INTERNATIONAL JOURNAL OF STRATEGIC PROPERTY MANAGEMENT
ISSN 1648-715X print / ISSN 1648-9179 online
2012 Volume 16(2): 201–217
doi:10.3846/1648715X.2012.688071

DEVELOPING A CONCESSION PRICING MODEL FOR PPP HIGHWAY PROJECTS

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Received 10 November 2011; accepted 9 January 2012

ABSTRACT. The concession pricing is one of the most important issues during the negotiation period of PPP contracts. Pricing should vary in accordance with risks assumed by the private sector and embody equitable risk sharing between the government and the private sector to lower the minimum feasible concession price and ensure effective risk management. In this study, a general concession pricing model is developed through cost-benefit analysis from the perspective of the private sector. The model integrates project risk variables, price parameters, and other financial elements into a concession pricing formula based on cash flow table. Meanwhile, to cope with the occurrence of unforeseeable losses triggered by risk factors, such as interest rate fluctuation, inflation, traffic volume change, etc., a price adjustment mechanism is established to adjust the initial price and ensure the project's financial viability. The concession pricing model and adjustment mechanism allow the government and the private sector to reach a consensus on the tariff scheme of a PPP project. It is believed that the model is beneficial to create a "win-win" situation for both the government and the private sector.

KEYWORDS: Public-private partnership; Concession pricing; Price adjustment; Risk factor; Highway project

1. INTRODUCTION

Roads play a pivotal role in the economic development of a nation by increasing its productivity and competitiveness (Singh and Kalidindi, 2006). Since 1990, under the guidance of the overall planning for state highway trunk line, China's highway construction picked up speed, the mileage of highway built each year rose from several dozen thousand meters to above one thousand kilometers as shown in Figure 1. By the end of 2008, the total mileage of China's highway had reached 60,300 km, which enabled it to rank second place in the world after the United States (China Investment Consultant, 2010).

In order to resist the adverse impact of the international economic environment and expand domestic demand, efforts will further be made to increase the annual investment scale in fixed asset of transport facilities in 2010 to reach one trillion RMB (6.8 RMB = 1 USD) in the context of global financial crisis. China's highway construction will once again pick up momentum. According to the current construction plan under way and the near future investment plan, it is expected that the annual newly added mileage of China's highway will be maintained at a level of 6000 km in the next four years (China Investment Consultant, 2010). China plans to complete its state highway network by 2020. By that time, the total mileage of highway open to the public will reach 100,000km (China Investment Consultant, 2010). However, inadequate government funding may limit the development of highways. The average construction cost of a highway project is around 4.4 million USD per kilometer in plains and rolling terrains and nearly 11.8 million USD per kilometer in mountainous regions. Such high construction costs may impose budgetary pressure on the government (Yang, 2007). In order to resolve the capital shortage, "Public-private partnership (PPP) financing modalities, with the ability of providing fund, efficient management, and technology have been identified by the Chinese government as innovative tools for leveraging financial and managerial resources to major infrastructure projects" (Asian Development Bank, 2005).

Owing to the special features of PPP projects, such as long operation cycle, high demand for capital, wide range of risk factors, and the complexity in the risk sharing structure, formulating a rational concession price based on equitable risk sharing is conducive to safeguard the rights and interests of both the government and the project company. However, early project practices and research studies indicated that the growth of Chinese PPP market has been greatly hindered by a lack of market pricing (Chen and Messner, 2005). The concession price not only determines the value assessment at the investment decision-making stage, but also can greatly affects the cash flow during the project operation period. It is the issue of the highest concern between both the government and the project company. While, the existing pricing for products or services of PPP project lacks theoretical foundation and scientific pricing rules, which leads the concession

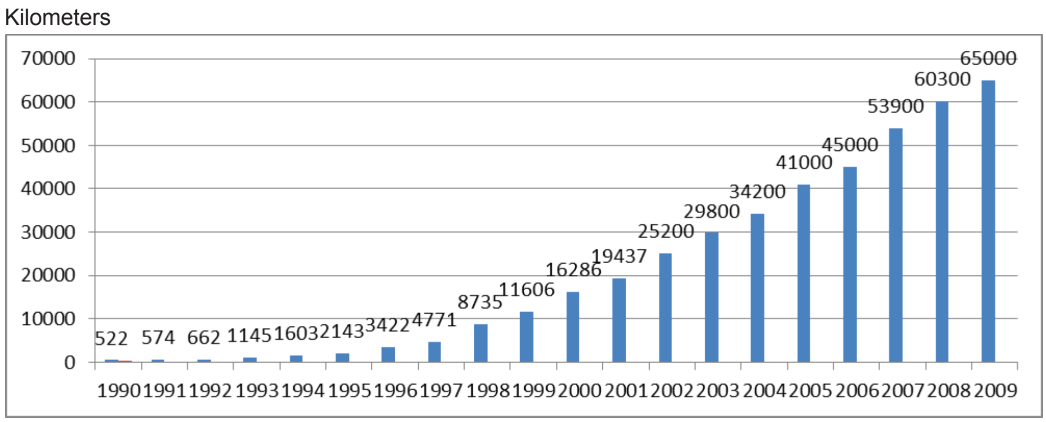


Figure 1. Development history of highway system in China

price to be fixed either too high or too low (Li, 2007). This study aims at developing a scientific and rational concession pricing model for PPP highway projects. It is expected that the proposed pricing model can enable the PPP model to better promote highway development. This research framework proposed can also be used as a reference to study other facilities' pricing problems.

2. LITERATURE REVIEW

Over the past ten years, a large number of PPP highway projects have been procured through concession contracts in China. Meanwhile, an increasing number of studies on PPP projects' management were conducted covering a wide range of topics such as risk management, concession pricing, legal issues, government supervision, etc. Among them, equitable risk allocation/sharing and concession pricing are two of the top issues of the concern to PPP practitioners and are closely related to a PPP project' success (Sun, 2006). The essence of PPP model is the risk re-allocation between the government and the private sector (Ke et al., 2009). The success of PPP projects is greatly depends on the transfer of risks to the parties best able to manage them (Singh and Kalidindi, 2006). An appropriate incentive scheme based on risk allocation would instigate concessionaires to improve their performance (Ye and Tiong, 2003). The concessionaire can also enjoy the gain generated from risk management through charging the specific risks assumed in the form of risk premium. Like any other capital investment programs, a PPP project is financially viable only if it attains a reasonable return rate (Ng et al., 2007). However, recent project practice reveals that a great number of PPP highway projects are actually not profitable (Deng, 2007).

Due to a lack of rational market pricing and price adjustment mechanism, the cash flow estimation of PPP highway projects is usually overshadowed by risks and uncertainties such as construction cost overrun, inflation, low traffic volume, and excessive renegotiation. The concession tariff (price) should be a variable, which may be increased if the specified risk factors are worse than expected or lowered if they are better than expected. Concession price based on inequitable risk sharing may protect the concessionaire from commercial risks, but may also discourage efforts in efficiency and cost control (Chen and Messner, 2005). While, risk allocation is not a rigid framework, when risk sharing is applied to specific project located in different areas, it must be strategically suited for the local social, legal, economic, political, technological environments and project characters (Yang, 2007). The more risk the private sector commits to a project, the higher concession price the private sector is more likely to charge. To calculate an appropriate concession price for a given PPP highway project, it is essential to understand its risk sharing structure.

PPP practitioners are trying to develop a better toll/ tariff or concession period model for their PPP projects (Ng and Xie, 2008; Xu et al., 2012). A lot of financial tools such as the cost-benefit analysis, net present value (NPV), NPV-at-risk have been initiated. Li (2007) designed a concession pricing model via cost-benefit analysis based on NPV calculation, and was verified by a typical case. Shen and Wu (2005) proposed a BOTCcM model with the consideration of risk impact for formulating a concession period. Ye and Tiong (2003) evaluated the mean NPV and NPV-at-risk of different concession period structures with Monte Carlo simulation based on an assumption that the variable obeys normal distribution. Sun (2006) built a pricing model for BOT products based on risk allocation and proposed a suit of methods to quantify risks. Singh and Kalidindi (2006) developed a traffic revenue risk management framework for PPP road projects through Annuity Model in India and discussed the qualitative risk allocation, payment mechanism, and concessionaire selection frameworks in detail. Ng et al. (2007) proposed a simulation model for optimizing the concession period of public-private partnerships schemes. Their results show that the risks and uncertainties, such as a change in inflation rate, traffic flow, and operation cost, could highly influence the decision on the concession period.

The basic guideline for determining the concession price is that the concession price should allow the concessionaire to recoup investment costs and earn reasonable profits within concession period, and make the government to achieve Value for Money (Zhang, 2009). While, a comprehensive literature review reveal that a systemic consideration of pricing parameters for concession pricing model is still not available. Concession contractual terms are normally grounded on pro forma financial statements conducted during the feasibility study stage of the PPP highway project. Change in any one of the terms will likely alter the cash flow and deviate from the expected project return (Liou and Huang, 2008). Thus, a price adjustment mechanism in the concession contract that allows the concessionaire to adjust the toll/tariff is also indispensable (Ng et al., 2007).

3. RESEARCH METHODOLOGY

The general framework of this research is shown in Figure 2. The research methods employed in this study encompass a comprehensive literature review, a cost-benefit analysis, case study and a fuzzy set theory. A total of four steps are conducted to establish this concession pricing model and price adjustment mechanism for PPP highway projects.

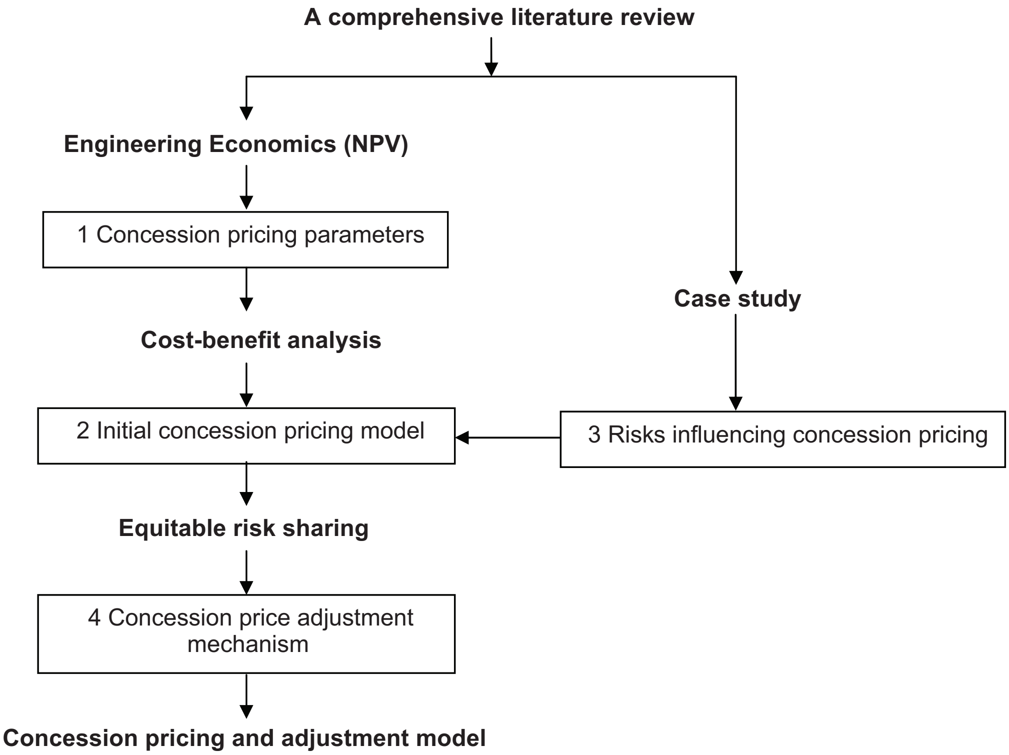


Figure 2. The research flow of concession pricing and adjustment model for PPP highway projects

Step 1: The concession pricing parameters of PPP highway projects were first compiled and discussed based on a comprehensive literature review.

Step 2: A concession pricing model is then developed through a cost-benefit analysis from the private sector's perspective based on the cash flow table. However, the concession price is determined at the biding stage which is calculated before the actual occurrence of risks. There may be a big difference between the forecasted cash flow and the actual cost and benefit of PPP projects.

Step 3: Thus, case studies were adopted to explore the critical risk factors influencing the concession price determination of PPP highway projects and eight critical factors that may have a significant impact on cost and benefit of PPP highway projects were extracted through content analysis.

Step 4: Finally, a price adjustment mechanism is developed to adjust the initial concession price based on equitable risk sharing.

4. CONCESSION PRICING PARAMETERS

The primary element of price design in a PPP project is to determine a reasonable base tariff to ensure that the project is financially viable (Cheng and Tiong, 2005). Net Present Value (NPV) employed in the investment decision-making is applied as one of the most appropriate indicators. The NPV of a PPP highway project refers to the sum of the present values of a stream of cash flow. If NPV is equal to or above 0, the project is acceptable, and vice versa. The general equation for the NPV calculation is as follows.

$$NPV = \sum_{i=0}^{n} NCF = \frac{NCF_0}{(1+i)^0} + \frac{NCF_1}{(1+i)^1} + \frac{NCF_2}{(1+i)^2} + \cdots + \frac{NCF_n}{(1+i)^n} = \frac{(CI - C0)_0}{(1+i)^0} + \frac{(CI - C0)_1}{(1+i)^1} + \frac{(CI - C0)_2}{(1+i)^2} + \cdots + \frac{(CI - C0)_n}{(1+i)^n} \geq 0$$

where: NCF_i = net cash flow relative to point in time i; CI_i = cash onflow relative to point in time i; CO_i = cash outflow relative to point in time i; n = concession period; i = discount rate.

In this study, cash flow analysis was adopted as the basis for concession price determination. The price determination parameters can be classified into two categories (Figure 3). One is the cash outflow parameters, which comprise total construction investment cost and operation cost. The other is the cash inflow parameters, which include concession period, expected Internal Rate of Return, daily vehicle flow, and concession price. The concession price can be determined by five other parameters through NPV calculation. This forms the basis for the development of concession pricing formula.

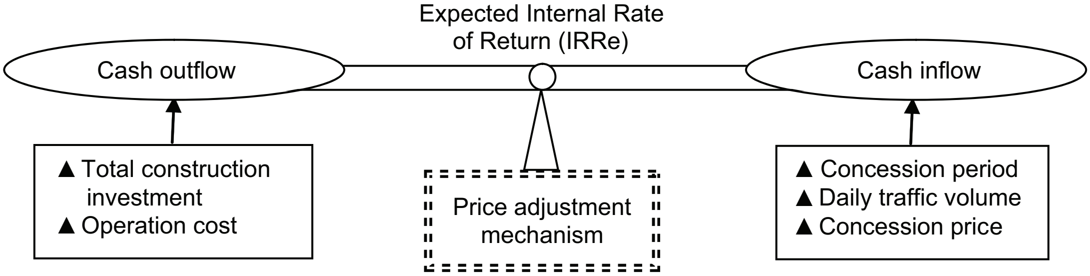


Figure 3. Concession pricing parameters for PPP highway projects

Total construction investment cost. Total investment for the construction of highway projects consists of building engineering cost, purchase cost for equipment, tools and instruments, installation engineering cost, other engineering costs, reserve fund (reserve for appreciation, basic reserve fund) and interest during construction period. It is the cash outflow incurred during the construction period, and is one of the key factors affecting the pricing of PPP highway projects. The higher the total investment is, the larger the project cost will be. Thereby, the concession price will surely become higher to ensure its minimum investment return rate of the concessionaire.

Operating cost. Operating cost refers to cash outflow incurred during the operation period of the PPP highway projects, which mainly includes: power fee (road lamp), labor welfare fee, daily maintenance fee, management fee, taxation fee, etc.

Daily vehicle flow. The volume of traffic flow is the primary factor that directly affects the project's financial benefits. If the traffic flow fails to reach the expected level or fails to reach the expected growth rate, the project will not have sufficient cash flow to pay back principal and interest to the creditor, pay off operation expenses and garner profit. The volume of traffic flow is affected by a variety of factors, which depends on the economic condition of relevant regions where the highway is located, the population of vehicles and users' inclination to pay driving expenses, etc (Yang, 2007). Due to the difficulty to provide long term forecast on the social economic development of a country or region, there is often a tendency to exaggerate traffic flow at the stage of feasibility study of projects (Bain and Plantagie 2003). Many projects are therefore exposed to potential risks of relatively large inadequacy in traffic flow (Li, 2007).

Concession Term. As an index of time and economics, Concession Term (CT) exerts direct impact on the size of the project's investment return. From the perspective of private investors, CT is the economic cycle of the highway project, and they hope CT to be as long as possible so that their chances to earn profits and the amount of profits will be greater. However, the local government has opposite idea. They hope the CT to be as short as possible so that its control and ownership of the project can be realized sooner. Judging from existing project statistics, most PPP projects in countries around the world adopt fixed concession term, such as 407 Highway in Canada, Citong Bridge in China and the South-North Highway Project in Malaysia (Yang, 2007), which allow the private sector bid the project through concession pricing.

Expected Internal Rate of Return. IRRe is one of the key factors in determining the concession price of PPP projects. It is required to guarantee that the investors can return the bank's loan and interests, recover capital and achieve the rational investment returns. If the IRRe is fixed too high, it will surely result in the concession term too long or the concession price too high, thus harm the interests of both the government and the public. In contrast, if the concession price is fixed too low, it will be unfavorable for attracting private investors. At present, the determination of Internal Rate of Return is invariably subject to subjective assumption. According to established practices in China, the Internal Rate of Return for investors of large infrastructure facility is around 15% (Li, 2007).

5. CONCESSION PRICING MODEL FOR PPP HIGHWAY PROJECTS

The principle for pricing of a PPP project is to safeguard the interests of the public, meanwhile ensuring that the private sector has rational profits through appropriate risk management. In other words, products or services of a public engineering project (social benefits) should be provided at the lowest price without damaging the survival ability of the project and be equipped with sufficient incentives to encourage the private sector to provide and improve services (Li, 2007). Cost-benefit analysis is employed here to analyze cash flow, which has been reported by Li (2007). However, corrections and revisions are made in this study based on Li (2007)'s research. Cost-benefit analysis compares the cost and benefit of the project and ensures the project to be economically feasible. A commonly used index is BCR (Benefit Cost Ratio), which is the ratio between the benefit of net present value acquired during operation period of a PPP project and the cost of net present value invested in the construction period. When BCR $\geq$ 1, the benefit of net present value is equal to or greater than the cost of present value at the expected Internal Rate of Return, the project is economically rational, and vice versa (Huang, 2004). In this study, cost-benefit analysis takes "table of financial cash flow for project capital fund" as the basis. It reflects the viewpoint of the investors, adopts capital fund as the calculation target, and regards loan interest payment and principal payback as cash outflow (Huang 2004). The simplified table of financial cash flow for project capital fund is shown in Table 1, which aims to review the profit earning ability of the capital fund after deducting the income tax.

Table 1. Simplified cash flow of project capital fund from the perspective of the private sector

	Construction period	Operation period	Transfer period
Cash inflow	0	– Sales income (P_t Q_t) – Other cash inflow ($Y1_t$ + $Y2_t$)	0
Cash outflow	– Project capital fund C_t	– Payback of loan principal Pl_t – Payment of loan interest (L_tR_t) – Operation cost C_{ot} – Business tax TA_t – Sales tax and extra charges TB_t – Income tax TC_t	0

Concession price in the tth year P_t,
Daily average traffic flow in the tth year Q_t,
Other operation income in the tth year (i.e. advertisement income etc) $Y1_t$,
Government subsidy in the tth year $Y2_t$,
Project capital fund in the tth year C_t,
Payment of loan principle in the tth year Pl_t,
Loan balance in the tth year L_t,
Interest in the tth year R_t,
Operation cost in the tth year C_{ot},
Total cost in the tth year OC_t,
Business tax and tax rate in the tth year TA_t, $T1_t$,
Sales tax extra charges and tax rate in the tth year TB_t, $T2_t$,
Income tax and tax rate in the tth year TC_t, $T3_t$,
TC is the Concession Term,
T0 is construction period,
D_t Depreciation fee.

Based on Table 1, the annual benefit net value and capital fund net present value can be derived as follow.

1) Annual benefit net value =

Sales income + Other cash inflow – Loan principal – Loan interest – Operation cost – Business tax – Extra charges of sales tax – Income tax =

$$P_tQ_t + Y_{1t} + Y_{2t} - P_{lt} - L_tR_t - C_{ot} - TA_t - TB_t - TC_t \qquad (1)$$

2) Capital fund net present value =

$$\sum_{t=1}^{T_0} \frac{C_t}{(1+i)^t} \qquad (2)$$

where: Concession price in the t[th] year $P_t = P(1 + INF)^t$; P denotes initial price; INF denotes inflation rate.

Operation cost C_{ot} = Total cost – Depreciation fee – Amortization charge – Financial fee =

$$OC_t - D_t - 0 - L_tR_t = OC_t - OI/TC - L_tR_t$$

where: OI denotes total cost; TC denotes concession term.

Provided that it discounts the income and expenditure to a reference time point T_0. According to cost benefit analysis B = C, the BCR equation can be derived as Equation 3.

$$BCR = \frac{B}{C} = \frac{\sum_{t=T_0+1}^{T_c} (P_tQ_t + Y_{1t} + Y_{2t}Pl_t - L_tR_t - C_{0t} - TA_t - TB_t - TC_t)(1+i)^{-t}}{\sum_{t=1}^{T_0} \frac{C_t}{(1+i)^t}} = 1 \qquad (3)$$

Then, the concession pricing formula of a PPP highway project can be determined.

$$P_t = \frac{\sum_{t=1}^{T_0} \frac{C_t}{(1+i)^t} - \sum_{t=T_{0+1}}^{T_c} (Y_{1t} + Y_{2t}Pl_t - L_tR_t - C_{0t} - TA_t - TB_t - TC_t)(1+i)^{-t}}{\sum_{t=T_{0+1}}^{T_c} Q_t(1+i)^{-t}} \qquad (4)$$

$$P = \frac{\sum_{t=1}^{T_0} \frac{C_t}{(1+i)^t} - \sum_{t=T_{0+1}}^{T_c} (Y_{1t} + Y_{2t})(1+i)^{-t} + \sum_{t=T_{0+1}}^{T_c} (Pl_t + L_tR_t)(1+i)^{-t} + \sum_{t=T_{0+1}}^{T_c} (OC_t - \frac{OI}{TC} - L_tR_t) \times (1+i)^{-t} + \sum_{t=T_{0+1}}^{T_c} (TA_t + TB_t + TC_t)(1+i)^{-t}}{(1+INF)^t \sum_{t=T_{0+1}}^{T_c} Q_t(1+i)^{-t}}$$

where: Business tax $TA_t = (P_t Q_t + Y1_t)T_{1t}$; Extra charges of sales tax $TB_t = (P_tQ_t + Y1_t)T_{1t}.T_{2t}$; Income tax $TC_t = \{P_tQ_t + Y1_t + Y_{2t} - OC_t - (P_tQ_t + Y1_t) T_{1t} - (P_tQ_t + Y1_t)T_{1t}.T_{2t}\}T_{3t}$.

Based on formula (4), the PPP participants only need to input the actual numerical value of variables into the formula. Then the initial price of a PPP highway project can be calculated. However, before confirming the calculated initial price, the affordability of the public is another factor deserving consideration (Li, 2007). If the price exceeds the affordability of the public, the government or private sector can further extend the concession period through fixing the maximum concession price calculated by formula 4.

6. RISK FACTORS INFLUENCING CONCESSION PRICING

From formula 4, it can be seen that the above initial price is determined at the bidding stage of PPP projects based on the forecast of cash flow, which is subjective and is conducted before the project starts (i.e. before the actual occurrence of risks). Price adjustment is therefore indispensable for coping with the risks in the process of project implementation, especially some risks beyond the management ability of private sector, such as government intervention risk, inflation risk, market risk, etc. (Tiong et al., 1997; Yu, 2006; Shen and Wu, 2005). Ng et al. (2007) and Xu et al. (2011) believed that it is necessary to identify the potential risk factors that could have serious effects on cash flow during the construction and operation period of PPP projects and to examine the effects on the cost and benefit. Seven real cases were scrutinized to explore the risk factors influencing price setting of PPP highway projects. The general information of the seven cases is compiled and shown in Table 2 (for more detailed information about these cases, please refer to Sun, 2006; Li, 2007 and Yang, 2007) and eight potential risks that may have a strong impact on concession pricing of PPP

Table 2. General information of the eight selected PPP highway projects

Project name/ location	Length	Total investment	Concessionaire	Concession period (years)	Construction (year)	Status
1. Yu-Sui highway	111.8 KM	0.7 biliion USD	Chongqin Tie faYu-sui highway company limited	30	2004	Open to the public
2. Malaysia north - south highway	900 KM	1.8 billion USD	United Engineer	30	1988	Open to the public
3. Hong Kong Dong Qu submarine tunnel project	2.2 KM	565 million USD	New Hong Kong Tunnel Company Limited	30 (highway) 20 (railway)	1986	Open to the public
4. HuangYan highway	143.205 KM	0.94 billion USD	Chinese railroad engineering company	28	2002	Open to the public
5. Jin-xiang highway	73 KM	0.32 billion USD	Jin Xiang expressway construction development corporation	24	2000	Open to the public
6. Hubei Xiang-jing highway	185 KM	0.66 billion USD	Ge Zhou dam company	30	2001	Open to the public
7. Cen-wu highway	65.3 KM	0.40 billion USD	Cen-Wu highway company	29	2003	Open to the public

highway projects were extracted through content analysis. It comprises 1) completion risk, 2) market risk, 3) legislative risk, 4) force majeure, 5) operation cost risk, 6) inflation risk, 7) interest rate fluctuation, and 8) government subsidy as shown in Table 3.

The estimated cash outflow (cost) and cash inflow (benefit) of PPP highway projects could be highly influenced by these factors as demonstrated in Figure 4. The corresponding relationship between risk factors and variables of concession pricing formula is demonstrated in Figure 5. It is essential for both the private sector and the government to take into account the impact of these risks when considering concession pricing design. Although only eight critical risks are demonstrated here, other critical risks that the project promoter encountered may also have a direct impact on the pricing formula. Shen and Wu (2005) and Ng et al. (2007) regard that it is reasonable and beneficial to incorporate risk variables into the concession price determination.

7. CONCESSION PRICE ADJUSTMENT MECHANISM

The concession pricing model incorporated the risk variables into the pricing formula, the price adjustment of a PPP project can be conducted directly through adjusting the corresponding variables. Thus, the price adjustment issue can be further turned into the process of 1) determining the actual change range of risk variables and 2) calculating the adjustment value of risk variables (i.e. risk allocation between the government and the private sector).

Step 1: determining the actual change range of risk variables

Table 3. Critical risk factors influencing concession pricing of PPP highway projects

No	Influence factors	1. Yu-Sui highway	2. Malaysia north - south highway	3. Hong Kong Dong Qu submarine tunnel project	4. HuangYan highway	5. Jin-xiang highway	6. Hubei Xiang-jing highway	7. Cen-wu highway
1	Completion risk	▲	▲	▲	▲	▲		▲
2	Operation cost overrun				▲			
3	Market risk	▲	▲			▲	▲	
	Competition of similar projects							▲
4	Legislative change	▲				▲		
5	Inflation risk		▲			▲		
6	Interest rate change		▲	▲		▲		
7	Force majeure				▲		▲	
8	Other cash inflow							
	Government subsidy		▲	▲			▲	

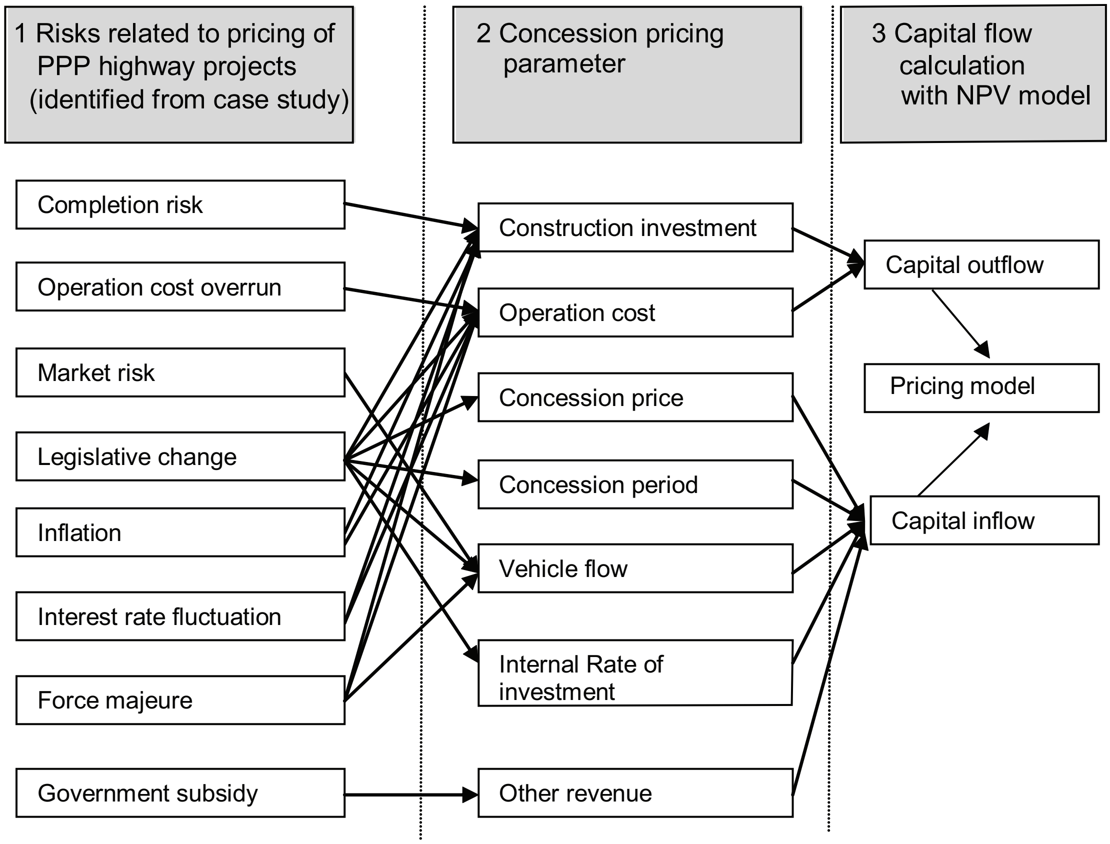
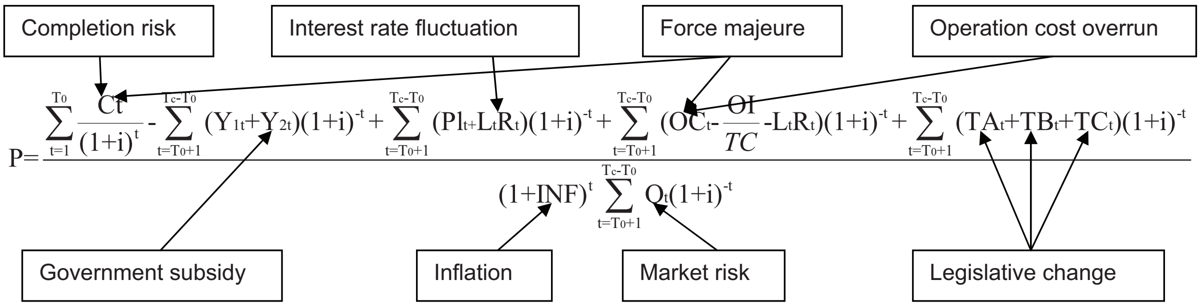


Figure 4. The relationship between risk factors and cash flow (adopted from Yang, 2007)



$$P=\frac{\sum_{t=1}^{T_0}\frac{C_t}{(1+i)^t}-\sum_{t=T_0+1}^{T_c-T_0}(Y_{1t}+Y_{2t})(1+i)^{-t}+\sum_{t=T_0+1}^{T_c-T_0}(Pl_t+L_tR_t)(1+i)^{-t}+\sum_{t=T_0+1}^{T_c-T_0}\left(OC_t-\frac{OI}{TC}-L_tR_t\right)(1+i)^{-t}+\sum_{t=T_0+1}^{T_c-T_0}(TA_t+TB_t+TC_t)(1+i)^{-t}}{(1+INF)^t\sum_{t=T_0+1}^{T_c-T_0}Q_t(1+i)^{-t}}$$

Figure 5. The relationship between risk factors and concession pricing formula

The determination of actual change range of risk variables can be classified into two types. One is the risk variables, which can be determined directly according to the actual project data (such as: interest rate fluctuation, government subsidy, inflation, and traffic volume). The other needs to calculate the actual loss accused by risk events (such as: completion risk, force majeure, operation cost overrun, legislative change). The value of actual loss can be obtained based on the product summation of price and quantities of new added resources inputted to project including additional added work quantities, materials, labor, equipment input, and so on. According to new added Bill of Quantities, it can be easily calculated.

Step 2: calculating the adjustment value of risk variables

The private sector can only obtain compensation on the risks that are assumed by the government. meanwhile, the government will don't make compensation to the private sector for the loss accused by risks assumed by the private sector. Likewise, for the risks shared by both parties, only the part assumed by the government is allowed to be compensated through price adjustment or concession period extension. However, the determination of equitable risk (responsibility) sharing, especially quantitative risk allocation, is a difficult process, as the concession contract usually lacks explicit definition and explanation on it. Quantitative risk allocation between the government and the private sector is therefore becomes a barrier, which must be tackled before calculating concession price adjustment.

It is well known that concession price based on inequitable risk sharing may protect the concessionaire from commercial risks, however, it may also discourage efforts related to efficiency and cost control (Chen and Messner, 2005). The more risk the private sector assumes in a project, the higher concession price the private sector aims to obtain. According to Ke (2009) and Li (2005)'s survey results, out of the above eight risk factors, legislative change risk and government subsidy risk are preferably allocated to the government, completion risk and operation cost overrun risk are preferably undertaken by the private sector, and the other four risks are preferably assumed by both parties jointly as shown in Table 4.

However, their research results are subjective and implicit in actual application. The fundamental principle for risk allocation is that risks associated with the implementation and delivery of services should be allocated to the party best able to manage the risk in a cost effective manner (Loosemore and McCarthy, 2007) under the limit of government regulatory and public satisfaction (Deng et al., 2006). While, different private enterprises or local governments have different resources, risk management capability, PPP experience and risk preference. Thus it is impractical to allocate risk by using a rigid risk allocation framework, especially for risks assumed by both parties jointly. To resolve this problem, a quantitative risk allocation model should be applied for the adjustment of risk variables. Criteria for quantitative risk allocation are listed in Table 5. The practitioner can determine appropriate weightings for risk allocation criteria based on their specific project context and set (select) membership function for each critical allocation criteria by using Fuzzy Set Theory (Figure 6 and Table 6). The quantitative calculations of risk allocation between the government and the private sector can be derived by evaluating the Risk Carrying Capability Index of each part, and the proportion of risk assumed by each part can therefore be determined (as shown in Table 5).

Moreover, the automation process of the risk allocation model is developed for the convenience of end users with the use of Visual Basic for Application (VBA) as shown in Figure 7. The computerized model can help reduce human and mathematical errors as data can be directly inputted by project participants and data analysis is then performed by the computerized procedure instead of the manual calculation. Participants can simply input their individual project information and data based on their resources and risk management capability and the computerized system will provide an equitable risk allocation proportion between the government and the private sector directly. By using this model, the proportion of risk loss compensated to the private sector by the government can be calculated.

Table 4. Risk allocation framework and pricing formula influenced by risk factors

Risk factors	Pricing formula influenced by risk factors	Risk allocation			Remark
		Pub.	Sh.	Pri.	
Completion risk	$E1=\sum_{t=1}^{T_0}\frac{Ct}{(1+i)^t}$			▲	Completion risk is generally undertaken by the private sector. However, for schedule delay or cost overrun accused by the government action, the government should provide compensation.
Market risk	$E6=(1+INF)^t\sum_{t=T_0+1}^{T_c-T_0}Q_t(1+i)^{-t}$		▲		The market risk is usually undertaken by the government and the project company jointly. In order to ensure relatively stable cash flow, the government will generally sign agreement with the project company to offer guarantee on market risk through articles of "guarantee for minimum traffic flow" or/and "competition protection".
Operation cost overrun	$E4=\sum_{t=T_0+1}^{T_c-T_0}(OC_t-\frac{OI}{TC}-L_tR_t)(1+i)^{-t}$			▲	Operation cost overrun risk is assumed by the private sector.
Legislative change	$E5=\sum_{t=T_0+1}^{T_c-T_0}(TA_t+TB_t+TC_t)(1+i)^{-t}$	▲			As only the government has the right to constitute and enforce law, meanwhile has the capability to manage it and sustain its consequence. Thus it is rational that the government undertakes legislative risk.
Inflation	$E6=(1+INF)^t\sum_{t=T_0+1}^{T_c-T_0}Q_t(1+i)^{-t}$		▲		Inflation risk is jointly undertaken by the government and the project company. The project company undertakes the inflation risk within certain range. When inflation rate exceeds the preset limit, the government will bear the surplus risk.
Interest rate fluctuation	$E3=\sum_{t=T_{0+1}}^{T_c-T_0}(Pl_t+L_tR_t)(1+i)^{-t}$		▲		Same with the inflation risk.
Government subsidy	$E2=\sum_{t=T_{0+1}}^{T_c-T_0}(Y_{1t}+Y_{2t})(1+i)^{-t}$	▲			The government has the responsibility to offer compensations on the difference between expected cash inflow and actual cash inflow through certain measures to enable the private enterprise to be able obtain reasonable profit.
Force majeure	$E1=\sum_{t=1}^{T_0}\frac{Ct}{(1+i)^t}$, $E4=\sum_{t=T_{0+1}}^{T_c-T_0}(OC_t-\frac{OI}{TC}-L_tR_t)(1+i)^{-t}$		▲		Force majeure is usually undertaken by the government and the private sector jointly.

Table 5. Calculation of Risk Carrying Capability Index

Risk Carrying Capability Index of the government or the private sector			
Risk allocation criteria	Weighting (w)	Membership function of risk allocation criteria (r)	Membership function of Risk Carry Capability Index (b)
1. The ability to avoid, minimize, monitor, and control the chance of risk occurrence	W1	Option please refer to Figure 6	
2. The ability to minimize the loss if risk occurs	W2	Option please refer to Figure 6	
3. The ability to bear the risk at the lowest price	W3	Option please refer to Figure 6	
4. Be able to get reasonable and acceptable premium	W4	Option please refer to Figure 6	M (•,⊕),
5. The ability to sustain the consequences of the risk	W5	Option please refer to Figure 6	$b_j = \min(1, \sum_{i=1}^{m} w_i \times r_{ij})$
6. Be able to assume the direct loss	W6	Option please refer to Figure 6	$\forall b_j \in B$
7. The ability to foresee the risk	W7	Option please refer to Figure 6	
8. Be able to enhance risk undertaker's credibility, reputation and efficiency in risk management	W8	Option please refer to Figure 6	
9. Risk attitude	W9	Option please refer to Figure 6	

Table 6. Membership function for each criterion

Criteria	Degree of membership	Normalized membership functions
Very Low (VL)	(1.0, 0.5, 0.0, 0.0, 0.0)	(0.67, 0.33, 0.00, 0.00, 0.00)
Low (L)	(0.5, 1.0, 0.5, 0.0, 0.0)	(0.25, 0.50, 0.25, 0.00, 0.00)
Medium (M)	(0.0, 0.5, 1.0, 0.5, 0.0)	(0.00, 0.25, 0.50, 0.25, 0.00)
High (H)	(0.0, 0.0, 0.5, 1.0, 0.5)	(0.00, 0.00, 0.25, 0.50, 0.25)
Very High (VH)	(0.0, 0.0, 0.0, 0.5, 1.0)	(0.00, 0.00, 0.00, 0.33, 0.67)

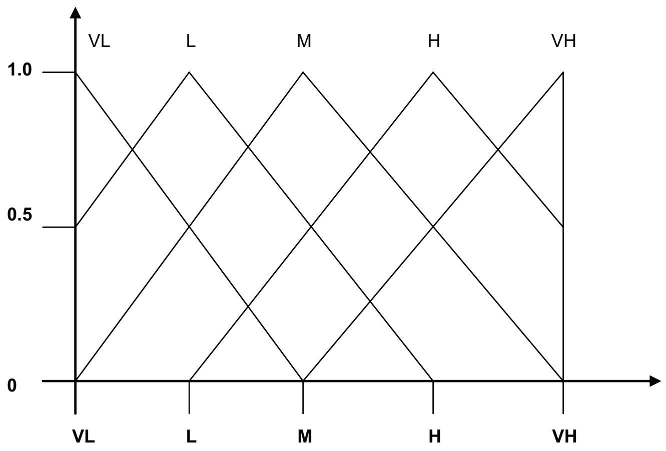


Figure 6. Membership grades of evaluation set

Take "inflation risk" as an example, which is usually undertaken by the government and the project company jointly. Provided that there is an increase of a PPP project's inflation rate by 10% during the construction period, namely, the actual change in inflation risk variable is 10%. It makes the construction cost overrun and thus reduces the Expected Return Rate of Investment. In order to keep the project financial viable and maintain due incentive on the private sector, part of inflation risk loss that is assumed by the government should be compensated to the private sector through adjusting inflation variable based on formula 4 and recalculating a new concession price. The adjustment value of inflation risk variable can be determined through quantitative risk allocation via computerized fuzzy allocation model as shown in Figure 7. (In this case, the weightings of risk allocation criteria are assumed as 0.15, 0.13, 0.125, 0.11, 0.10, 0.115, 0.10, 0.09, 0.08 and the fuzzy memberships are selected by research team members randomly as shown in Figure 7). The calculation result indicates that about 46.8% inflation risk should be undertaken by the government based on both parties risk management capability, incentive obtained and risk preference, thus the adjustment value of inflation risk variable is 10% × 46.8% = 4.68%. The new inflation value can then directly input equation 4 for concession price adjustment. Moreover, it should be note that all concession parameters are interrelated, the calculator needs to reconsider all parameters as a whole and recalculate the concession price. Until now, the concession pricing and price adjustment of PPP highway projects are thoroughly resolved.

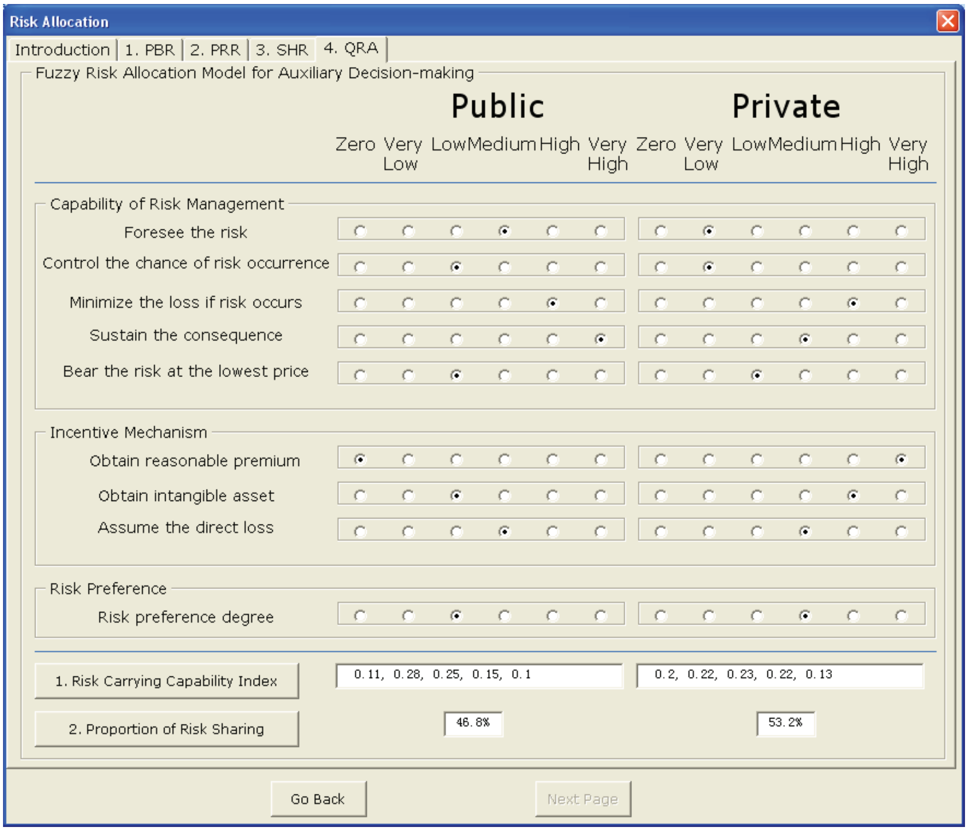


Figure 7. Interface of a computerized risk allocation model

8. CONCLUSIONS

The principle for pricing of a PPP project is to safeguard the interests of the public, meanwhile ensuring that the private sector can obtain reasonable profits through appropriate risk management. In this paper, six parameters for determining concession pricing were identified by cash flow analysis based on engineering economics theory. It comprises total construction investment cost, operating cost, concession period, expected Internal Rate of Return, daily vehicle flow and concession price. A concession pricing model was then developed through cost-benefit analysis based on the capital fund cash flow table from the private sector's perspective. Subsequently, eight potential risk factors with potentially serious effects on the cost and benefits of construction and operation of PPP highway projects were identified from prior case studies and the relationship between risk factors and price determination variables were demonstrated. Finally, a rational price adjustment mechanism is established to adjust the initial concession price based on equitable risk sharing. To facilitate the quantitative determination of risk allocation, a computerized fuzzy model with Visual Basic for Application has been developed. However, one limitation of this model is that the price adjustment mechanism proposed needs further verification with real project data in subsequent studies. Research findings presented in this paper are believed to be beneficial to the development and application of PPP at large and enable interested investors to better understand the concession pricing of PPP projects.

ACKNOWLEDGEMENTS

The work described in this paper was supported by the National Natural Science Foundation of China (Project No. 71101130) and a teaching reform project funded by the Zhejiang Sci-tech University (el1136). Special gratitude is also extended to a joint grant from the Research Grants Council of the Hong Kong Special Administrative Region, China (RGC Project No. N_PolyU5114/05E) and the National Natural Science Foundation of China (Project No. 70731160634).

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