	2009	943.9	10099	3470	19639	2789	10717
Jinju	2008	944.3	9660	3796	13671	2131	10508
Jinju	2007	953.7	9862	3779	10506	5381	23083
Jinju	2006	954.8	9615	3781	18207	6267	21053
Pohang	2010	570.2	14956	5288	15223	2512	6551
Pohang	2009	698.7	13728	5086	26427	2894	13337
Pohang	2008	704.3	13630	5173	24145	3594	5494
Pohang	2007	704.3	14398	4065	24265	6261	5232
Pohang	2006	704.3	14104	4351	18944	3700	5797
Youngju	2010	413.6	9074	2638	12441	1506	7527
Youngju	2009	557.3	8463	2753	12733	542	9441
Youngju	2008	550.7	8004	3016	15688	582	4702
Youngju	2007	552.5	8213	2623	17001	514	1468
Youngju	2006	552.5	8227	2970	22220	1643	3048
Jinyoung	2010	456	19265	4346	11435	767	12062
Jinyoung	2009	584	16479	4426	9921	1685	8482
Jinyoung	2008	528	16991	4439	9363	3267	5915
Jinyoung	2007	538	17888	3497	8062	1370	3880
Jinyoung	2006	574	17100	3013	8344	3454	4531

2. National Expressway

(Construction)

Project	Length (km)	Construction start (yy-mm)	Construction cost (start) (million KRW)	Completion (yy-mm)	Construction cost (million KRW)	Winning bid ratio
Dangjin-Seochun 1	14.30	96-12	157,080	01-11	178,244	89.00
Dangjin-Seochun 2	12.82	96-12	108,300	01-11	106,732	89.00
Dangjin-Seochun 3	10.10	96-12	97,559	01-11	105,888	84.00
Dangjin-Seochun 4	12.60	96-12	128,500	01-11	139,088	89.00
Dangjin-Seochun 5	10.22	96-12	104,171	01-11	112,546	87.00
Dangjin-Seochun 6	10.29	96-12	118,800	01-11	129,827	89.00
Dangjin-Seochun 7	12.40	96-12	106,311	01-11	120,163	88.00
Dangjin-Seochun 8	10.90	96-12	79,159	01-11	112,099	67.00
Dangjin-Seochun 9	10.37	96-12	102,990	01-11	116,852	88.00
Gumi-Dongdaegu 1	11.62	97-12	155	03-12	169	96.33
Gumi-Dongdaegu 2	9.90	97-12	140	03-12	151	95.60
Gumi-Dongdaegu 4	10.46	97-12	160	03-12	171	94.29
Gumi-Dongdaegu 5	8.56	98-10	153	03-12	161	69.86
Gumi-Dongdaegu 6	9.76	98-10	132	03-12	141	71.11
Daegu-Pohang 1	13.30	01-11	79,841	07-12	134,695	69.68
Daegu-Pohang 2	9.10	01-11	98,585	07-12	126,281	65.98
Daegu-Pohang 3	4.40	01-11	59,950	07-12	83,473	55.47
Daegu-Pohang 4	2.61	01-11	76,546	07-12	87,620	82.33
Daegu-Pohang 5	3.41	01-11	95,117	07-12	113,197	67.76
Daegu-Pohang 6	4.62	01-11	76,135	07-12	82,221	82.05
Daegu-Pohang 7	7.50	01-11	82,169	07-12	101,533	69.59
Daegu-Pohang 8	6.00	01-11	79,005	07-12	98,052	81.06
Daegu-Pohang 9	6.26	01-11	111,376	07-12	129,511	69.64
Jinju-Tongyoung 1	13.24	97-05	120,560	05-12	213,000	95.22
Jinju-Tongyoung 2	10645.00	97-05	203,000	05-12	217,100	-
Jinju-Tongyoung 3	11.42	97-05	133,000	05-12	150,200	80.31
Jinju-Tongyoung 4	12.60	97-05	212,900	05-12	247,400	-
Hyungpoong-Gimchun 1	8.42	01-12	107,437	07-12	145,404	66.65
Hyungpoong-Gimchun 2	12.30	01-12	120,900	07-12	164,776	65.77
Hyungpoong-Gimchun 3	14.60	01-12	95,227	07-12	120,140	66.46
Hyungpoong-Gimchun 4	14.50	01-12	129,500	07-12	161,064	59.29
Hyungpoong-Gimchun 6	6.04	01-12	98,670	07-12	121,667	67.07
Mooan-Gwangju 1	10.34	02-12	69,379	07-12	77,887	61.04
Mooan-Gwangju 2	9.03	02-12	67,940	07-12	75,823	58.65
Mooan-Gwangju 3	7.70	02-12	66,292	07-12	66,652	61.76
Mooan-Gwangju 4	8.76	02-12	68,099	09-11	86,948	61.11
Mooan-Gwangju 5	5.53	02-12	72,671	08-08	92,977	78.07
Daejeon-Dangjin 1	8.54	01-12	134,037	09-12	167,428	67.34
Daejeon-Dangjin 2	10.90	01-12	83,315	09-08	108,301	66.55
Daejeon-Dangjin 3	8.80	01-12	103,078	09-08	142,563	70.01
Daejeon-Dangjin 4	9.04	01-12	150,348	09-08	197,830	68.36
Daejeon-Dangjin 5	8.54	01-12	133,232	09-08	159,992	67.73
Daejeon-Dangjin 6	8.82	01-12	103,587	09-08	138,038	68.15
Daejeon-Dangjin 7	9.70	01-12	132,990	09-08	161,311	67.82
Daejeon-Dangjin 8	14.54	01-12	108,032	09-08	134,184	76.34
Daejeon-Dangjin 9	12.98	01-12	101,982	09-11	134,939	77.76
Seochun-Gongju 1	10.85	01-12	119,130	09-08	149,506	67.64
Seochun-Gongju 2	7.00	01-12	79,981	09-08	105,090	64.62
Seochun-Gongju 3	9.90	01-12	94,437	09-08	112,084	69.25
Seochun-Gongju 4	10.24	01-12	81,930	09-08	98,452	65.81
Seochun-Gongju 5	6.74	01-12	69,925	09-08	91,200	80.62
Seochun-Gongju 6	7.58	01-12	60,802	09-08	75,971	80.82
Seochun-Gongju 7	9.05	01-12	70,068	09-08	102,852	63.67
Choonchun-Donghongchun 1	4.56	04-03	58,080	09-12	71,276	50.93
Choonchun-Donghongchun 2	4.58	04-03	54,436	09-12	89,036	54.58
Choonchun-Donghongchun 3	3.92	04-03	61,000	09-12	71,592	59.28
Choonchun-Donghongchun 4	4.03	04-03	87,658	09-12	111,657	65.99
Junju-Namwon 1	7.20	04-12	88,432	10-12	113,875	73.08
Junju-Namwon 2	7.30	04-12	81,776	10-12	91,517	59.85
Junju-Namwon 3	4.00	04-12	64,049	10-12	79,836	56.49
Junju-Namwon 4	4.90	04-12	62,386	10-12	79,712	57.00
Junju-Namwon 5	6.90	04-12	67,930	10-12	82,809	56.32
Junju-Namwon 6	7.60	04-12	67,433	10-12	83,264	60.23
Junju-Namwon 7	10.90	05-03	90,006	10-12	102,511	56.99
Yangje-Gihung 1	7.73	06-06	72,589	10-11	96,226	55.25
Yangje-Gihung 2	13.19	06-06	73,014	10-12	141,472	78.00

(Operation)

Region	Office	Year	Length (km)	AADT (vehicles)	Management cost (million KRW)	General maintenance cost (million KRW)	Re-pavement cost (million KRW)	Road structure maintenance cost (million KRW)
Seoul metroplitan	Incheon	2010	49	155437	11759	4083	1027	1074
Seoul metroplitan	Incheon	2009	49	150687	14993	4003	901	2204
Seoul metroplitan	Incheon	2008	49	145858	15340	3601	490	1563
Seoul metroplitan	Incheon	2007	49	147352	14249	3329	428	5013
Seoul metroplitan	Incheon	2006	49	138929	13969	3143	768	129
Seoul metroplitan	Sihung	2010	51	134748	18864	4203	1064	571
Seoul metroplitan	Sihung	2009	51	132235	22130	4357	1032	2492
Seoul metroplitan	Sihung	2008	51	124858	23609	4081	1706	1448
Seoul metroplitan	Sihung	2007	51	126757	21805	3745	828	464
Seoul metroplitan	Sihung	2006	51	123589	19849	3068	731	2117
Seoul metroplitan	Gunpo	2010	52	131489	16660	4504	1608	2351
Seoul metroplitan	Gunpo	2009	52	129273	19124	4332	2188	2168
Seoul metroplitan	Gunpo	2008	52	128427	21541	3689	3293	3295
Seoul metroplitan	Gunpo	2007	52	126782	20162	3341	1934	6436
Seoul metroplitan	Gunpo	2006	51	121046	18735	3275	3864	4960
Seoul metroplitan	Suwon	2010	56	159125	22955	4484	120	934
Seoul metroplitan	Suwon	2009	56	152214	29168	4838	1777	2650
Seoul metroplitan	Suwon	2008	56	154241	32079	4715	2293	345
Seoul metroplitan	Suwon	2007	56	164536	29001	4287	2155	961
Seoul metroplitan	Suwon	2006	56	158416	27610	3726	1632	300
Seoul metroplitan	Gyungan	2010	72	68225	15478	3558	413	65
Seoul metroplitan	Gyungan	2009	72	66101	17741	3619	1821	4393
Seoul metroplitan	Gyungan	2008	72	64543	19060	3289	918	3186
Seoul metroplitan	Gyungan	2007	72	63568	18065	3644	248	4639
Seoul metroplitan	Gyungan	2006	72	60011	17565	3408	1530	1507
Seoul metroplitan	Dongseoul	2010	48	166910	16271	4643	2566	12856
Seoul metroplitan	Dongseoul	2009	48	164935	21955	4487	2129	12055
Seoul metroplitan	Dongseoul	2008	48	157550	23318	4064	1963	11763
Seoul metroplitan	Dongseoul	2007	48	160040	21287	3883	2186	8076
Seoul metroplitan	Dongseoul	2006	48	151888	20185	3549	1818	3501
Gangwon	Wonju	2010	72	39937	8543	3248	95	1837
Gangwon	Wonju	2009	72	36611	9474	3037	2065	1129
Gangwon	Wonju	2008	72	36848	11	2748	2073	3313
Gangwon	Wonju	2007	72	41762	9362	2193	1359	87
Gangwon	Wonju	2006	72	40148	10107	2159	1608	0
Gangwon	Daegwanryung	2010	74	23870	12929	3292	1490	768
Gangwon	Daegwanryung	2009	74	21650	15736	3503	2344	1035
Gangwon	Daegwanryung	2008	74	21497	15906	3064	1672	2494
Gangwon	Daegwanryung	2007	74	22349	15189	3056	0	338
Gangwon	Daegwanryung	2006	74	22551	15063	2754	1161	2293
Gangwon	Gangnung	2010	75	11073	10798	2492	-	85
Gangwon	Gangnung	2009	60	9990	11230	2504	695	144
Gangwon	Gangnung	2008	60	10840	12527	1977	538	-
Gangwon	Gangnung	2007	60	10364	11310	2936	267	-
Gangwon	Gangnung	2006	60	9721	11484	1814	334	-
Gangwon	Hongchun	2010	74	18492	7627	2632	-	2162
Gangwon	Hongchun	2009	74	17517	8947	2904	1049	1252
Gangwon	Hongchun	2008	74	14549	9648	2874	2444	604
Gangwon	Hongchun	2007	74	14652	9113	2763	759	13
Gangwon	Hongchun	2006	74	14251	8863	2156	678	1290
Choonchung	Jaechun	2010	66	17492	10944	2849	394	2201
Choonchung	Jaechun	2009	66	12646	10404	2666	-	3253
Choonchung	Jaechun	2008	66	12633	11104	3372	352	3658
Choonchung	Jaechun	2007	66	15790	10236	2393	152	-
Choonchung	Jaechun	2006	66	15024	10249	1940	1223	-
Choonchung	Chungju	2010	89	34794	9764	2625	662	264
Choonchung	Chungju	2009	71	37006	10289	3026	837	165
Choonchung	Chungju	2008	71	35013	11293	2348	598	169
Choonchung	Chungju	2007	71	36117	10969	2266	0	134
Choonchung	Chungju	2006	71	37061	11431	1808	51	-
Choonchung	Chunan	2010	56	105630	8832	3344	335	568
Choonchung	Chunan	2009	56	103079	10221	4128	150	918
Choonchung	Chunan	2008	56	105314	11366	3383	-	423
Choonchung	Chunan	2007	56	103764	10831	4075	336	-
Choonchung	Chunan	2006	56	100124	11277	3881	8	-
Choonchung	Daejeon	2010	57	73482	9842	3754	265	317
Choonchung	Daejeon	2009	57	70140	12603	4260	218	1306
Choonchung	Daejeon	2008	57	69027	14089	3809	174	1135
Choonchung	Daejeon	2007	57	78470	12889	3878	73	270
Choonchung	Daejeon	2006	57	78275	12651	3635	-	-

Choonchung	Nonsan	2010	65	36753	9685	2930	-	713
Choonchung	Nonsan	2009	65	35522	8364	3191	70	456
Choonchung	Nonsan	2008	65	32593	11512	2747	321	150
Choonchung	Nonsan	2007	65	30807	10508	2772	155	143
Choonchung	Nonsan	2006	65	30336	11032	2741	-	-
Choonchung	Jinchun	2010	81	47438	11492	4654	1794	-
Choonchung	Jinchun	2009	81	41944	10936	3278	1394	-
Choonchung	Jinchun	2008	59	38581	10480	3110	266	-
Choonchung	Jinchun	2007	59	48604	10159	3266	398	-
Choonchung	Jinchun	2006	59	46644	9872	2933	189	-
Choonchung	Youngdong	2010	55	35070	8008	3059	966	478
Choonchung	Youngdong	2009	55	32332	9225	3056	1476	-
Choonchung	Youngdong	2008	55	30083	9654	2930	-	130
Choonchung	Youngdong	2007	55	47489	9008	3209	-	-
Choonchung	Youngdong	2006	55	44026	9458	2632	445	-
Choonchung	Mooju	2010	84	19414	12372	3207	1499	-
Choonchung	Mooju	2009	84	16796	14211	3762	-	-
Choonchung	Mooju	2008	84	15978	14635	3211	-	-
Choonchung	Mooju	2007	84	19779	14487	3203	788	-
Choonchung	Mooju	2006	84	20710	14318	2527	-	-
Choonchung	Dangjin	2010	74	41163	11395	2456	238	1407
Choonchung	Dangjin	2009	74	39541	13201	2851	808	401
Choonchung	Dangjin	2008	72	42471	13188	2539	420	413
Choonchung	Dangjin	2007	72	40018	12198	2149	245	284
Choonchung	Dangjin	2006	72	37059	12744	2043	534	-
Choonchung	Boryung	2010	72	24527	10833	2512	1524	1232
Choonchung	Boryung	2009	72	24957	10728	2628	4055	387
Choonchung	Boryung	2008	76	23553	10898	2215	404	300
Choonchung	Boryung	2007	68	22446	9434	2131	539	-
Choonchung	Boryung	2006	68	20773	9769	1958	-	-
Choonchung	Boeon	2010	79	26306	9036	2641	-	159
Choonchung	Boeon	2009	79	20979	11414	2632	-	382
Choonchung	Boeon	2008	79	20332	11162	2189	-	-
Choonchung	Gongju	2010	79	20551	9983	2460	-	239
Choonchung	Gongju	2009	79	18860	5681	1210	-	-
Choonchung	Buyeo	2010	75	12788	10094	2410	452	24
Choonchung	Buyeo	2009	75	11163	6954	1368	343	
Honam	Junju	2010	73	34940	10827	3232	713	344
Honam	Junju	2009	73	32095	12497	3919	1014	146
Honam	Junju	2008	73	32282	13604	4169	2841	536
Honam	Junju	2007	73	31696	12581	3886	508	610
Honam	Junju	2006	73	33304	12585	3313	2580	860
Honam	Gwangju	2010	74	36545	12144	3327	748	606
Honam	Gwangju	2009	74	32858	14315	3519	500	786
Honam	Gwangju	2008	76	29598	15144	3284	2328	220
Honam	Gwangju	2007	76	31133	15371	4439	341	248
Honam	Gwangju	2006	76	32992	14028	3449	2260	283
Honam	Soonchun	2010	73	27006	10494	3698	696	509
Honam	Soonchun	2009	73	24260	12528	3388	1200	1904
Honam	Soonchun	2008	73	22698	13382	3481	1031	2702
Honam	Soonchun	2007	73	21946	12276	3273	1500	1649
Honam	Soonchun	2006	73	22486	11946	3456	2310	-
Honam	Namwon	2010	88	9262	7029	2195	874	140
Honam	Namwon	2009	88	8315	8424	2452	-	-
Honam	Namwon	2008	88	7917	9018	2639	508	-
Honam	Namwon	2007	88	7471	7333	2543	926	-
Honam	Namwon	2006	90	6570	7116	2799	-	1450
Honam	Hampyung	2010	80	15573	9392	3283	202	156
Honam	Hampyung	2009	80	14421	11614	3324	1630	419
Honam	Hampyung	2008	79	13229	13152	3174	1228	160
Honam	Hampyung	2007	77	9337	9680	2891	930	231
Honam	Hampyung	2006	77	10797	8967	2209	-	-
Honam	Booan	2010	80	19443	10545	2893	2779	2290
Honam	Booan	2009	80	16990	12003	3142	5740	895
Honam	Booan	2008	79	15226	12207	2784	1973	-
Honam	Booan	2007	69	11425	11917	2735	2082	-
Honam	Booan	2006	69	10921	11842	2404	1921	-
Honam	Damyang	2010	65	19052	8127	2636	584	-
Honam	Damyang	2009	65	17302	10455	3070	1832	481
Honam	Damyang	2008	65	15693	10462	2755	1878	-
Honam	Damyang	2007	-	-	1524	-	506	-
Honam	Damyang	2006	-	-	-	-	-	-
Honam	Jinan	2010	59	11422	10328	2190	94	-
Honam	Jinan	2009	59	8744	12061	2177	-	12
Honam	Jinan	2008	59	7309	12355	2120	-	-

Honam	Jinan	2007	-	-	1924	1991	-	-
Honam	Jinan	2006	-	-	-	-	-	-
Youngnam	Gumi	2010	73	70143	8835336	2867867	399000	603000
Youngnam	Gumi	2009	73	64295	9746814	3093362	275000	122000
Youngnam	Gumi	2008	73	61315	10880050	2163918	-	-
Youngnam	Gumi	2007	73	82412	10449131	2607650	43000	-
Youngnam	Gumi	2006	73	78949	10239119	2146000	-	-
Youngnam	Daegu	2010	72	70352	13152	3778	390	145
Youngnam	Daegu	2009	72	64297	14344	2776	765	662
Youngnam	Daegu	2008	72	61099	15285	2319	1631	239
Youngnam	Daegu	2007	72	64722	14575	2749	1245	250
Youngnam	Daegu	2006	72	60677	13601	2090	-	-
Youngnam	Goryung	2010	88	12202	8247	2153	887	-
Youngnam	Goryung	2009	88	10786	9628	2266	295	756
Youngnam	Goryung	2008	88	9933	11046	2273	416	819
Youngnam	Goryung	2007	88	9723	9677	1654	433	864
Youngnam	Goryung	2006	88	9386	9107	2085	-	-
Youngnam	Gunwi	2010	85	32589	15466	3112	1058	1513
Youngnam	Gunwi	2009	85	39758	18481	3573	462	429
Youngnam	Gunwi	2008	85	38652	19813	3591	1009	691
Youngnam	Gunwi	2007	85	40729	17352	2461	1809	235
Youngnam	Gunwi	2006	85	40271	18475	3246	2107	0
Youngnam	Youngju	2010	68	14238	7790	2423	549	1867
Youngnam	Youngju	2009	68	13686	9582	2530	408	618
Youngnam	Youngju	2008	68	12884	10552	2351	351	-
Youngnam	Youngju	2007	68	13058	9274	1724	180	-
Youngnam	Youngju	2006	68	13004	9933	1851	660	-
Youngnam	Youngchun	2010	69	23503	10304	2663	-	259
Youngnam	Youngchun	2009	69	21434	11418	2584	462	121
Youngnam	Youngchun	2008	68	19897	13209	1674	-	-
Youngnam	Youngchun	2007	68	19408	12159	1912	-	-
Youngnam	Youngchun	2006	68	19396	11604	1622	-	-
Youngnam	Woolsan1	2010	47	21510	9091	1969	-	-
Youngnam	Woolsan1	2009	47	20697	8611	3125	-	-
Youngnam	Woolsan1	2008	47	14390	47	6	-	-
Youngnam	Woolsan2	2010	44	44130	2120	1580	88	3938
Youngnam	Woolsan2	2009	44	37714	2738	1731	0	2603
Youngnam	Woolsan2	2008	67	36756	10339	2374	135	1074
Youngnam	Woolsan2	2007	67	48262	9913	2751	158	2600
Youngnam	Woolsan2	2006	67	44937	9430	1964	400	7804
Youngnam	Yangsan	2010	76	71379	17561	3717	1354	6203
Youngnam	Yangsan	2009	76	68235	22687	4266	1442	3210
Youngnam	Yangsan	2008	53	67806	21664	3027	5155	310
Youngnam	Yangsan	2007	53	77856	18211	2624	286	3956
Youngnam	Yangsan	2006	53	74623	18076	2326	608	4550
Youngnam	Changryung	2010	68	39749	3183	163	806	1314
Youngnam	Changryung	2009	68	35270	2847	190	1742	2728
Youngnam	Changryung	2008	68	33936	2401	171	718	4573
Youngnam	Changryung	2007	68	29816	2072	294	616	2140
Youngnam	Changryung	2006	68	29530	2058	256	876	432
Youngnam	Changwon	2010	80	68565	18761	4593	1545	4272
Youngnam	Changwon	2009	80	65386	19104	4173	800	7437
Youngnam	Changwon	2008	80	64428	21037	3610	1117	2482
Youngnam	Changwon	2007	80	63986	18568	3496	2758	162
Youngnam	Changwon	2006	80	63693	18528	3149	1653	2000
Youngnam	Jinju	2010	75	43878	14099	3076	1025	4473
Youngnam	Jinju	2009	75	41116	13435	3020	2972	1959
Youngnam	Jinju	2008	75	39461	13350	2627	1414	250
Youngnam	Jinju	2007	75	40370	12973	3005	2000	500
Youngnam	Jinju	2006	75	40693	11511	2381	3069	150
Youngnam	Sanchung	2010	79	21038	6734	3234	874	1091
Youngnam	Sanchung	2009	79	18989	6735	3352	833	1648
Youngnam	Sanchung	2008	79	18194	7047	2650	561	3170
Youngnam	Sanchung	2007	79	20399	5713	2372	1383	91
Youngnam	Sanchung	2006	79	21283	5340	2173	1446	300

3. National Railway

(Construction)

Classification	Railway	Project	Contract	Construction start date	Completion date	Construction cost (start) (million KRW)	Construction cost (completion) (million KRW)	Winning bid ratio (%)
High Speed Railway	Kyungbu line	Busan train depot constructon	Earth work/Structure	2002-01-11	2004-04-21	109,260	126,936	70.28
High Speed Railway	Kyungbu line	Section 1-1	Earth work/Structure	1996-04-25	2004-03-31	222,794	371,324	91.40
High Speed Railway	Kyungbu line	Section 10-4	Earth work/Structure	2002-10-23	2007-10-31	78,355	92,599	69.18
High Speed Railway	Kyungbu line	Section 10-5	Earth work/Structure	2002-11-06	2007-12-31	96,965	112,514	69.19
High Speed Railway	Kyungbu line	Section 11-1	Earth work/Structure	2002-06-18	2007-10-31	100,575	123,460	70.04
High Speed Railway	Kyungbu line	Section 11-2	Earth work/Structure	2003-03-13	2007-10-12	78,900	93,649	59.05
High Speed Railway	Kyungbu line	Section 11-3	Earth work/Structure	2003-02-24	2007-11-23	78,900	81,494	57.87
High Speed Railway	Kyungbu line	Section 11-4	Earth work/Structure	2003-03-03	2008-06-30	67,509	83,489	58.03
High Speed Railway	Kyungbu line	Section 12-2	Earth work/Structure	2004-01-13	2008-07-30	57,483	69,347	53.17
High Speed Railway	Kyungbu line	Secton 12-2	Earth work/Structure	2004-01-13	2008-05-30	54,500	64,803	50.85
High Speed Railway	Kyungbu line	Section 12-4	Earth work/Structure	2004-02-20	2009-04-30	63,256	111,940	56.13
High Speed Railway	Kyungbu line	Section 12-5	Earth work/Structure	2004-02-20	2008-10-31	65,910	86,952	51.80
High Speed Railway	Kyungbu line	Section 13-1	Earth work/Structure	2005-03-31	2009-01-31	107,900	130,634	63.61
High Speed Railway	Kyungbu line	Section 13-2	Earth work/Structure	2005-04-19	2009-04-10	94,779	122,545	63.63
High Speed Railway	Kyungbu line	Section 13-3	Earth work/Structure	2003-11-27	2009-06-26	169,261	184,121	87.11
High Speed Railway	Kyungbu line	Section 12-4	Earth work/Structure	2003-11-27	2008-12-30	139,033	158,838	82.39
High Speed Railway	Kyungbu line	Section 14-1	Earth work/Structure	2002-07-08	2009-03-31	141,874	207,900	69.07
High Speed Railway	Kyungbu line	Seciton 14-2	Earth work/Structure	2002-11-18	2009-05-04	170,566	193,521	82.91
National Railway	Kyungwon line (double track)	Uijungbu-Dongdoochun 1	Earth work/Structure	1997-12-29	2007-12-31	88,330	149,598	94.70
National Railway	Kyungwon line (double track)	Uijungbu-Dongdoochun 2	Earth work/Structure	1997-10-08	2008-05-31	98,670	209,754	93.25
National Railway	Kyungwon line (double track)	Uijungbu-Dongdoochun 3	Earth work/Structure	1997-10-08	2008-06-30	119,130	185,899	94.88
National Railway	Ori-Suwon	Ori-Jukjun	Earth work/Structure	2002-09-16	2008-06-30	43,636	85,623	100.00
National Railway	Chungryangri-Dukso	Chungryangri-Dukso 1	Earth work/Structure	1998-12-28	2009-12-31	57,129	129,764	72.10
National Railway	Chungryangri-Dukso	Chungryangri-Dukso 2	Earth work/Structure	1997-10-08	2006-06-30	68,552	105,772	72.75
National Railway	Nambuk line	Entrance facility site development	Earth work/Structure	2005-10-26	2007-12-24	36,811	40,457	73.77
National Railway	Suwon-Chunan	Suwon-Chunan 1	Earth work/Structure	1996-10-28	2006-07-30	33,588	76,904	92.30
National Railway	Suwon-Chunan	Suwon-Chunan 5	Earth work/Structure	1996-09-10	2005-04-30	37,150	61,957	93.65
National Railway	Suwon-Chunan	Suwon-Chunan 6	Earth work/Structure	1996-11-19	2005-08-15	35,270	70,956	90.60
National Railway	Kyungbu line	Okchun-Jitan improvement	Earth work/Structure	2003-12-24	2007-08-31	30,613	37,230	80.19
National Railway	Jochiwon-Daegu	Daepyung over-crossing	Earth work/Structure	2007-08-27	2008-12-26	6,428	7,496	84.56
National Railway	Jochiwon-Daegu	Whanggan-Chupoongryung improvement	Earth work/Structure	2002-12-24	2006-12-27	21,697	26,088	84.23
National Railway	Samrangjin-Jinju	Section 5	Earth work/Structure	2003-12-23	2009-12-31	161,900	197,021	94.79
National Railway	Kyungchoon line	Section 3	Earth work/Structure	2002-12-24	2007-11-20	71,987	122,323	80.06
National Railway	Daegu line (reconstruction)	Section 1	Earth work/Structure	1997-08-27	2005-11-30	29,656	37,977	94.04
National Railway	Daegu line (reconstruction)	Section 2	Earth work/Structure	1997-08-27	2004-12-20	39,633	52,545	93.89
National Railway	Daegu line (reconstruction)	Section 3	Earth work/Structure	1997-09-25	2007-12-31	42,999	78,647	75.79
National Railway	Busan new port line	Section 4	Earth work/Structure	2003-12-04	2008-11-10	152,332	167,313	93.98
National Railway	Youngnam cargo terminal line	Site development	Earth work/Structure	2006-12-05	2009-08-31	10,165	14,005	78.37
National Railway	Incheon International Airport l	Railway under landingway	Earth work/Structure	2005-07-11	2007-12-18	21,690	22,267	78.00
National Railway	Janghang line	Janghang-Gunsan	Earth work/Structure	2000-05-15	2009-12-20	160,373	203,045	73.49
National Railway	Janghang line	Section 3	Earth work/Structure	2001-11-17	2009-12-20	81,570	117,379	80.25
National Railway	Janghang line	Section 4	Earth work/Structure	2001-05-28	2009-12-20	107,013	171,228	60.00
National Railway	Janghang line	Section 5	Earth work/Structure	2001-05-28	2009-12-20	149,166	206,967	60.58
National Railway	Janghang line	Section 1-1	Earth work/Structure	2001-11-15	2009-12-20	61,479	89,328	80.20
National Railway	Janghang line	Secton 1-2	Earth work/Structure	2001-11-17	2009-12-20	57,812	72,412	80.27
National Railway	Janghang line	Setion 2-1	Earth work/Structure	2001-11-17	2009-12-20	60,595	85,673	80.27
National Railway	Chungan-Onyangonchun	Section 2-2	Earth work/Structure	2001-11-17	2009-12-20	64,676	77,051	80.26
National Railway	Chungan-Onyangonchun	Track bed improvement	Earth work/Structure	2000-05-04	2009-12-20	172,271	288,430	73.00
National Railway	Junla line	Sinri-Soonchun 4	Earth work/Structure	1998-06-12	2005-04-30	116,100	140,515	94.23
National Railway	Junla line	Sinri-soonchun 7	Earth work/Structure	1999-05-25	2004-12-09	67,364	81,970	70.23
National Railway	Jungbu cargo terminal line	Track bed improvement	Earth work/Structure	2006-11-06	2009-09-30	38,319	39,994	78.26
National Railway	Dukso-wonju	Section 3	Earth work/Structure	2001-03-03	2009-12-31	182,935	196,112	94.98
National Railway	Honam cargo terminal line	Track bed improvement	Earth work/Structure	2002-11-25	2005-03-13	31,084	35,706	79.75
National Railway	Songjungri-Mokpo	Section 7	Earth work/Structure	1999-05-20	2004-12-10	85,011	116,175	71.24
National Railway	DRMO	Track bed improvement	Earth work/Structure	2008-10-28	2009-06-30	223	222	87.00
High Speed Railway	Kyungbu line	Gwangmyung station	Building/Equipment	1999-12-16	2004-04-30	86,468	118616	75.13
High Speed Railway	Kyungbu line	Daegu-Gomo track station	Building/Equipment	2007-03-01	2008-06-05	6,102	5636	84.50
High Speed Railway	Kyungbu line	Youngdong Comprehesive maintenance ce	Building/Equipment	2003-08-21	2004-09-30	7,983	10583	80.80
High Speed Railway	Kyungbu line	Chunan Asan station (Equipment)	Building/Equipment	1997-03-10	2004-01-07	8,906	11647	71.15
High Speed Railway	Kyungbu line	Chunan Asan station	Building/Equipment	1996-07-29	2004-03-31	99,814	66039	94.94
High Speed Railway	Kyungbu line	Whalchun equipment centre	Building/Equipment	2008-01-08	2009-07-07	4,574	4557	84.56
High Speed Railway	Kyungbu line	Goyang train depot building	Building/Equipment	2005-11-30	2006-10-31	2,872	3799	84.67
Metropolitan Railway	Kyungwon line (double track)	Dukjung station	Building/Equipment	2005-07-27	2008-03-12	12,128	16261	79.15
Metropolitan Railway	Kyungwon line (double track)	Army base moving and reconstruction	Building/Equipment	2003-12-30	2007-06-12	7,815	10155	91.99
Metropolitan Railway	Yongsan-Munsan	Seoul Train station building	Building/Equipment	2002-12-16	2005-05-13	4,612	5924	85.48
Metropolitan Railway	Yongsan-Munsan	Susack Station	Building/Equipment	2001-12-28	2009-09-15	7,427	10397	85.50
Metropolitan Railway	Yongsan-Munsan	Wolong Station	Building/Equipment	2003-09-30	2005-11-11	3,070	4413	86.75
Metropolitan Railway	Yongsan-Munsan	Hangsin Station	Building/Equipment	2003-09-15	2008-04-30	6,916	9618	86.21
Metropolitan Railway	Yongsan-Munsan	Susack Train Station	Building/Equipment	2006-12-04	2008-12-31	4,095	4095	85.67
Metropolitan Railway	Kyungwon line (double track)	Naehang Station	Building/Equipment	2004-11-20	2007-09-19	28,759	36628	78.12
Metropolitan Railway	Kyungwon line (double track)	Uijungbubukbu Station	Building/Equipment	2004-08-12	2007-04-18	20,795	21841	78.76
Metropolitan Railway	Chunryangri-Dukso	Donong Substation	Building/Equipment	2002-05-03	2005-08-22	3,586	4358	86.77
Metropolitan Railway	Chunryangri-Dukso	Guri and Sampae Station	Building/Equipment	2002-10-21	2006-05-20	7,556	11450	85.30
Metropolitan Railway	Chunryangri-Dukso	Donong Station	Building/Equipment	2002-01-25	2006-04-28	11,460	26757	85.10
Metropolitan Railway	Chunryangri-Dukso	Songgok Station	Building/Equipment	2001-12-29	2006-06-30	4,155	6850	80.00
Metropolitan Railway	Chunryangri-Dukso	Hoegi Station	Building/Equipment	2001-12-29	2006-06-30	8,262	16962	72.13
Metropolitan Railway	Chunryangri-Dukso	Joongwha station	Building/Equipment	2004-09-22	2006-06-30	5,212	6543	83.00
National Railway	Nambuk line	Entrance facility	Building/Equipment	2006-09-11	2007-12-24	21,540	23341	78.02
National Railway	Nambuk line	Dorasan Station	Building/Equipment	2004-10-01	2006-04-30	10,127	20027	78.15
National Railway	Jeojin-38 line	Jejin Station	Building/Equipment	2003-12-29	2007-06-22	9,833	18523	84.47
National Railway	Jochiwon-Daegu	Sagok Substation	Building/Equipment	2003-09-15	2006-08-31	6,863	8118	86.20
National Railway	Jochiwon-Daegu	Okchun Substation	Building/Equipment	2003-09-18	2006-09-30	9,602	9909	85.08
National Railway	Jochiwon-Daegu	Sintanjin Station	Building/Equipment	2002-11-19	2004-12-31	2,028	4925	86.77

National Railway	Kyungin 2	Incheon Sation	Building/Equipment	2002-07-03	2004-09-23	142	305	86.47
National Railway	Kyungin 2	Jaemulpo station	Building/Equipment	1999-11-17	2004-09-12	5,151	6764	81.19
National Railway	Kyungchoon line	Temporary replacement building	Building/Equipment	2005-05-16	2005-11-11	2,039	2256	84.68
National Railway	Kyungchoon line	Pyungnae Station	Building/Equipment	2005-02-21	2006-10-20	6,028	6621	83.00
National Railway	Daegu line (reconstruction)	Gachun Station	Building/Equipment	2007-06-11	2007-12-07	1,068	1145	85.75
National Railway	Daegu line (reconstruction)	Gumgang Station	Building/Equipment	2003-11-26	2005-10-20	940	1298	87.77
National Railway	Daegu line (reconstruction)	Daegu Substation	Building/Equipment	2004-06-09	2004-12-30	937	1375	84.81
National Railway	Daegu line (reconstruction)	Feight Station building	Building/Equipment	2003-09-22	2005-09-15	1,664	1967	86.78
National Railway	Dukso-wonju	Yangsoo Station	Building/Equipment	2007-12-26	2009-12-25	13,708	13708	78.02
National Railway	Dukso-wonju	Wonduk tempory station	Building/Equipment	2008-06-30	2008-10-29	815	815	86.79
National Railway	Dukso-wonju	Jipyung Station	Building/Equipment	2005-12-13	2009-12-13	1,848	1848	84.67
National Railway	Dongbu train depot	Dongbu Train office	Building/Equipment	1997-11-25	2005-06-30	167,332	204233	98.60
National Railway	Jeojin-38 line	Entrance facility building	Building/Equipment	2007-09-21	2008-09-20	14,210	14210	78.00
National Railway	Suseo-Sunrung	Gaepo 1 Station	Building/Equipment	2003-04-21	2004-10-11	7,281	11546	91.99
National Railway	Suwon-Chunan	Seoujungri Station	Building/Equipment	1998-10-12	2004-07-31	5,422	7201	91.93
National Railway	Suwon-Chunan	Sema Station	Building/Equipment	2002-11-18	2006-02-28	4,050	5978	91.95
National Railway	Suwon-Chunan	Songtan Station	Building/Equipment	1998-12-07	2004-07-31	5,787	7447	91.88
National Railway	Suwon-Chunan	Suchung and Habuk Station	Building/Equipment	2002-11-18	2006-08-31	9,890	12676	91.83
National Railway	Suwon-Chunan	Jije Station	Building/Equipment	2002-11-18	2006-07-31	7,745	12288	91.93
National Railway	Suwon-Chunan	Chunan temporary station	Building/Equipment	2000-08-09	2004-12-19	5,950	20284	90.60
National Railway	Soonchun-Yeosoo	Soonchun train office	Building/Equipment	2003-05-24	2004-08-31	2,458	2832	86.89
National Railway	Donghae-Gangrung	Mangsang Station 1	Building/Equipment	2003-11-12	2005-06-12	918	1256	86.74
National Railway	Donghae-Gangrung	Mangsang Station 2	Building/Equipment	2003-12-20	2005-06-24	2,526	3977	86.75
National Railway	Onyangonchun-Sinchang	Sinchang Station	Building/Equipment	2007-12-25	2008-12-24	6,221	4170	84.50
National Railway	Janghang line	Daechun Station	Building/Equipment	2006-11-20	2008-03-31	9,422	9667	78.13
National Railway	Chunan-Onyangonchun	Dogo-onchun Station	Building/Equipment	2006-11-20	2008-12-31	10,193	10936	78.01
National Railway	Janghang line	Sinjanghang Station	Building/Equipment	2006-11-20	2008-03-31	11,348	12446	78.07
National Railway	Janghang line	Yesan Station	Building/Equipment	2007-07-10	2009-05-31	9,196	10100	78.20
National Railway	Janghang line	Pangyo Station	Building/Equipment	2007-07-10	2009-05-31	7,633	10621	84.51
National Railway	Janghang line	Hongsung Station	Building/Equipment	2007-07-09	2009-05-31	8,634	8072	78.02
National Railway	Junla line	Namwon Station	Building/Equipment	2002-05-18	2004-08-14	5,498	7185	86.27
National Railway	Jochiwon-Daegu	Yongdong Substation	Building/Equipment	2005-05-17	2006-09-16	4,669	4607	83.00
National Railway	Jochiwon-Daegu	Oegwan substation	Building/Equipment	2005-05-19	2006-09-11	4,468	4594	83.03
National Railway	Jochiwon-Daegu	Ewon Substation	Building/Equipment	2005-10-28	2006-04-26	1,780	1779	84.67
National Railway	Chunan-Onyangonchun	Bongmyung Station	Building/Equipment	2007-08-01	2009-05-31	13,286	13886	87.04
National Railway	Chunan-Onyangonchun	Onyangonchun Station	Building/Equipment	2005-06-09	2009-05-31	14,415	18406	78.13
National Railway	Honam cargo terminal line	Anpyung Station	Building/Equipment	2003-11-26	2004-12-31	959	1107	86.71
National Railway	Honam cargo terminal line	Cargo terminal building	Building/Equipment	2004-07-05	2004-12-21	474	508	85.50
National Railway	Songjungri-Mokpo	Mokpo staton Roof replacement	Building/Equipment	2003-03-19	2004-02-19	1,694	2442	86.77
High Speed Railway	Kyungbu line	Gomo track installation	Track	10/11/2005	20/12/2006	3,673	4,189	85.00
High Speed Railway	Kyungbu line	Goyang train depot track installation	Track	21/11/2005	31/12/2006	1,841	1,931	84.70
Metropolitan Railway	Kyungwon line (double track)	Uijungbu-Dongan track installation	Track	14/10/2004	28/12/2007	17,535	17,344	80.43
Metropolitan Railway	Yongsan-Munsan	Woonjung-Munsan track installation	Track	17/11/2000	30/06/2009	3,878	25,072	87.05
Metropolitan Railway	Dukso-wonju	Songgok-Dukso track installation	Track	19/06/2002	30/04/2006	3,476	6,832	86.89
National Railway	Jeojin-38 line	Jeojin-38 line track installation	Track	20/11/2003	01/11/2006	2,397	6,903	86.81
National Railway	Suwon-Chunan	Byungjum train depot track installation	Track	03/09/2009	31/12/2009	916	916	86.49
National Railway	Jochiwon-Daegu	Naepan tunnel track installation	Track	24/08/2004	31/08/2005	1,146	1,887	84.67
National Railway	Nambuk line	Entrance facility track installation	Track	16/08/2007	24/12/2007	1,259	1,287	85.76
National Railway	Kyungchoon line	Sinnam-Namchoonchun track installation	Track	27/12/2004	20/12/2005	2,449	2,135	84.77
National Railway	Youngnam cargo terminal line	Youngnam cargo terminal track installation	Track	22/02/2008	31/12/2009	3,702	4,081	85.79
National Railway	Janghang line	Mosan-Onyangonchun track installation	Track	04/10/2005	31/05/2006	1,142	1,393	85.13
National Railway	Janghang line	Sinjanghang-Daeya track installation	Track	20/11/2006	31/12/2008	11,927	9,408	78.53
National Railway	Onyangonchun-Sinchang	Onyangonchun-Sinsung track installation	Track	07/12/2006	31/12/2009	19,358	20,766	66.00
National Railway	Janghang line	Jupo-Sinjanghang track installation	Track	20/11/2006	30/06/2009	14,490	14,770	78.48
National Railway	Chunan-Onyangonchun	Chunan-Onyangonchun track installation	Track	23/06/2006	30/12/2008	8,077	8,725	84.15
National Railway	Junla line	Iksan-Dongsoonchun track installation	Track	01/08/2005	20/10/2006	4,143	4,065	83.26
National Railway	Jochiwon-Daegu	Jochiwon-Daegu track installation	Track	08/08/2005	31/12/2007	11,772	14,415	80.46
National Railway	Jungbu cargo terminal line	Track installation	Track	22/09/2008	31/12/2009	4,627	4,626	85.58
National Railway	Honam cargo terminal line	Track installation	Track	15/08/2004	28/02/2005	2,125	2,325	84.77
National Railway	DRMO	Track installation	Track	18/12/2008	30/06/2009	233	233	87.00
High Speed Railway	Kyungbu line	Daegu-Busan grounding	Electiricity	29/11/2003	30/06/2009	1,275	1533	80.00
High Speed Railway	Kyungbu line	Daegu Substation power transmission	Electiricity	21/08/2008	28/02/2009	1,147	1147	86.34
High Speed Railway	Kyungbu line	Daejeon-Daegu traction line	Electiricity	05/07/2001	30/04/2004	21,359	24977	83.46
High Speed Railway	Kyungbu line	Busan train depot power facility	Electiricity	04/02/2002	31/03/2004	10,137	11647	73.91
High Speed Railway	Kyungbu line	Busan train depot traction line	Electiricity	30/05/2002	31/03/2004	5,135	5854	81.37
High Speed Railway	Kyungbu line	Goyang train depot traction line	Electiricity	21/11/2005	31/12/2006	836	1029	84.67
High Speed Railway	Kyungbu line	Busanjin power facility	Electiricity	22/02/2006	21/09/2009	7,758	11410	78.09
High Speed Railway	Youngnam cargo terminal line	Terminal power facility	Electiricity	19/02/2008	30/12/2008	2,550	2486	85.69
Metropolitan Railway	Kyungwon line (double track)	Junae Staton power facility	Electiricity	08/11/2004	28/12/2007	6,448	9572	83.00
Metropolitan Railway	Kyungwon line (double track)	Army base moving and reconstruction (pov	Electiricity	02/08/2004	30/06/2007	585	699	84.67
Metropolitan Railway	Kyungwon line (double track)	Uijungbu-Bukbu electricity obstacles remo	Electiricity	14/09/1998	31/12/2007	3,057	6399	90.01
Metropolitan Railway	Yongsan-Munsan	Gajoa-Mousan power facility	Electiricity	29/12/2003	16/01/2009	6,122	6711	85.88
Metropolitan Railway	Yongsan-Munsan	Hangsin Station power facility	Electiricity	21/11/2003	10/02/2008	705	1438	86.75
Metropolitan Railway	Suseo-Sunrung	Bundang train depot traction line	Electiricity	14/07/1997	20/12/2007	1,720	3618	89.95
Metropolitan Railway	Ori-Suwon	Ori-train depot power facility	Electiricity	06/09/2004	05/08/2008	6,318	6151	83.08
Metropolitan Railway	Dukso-wonju	Dukso-Paldang power facility	Electiricity	02/10/2007	31/12/2007	286	306	85.67
Metropolitan Railway	Chungryangri-Dukso	Dukso-Palding electro-obstacles removing	Electiricity	19/11/2004	20/12/2005	838	891	84.67
Metropolitan Railway	Chungryangri-Dukso	Mangwoo-Dukson power facility	Electiricity	19/10/2000	30/11/2006	10,702	15686	83.26
Metropolitan Railway	Dukso-wonju	Guri Station power facility	Electiricity	25/04/2002	26/05/2006	1,283	3540	86.75
Metropolitan Railway	Dukso-wonju	Hogui station power facility	Electiricity	29/04/2002	31/12/2009	1,498	3727	86.75
Metropolitan Railway	Chungryangri-Dukso	Chungraying-Dukso power facility	Electiricity	03/09/2001	30/06/2006	1,026	2462	86.75
National Railway	Yongsan-Munsan	Dorasan station power facility	Electiricity	22/10/2004	25/05/2006	819	2084	84.67
National Railway	Jeojin-38 line	Jeojin-38 line power facility	Electiricity	09/12/2003	30/06/2006	1,765	2494	86.75
National Railway	Suwon-Chunan	Doonpo bridge lighting	Electiricity	23/04/2001	25/05/2005	781	897	87.00
National Railway	Suwon-Chunan	Seojungri staton power facility	Electiricity	30/12/1998	25/05/2005	1,081	3967	88.00
National Railway	Suwon-Chunan	Sema station power facility	Electiricity	11/04/2005	30/06/2006	2,178	2997	84.67
National Railway	Suwon-Chunan	Suwon-Osan tracktion line	Electiricity	06/11/1998	08/12/2005	13,920	25159	70.00
National Railway	Suwon-Chunan	Suwon-Chunan power facility	Electiricity	29/11/2000	20/06/2005	903	1609	86.81
National Railway	Suwon-Chunan	Suwon-Pyungtaek power facility	Electiricity	29/12/1999	30/12/2004	1,666	3559	83.00
National Railway	Suwon-Chunan	Osan-Pyungtaek traction line	Electiricity	06/11/1998	08/12/2005	13,109	18359	69.00
National Railway	Suwon-Chunan	Osan station power facility	Electiricity	30/12/1998	30/12/2004	1,232	2052	87.00
National Railway	Suwon-Chunan	Pyungtaek-Chunan power facility	Electiricity	29/12/1999	30/12/2004	1,228	1957	81.00
National Railway	Suwon-Chunan	Pyungtaek-Chunan traction line	Electiricity	18/11/1998	08/12/2005	16,083	23226	71.25
National Railway	Dangjung station	Dangjung station eletro-obstables removing	Electiricity	13/08/2008	31/12/2009	2,137	2137	86.36
National Railway	Dangjung station	Dangjung station power facility	Electiricity	24/09/2008	26/02/2010	565	564	86.34
National Railway	Jochiwon-Daegu	Apo-Sindong power facility	Electiricity	25/09/2002	31/12/2007	22,944	44042	83.84
National Railway	Jochiwon-Daegu	Okchun-Whanggna power facility	Electiricity	23/07/2002	31/12/2006	22,813	42193	79.57
National Railway	Jochiwon-Daegu	Jochwon-Daejeon power facility	Electiricity	23/07/2002	30/09/2005	17,711	32634	83.74
National Railway	Jochiwon-Daegu	Jochiwon-Whanggan power facility	Electiricity	07/11/2002	31/12/2006	3,507	6375	86.78
National Railway	Jochiwon-Daegu	Whanggan-Sinpo power facility	Electiricity	25/11/2002	31/12/2006	4,842	12837	85.76

National Railway	Jochiwon-Daegu	Whanggan-Apo power facility	Electiricity	23/07/2002	31/12/2006	25,520	43503	82.36
National Railway	Kyungin 2	Dongam station power facility	Electiricity	13/12/1999	27/12/2004	1,439	2034	80.40
National Railway	Kyungin 2	Dongincheon station power facility	Electiricity	24/05/2002	08/04/2006	282	1246	86.75
National Railway	Kyungin 2	Bupyung-Juan traction line	Electiricity	14/07/1997	27/12/2004	7,337	13161	93.97
National Railway	Kyungin 2	Juan-Incheon power facility	Electiricity	18/08/1999	26/12/2005	752	1228	88.73
National Railway	Kyungin 2	Juan-Incheon traction line	Electiricity	03/09/1999	31/03/2006	7,680	8841	73.64
National Railway	Daegu line (reconstruction)	Gachun station power facility	Electiricity	11/06/2007	07/12/2007	246	260	86.62
National Railway	Daegu line (reconstruction)	Dongdaegu-Chungchun power facility	Electiricity	01/12/2000	31/08/2008	1,068	2822	86.75
National Railway	Suseo-Sunrung	Suseo-Sunrung power facility	Electiricity	13/12/2001	17/09/2004	250	648	87.80
National Railway	Ori-Suwon	Yongdong station power facility	Electiricity	28/12/2001	18/10/2004	2,624	7968	83.00
National Railway	Soonchun-Yeosoo	Soonchun train office power facility	Electiricity	04/09/2003	28/10/2004	435	659	86.76
National Railway	Donghae-Gangrung	Donghae-Gangrung power facility 1	Electiricity	31/10/2003	30/11/2005	1,013	2315	86.75
National Railway	Donghae-Gangrung	Donghae-Gangrung traction line	Electiricity	29/05/2002	30/12/2005	9,388	17071	83.97
National Railway	Donghae-Gangrung	Donghae-Gangrung power facility 2	Electiricity	02/12/2002	31/12/2005	308	475	86.77
National Railway	Janghang line	Ganchi-Daeya power facility	Electiricity	25/06/2007	30/12/2008	7,219	6490	84.53
National Railway	Janghang line	Dogo-onchun Station power facility	Electiricity	25/06/2007	31/05/2009	5,527	6254	84.73
National Railway	Janghang line	Sinchang-Sinsung power facility	Electiricity	25/06/2007	30/12/2008	4,498	4430	84.51
National Railway	Janghang line	Sinchang Station power facility	Electiricity	18/12/2007	31/12/2008	866	858	85.67
National Railway	Janghang line	Yesan Station power facility	Electiricity	02/06/2008	31/05/2009	4,585	4606	86.38
National Railway	Onyangonchun-Sinchang	Onyangonchun-Sinsung power facility	Electiricity	20/11/2007	31/12/2008	2,050	2178	85.71
National Railway	Onyangonchun-Sinchang	Onyangonchun Station power facility	Electiricity	30/11/2005	31/03/2009	1,515	2732	84.67
National Railway	Chunan-Onyangonchun	Chunan-Onyangonchun power facility 1	Electiricity	22/07/2005	31/03/2009	11,648	13946	78.24
National Railway	Chunan-Onyangonchun	Mosan station power facility	Electiricity	17/09/2007	31/03/2009	1,461	1692	85.67
National Railway	Chunan-Onyangonchun	Chunan-Onynagonchun Power facility 2	Electiricity	21/08/2007	31/03/2009	577	610	85.67
National Railway	Chunan-Onyangonchun	Electro-obstacles removing	Electiricity	30/11/2004	30/12/2005	207	207	86.00
National Railway	Janghang line	Jupo station electro-obstacles removing	Electiricity	20/08/2004	25/12/2004	38	44	86.00
National Railway	Junla line	Namwon Station power facility	Electiricity	15/04/2002	10/08/2004	1,055	1824	86.75
National Railway	Junla line	Bongchun station power facility	Electiricity	26/04/2001	31/05/2005	591	1375	86.75
National Railway	Junla line	Seodo-Gumji power facility	Electiricity	25/04/2002	10/08/2004	1,514	2247	86.75
National Railway	Soonchun-Yeosoo	Soonchun-Yeosoo electro-obstacles remov	Electiricity	31/07/2007	22/09/2008	433	434	85.67
National Railway	Jungbu cargo terminal line	Terminal power facility	Electiricity	18/12/2008	31/12/2009	4,409	4409	86.36
National Railway	Dukso-wonju	Gooksoo-Gudon power lines	Electiricity	17/06/2005	14/11/2005	657	608	84.67
National Railway	Dukso-wonju	Yangpyung station power lines 1	Electiricity	07/11/2005	30/12/2005	150	141	85.99
National Railway	Dukso-wonju	Yangpyung sation power lines 2	Electiricity	26/04/2006	30/07/2008	1,800	1854	84.67
National Railway	Dukso-wonju	Yongmun station power facility	Electiricity	23/05/2008	30/12/2009	556	556	86.34
National Railway	Dukso-wonju	Paldang-Guksoo power facility	Electiricity	30/05/2008	30/11/2008	1,000	1000	86.34
National Railway	Honam cargo terminal line	terminal line power facility	Electiricity	12/12/2003	31/12/2004	365	906	86.75
National Railway	Songjungri-Mokpo	Hakgyo-Mokpo power facility	Electiricity	01/06/2000	31/05/2004	2,660	7994	82.98
National Railway	Songjungri-Mokpo	Anpyung Station power facility	Electiricity	10/08/2004	17/10/2004	105	105	84.00
National Railway	Songjungri-Mokpo	Anpyung Satation traction line	Electiricity	05/11/2004	31/12/2004	423	740	82.98
High Speed Railway	Kyungbu line	Daegu-Daejeon train communication syste	Communication	08/06/2001	29/04/2004	5,801	5475	80.66
High Speed Railway	Kyungbu line	Busan train depot communication system	Communication	08/06/2002	31/03/2004	7,214	8217	81.45
Metropolitan Railway	Kyungwon line (double track)	Uijungbu-Dongan communication system	Communication	15/11/2000	28/12/2007	2,008	4357	86.76
Metropolitan Railway	Yongsan-Munsan	Susack station communication system	Communication	28/11/2002	10/12/2009	844	923	86.75
Metropolitan Railway	Yongsan-Munsan	Hangsin station communication system	Communication	21/11/2003	30/11/2009	625	973	86.75
Metropolitan Railway	Ori-Suwon	Ori-Bungdang depot communication syster	Communication	18/07/2004	31/07/2008	725	708	84.69
Metropolitan Railway	Dukso-wonju	Guri station communication system	Communication	29/04/2002	31/08/2006	1,763	3230	86.75
Metropolitan Railway	Dukso-wonju	Dukso-Yongmun communication system	Communication	21/09/2007	31/12/2009	3,183	3183	85.67
National Railway	Yongsan-Munsan	Dorasan station communication system	Communication	12/10/2004	25/05/2006	864	1415	84.67
National Railway	Jeojin-38 line	Jeojin-38 line communication system	Communication	09/12/2003	30/06/2007	913	1705	86.96
National Railway	Dangjung station	Dangjung station communication system	Communication	01/08/2008	26/02/2010	1,434	1433	86.34
National Railway	Suwon-Chunan	Seojungri station communication system	Communication	28/12/1998	20/12/2004	874	1583	90.00
National Railway	Suwon-Chunan	Serew station communication system	Communication	26/12/1998	20/12/2004	862	1539	90.00
National Railway	Suwon-Chunan	Suwon-Pyungtaek communication system	Communication	18/09/1999	20/12/2004	1,991	2658	90.00
National Railway	Jochiwon-Daegu	Youngdong -Sindong communication syster	Communication	02/10/2002	31/12/2006	7,224	9409	85.60
National Railway	Jochiwon-Daegu	Jochiwon-Youngdong communication syste	Communication	02/09/2002	31/12/2006	3,875	6052	86.75
National Railway	Jochiwon-Daegu	Jochiwon-Daegu communication system	Communication	01/06/2006	30/12/2006	2,544	2654	84.69
National Railway	Suwon-Chunan	Chunan station communication system	Communication	13/12/2001	20/12/2004	1,232	2546	86.75
National Railway	Suwon-Chunan	Pyungtaek-Chunan communication system	Communication	07/09/1999	20/12/2004	1,384	1961	90.00
National Railway	Jochiwon-Daegu	Pyungtaek station communication system	Communication	07/10/2003	30/04/2005	693	1427	86.75
National Railway	Kyungin 2	Youngdungpo-Incheon communication syst	Communication	30/07/2001	31/12/2005	353	486	86.75
National Railway	Kyungin 2	Dowon station communication system	Communication	20/12/1999	08/12/2004	283	444	84.95
National Railway	Kyungin 2	Dongam station communication system	Communication	04/08/1999	10/08/2004	988	1515	90.00
National Railway	Kyungin 2	Dongincheon Station communication syster	Communication	03/06/2002	30/03/2006	416	1134	86.74
National Railway	Kyungin 2	Bupyung-Incheon communication system	Communication	13/09/1999	27/12/2005	547	989	90.00
National Railway	Samrangjin-Jinju	Samrangjin-Jinju communication system	Communication	01/11/2007	31/12/2008	1,213	724	85.67
National Railway	Busan-Woolsan	Busan-Ilgwang communication system	Communication	05/12/2008	20/12/2009	1,296	1296	86.36
National Railway	Suseo-Sunrung	Gaepo station communication system	Communication	17/12/2001	18/10/2004	1,144	2488	86.76
National Railway	Suseo-Sunrung	Sunrung-Suseo communication system	Communication	08/07/2002	31/08/2004	2,182	2331	86.75
National Railway	Suwon-Chunan	Suwon station communication system	Communication	17/12/2001	30/06/2004	433	451	86.75
National Railway	Soonchun-Yeosoo	Soonchun train offince communication syst	Communication	04/09/2003	30/06/2005	362	659	86.75
National Railway	Youngnam cargo terminal line	Terminal communication system	Communication	20/02/2008	31/12/2008	311	225	85.68
National Railway	Donghae-Gangrung	Donghae-Gangrung communication system	Communication	12/08/2002	23/12/2005	3,453	6597	86.75
National Railway	Janghang line	Janghang line communication system 1	Communication	26/05/2005	27/12/2005	88	88	86.05
National Railway	Janghang line	Sinchang-Daeya communication system	Communication	25/06/2007	31/08/2009	17,518	16225	78.45
National Railway	Janghang line	Yesan station communication system	Communication	02/06/2008	30/06/2009	1,923	1826	86.38
National Railway	Onyangonchun-Sinchang	Sinchang station communication system	Communication	10/12/2007	31/12/2008	381	340	85.84
National Railway	Chunan-Onyangonchun	Bongmyung station communication system	Communication	27/08/2007	31/01/2009	561	559	85.73
National Railway	Chunan-Onyangonchun	Chunan-Onyangonchun communication sys	Communication	21/12/2004	31/03/2009	1,445	2644	84.67
National Railway	Janghang line	Janghang line communication system 2	Communication	15/07/2004	31/12/2004	405	419	84.67
National Railway	Junla line	Namwon station communication system	Communication	01/06/2002	20/08/2004	442	808	86.76
National Railway	Junla line	Bongchun station communication system	Communication	26/04/2001	21/07/2004	362	463	86.75
National Railway	Junla line	Sansung-Soonchun communication system	Communication	19/06/2002	20/08/2004	1,484	1933	86.76
National Railway	Soonchun-Yeosoo	Soonchun-Yeosoo communication system	Communication	01/08/2007	23/09/2008	589	590	85.67
National Railway	Junla line	Imsil-Gumji communication system	Communication	11/06/2002	20/08/2004	494	508	86.84
National Railway	Junla line	Junju-Sansung communication system	Communication	19/06/2002	20/08/2004	2,102	2338	86.75
National Railway	Jungbu cargo terminal line	Terminal communication system	Communication	05/12/2008	04/12/2009	765	764	86.34
National Railway	Dukso-wonju	Yongmoon station communication system	Communication	19/12/2008	31/12/2009	861	861	86.34
National Railway	Dukso-wonju	Jipyung station communication system	Communication	04/07/2008	31/12/2009	433	433	86.43
National Railway	Honam cargo terminal line	Terminal communication system	Communication	12/12/2003	27/12/2004	671	729	86.64

National Railway	DRMO	Communication system	Communication	24/12/2008	23/04/2009	47	47	87.03
High Speed Railway	Kyungbu line	Daejeon-Daegu signalling	Signalling	28/07/2001	31/01/2004	16,500	18489	79.58
High Speed Railway	Kyungbu line	Busan train depot signalling	Signalling	16/02/2002	31/03/2004	6,364	6190	81.77
High Speed Railway	Kyungbu line	Seoul-Daegu CTC	Signalling	31/01/2002	30/04/2004	957	1528	83.15
High Speed Railway	Kyungbu line	Busanjin Station Signalling	Signalling	08/02/2006	31/08/2007	1,594	2730	84.70
High Speed Railway	Kyungbu line	Goyang train depot Signalling	Signalling	08/11/2005	31/12/2006	789	1236	84.78
Metropolitan Railway	Kyungwon line (double track)	Jijang station Signalling	Signalling	03/07/1999	31/12/2005	147	149	91.96
Metropolitan Railway	Kyungwon line (double track)	Uijungbu-Dongan Signalling 1	Signalling	07/10/2004	30/12/2007	518	605	84.70
Metropolitan Railway	Kyungwon line (double track)	Uijungbu-Dongan Signalling 2	Signalling	21/11/2004	30/12/2007	6,361	9946	83.37
Metropolitan Railway	Kyungwon line (double track)	Uijungbu station signalling 1	Signalling	09/06/1999	31/12/2005	85	55	92.69
Metropolitan Railway	Kyungwon line (double track)	Uijungbu station signalling 2	Signalling	20/07/1999	24/12/2005	125	202	94.75
Metropolitan Railway	Kyungwon line (double track)	Uijungbu station signalling 3	Signalling	24/05/1999	24/12/2005	510	1263	90.00
Metropolitan Railway	Ori-Jukjeon	Ori-Bungdang depot signalling 1	Signalling	28/07/2004	31/08/2008	248	227	84.70
Metropolitan Railway	Ori-Jukjeon	Ori-Bungdang depot signalling 2	Signalling	24/09/2004	31/08/2008	5,193	6467	84.46
Metropolitan Railway	Dukso-wonju	Dukso-Paldang signalling	Signalling	20/09/2007	30/12/2007	1,517	2022	85.71
Metropolitan Railway	Dukso-wonju	Donong station signalling	Signalling	01/07/2002	30/12/2005	103	252	86.89
Metropolitan Railway	Chungryangri-Dukso	Mangwoo-Dukso signalling	Signalling	15/09/2000	30/06/2006	1,762	4387	86.79
National Railway	Jeojin-38 line	Jeojin-38 line signalling 1	Signalling	11/11/2003	31/12/2006	36	76	87.83
National Railway	Jeojin-38 line	Jeojin-38 line signalling 2	Signalling	15/12/2003	31/12/2006	1,236	2390	86.75
National Railway	Suwon-Chunan	Sungwhan-Chunan signalling	Signalling	14/09/1998	04/06/2005	4,352	13399	90.00
National Railway	Suwon-Chunan	Sungwhan statin signalling removing	Signalling	09/12/1999	30/12/2004	234	439	88.94
National Railway	Suwon-Chunan	Serew station signalling removing	Signalling	04/12/1999	30/12/2004	239	453	91.52
National Railway	Suwon-Chunan	Suwon-Byungjum signalling	Signalling	28/09/1998	30/04/2005	3,411	9520	90.10
National Railway	Suwon-Chunan	Osan-Pyungtaek signalling	Signalling	01/09/1998	04/06/2005	3,822	13552	90.04
National Railway	Suwon-Chunan	Pyungtaek station signalling removing	Signalling	04/12/1999	30/12/2004	241	357	89.34
National Railway	Suwon-Chunan	Suwon station signalling removing	Signalling	18/10/2000	30/12/2004	179	362	86.82
National Railway	Suwon-Chunan	Chunan station signalling removing	Signalling	19/10/2000	30/04/2005	164	389	86.91
National Railway	Dangjung station	Gunpo-Uiwang signalling	Signalling	25/08/2008	28/02/2010	1,361	1360	87.11
National Railway	Suwon-Chunan	Byungjum train depot signalling	Signalling	01/08/2008	31/01/2010	1,083	1082	86.35
National Railway	Jochiwon-Daegu	Bugang station signalling	Signalling	21/11/2003	27/12/2004	155	225	86.75
National Railway	Suwon-Chunan	Semaoe sation signalling	Signalling	13/12/2006	27/12/2006	70	70	97.46
National Railway	Jochiwon-Daegu	Apo-Sindong signalling	Signalling	25/10/2002	31/12/2006	3,519	6458	86.88
National Railway	Jochiwon-Daegu	Yongdong station signalling	Signalling	25/11/2003	29/12/2004	101	107	87.02
National Railway	Jochiwon-Daegu	Okchun-Whanggan signalling	Signalling	25/10/2002	30/12/2006	3,706	7507	86.84
National Railway	Jochiwon-Daegu	Oegwan station signalling	Signalling	21/11/2003	25/11/2004	144	139	86.98
National Railway	Jochiwon-Daegu	Jochiwon-Daejeon signalling	Signalling	25/10/2002	27/10/2005	2,949	6303	86.76
National Railway	Suwon-Chunan	Chunan station signalling	Signalling	23/12/2002	02/05/2005	583	1959	86.74
National Railway	Jochwon-Daegu	Whanggan-Apo signalling	Signalling	04/11/2002	31/12/2006	4,469	7389	85.72
National Railway	Nambuk line	Entrance facility signalling	Signalling	30/08/2007	24/12/2007	1,301	1380	85.74
National Railway	Kyungin 2	Juan-Incheon signalling	Signalling	28/09/2000	30/03/2006	1,765	3335	87.75
National Railway	Daegu line (reconstruction)	Dongdaegu-Chungchun signalling	Signalling	01/12/1998	31/08/2008	2,630	5460	90.04
National Railway	Busan-Woolsan	Songjung-Joachun signalling	Signalling	28/10/2004	24/12/2004	44	44	86.02
National Railway	Youngnam cargo terminal line	Terminal signalling	Signalling	20/02/2008	31/12/2009	1,801	1897	85.69
National Railway	Donghae-Gangrung	Donghae-Gangrung signalling	Signalling	05/08/2002	23/12/2005	1,387	5103	86.74
National Railway	Janghang line	Signalling obstacles removing	Signalling	12/05/2005	30/12/2005	197	609	86.11
National Railway	Janghang line	Janghang line signalling	Signalling	22/06/2007	30/12/2008	1,634	1207	85.77
National Railway	Janghang line	Sinchang-Hongsung signalling	Signalling	16/07/2007	30/10/2009	8,643	10582	78.60
National Railway	Janghang line	Sinchang-Daeya signalling	Signalling	16/07/2007	30/10/2009	11,313	8968	78.23
National Railway	Chunan-Onyangonchun	Chunan-Onyangonchun signalling	Signalling	02/11/2004	31/03/2009	4,018	9210	84.97
National Railway	Janghang line	Hongsung-Woonchun signalling	Signalling	16/07/2007	30/10/2009	8,646	7467	78.01
National Railway	Janghang line	Sigalling obstacles removing	Signalling	28/07/2004	29/12/2004	592	592	84.67
National Railway	Junla line	Namwon station signalling 1	Signalling	08/10/2001	31/10/2004	327	718	87.22
National Railway	Junla line	Namwon station signalling 2	Signalling	22/07/2002	31/03/2005	782	2746	86.82
National Railway	Junla line	Bongchun station signalling 1	Signalling	04/07/2001	30/06/2005	149	356	91.58
National Railway	Junla line	Bongchun station signalling 2	Signalling	17/06/2001	30/06/2005	623	2805	86.76
National Railway	Soonchun-Yeosoo	Soonchun-Yeosoo signalling obstacles rem	Signalling	03/08/2007	30/06/2009	987	987	85.79
National Railway	Jungbu cargo terminal line	Terminal signalling	Signalling	10/12/2008	31/12/2009	2,094	2093	86.49
National Railway	Dukso-wonju	Dukso-Paldang signalling	Signalling	22/12/2006	31/12/2007	615	942	85.75
National Railway	Dukso-wonju	Samgok-Dodam signalling	Signalling	03/12/2004	23/12/2004	36	36	86.02
National Railway	Dukso-wonju	Sangok station signalling 1	Signalling	09/11/2005	25/08/2006	97	145	85.99
National Railway	Dukso-wonju	Sangok station signalling 2	Signalling	11/04/2006	22/12/2006	574	774	84.76
National Railway	Dukso-wonju	Yangpyung sation signalling obstacles remo	Signalling	24/10/2005	23/12/2005	17	25	86.01
National Railway	Honam cargo terminal line	Terminal signalling 1	Signalling	05/08/2004	15/03/2005	97	102	84.90
National Railway	Honam cargo terminal line	Terminal signalling 2	Signalling	31/12/2003	15/03/2005	641	1064	86.77
National Railway	Songjungri-Mokpo	Mooan-Mokpo signalling	Signalling	08/12/1999	31/03/2004	1,666	4522	83.04
National Railway	DRMO	DRMO line signalling	Signalling	26/12/2008	13/07/2009	246	245	87.07

(Operation)

Line	Year	Personnel cost (million KRW)	Management cost (millon KRW)	Maintenance cost (million KRW)	Line	Year	Personnel cost (million KRW)	Management cost (millon KRW)	Maintenance cost (million KRW)
Kyungbu line	2010	332,721	305,279	84,646	Kyungui line	2010	19,288	10,689	4,278
Kyungbu line	2009	346,040	290,550	94,811	Kyungui line	2009	32,339	18,242	4,307
Kyungbu line	2008	383,397	336,484	91,271	Kyungui line	2008	34,939	24,379	5,062
Kyungbu line	2007	339,125	331,106	110,964	Kyungui line	2007	28,958	21,104	2,192
Kyungbu line	2006	321,534	337,415	74,020	Kyungui line	2006	22,857	20,209	1,656
Kyungbu line	2005	278,784	375,265	67,710	Kyungui line	2005	21,898	24,476	1,595
Kyungbu line	2004	769,215			Kyungui line	2004	39,293		
Kyungbu line	2003	934,338			Kyungui line	2003	37,275		
Kyungbu line	2002	842,186			Kyungui line	2002	33,146		
Kyungbu line	2001	785,186			Kyungui line	2001	28,204		
Honam line	2010	75,012	55,688	19,918	Gyioe line	2010	378	194	30
Honam line	2009	78,646	51,877	20,751	Gyioe line	2009	326	136	36
Honam line	2008	86,038	58,990	21,567	Gyioe line	2008	486	218	50
Honam line	2007	73,265	59,723	23,197	Gyioe line	2007	490	330	29
Honam line	2006	66,535	61,839	7,596	Gyioe line	2006	789	592	150
Honam line	2005	55,658	65,421	8,712	Gyioe line	2005	880	629	196
Honam line	2004	144,836			Gyioe line	2004	5,033		
Honam line	2003	168,065			Gyioe line	2003	6,265		
Honam line	2002	146,291			Gyioe line	2002	5,994		
Honam line	2001	144,397			Gyioe line	2001	6,049		
Joongang line	2010	137,647	77,382	25,898	Kyungbuk line	2010	7,621	4,870	998
Joongang line	2009	141,432	71,655	34,433	Kyungbuk line	2009	7,352	4,012	907
Joongang line	2008	156,308	84,905	35,719	Kyungbuk line	2008	7,737	4,140	872
Joongang line	2007	129,618	81,295	39,998	Kyungbuk line	2007	6,004	4,119	1,045
Joongang line	2006	121,174	82,960	40,533	Kyungbuk line	2006	6,793	4,758	1,054
Joongang line	2005	117,458	89,715	41,363	Kyungbuk line	2005	6,258	4,865	1,116
Joongang line	2004	252,766			Kyungbuk line	2004	41,266		
Joongang line	2003	249,951			Kyungbuk line	2003	27,409		
Joongang line	2002	225,998			Kyungbuk line	2002	22,297		
Joongang line	2001	215,656			Kyungbuk line	2001	18,868		
Junla line	2010	58,091	47,507	13,026	Gunsan line	2010			
Junla line	2009	60,557	41,650	13,848	Gunsan line	2009			
Junla line	2008	66,283	49,792	14,743	Gunsan line	2008			
Junla line	2007	57,897	47,604	16,411	Gunsan line	2007	2,729	1,901	243
Junla line	2006	54,891	50,190	17,720	Gunsan line	2006	3,593	2,434	516
Junla line	2005	49,623	50,884	17,092	Gunsan line	2005	3,663	2,397	555
Junla line	2004	101,841			Gunsan line	2004	9,726		
Junla line	2003	105,506			Gunsan line	2003	9,664		
Junla line	2002	93,293			Gunsan line	2002	7,480		
Junla line	2001	87,791			Gunsan line	2001	8,301		
Youngdong line	2010	58,282	28,963	7,318	Taebak line	2010	31,642	15,540	5,305
Youngdong line	2009	59,382	27,481	9,622	Taebak line	2009	34,088	14,885	7,964
Youngdong line	2008	66,238	30,049	10,011	Taebak line	2008	35,865	16,388	8,399
Youngdong line	2007	60,957	33,710	12,120	Taebak line	2007	29,395	16,948	9,134
Youngdong line	2006	56,312	34,043	9,649	Taebak line	2006	33,093	19,545	10,079
Youngdong line	2005	49,103	33,477	9,282	Taebak line	2005	30,476	18,022	9,730
Youngdong line	2004	110,857			Taebak line	2004	67,463		
Youngdong line	2003	103,022			Taebak line	2003	65,291		
Youngdong line	2002	93,419			Taebak line	2002	58,034		
Youngdong line	2001	89,451			Taebak line	2001	54,760		
Kyungjun line	2010	52,130	32,150	4,738	Donghae line	2010	62,438	37,034	7,234
Kyungjun line	2009	52,830	28,492	4,805	Donghae line	2009	62,733	33,948	7,684
Kyungjun line	2008	58,625	33,939	5,098	Donghae line	2008	67,231	38,143	7,676
Kyungjun line	2007	48,756	33,619	5,841	Donghae line	2007	55,035	36,860	7,270
Kyungjun line	2006	48,186	39,723	6,137	Donghae line	2006	40,846	28,867	6,528
Kyungjun line	2005	43,651	40,930	5,706	Donghae line	2005	42,585	31,152	6,632
Kyungjun line	2004	112,098			Donghae line	2004	95,858		
Kyungjun line	2003	117,211			Donghae line	2003	109,767		
Kyungjun line	2002	106,617			Donghae line	2002	100,165		
Kyungjun line	2001	97,089			Donghae line	2001	95,742		
Chungbuk line	2010	31,592	23,557	8,694	Jinhae line	2010	1,704	1,153	224
Chungbuk line	2009	34,490	23,297	12,753	Jinhae line	2009	1,668	1,101	211
Chungbuk line	2008	37,823	26,151	13,584	Jinhae line	2008	1,641	1,246	179
Chungbuk line	2007	29,281	24,575	12,801	Jinhae line	2007	1,378	1,083	93
Chungbuk line	2006	35,004	28,539	16,210	Jinhae line	2006	1,488	1,074	63
Chungbuk line	2005	29,242	28,591	14,984	Jinhae line	2005	1,233	664	69
Chungbuk line	2004	66,281			Jinhae line	2004	4,548		
Chungbuk line	2003	68,109			Jinhae line	2003	4,704		
Chungbuk line	2002	58,869			Jinhae line	2002	4,288		
Chungbuk line	2001	54,049			Jinhae line	2001	3,958		
Kyungwon line	2010	27,248	15,472	1,800	Daegu line	2010	8,480	7,075	1,888
Kyungwon line	2009	26,241	16,111	1,770	Daegu line	2009	8,679	6,577	2,064
Kyungwon line	2008	22,795	15,378	1,841	Daegu line	2008	9,568	7,625	1,864
Kyungwon line	2007	19,836	15,557	2,641	Daegu line	2007	7,585	6,946	1,883
Kyungwon line	2006	21,838	17,828	3,009	Daegu line	2006	7,682	6,529	2,798
Kyungwon line	2005	25,960	23,520	2,965	Daegu line	2005	10,278	9,076	2,513
Kyungwon line	2004	103,425			Daegu line	2004	20,450		
Kyungwon line	2003	106,837			Daegu line	2003	20,749		
Kyungwon line	2002	99,444			Daegu line	2002	19,345		
Kyungwon line	2001	96,091			Daegu line	2001	17,983		
Kyungchoon line	2010	20,265	15,553	5,072	Janghang line	2010	36,060	31,449	9,351
Kyungchoon line	2009	22,088	14,889	5,086	Janghang line	2009	36,593	28,428	9,376
Kyungchoon line	2008	23,914	16,928	5,585	Janghang line	2008	42,709	32,826	9,197
Kyungchoon line	2007	19,968	14,989	5,811	Janghang line	2007	34,182	27,880	9,764
Kyungchoon line	2006	19,521	15,273	7,029	Janghang line	2006	33,036	30,166	10,197
Kyungchoon line	2005	17,156	15,910	7,556	Janghang line	2005	27,574	27,158	9,877
Kyungchoon line	2004	34,778			Janghang line	2004	56,390		
Kyungchoon line	2003	31,438			Janghang line	2003	53,759		
Kyungchoon line	2002	30,455			Janghang line	2002	49,318		
Kyungchoon line	2001	28,089			Janghang line	2001	47,625		

Appendix M Data for meta-analysis

trans_programme	ppp	project	M_VFM	SE_prj_ppp	length	completion_delay	BCR	discount_rate	cpi	xchequer_bon	mode1_D	ppp_D	region_D	application_ratio	traffic_volume
National Highway	BTL	Todang-Gwansan	4.8	4.67066	9.24	0	2.136	7.5	3.5	6.9	0	0	0	88.55	100
National Highway	BTL	Todang-Gwansan	25	4.67066	9.24	1	2.136	7.5	3.5	6.9	0	0	0	88.55	100
National Highway	BTL	Todang-Gwansan	43.7	4.67066	9.24	2	2.136	7.5	3.5	6.9	0	0	0	88.55	100
National Highway	BTL	Todang-Gwansan	61	4.67066	9.24	3	2.136	7.5	3.5	6.9	0	0	0	88.55	100
National Highway	BTL	Todang-Gwansan	76.9	4.67066	9.24	4	2.136	7.5	3.5	6.9	0	0	0	88.55	100
National Highway	BTL	Todang-Gwansan	56.6	4.67066	9.24	2.742	2.136	7.5	3.5	6.9	0	0	0	88.55	100
National Highway	BTL	Todang-Gwansan	0.2	4.67066	9.24	0	2.136	7.5	3.5	6.9	0	0	0	84.5746	100
National Highway	BTL	Todang-Gwansan	20.6	4.67066	9.24	1	2.136	7.5	3.5	6.9	0	0	0	84.5746	100
National Highway	BTL	Todang-Gwansan	39.4	4.67066	9.24	2	2.136	7.5	3.5	6.9	0	0	0	84.5746	100
National Highway	BTL	Todang-Gwansan	52.4	4.67066	9.24	2.742	2.136	7.5	3.5	6.9	0	0	0	84.5746	100
National Highway	BTL	Todang-Gwansan	56.8	4.67066	9.24	3	2.136	7.5	3.5	6.9	0	0	0	84.5746	100
National Highway	BTL	Todang-Gwansan	72.9	4.67066	9.24	4	2.136	7.5	3.5	6.9	0	0	0	84.5746	100
National Highway	BTL	Todang-Gwansan	0.2	4.67066	9.24	0	2.136	7.5	3.5	6.9	0	0	0	88.55	68.6
National Highway	BTL	Todang-Gwansan	14.4	4.67066	9.24	1	2.136	7.5	3.5	6.9	0	0	0	88.55	68.6
National Highway	BTL	Todang-Gwansan	27.5	4.67066	9.24	2	2.136	7.5	3.5	6.9	0	0	0	88.55	68.6
National Highway	BTL	Todang-Gwansan	36.5	4.67066	9.24	2.742	2.136	7.5	3.5	6.9	0	0	0	88.55	68.6
National Highway	BTL	Todang-Gwansan	39.6	4.67066	9.24	3	2.136	7.5	3.5	6.9	0	0	0	88.55	68.6
National Highway	BTL	Todang-Gwansan	50.6	4.67066	9.24	4	2.136	7.5	3.5	6.9	0	0	0	88.55	68.6
National Highway	BTL	Todang-Gwansan	-4.4	4.67066	9.24	0	2.136	7.5	3.5	6.9	0	0	0	84.5746	68.6
National Highway	BTL	Todang-Gwansan	10	4.67066	9.24	1	2.136	7.5	3.5	6.9	0	0	0	84.5746	68.6
National Highway	BTL	Todang-Gwansan	23.2	4.67066	9.24	2	2.136	7.5	3.5	6.9	0	0	0	84.5746	68.6
National Highway	BTL	Todang-Gwansan	35.4	4.67066	9.24	3	2.136	7.5	3.5	6.9	0	0	0	84.5746	68.6
National Highway	BTL	Todang-Gwansan	46.6	4.67066	9.24	4	2.136	7.5	3.5	6.9	0	0	0	84.5746	68.6
National Highway	BTL	Todang-Gwansan	32.3	4.67066	9.24	2.742	2.136	7.5	3.5	6.9	0	0	0	84.5746	68.6
National Highway	BTL	Dongup-Hanlim	0.78	2.02465	7.29	0	1.23	5.5	3.77	3.38	0	0	1	88.55	100
National Highway	BTL	Dongup-Hanlim	8.82	2.02465	7.29	1	1.23	5.5	3.77	3.38	0	0	1	88.55	100
National Highway	BTL	Dongup-Hanlim	16.35	2.02465	7.29	2	1.23	5.5	3.77	3.38	0	0	1	88.55	100
National Highway	BTL	Dongup-Hanlim	23.41	2.02465	7.29	3	1.23	5.5	3.77	3.38	0	0	1	88.55	100
National Highway	BTL	Dongup-Hanlim	30.01	2.02465	7.29	4	1.23	5.5	3.77	3.38	0	0	1	88.55	100
National Highway	BTL	Dongup-Hanlim	21.58	2.02465	7.29	2.742	1.23	5.5	3.77	3.38	0	0	1	88.55	100
National Highway	BTL	Dongup-Hanlim	-3.54	2.02465	7.29	0	1.23	5.5	3.77	3.38	0	0	1	84.5746	100
National Highway	BTL	Dongup-Hanlim	4.62	2.02465	7.29	1	1.23	5.5	3.77	3.38	0	0	1	84.5746	100
National Highway	BTL	Dongup-Hanlim	12.28	2.02465	7.29	2	1.23	5.5	3.77	3.38	0	0	1	84.5746	100
National Highway	BTL	Dongup-Hanlim	17.6	2.02465	7.29	2.742	1.23	5.5	3.77	3.38	0	0	1	84.5746	100
National Highway	BTL	Dongup-Hanlim	19.46	2.02465	7.29	3	1.23	5.5	3.77	3.38	0	0	1	84.5746	100
National Highway	BTL	Dongup-Hanlim	26.18	2.02465	7.29	4	1.23	5.5	3.77	3.38	0	0	1	84.5746	100
National Highway	BTL	Dongup-Hanlim	-2.93	2.02465	7.29	0	1.23	5.5	3.77	3.38	0	0	1	88.55	68.6
National Highway	BTL	Dongup-Hanlim	2.02	2.02465	7.29	1	1.23	5.5	3.77	3.38	0	0	1	88.55	68.6
National Highway	BTL	Dongup-Hanlim	6.63	2.02465	7.29	2	1.23	5.5	3.77	3.38	0	0	1	88.55	68.6
National Highway	BTL	Dongup-Hanlim	9.79	2.02465	7.29	2.742	1.23	5.5	3.77	3.38	0	0	1	88.55	68.6
National Highway	BTL	Dongup-Hanlim	10.92	2.02465	7.29	3	1.23	5.5	3.77	3.38	0	0	1	88.55	68.6
National Highway	BTL	Dongup-Hanlim	14.89	2.02465	7.29	4	1.23	5.5	3.77	3.38	0	0	1	88.55	68.6
National Highway	BTL	Dongup-Hanlim	-7.25	2.02465	7.29	0	1.23	5.5	3.77	3.38	0	0	1	84.5746	68.6
National Highway	BTL	Dongup-Hanlim	-2.17	2.02465	7.29	1	1.23	5.5	3.77	3.38	0	0	1	84.5746	68.6
National Highway	BTL	Dongup-Hanlim	2.56	2.02465	7.29	2	1.23	5.5	3.77	3.38	0	0	1	84.5746	68.6
National Highway	BTL	Dongup-Hanlim	6.97	2.02465	7.29	3	1.23	5.5	3.77	3.38	0	0	1	84.5746	68.6
National Highway	BTL	Dongup-Hanlim	11.06	2.02465	7.29	4	1.23	5.5	3.77	3.38	0	0	1	84.5746	68.6
National Highway	BTL	Dongup-Hanlim	5.81	2.02465	7.29	2.742	1.23	5.5	3.77	3.38	0	0	1	84.5746	68.6
National Expressway	BTL	Suwon-Pyungtaek	33.6	36.2076	38.5	0	2.717	7.5	3.5	6.9	0	0	0	82.14	100
National Expressway	BTL	Suwon-Pyungtaek	197.5	36.2076	38.5	1	2.717	7.5	3.5	6.9	0	0	0	82.14	100
National Expressway	BTL	Suwon-Pyungtaek	349.5	36.2076	38.5	2	2.717	7.5	3.5	6.9	0	0	0	82.14	100
National Expressway	BTL	Suwon-Pyungtaek	490.3	36.2076	38.5	3	2.717	7.5	3.5	6.9	0	0	0	82.14	100
National Expressway	BTL	Suwon-Pyungtaek	620.7	36.2076	38.5	4	2.717	7.5	3.5	6.9	0	0	0	82.14	100
National Expressway	BTL	Suwon-Pyungtaek	243.3	36.2076	38.5	1.296	2.717	7.5	3.5	6.9	0	0	0	82.14	100
National Expressway	BTO	Suwon-Pyungtaek	-88.1	42.5677	38.5	0	2.717	7.5	3.5	6.9	0	1	0	82.14	100
National Expressway	BTO	Suwon-Pyungtaek	112.1	42.5677	38.5	1	2.717	7.5	3.5	6.9	0	1	0	82.14	100
National Expressway	BTO	Suwon-Pyungtaek	297.7	42.5677	38.5	2	2.717	7.5	3.5	6.9	0	1	0	82.14	100
National Expressway	BTO	Suwon-Pyungtaek	469.9	42.5677	38.5	3	2.717	7.5	3.5	6.9	0	1	0	82.14	100
National Expressway	BTO	Suwon-Pyungtaek	629.5	42.5677	38.5	4	2.717	7.5	3.5	6.9	0	1	0	82.14	100
National Expressway	BTO	Suwon-Pyungtaek	168.1	42.5677	38.5	1.296	2.717	7.5	3.5	6.9	0	1	0	82.14	100
National Expressway	BTL	Suwon-Pyungtaek	17.1	36.2076	38.5	0	2.717	7.5	3.5	6.9	0	0	0	78.8001	100
National Expressway	BTL	Suwon-Pyungtaek	181.7	36.2076	38.5	1	2.717	7.5	3.5	6.9	0	0	0	78.8001	100
National Expressway	BTL	Suwon-Pyungtaek	227.7	36.2076	38.5	1.296	2.717	7.5	3.5	6.9	0	0	0	78.8001	100
National Expressway	BTL	Suwon-Pyungtaek	334.3	36.2076	38.5	2	2.717	7.5	3.5	6.9	0	0	0	78.8001	100
National Expressway	BTL	Suwon-Pyungtaek	475.7	36.2076	38.5	3	2.717	7.5	3.5	6.9	0	0	0	78.8001	100
National Expressway	BTL	Suwon-Pyungtaek	606.7	36.2076	38.5	4	2.717	7.5	3.5	6.9	0	0	0	78.8001	100
National Expressway	BTO	Suwon-Pyungtaek	-104.6	42.5677	38.5	0	2.717	7.5	3.5	6.9	0	1	0	78.8001	100
National Expressway	BTO	Suwon-Pyungtaek	96.2	42.5677	38.5	1	2.717	7.5	3.5	6.9	0	1	0	78.8001	100
National Expressway	BTO	Suwon-Pyungtaek	152.4	42.5677	38.5	1.296	2.717	7.5	3.5	6.9	0	1	0	78.8001	100
National Expressway	BTO	Suwon-Pyungtaek	282.5	42.5677	38.5	2	2.717	7.5	3.5	6.9	0	1	0	78.8001	100
National Expressway	BTO	Suwon-Pyungtaek	455.2	42.5677	38.5	3	2.717	7.5	3.5	6.9	0	1	0	78.8001	100
National Expressway	BTO	Suwon-Pyungtaek	615.4	42.5677	38.5	4	2.717	7.5	3.5	6.9	0	1	0	78.8001	100
National Expressway	BTL	Suwon-Pyungtaek	24.8	36.2076	38.5	0	2.717	7.5	3.5	6.9	0	0	0	82.14	68.64
National Expressway	BTL	Suwon-Pyungtaek	139.4	36.2076	38.5	1	2.717	7.5	3.5	6.9	0	0	0	82.14	68.64
National Expressway	BTL	Suwon-Pyungtaek	171.2	36.2076	38.5	1.296	2.717	7.5	3.5	6.9	0	0	0	82.14	68.64
National Expressway	BTL	Suwon-Pyungtaek	245.5	36.2076	38.5	2	2.717	7.5	3.5	6.9	0	0	0	82.14	68.64
National Expressway	BTL	Suwon-Pyungtaek	343.6	36.2076	38.5	3	2.717	7.5	3.5	6.9	0	0	0	82.14	68.64
National Expressway	BTL	Suwon-Pyungtaek	434.3	36.2076	38.5	4	2.717	7.5	3.5	6.9	0	0	0	82.14	68.64
National Expressway	BTO	Suwon-Pyungtaek	50.1	42.5677	38.5	0	2.717	7.5	3.5	6.9	0	1	0	82.14	68.64
National Expressway	BTO	Suwon-Pyungtaek	189.6	42.5677	38.5	1	2.717	7.5	3.5	6.9	0	1	0	82.14	68.64
National Expressway	BTO	Suwon-Pyungtaek	228.4	42.5677	38.5	1.296	2.717	7.5	3.5	6.9	0	1	0	82.14	68.64
National Expressway	BTO	Suwon-Pyungtaek	318.8	42.5677	38.5	2	2.717	7.5	3.5	6.9	0	1	0	82.14	68.64
National Expressway	BTO	Suwon-Pyungtaek	438.4	42.5677	38.5	3	2.717	7.5	3.5	6.9	0	1	0	82.14	68.64
National Expressway	BTO	Suwon-Pyungtaek	549.2	42.5677	38.5	4	2.717	7.5	3.5	6.9	0	1	0	82.14	68.64
National Expressway	BTL	Suwon-Pyungtaek	8	36.2076	38.5	0	2.717	7.5	3.5	6.9	0	0	0	78.8001	68.64
National Expressway	BTL	Suwon-Pyungtaek	123.2	36.2076	38.5	1	2.717	7.5	3.5	6.9	0	0	0	78.8001	68.64
National Expressway	BTL	Suwon-Pyungtaek	229.9	36.2076	38.5	2	2.717	7.5	3.5	6.9	0	0	0	78.8001	68.64
National Expressway	BTL	Suwon-Pyungtaek	328.6	36.2076	38.5	3	2.717	7.5	3.5	6.9	0	0	0	78.8001	68.64
National Expressway	BTL	Suwon-Pyungtaek	420	36.2076	38.5	4	2.717	7.5	3.5	6.9	0	0	0	78.8001	68.64
National Expressway	BTL	Suwon-Pyungtaek	155.2	36.2076	38.5	1.296	2.717	7.5	3.5	6.9	0	0	0	78.8001	68.64
National Expressway	BTO	Suwon-Pyungtaek	33.3	42.5677	38.5	0	2.717	7.5	3.5	6.9	0	1	0	78.8001	68.64
National Expressway	BTO	Suwon-Pyungtaek	173.4	42.5677	38.5	1	2.717	7.5	3.5	6.9	0	1	0	78.8001	68.64
National Expressway	BTO	Suwon-Pyungtaek	303.3	42.5677	38.5	2	2.717	7.5	3.5	6.9	0	1	0	78.8001	68.64
National Expressway	BTO	Suwon-Pyungtaek	423.5	42.5677	38.5	3	2.717	7.5	3.5	6.9	0	1	0	78.8001	68.64

National Expressway	BTO	Suwon-Pyungtaek	534.9	42.5677	38.5	4	2.717	7.5	3.5	6.9	0	1	0	78.8001	68.64
National Expressway	BTO	Suwon-Pyungtaek	212.5	42.5677	38.5	1.296	2.717	7.5	3.5	6.9	0	1	0	78.8001	68.64
National Expressway	BTL	Bongdam-Songsan	12.7	5.79551	18.46	0	1.17	5.5	2.99	4.72	0	0	0	82.14	100
National Expressway	BTL	Bongdam-Songsan	37.4	5.79551	18.46	1	1.17	5.5	2.99	4.72	0	0	0	82.14	100
National Expressway	BTL	Bongdam-Songsan	60.7	5.79551	18.46	2	1.17	5.5	2.99	4.72	0	0	0	82.14	100
National Expressway	BTL	Bongdam-Songsan	82.5	5.79551	18.46	3	1.17	5.5	2.99	4.72	0	0	0	82.14	100
National Expressway	BTL	Bongdam-Songsan	103	5.79551	18.46	4	1.17	5.5	2.99	4.72	0	0	0	82.14	100
National Expressway	BTL	Bongdam-Songsan	44.3	5.79551	18.46	1.296	1.17	5.5	2.99	4.72	0	0	0	82.14	100
National Expressway	BTO	Bongdam-Songsan	-47.5	12.0032	18.46	0	1.17	5.5	2.99	4.72	0	1	0	82.14	100
National Expressway	BTO	Bongdam-Songsan	-6	12.0032	18.46	1	1.17	5.5	2.99	4.72	0	1	0	82.14	100
National Expressway	BTO	Bongdam-Songsan	33.2	12.0032	18.46	2	1.17	5.5	2.99	4.72	0	1	0	82.14	100
National Expressway	BTO	Bongdam-Songsan	70.1	12.0032	18.46	3	1.17	5.5	2.99	4.72	0	1	0	82.14	100
National Expressway	BTO	Bongdam-Songsan	104.9	12.0032	18.46	4	1.17	5.5	2.99	4.72	0	1	0	82.14	100
National Expressway	BTO	Bongdam-Songsan	5.7	12.0032	18.46	1.296	1.17	5.5	2.99	4.72	0	1	0	82.14	100
National Expressway	BTL	Bongdam-Songsan	3.6	5.79551	18.46	0	1.17	5.5	2.99	4.72	0	0	0	78.8001	100
National Expressway	BTL	Bongdam-Songsan	28.6	5.79551	18.46	1	1.17	5.5	2.99	4.72	0	0	0	78.8001	100
National Expressway	BTL	Bongdam-Songsan	35.5	5.79551	18.46	1.296	1.17	5.5	2.99	4.72	0	0	0	78.8001	100
National Expressway	BTL	Bongdam-Songsan	52	5.79551	18.46	2	1.17	5.5	2.99	4.72	0	0	0	78.8001	100
National Expressway	BTL	Bongdam-Songsan	74.1	5.79551	18.46	3	1.17	5.5	2.99	4.72	0	0	0	78.8001	100
National Expressway	BTL	Bongdam-Songsan	94.9	5.79551	18.46	4	1.17	5.5	2.99	4.72	0	0	0	78.8001	100
National Expressway	BTO	Bongdam-Songsan	-56.6	12.0032	18.46	0	1.17	5.5	2.99	4.72	0	1	0	78.8001	100
National Expressway	BTO	Bongdam-Songsan	-14.9	12.0032	18.46	1	1.17	5.5	2.99	4.72	0	1	0	78.8001	100
National Expressway	BTO	Bongdam-Songsan	-3.1	12.0032	18.46	1.296	1.17	5.5	2.99	4.72	0	1	0	78.8001	100
National Expressway	BTO	Bongdam-Songsan	24.5	12.0032	18.46	2	1.17	5.5	2.99	4.72	0	1	0	78.8001	100
National Expressway	BTO	Bongdam-Songsan	61.7	12.0032	18.46	3	1.17	5.5	2.99	4.72	0	1	0	78.8001	100
National Expressway	BTO	Bongdam-Songsan	96.8	12.0032	18.46	4	1.17	5.5	2.99	4.72	0	1	0	78.8001	100
National Expressway	BTL	Bongdam-Songsan	7.7	5.79551	18.46	0	1.17	5.5	2.99	4.72	0	0	0	82.14	68.64
National Expressway	BTL	Bongdam-Songsan	25.8	5.79551	18.46	1	1.17	5.5	2.99	4.72	0	0	0	82.14	68.64
National Expressway	BTL	Bongdam-Songsan	30.7	5.79551	18.46	1.296	1.17	5.5	2.99	4.72	0	0	0	82.14	68.64
National Expressway	BTL	Bongdam-Songsan	42.7	5.79551	18.46	2	1.17	5.5	2.99	4.72	0	0	0	82.14	68.64
National Expressway	BTL	Bongdam-Songsan	58.5	5.79551	18.46	3	1.17	5.5	2.99	4.72	0	0	0	82.14	68.64
National Expressway	BTL	Bongdam-Songsan	73.4	5.79551	18.46	4	1.17	5.5	2.99	4.72	0	0	0	82.14	68.64
National Expressway	BTO	Bongdam-Songsan	48.6	12.0032	18.46	0	1.17	5.5	2.99	4.72	0	1	0	82.14	68.64
National Expressway	BTO	Bongdam-Songsan	78.1	12.0032	18.46	1	1.17	5.5	2.99	4.72	0	1	0	82.14	68.64
National Expressway	BTO	Bongdam-Songsan	86.4	12.0032	18.46	1.296	1.17	5.5	2.99	4.72	0	1	0	82.14	68.64
National Expressway	BTO	Bongdam-Songsan	106	12.0032	18.46	2	1.17	5.5	2.99	4.72	0	1	0	82.14	68.64
National Expressway	BTO	Bongdam-Songsan	132.2	12.0032	18.46	3	1.17	5.5	2.99	4.72	0	1	0	82.14	68.64
National Expressway	BTO	Bongdam-Songsan	156.9	12.0032	18.46	4	1.17	5.5	2.99	4.72	0	1	0	82.14	68.64
National Expressway	BTL	Bongdam-Songsan	-1.4	5.79551	18.46	0	1.17	5.5	2.99	4.72	0	0	0	78.8001	68.64
National Expressway	BTL	Bongdam-Songsan	16.9	5.79551	18.46	1	1.17	5.5	2.99	4.72	0	0	0	78.8001	68.64
National Expressway	BTL	Bongdam-Songsan	34	5.79551	18.46	1.296	1.17	5.5	2.99	4.72	0	0	0	78.8001	68.64
National Expressway	BTL	Bongdam-Songsan	50.1	5.79551	18.46	2	1.17	5.5	2.99	4.72	0	0	0	78.8001	68.64
National Expressway	BTL	Bongdam-Songsan	65.2	5.79551	18.46	3	1.17	5.5	2.99	4.72	0	0	0	78.8001	68.64
National Expressway	BTL	Bongdam-Songsan	21.9	5.79551	18.46	4	1.17	5.5	2.99	4.72	0	0	0	78.8001	68.64
National Expressway	BTO	Bongdam-Songsan	39.4	12.0032	18.46	0	1.17	5.5	2.99	4.72	0	1	0	78.8001	68.64
National Expressway	BTO	Bongdam-Songsan	69.3	12.0032	18.46	1	1.17	5.5	2.99	4.72	0	1	0	78.8001	68.64
National Expressway	BTO	Bongdam-Songsan	97.4	12.0032	18.46	1.296	1.17	5.5	2.99	4.72	0	1	0	78.8001	68.64
National Expressway	BTO	Bongdam-Songsan	123.8	12.0032	18.46	2	1.17	5.5	2.99	4.72	0	1	0	78.8001	68.64
National Expressway	BTO	Bongdam-Songsan	148.7	12.0032	18.46	3	1.17	5.5	2.99	4.72	0	1	0	78.8001	68.64
National Expressway	BTO	Bongdam-Songsan	77.6	12.0032	18.46	4	1.17	5.5	2.99	4.72	0	1	0	78.8001	68.64
National Railway	BTL	Sosa-Wonsi	-14.7	16.9217	23.3	0	1.169	6.5	2.92	5.4	1	0	0	90.71	100
National Railway	BTL	Sosa-Wonsi	58.3	16.9217	23.3	1	1.169	6.5	2.92	5.4	1	0	0	90.71	100
National Railway	BTL	Sosa-Wonsi	126	16.9217	23.3	2	1.169	6.5	2.92	5.4	1	0	0	90.71	100
National Railway	BTL	Sosa-Wonsi	188.8	16.9217	23.3	3	1.169	6.5	2.92	5.4	1	0	0	90.71	100
National Railway	BTL	Sosa-Wonsi	201.5	16.9217	23.3	3.357	1.169	6.5	2.92	5.4	1	0	0	90.71	100
National Railway	BTL	Sosa-Wonsi	246.9	16.9217	23.3	4	1.169	6.5	2.92	5.4	1	0	0	90.71	100
National Railway	BTO	Sosa-Wonsi	-31.1	19.566	23.3	0	1.169	6.5	2.92	5.4	1	1	0	90.71	100
National Railway	BTO	Sosa-Wonsi	62.2	19.566	23.3	1	1.169	6.5	2.92	5.4	1	1	0	90.71	100
National Railway	BTO	Sosa-Wonsi	148.9	19.566	23.3	2	1.169	6.5	2.92	5.4	1	1	0	90.71	100
National Railway	BTO	Sosa-Wonsi	229.5	19.566	23.3	3	1.169	6.5	2.92	5.4	1	1	0	90.71	100
National Railway	BTO	Sosa-Wonsi	248.3	19.566	23.3	3.357	1.169	6.5	2.92	5.4	1	1	0	90.71	100
National Railway	BTO	Sosa-Wonsi	304.3	19.566	23.3	4	1.169	6.5	2.92	5.4	1	1	0	90.71	100
National Railway	BTL	Sosa-Wonsi	6.4	16.9217	23.3	0	1.169	6.5	2.92	5.4	1	0	0	93.027	100
National Railway	BTL	Sosa-Wonsi	78.7	16.9217	23.3	1	1.169	6.5	2.92	5.4	1	0	0	93.027	100
National Railway	BTL	Sosa-Wonsi	145.8	16.9217	23.3	2	1.169	6.5	2.92	5.4	1	0	0	93.027	100
National Railway	BTL	Sosa-Wonsi	207.8	16.9217	23.3	3	1.169	6.5	2.92	5.4	1	0	0	93.027	100
National Railway	BTL	Sosa-Wonsi	220.1	16.9217	23.3	3.357	1.169	6.5	2.92	5.4	1	0	0	93.027	100
National Railway	BTL	Sosa-Wonsi	265.3	16.9217	23.3	4	1.169	6.5	2.92	5.4	1	0	0	93.027	100
National Railway	BTO	Sosa-Wonsi	-10	19.566	23.3	0	1.169	6.5	2.92	5.4	1	1	0	93.027	100
National Railway	BTO	Sosa-Wonsi	82.6	19.566	23.3	1	1.169	6.5	2.92	5.4	1	1	0	93.027	100
National Railway	BTO	Sosa-Wonsi	168.6	19.566	23.3	2	1.169	6.5	2.92	5.4	1	1	0	93.027	100
National Railway	BTO	Sosa-Wonsi	248.5	19.566	23.3	3	1.169	6.5	2.92	5.4	1	1	0	93.027	100
National Railway	BTO	Sosa-Wonsi	266.9	19.566	23.3	3.357	1.169	6.5	2.92	5.4	1	1	0	93.027	100
National Railway	BTO	Sosa-Wonsi	322.7	19.566	23.3	4	1.169	6.5	2.92	5.4	1	1	0	93.027	100
National Railway	BTL	Sosa-Wonsi	-20.8	16.9217	23.3	0	1.169	6.5	2.92	5.4	1	0	0	90.71	50.71
National Railway	BTL	Sosa-Wonsi	20.2	16.9217	23.3	1	1.169	6.5	2.92	5.4	1	0	0	90.71	50.71
National Railway	BTL	Sosa-Wonsi	57.9	16.9217	23.3	2	1.169	6.5	2.92	5.4	1	0	0	90.71	50.71
National Railway	BTL	Sosa-Wonsi	92.5	16.9217	23.3	3	1.169	6.5	2.92	5.4	1	0	0	90.71	50.71
National Railway	BTL	Sosa-Wonsi	95.5	16.9217	23.3	3.357	1.169	6.5	2.92	5.4	1	0	0	90.71	50.71
National Railway	BTL	Sosa-Wonsi	124.1	16.9217	23.3	4	1.169	6.5	2.92	5.4	1	0	0	90.71	50.71
National Railway	BTO	Sosa-Wonsi	86.5	19.566	23.3	0	1.169	6.5	2.92	5.4	1	1	0	90.71	50.71
National Railway	BTO	Sosa-Wonsi	137.8	19.566	23.3	1	1.169	6.5	2.92	5.4	1	1	0	90.71	50.71
National Railway	BTO	Sosa-Wonsi	185.1	19.566	23.3	2	1.169	6.5	2.92	5.4	1	1	0	90.71	50.71
National Railway	BTO	Sosa-Wonsi	228.7	19.566	23.3	3	1.169	6.5	2.92	5.4	1	1	0	90.71	50.71
National Railway	BTO	Sosa-Wonsi	234.9	19.566	23.3	3.357	1.169	6.5	2.92	5.4	1	1	0	90.71	50.71
National Railway	BTO	Sosa-Wonsi	268.8	19.566	23.3	4	1.169	6.5	2.92	5.4	1	1	0	90.71	50.71
National Railway	BTL	Sosa-Wonsi	0.3	16.9217	23.3	0	1.169	6.5	2.92	5.4	1	0	0	93.027	50.71
National Railway	BTL	Sosa-Wonsi	40.6	16.9217	23.3	1	1.169	6.5	2.92	5.4	1	0	0	93.027	50.71
National Railway	BTL	Sosa-Wonsi	77.6	16.9217	23.3	2	1.169	6.5	2.92	5.4	1	0	0	93.027	50.71
National Railway	BTL	Sosa-Wonsi	111.5	16.9217	23.3	3	1.169	6.5	2.92	5.4	1	0	0	93.027	50.71
National Railway	BTL	Sosa-Wonsi	114.1	16.9217	23.3	3.357	1.169	6.5	2.92	5.4	1	0	0	93.027	50.71
National Railway	BTL	Sosa-Wonsi	142.5	16.9217	23.3	4	1.169	6.5	2.92	5.4	1	0	0	93.027	50.71
National Railway	BTO	Sosa-Wonsi	107.6	19.566	23.3	0	1.169	6.5	2.92	5.4	1	1	0	93.027	50.71
National Railway	BTO	Sosa-Wonsi	158.2	19.566	23.3	1	1.169	6.5	2.92	5.4	1	1	0	93.027	50.71
National Railway	BTO	Sosa-Wonsi	204.9	19.566	23.3	2	1.169	6.5	2.92	5.4	1	1	0	93.027	50.71
National Railway	BTO	Sosa-Wonsi	247.8	19.566	23.3	3	1.169	6.5	2.92	5.4	1	1	0	93.027	50.71
National Railway	BTO	Sosa-Wonsi	253.5	19.566	23.3	3.357	1.169	6.5	2.92	5.4	1	1	0	93.027	50.71
National Railway	BTO	Sosa-Wonsi	287.2	19.566	23.3	4	1.169	6.5	2.92	5.4	1	1	0	93.027	50.71
National Railway	BTL	Bujeon-Masan	35.78	2.27355	32	0	0.63	5.5	2.99	4.72	1	0	1	90.71	100
National Railway	BTL	Bujeon-Masan	37.77	2.27355	32	1	0.63	5.5	2.99	4.72	1	0	1	90.71	100
National Railway	BTL	Bujeon-Masan	39.06	2.27355	32	2	0.63	5.5	2.99	4.72	1	0	1	90.71	100
National Railway	BTL	Bujeon-Masan	39.61	2.27355	32	3	0.63	5.5	2.99	4.72	1	0	1	90.71	100
National Railway	BTL	Bujeon-Masan	39.51	2.27355	32	3.357	0.63	5.5	2.99	4.72	1	0	1	90.71	100
National Railway	BTL	Bujeon-Masan	39.48	2.27355	32	4	0.63	5.5	2.99	4.72	1	0	1	90.71	100
National Railway	BTL	Bujeon-Masan	46.05	2.27355	32	0	0.63	5.5	2.99	4.72	1	0	1	91.8648	100
National Railway	BTL	Bujeon-Masan	47.75	2.27355	32	1	0.63	5.5	2.99	4.72	1	0	1	91.8648	100
National Railway	BTL	Bujeon-Masan	48.75	2.27355	32	2	0.63	5.5	2.99	4.72	1	0	1	91.8648	100
National Railway	BTL	Bujeon-Masan	49.03	2.27355	32	3	0.63	5.5	2.99	4.72	1	0	1	91.8648	100
National Railway	BTL	Bujeon-Masan	48.82	2.27355	32	3.357	0.63	5.5	2.99	4.72	1	0	1	91.8648	100
National Railway	BTL	Bujeon-Masan	48.63	2.27355	32	4	0.63	5.5	2.99	4.72	1	0	1	91.8648	100
National Railway	BTL	Bujeon-Masan	26.75	2.27355	32	0	0.63	5.5	2.99	4.72	1	0	1	90.71	50.71
National Railway	BTL	Bujeon-Masan	24.31	2.27355	32	1	0.63	5.5	2.99	4.72	1	0	1	90.71	50.71
National Railway	BTL	Bujeon-Masan	21.4	2.27355	32	2	0.63	5.5	2.99	4.72	1	0	1	90.71	50.71
National Railway	BTL	Bujeon-Masan	17.98	2.27355	32	3	0.63	5.5	2.99	4.72	1	0	1	90.71	50.71
National Railway	BTL	Bujeon-Masan	16.53	2.27355	32	3.357	0.63	5.5	2.99	4.72	1	0	1	90.71	50.71
National Railway	BTL	Bujeon-Masan	14.08	2.27355	32	4	0.63	5.5	2.99	4.72	1	0	1	90.71	50.71
National Railway	BTL	Bujeon-Masan	37.02	2.27355	32	0	0.63	5.5	2.99	4.72	1	0	1	91.8648	50.71
National Railway	BTL	Bujeon-Masan	34.29	2.27355	32	1	0.63	5.5	2.99	4.72	1	0	1	91.8648	50.71
National Railway	BTL	Bujeon-Masan	31.1	2.27355	32	2	0.63	5.5	2.99	4.72	1	0	1	91.8648	50.71
National Railway	BTL	Bujeon-Masan	27.4	2.27355	32	3	0.63	5.5	2.99	4.72	1	0	1	91.8648	50.71
National Railway	BTL	Bujeon-Masan	25.83	2.27355	32	3.357	0.63	5.5	2.99	4.72	1	0	1	91.8648	50.71
National Railway	BTL	Bujeon-Masan	23.23	2.27355	32	4	0.63	5.5	2.99	4.72	1	0	1	91.8648	50.71

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