SAVING REFINANCING COST: THE OPTION VALUE OF REVENUE RISK-SHARING MECHANISMS IN TRANSPORTATION PUBLIC-PRIVATE PARTNERSHIPS (P3) PROJECTS

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Abstract: Uncertainties about total construction cost and operational revenues are two major risk factors in transportation P3 projects. These uncertainties put projects at risk of being unable to fulfill annual debt repayment obligations. When a project generates insufficient cash flow to service the debt in a certain year, it normally has to go for short-term financing by borrowing short-term loans. With the help of revenue risk-sharing mechanisms (RRSMs), supported projects may be able to get rid of unexpected interest disbursement. The objective of this paper is to critically examine and compare the option value of Contingent Finance Support (CFS) and Minimum Revenue Guarantee (MRG) in terms of saving refinancing cost for debt repayment. An integrated real options valuation model is created that utilizes a decision analysis method for pricing the technical project risk and a risk-neutral option pricing method for pricing the market risk. The integrated model quantifies the construction risk using the subjective probability distribution. The model prices the option value of RRSMs on saving project refinancing cost with consideration of market risk premium for uncertain traffic volume. The proposed model helps stakeholders better understand and measure the burden of assuring annual debt repayment under uncertain cash flow. The private sector can use the proposed model to evaluate the value of the RRSMs provided by the government in terms of reducing refinancing cost.

1 INTRODUCTION

With the benefits of improving investment efficiency, helping project selection, increasing competition, and extending borrowing constraints, public-private partnerships (P3) is attracting governments around world to use it to design, finance, build, operate, and maintenance infrastructure projects. A P3 turnpike project normally has a sizable amount of bank loan in its capital structure (Yescombe 2002), and the project may have the biggest debt repayment pressure at the beginning few years of operation. This is because the toll revenue, the major income of turnpikes, is positively correlated with the traffic volume which increases as years pass. Given that a project has a relatively small cash flow in the first few years of operation, the fiscal condition of the project would be worsen if the project expenditure increases due to commonly-seen cost overrun, or the project income decreases due to unexpected fluctuation of the traffic volume. Liquidity shortfall, which has been a severe problem in some emerging infrastructure P3 market (Luo and Joanna 2016), happens when a project has an insufficient cash flow to service mature debt repayment obligations. Despite the liquidity shortfall does not necessarily lead to project bankruptcy if the project successfully conducts a debt refinancing by borrowing new short-term loan to repay the existing mature debt. The liquidity shortfall inevitably increases the credit and default risk of the project (Caballero and Kurlat 2009). More intuitively, refinancing increases unexpected expenditure and further decreases the profitability of the project. In this paper, the authors 1) quantitatively reveal the latent refinancing cost under dynamic construction cost and toll revenue conditions, and 2) evaluate the option value of risk-sharing mechanisms in terms of saving refinancing cost and improve the profitability of the project with an integrated real options valuation model.

2 RESEARCH BACKGROUND

2.1 Risk-sharing Mechanisms

Studies have shown that traffic and revenue forecast tend to suffer “optimism bias”. The traffic volume is often overestimated due to difficulties in predicting economic conditions, demographic trends, or change in technology (FHWA 2016). To create a fair business environment and promote collaboration between the concessionaire and government, risk-sharing mechanisms are developed for revenue risk sharing. FHWA (2016) generalized common risk sharing mechanisms in infrastructure P3 projects. MRG and CFS have best overall performance in the aspects of value of money, fiscal impact, financeablility, and ease of implementation. Under a CFS mechanism, government provides a guarantee on the repayment of financing instead of revenue. Therefore, the there is no refinancing cost under a CFS mechanism while no extra cash flow besides debt repayment will be generated. Under a MRG, government agency guarantees revenues below a certain negotiated threshold, and thus partially retains revenue risk. Concessionaire may need to pay for the refinancing, if necessary, while it could be expected to generate extra cash flow and thus increase the profitability of a project even though there is no gap in debt repayment.

2.2 Risk-sharing Mechanisms

As the state-of-art financial engineering instrument providing evaluation on investment opportunities under dynamic market uncertainties, real option analysis has been used by many prior researchers to explore various kinds of options in transportation infrastructure investment. Real option analysis works for evaluating risk-sharing mechanisms because these mechanisms are essentially options that could be triggered under certain unfavorable market conditions, and are capable to bring benefits to concessionaire. With the help of a binomial lattice model to simulate traffic volume evolvements, Ho and Liu (2002) discussed the financial viability of Build-Operate-Transfer (BOT) projects. Ashuri et al. (2012) evaluated the MRG option by taking a risk-neutral method internalizing traffic demands risk. By constructing an analytical stochastics model to simulate dynamic traffic volume evolvements, Brandao and Saraiva (2008) measured the value of minimum traffic guarantee, Zhao et al. (2004) created a decision-making tool considering different project uncertainties, Garvin and Cheah (2004) explored the strategic value of project deferment, Huang and Chou (2006) performed a compound option pricing to evaluate the option to abandon, and Chiara et al. (2007) used European, Bermudan, and Australian option to valuate governmental guarantees. Real option analysis was also conducted beyond focus on dynamic traffic volume: Cheah and Liu (2006) evaluated government guarantees and subsidies, Liu et al. (2014) explored restriction competition in P3 projects.

After looking back into the existing studies, two areas to be improved in future studies were identified: 1) the model is expected to have flexibility to include multiple uncertainty sources. It is worthy to mention that unlike traffic volume, some uncertainties cannot be described as a time-dependent stochastic process (e.g. a “one-shot” investment in construction or maintenance); and more importantly 2) unlike the uncertainty of traffic volume that could be measured by market price (i.e., the risk premium), some uncertainties (e.g. construction cost overrun) are private information in essence, and thus are not suitable for risk-neutral pricing. A risk may have market premium only if it belongs to public information. Cost overrun risk varies from cases to cases. Different construction and management teams and even the same team at different time may have significantly different cost overrun risk in face of a same turnpike project. It is more appropriate to introduce individual risk preference to evaluate the risk of this kind. With a model including more uncertainties and being closer to the reality, the accuracy of project volatility calculation could be improved, which plays a crucial role in binomial lattice real options model (Brandão et al. 2012). In the following section, the authors will elaborate how the proposed integrated model gets improved in above mentioned areas.

3 INTEGRATED REAL OPTIONS MODEL

The proposed model consists of two parts. The first part describes risk-adjusted subjective probability distribution of cost overrun and the second part describes uncertainty of future values of AADT. Projectspecific data will then be substituted into the model, such as parameters of variables (e.g. the average growth rate of AADT, parameters of utility function, etc.), capital composition, and loan details (e.g. interest rate, loan term, repayment method, etc.). In the following step, Monte Carlo simulation will be performed to characterize concessionaire's risk profile in terms of annual debt service with and without risk sharing-mechanisms, respectively.

3.1 Risk-adjusted Probability Distribution

Taking the contract award as the reference point, existing studies (e.g. Bordat et al.2004, Eillis et al. 2007, Odeck 2004, Love et al. 2015) show that the mean value and probability distribution of cost-overruns of road construction projects delivered by innovative delivery method (e.g. Design-Build, Public-Private Partnerships, etc.) are similar in nature. Data in these studies have an approximate log-logistic distribution with mean values ranging from 4% to 14%. Eq. (1) is the probability distribution function (p.d.f.) of log-logistic distribution with shape parameter α (α>0), scale parameter β (β>0), and location parameter γ (x∈ [γ, +∞)). Even though practitioners in industry may have statistical results derived from individual database, we can use results in literature for model construction without loss of generality.

[1] $f(x) = \frac{\alpha}{\beta}(\frac{x-\gamma}{\beta})^{\alpha-1}[1+(\frac{x-\gamma}{\beta})^{\alpha}]^{-2}$

Risk premium, which is frequently seen in investment decision, reflects risk-aversion of investors. However, probability distributions derived from statistical analysis are risk-neutral. To better serve decision making under uncertainty, utility theory is applied to create risk-adjusted probability distribution which internalizes the risk preference of decision makers. Instead of a single value, inputs for the utility function of construction cost disbursement are a vector because disbursements happen repeatedly over time. The adopted utility function f should be able to represent multivariate risk aversion. Suggested by Meyer (1972), a multivariate risk-averse investor will always prefer portfolio A over B, where the portfolio A has equal probability to get reward (c_i, c_j') and (c_i', c_j) while the portfolio B has equal probability to get reward (c_i, c_j) and (c_i', c_j'). c_i, c_i' ($c_i < c_i'$) denote rewards at time i, and c_j, c_j' ($c_j < c_j'$) denote rewards at time j. The cash flows of portfolio A and B at other time points except i and j (i.e. $\forall c_k, k \in [1,n], k \neq i,j)$) are fixed. Preference for portfolio A over B reflects the fact that many investors are inclined to smooth cash flows rather than fluctuate cash flows, even though portfolio A and B have equal marginal probability distribution of each c_t. As Fraser (1990) demonstrated, the form of function in Eq. (2) is a simple and intuitive way to represent risk preference for a pair of attributes (c_i, c_j).

[2] $u(c_0, c_1, \dots, c_n) = g(\mathrm{NPV}(c_0, c_1, \dots, c_n))$

Exponential utility function denoted as $u(x) = (1-\exp(-aw))/a$ is commonly used in economics to represent risk attitudes which do not change with wealth level. Given the assumption that the risk preference of private sector is only up to its investment opportunity and business strategy, exponential utility is a suitable form for $g(\cdot)$ in Eq. (2). In this paper, exponential utility is expressed as the simplified form shown in Eq. (3), because linear transformation of utility function does not influence the calculation of risk premium:

[3] $g(x) = 1-\exp(\frac{x}{\rho})$

where ρ = the risk tolerance of private sector. McNamee and Celona (1990) gives an estimation of ρ, which is about one sixth of the company equity, based on observations across companies in different industries. This result supports the conclusion given by Howard (1988), whose data were original from companies in the oil and chemicals industries.

As the calculation of cost overrun rate is based on net present worth, i.e. $\mathrm{NPV}(c_0, c_1, \dots, c_n)$, the certainty equivalent (CE) of expected utility of disbursement can be expresses as:

[4] $-\exp\left(\frac{-CE}{\rho}\right) = \int[-\exp\left(\frac{-(1+r_c)x_0}{\rho}\right)] \cdot f(r_c)dr_c$

where r_c = the cost overrun rate with p.d.f. $f(r_c)$ in form of Eq. (1), $x_0 =$ the estimated construction cost at the time of contract award. Thus, the ratio of risk premium for construction cost overrun p_c is:

[5] $p_c = \frac{CE - x_0}{x_0} \times 100\%$

Risk-adjusted cost overrun rate $r_c{}'$ is denoted as:

[6] $r_c{}' = p_c + r_c$

with p.d.f. $f_{R_c{}'}$:

[7] $f_{R_c{}'}(r_c{}') = f_{R_c}(r_c{}' - p_c)$

where $f_{R_c}(r_c)$ is the p.d.f. of cost overrun rate r_c.

3.2 Binomial Lattice for Uncertain Future Traffic Volume

Binomial lattice model is applied in this study to describe future traffic volume, with the assumption that traffic volume follows geometric Brownian motion (GBM). GBM assumption frequently appears in real options analysis involving long-term traffic volume forecast (e.g., Ashuri et al 2012, Brandao and Saraiva 2008, Garvin and Cheah 2004). Solino and Lara Galera (2012) statistically demonstrated the rationality of this assumption by analyzing Spain turnpikes. In mathematical finance where GBM is commonly applied, binomial lattice is a frequently used tool to demonstrate the state at a certain time of a continuous stochastic process given that the initial state is known. For any state in the model having value *S*, there are always two possible values for the following state. The following state has probability *p* (0<*p*<1) to be *uS* and has probability 1-*p* to be *dS*. *d* and *u* (*d*<1<*u*) are reciprocals to each other. Even though the binomial lattice model treats a continuous process as if it were discrete, the model has a good approximation after short periods if the basic period length is short enough (Luenberger 2013). Taking basic period length as one month (i.e., Δ=1/12*year*), the binomial lattice model can be specified with parameters in Eq. (8):

[8] $u = e^{\sigma\sqrt{\Delta}} \qquad d = e^{-\sigma\sqrt{\Delta}} \qquad p = \frac{1}{2} + \frac{\mu}{2\sigma}\sqrt{\Delta}$

where $\mu = E[\ln(\frac{AADT_{n+1}}{AADT_n})]$, $\sigma = SD\left[\ln\left(\frac{AADT_{n+1}}{AADT_n}\right)\right]$ (i.e., the volatility of AADT), and AADT_n denotes the value of AADT in nth year.

To internalize the risk of uncertainty into option valuation process, Ashuri et al. (2012) suggested to subtract the product of Sharpe ratio and volatility from revenue growth rate. In the context of this study, that proposed method for calculating a' (i.e., the adjusted annual growth rate of AADT) can be specified as

[9] $a' = a - \sigma \cdot \frac{r_s}{\sigma_p}$

where $a = \frac{AADT_{n+1}}{AADT_n}$ (i.e., the annual growth rate of AADT), r_s =spread interest rate, $\sigma_p = SD[\ln\left(\frac{PV_1}{PV_0}\right)]$, and $PV_i =$ the present value of project at the end of year i, ($i = 0{,}1$).

3.3 Monte Carlo Simulation

Monte Carlo simulation helps the authors generate different cost overrun rates and series of random path in the traffic volume evolution. Either the cost overrun rates or the random paths of traffic volume evolvement are distributed as assumption. All random variables are independent. The authors characterized the latent refinancing cost and option values of RRSMs with all these generated random variables. In the *i*th year of each generated *n*-year random path, the annual taxable income of the project S_i is expressed as Eq. (10):

[10] $\mathrm{S}_i = \mathrm{OR}_i - \mathrm{OC}_i - \mathrm{LRS}_i - \mathrm{LRL} \qquad i = 1, 2, 3, \ldots, n$

where OR_i = operation revenue in the i^{th} year; OC_i = operation cost in the i^{th} year; LRS_i = short-term loan repayment in the i^{th} year; and LRL = annual long-term loan repayment.

The variables OR_i, OC_i, LRS_i and LRL in Eq.(10) can be calculated as follows:

[11] $\mathrm{OR}_i = \text{Ancillary Revenue} + 365 \cdot \mathrm{AADT}_i \cdot \text{Toll Fee}$

[12] $\mathrm{OC}_i = \text{Initial Operation Cost} \cdot (1 + \text{Expected Annual Growth Rate})^{i-1}$

[13] $\mathrm{LRS}_i = \begin{cases} (1 + \mathrm{APR}_s)|\mathrm{L}_{i-1} + \mathrm{S}_{i-1}|) & \text{if } \mathrm{L}_{i-1} + \mathrm{S}_{i-1} < 0 \\ 0 & otherwise \end{cases}$

[14] $\mathrm{LRL} = \frac{\text{Total Loan}\cdot(1+r_c{}')\cdot\mathrm{APR}_l\cdot(1+\mathrm{APR}_l)^n)}{(1+\mathrm{APR}_l)^n - 1}$

where APR_l = annual interest rate of long-term loan; APR_s = annual percentage rate of short-term loan; and L_i= liquidity available in the i^{th} year. Annual after-tax income is the source of liquidity. The amount of available liquidity is assumed not to exceed the predefined value.

In addition, the present value of refinancing cost RC can be calculated as follows:

[15] $\mathrm{PV(RC)} = \frac{\sum_{i=1}^{n}[(1+\mathrm{MARR})^{n-i}\cdot\mathrm{LRS}_i\cdot\frac{\mathrm{APR}_s}{(1+\mathrm{APR}_s)}]}{(1+r)^{(n-1)}}$

where r = risk-free discount rate; and MARR= minimum acceptable rate of return.

In the case of MRG options are provided, the operation revenue under guarantee OR'_i can be calculated by substituting AADT_i with AADT'_i, and AADT'_i can be calculated as follows:

[16] $\mathrm{AADT}'_i = max\ (r_g \cdot \text{Static Estimation of } \mathrm{AADT}_i, \text{Actual } \mathrm{AADT}_i)$

where r_g = the guaranteed rate of traffic volume specified in BOT contract.

In case of CFS options are provided, the refinancing cost reduces to zero because in such a mechanism debt repayment is guaranteed by government.

4 NUMERICAL EXAMPLE

4.1 Project Information

The Capital Beltway of China (Daxing to Tongzhou section) is a 38km highway connecting two suburb districts of Beijing. A joint venture leading by China Communications Construction Company won the $1.99 billion bid and got a 25-year concession period from the date construction completed (2018-2042). The capital structure of this project is 80% equity and 20% bank loans (equally split into two construction years). Interest payments begin at the end of the first construction year with principle payments to start at the end of the first operation year. In this project, APR_l is 5.9% and APR_s of accessible short-term loan (<1 year) is 5.25%. The loan takes an equal payment plan and will mature at the last year of concession period.

Anticipated annual toll revenue based on forecasted traffic volume is the main source of project cash inflows. Expectation of initial AADT is 16,715 pcu. Predictions of expected annual average AADT growth rate are 31.3% from 2018 to 2022, 7.9% from 2023 to 2027, 2.0% from 2028 to 2032, and 0.9% from 2033 to 2037. Moreover, the cap capacity of the highway is 120% of the static estimation. Negotiated toll rate is $0.25/ (pcu·km). Concessionaire can also expect to earn about $0.81 million each year besides toll revenue from affiliated facilities (e.g. gas station) as derived profits. The expenditure for operation and maintenance comes from project cash inflows, which is \$25.23 million in 2018 and grows by 3% each following year. In addition, the business tax rate is 25%.

As suggested by Cassimon et al. (2004), the authors take transportation industry index as the approach to access project volatility because the base project has not yet occurs. The annualized value of volatility σ is supposed to be 10%, and 8%, 20%, and 30% have also been tested in sensitivity test. Project discount rate (4.425%) is the sum of risk-free interest (3.835%) and spread (0.59%). Concessionaire plans to keep \$0.11 million liquidity reserve from 2018 to 2027, and to keep \$0.16 million as liquidity from 2028 to 2037. Beijing City Government has agreed to offer concessionaire an MRG option from 2018 to 2037 and the rate is 80%.

4.2 Summary of Results

The standard deviation of log-return present value (i.e.,$\ln\left(\frac{\mathrm{PV}_1}{\mathrm{PV}_0}\right)$) is 52.4% and 30.2% for the condition considering cost overrun and the condition not considering cost overrun, respectively. Thus, the project volatility σ_p is 52.4%. The project volatility is obviously underestimated if necessary uncertainty source is not included in the model. As the value of project volatility is used in many steps of the model, more accurate project volatility may obviously improve the accuracy of simulation result. This validates the importance of the flexibility to incorporate different kinds of uncertainties.

As shown in Figure 1(b), although the project is supposed to have a balance of payment with estimation under static condition, the project has a high liquidity shortfall risk in the first 10% of the repayment period with estimation under dynamic conditions. The project may be safe from liquidity shortfall risk in the latter 75% of the repayment period. Ignorance of dynamic expenditure and revenue conditions in debt schedule design may lead to a huge loss. As shown in Figure 1(a), the expectation of loss due to refinancing may as high as 6.5% of the total principle amount of the debt.

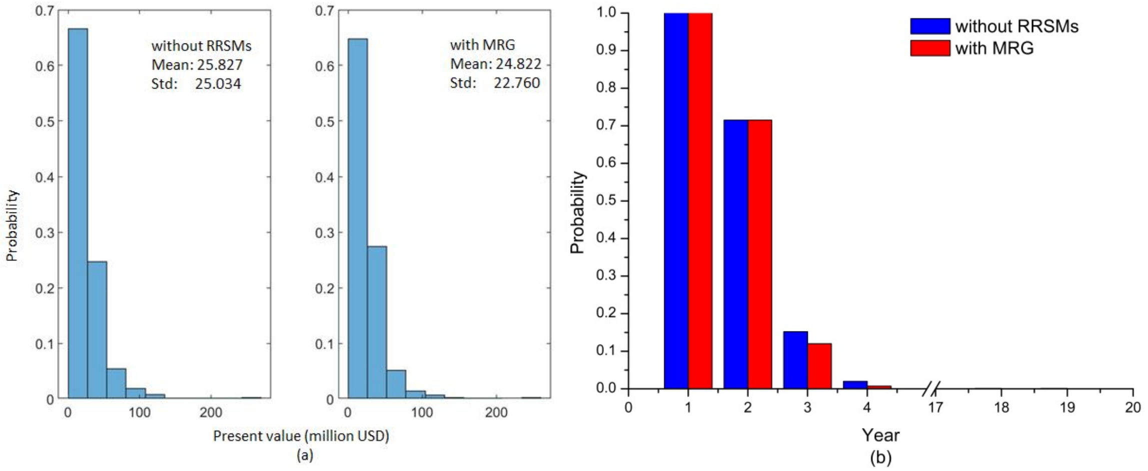
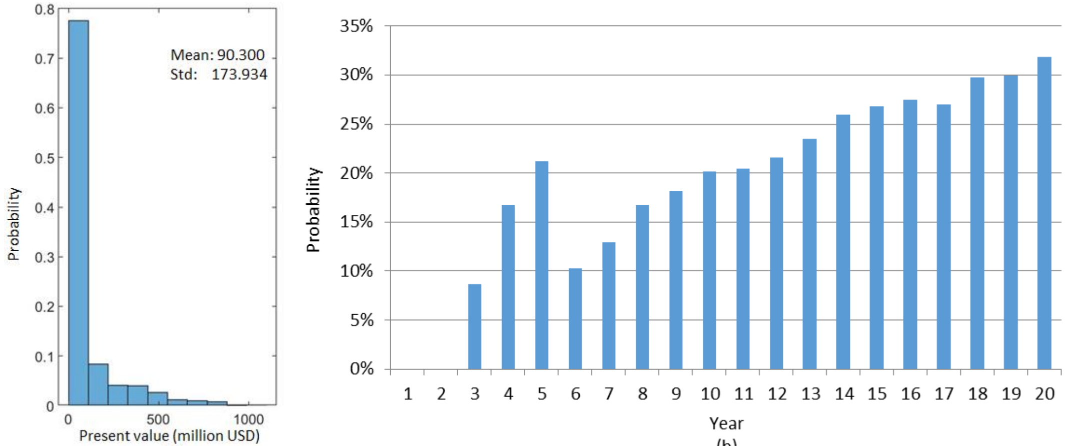


Figure 1: (a) Probability distribution of refinancing cost under different conditions; (b) probability distribution of the year in which the project requires refinancing

The difference of MRG and CFS is clearly revealed in respective definition. As a guarantee on debt repayment, CFS covers all repayment gaps and its option value is exactly the probable refinancing cost without any RRSMs. CFS provides no extra cash flow as subsidy besides the one necessary for debt repayment. On contrast, MRG, defined as a revenue guarantee mechanism, has a modest effect on either helping save refinancing cost or shortening risk period (Figure. 1(a)), while it provides lasting subsidy throughout the contract duration even if the project does not have difficulties in debt repayment (Figure 2).

Table 1 provides a comprehensive valuation of MRG and CFS. It could be found that MRG outperforms CFS in overall option value in the given example.



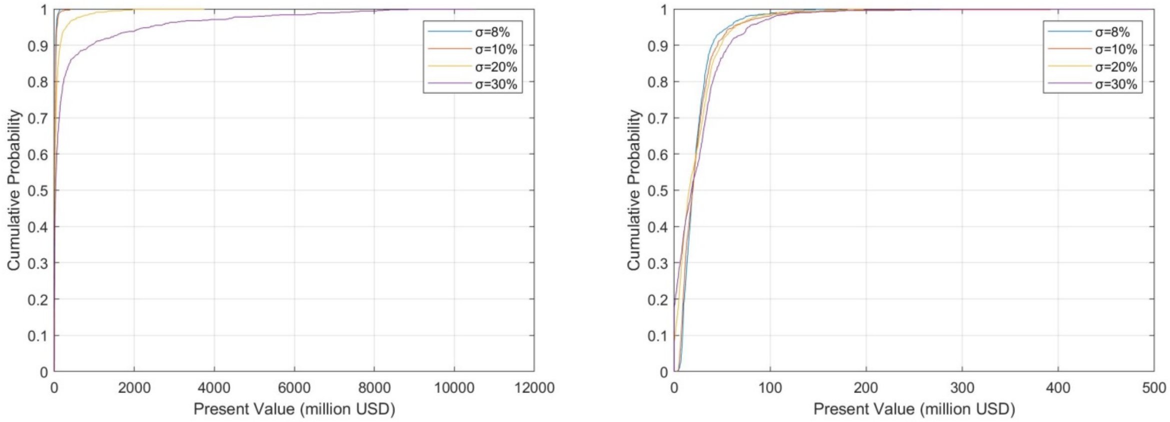
(a) (b)

Figure 2: (a) Probability distribution of the present value of extra cash flow generated by MRG; (b) probability distribution of the year in which MRG is required and no repayment gap exists

Table 1: Option value of MRG and CFS (million USD)

RRSMs	Value in saving refinancing cost	Value in generating extra profit cash flow	Sum
MRG	1.005	90.300	91.305
CFS	25.827	0	25.827

The authors also test the scenarios with traffic volatility $\sigma = 8\%, 20\%$, and 30% as sensitivity test as shown in Figure 3. Simulation results indicate that higher traffic volatility leads to bigger liquidity shortfall risk and associated higher refinancing cost. Static condition is an exception where $\sigma = 0$ and the project cash flow is sufficient for debt repayment. MRG significantly stabilizes the probable refinancing cost due to MRG is associated with static estimation. There is an incremental impact of traffic volatility on either MRG or CFS's option value.



(a) (b)

Figure 3: (a) probability distribution of the refinancing cost under different traffic volatilities (without RSMMs); (b) probability distribution of the refinancing cost under different traffic volatilities (with MRG)

5 Conclusion and Future Work

The beginning phase of a P3 infrastructure project normally has bigger debt repayment pressure due to comparatively weak revenue cash flow. The project is probable to suffer liquidity shortfall and has to take refinancing under dynamic project revenue and expenditure conditions even though the project was regarded as being capable to service debt repayment with static estimation. Refinancing generates sizable unexpected expenditure and undermines the profitability of the project. Revenue risk-sharing mechanisms stabilize the cash flow and reduce the refinancing cost when unfavorable conditions happen. The contribution of this paper is two-fold: firstly, the proposed dynamic model quantitatively calibrates latent refinancing cost which cannot be identified by static estimation. The model helps stakeholders have a better understanding on the burden of assuring debt repayment, and provides useful information for capital structure design. Secondly, the proposed model has sufficient flexibility to include multiple uncertainty sources. The included uncertainties could be time-dependent or time-independent, public information being suitable for risk-neutral pricing, or private information that should be measured by individual risk preference. In future, more revenue risk-sharing mechanisms should be included in the proposed valuation framework. The impacts of force majeure on project cash flow and liquidity shortfall risk should also be explored.

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