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Article

Computational Framework for the Determination of Duration and Revenue Sharing Rates in PPP Concession Renewal: A Monte Carlo and Risk Premium Approach

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Abstract. Public Private Partnership (PPP) has been extensively used as an innovative and integrated form of project delivery, especially for large-scale infrastructure projects. When a PPP concession is about to expire, the PPP law may require a study to compare benefits and risks as part of the decision to renew or end the contract. The study, based on expected value analysis, will be used by the contracting authority for negotiating with the incumbent over terms such as contract duration and revenue sharing rate. However, a major flaw of expected value analysis is the inability to provide a possible risk profile of the contracting agency or concessionaire. Accordingly, this paper presents a computational framework for determination of the contract duration and the revenue sharing rate using Monte Carlo simulation and a risk premium approach. The proposed framework can be used to depict the risk profile of the concessionaire under different contract durations and revenue sharing rates. To illustrate how the proposed model can be applied in practice, a PPP toll road project is adopted as the case study. The results of the study suggest that the revenue sharing rate is the key to the negotiation of the contract to be renewed. The proposed method may be used by governments for negotiation with an incumbent concessionaire or to achieve a fair price when a competitive retendering process is considered.

Keywords: PPP infrastructure, contract renewal, revenue share, risk analysis, Monte Carlo simulation.

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1. Introduction

Infrastructure plays a critical role in economic and social development [1]. It enables the delivery of goods and services that help stimulate economic growth and ensure people's quality of life. In recent decades, a program called Public Private Partnership (PPP) has been increasingly used by governments around the world as an innovative way of financing large-scale infrastructure projects. Public Private Partnership may be defined as a contractual relationship governing a long-term public-sector acquisition and private sector provision of public works and services [2, 3]. Very often, PPP projects are arranged using a mechanism called Build-Operate-Transfer (BOT) in which a public entity (i.e., a contracting authority) is involved in contracting a private entity to design, finance, build, operate, and maintain a facility for an agreed period (i.e., concession period), and then transfer the facility to the public entity at the end of concession period. A variant of a BOT contract is Build-Transfer-Operate (BTO) in which the transfer of the facility occurs at the completion of construction.

In some countries such as Thailand, when a PPP concession is about to expire, the PPP law requires a study to compare benefits and risk as part of the decision to renew or end the contract. Usually, the study, based on expected value or deterministic analysis, will be conducted, and the results will be used by the contracting authority for negotiating with the incumbent over terms such as contract duration and revenue sharing rate. However, a major flaw of expected value analysis is the inability to provide a possible risk profile of the contracting agency or concessionaire, i.e., a range of possible outcomes [4]. Therefore, before making a decision related to the expiration of a PPP contract, the contracting authority may need additional information about the risk profile of the contracting agency itself and that of the concessionaire.

The main benefit of concession renewal is that it offers an important incentive to the incumbent to perform satisfactorily and comply with both contracted and non-contractible quality standards. Thus, concession renewal can be treated as a reward for good past performance [5]. It also gives the public agency an *exit option* so that the agency can manage the project itself or retender the project using auction methods, such as the Least-Present-Value-of-Revenue (LPVR) proposed by Engel *et al.* [6] (see Fig. 1 for the public agency's available options illustrated as a decision tree). As shown in Fig. 1, the decision tree contains a sequence of alternating decision nodes and chance nodes. Decision nodes are the moments when possible courses of action are considered and a decision is made. Chance nodes represent the probabilities that different future outcomes may occur in the period(s) after a decision is made. In the renewal of a concession contract, two of the most significant negotiated terms are:

(1) the length or duration
(2) the revenue sharing mechanism of the new concession.

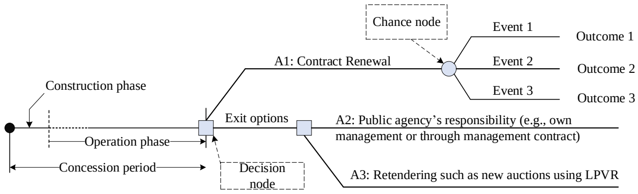

Fig. 1. Alternatives available at the end of a PPP concession contract.

Therefore, the aim of this paper is to equip the contracting authority, which is the decision maker (DM) of a PPP project, with a simple and straightforward computational model for the determination of the duration of the contract to be renewed, denoted as M , and the optimal revenue sharing rate, denoted as λ , that will ensure both the *efficiency* and *bankability* of the infrastructure project. In the proposed computational framework, we also present how the risk-adjusted discount rate associated with each type of cash flow should be computed so that the contract duration and the revenue sharing rate can be appropriately determined. For risk-based analysis, both sensitivity analysis and Monte Carlo simulation will be employed to provide the risk profile of the concessionaire, based on different revenue sharing rates, so as to bracket an appropriate range for the revenue sharing rate, i.e., $[\lambda_l, \lambda_u]$, which can be employed by the contracting agency in the negotiation with the incumbent. In addition, to illustrate how the proposed model can be used in practice, a real project, namely, the Second Stage Expressway System (SSES), an elevated BTO road located in Bangkok, will be adopted for the case study.

The remainder of the paper is structured as follows. We begin by providing a literature review, followed by an explanation of a method commonly used for determining the contract period of a PPP arrangement. Next, we present a computational framework for the determination of contract time and revenue sharing rate, followed by a risk analysis using sensitivity analysis and Monte Carlo simulation, with a brief discussion of the principles employed to determine the contract duration and the optimal revenue sharing rate. Then, we address the issue of risk premium calculation used in valuing public and private projects. Once the computational framework has been fully explained, the model will be populated with data from a case study project to provide a numerical example that illustrates how the proposed framework and method can be applied in practice. This is followed by the results and discussion. Finally, we close the paper with conclusions and implications of the findings.

2. Literature Review

The rationale for introducing PPPs into infrastructure provision comprises the many expected advantages of *bundling the project phases* and making use of the profit seeking motives, diligence, and experience of private parties [7]. From an economic viewpoint, the justification for PPPs is that they increase efficiency by aligning the incentives of the involved parties [8]. To some, PPPs may also be viewed as a way of introducing private sector technology and innovation to the provision of public services with improved operational efficiency [9].

In principles, the designs of PPP contracts depend largely on how risks are allocated between the public and the private parties [10], which is essentially the core principle of PPPs (i.e., risks should be transferred to the party that can best manage them, and with the lowest possible costs). For example, in a Build-Operate-Transfer (BOT) setting, a private company (also known as a concessionaire) is responsible for the risks related to the design, financing, construction, and operation and maintenance (O&M) of the project for an agreed period (the concession period). The private company also assumes exogenous risks, such as market or demand risk, during the operation period. The improved risk management of this BOT arrangement, in theory, plays a crucial role in increasing the efficiency of delivery of the project.

However, this is not a one-way street; PPPs have also been the subject of criticism. For example, risk sharing between the government and concessionaires has always been a concern among practitioners and policy makers [11]. In addition, PPPs usually involve several parties with *diverging goals*, making them vulnerable to an economic dilemma known as a principal-agent (P-A) problem [12]. Moreover, there are issues related to the inherently incomplete nature of PPP contracts (e.g., problems with renegotiation of contracts and the potential opportunistic behavior of concessionaires) [13]. Finally, in reality, risk is always changing, and optimal risk allocation may not be attainable. As a result, in the face of unprecedented high risk, renegotiation of a contract may be unavoidable. These characteristics of PPP projects make it very difficult for the contracting agency to design optimal risk allocation at the outset of the PPP contract.

In a PPP arrangement, the high cost of financing the project will be recovered through fee revenues generated by the services/products provided by the project over the contract period. Just as construction and operation and maintenance (O&M) costs are certainly subject to risk, so are the revenues to be received over the operation period, which are subject to market or economic risks. Therefore, the determination of an appropriate concession period is crucial to the PPP project's financial viability.

The United Nations Economic and Social Commission for Asia and the Pacific (ESCAP), for example, recommends that concession periods range between 15 and 30 years, depending on the results of each project's financial analysis [14]. However, for typical PPP transportation projects in Thailand, the concession period is assumed to be at least 30 years, which is long enough to allow the concessionaire to recoup the initial investment and O&M costs, plus a sufficient amount of profit for the assumed risk. Because of the long period of the PPP contract and substantial risk transfer to the private entity, there has been a focus on risk analysis in several PPP studies, such as the study of critical risk factors (CRFs) in Vietnam by Likhitruangsilp *et al.* [15], and risk reduction through the bundling of small and medium PPP projects by Kato and Matsumaru [16].

In theory, *concession duration* can be determined in two ways: one is exogenous, the other is endogenous.

The exogenous approach is widely used by public agencies at the design stage. In this case, the contract duration is determined by exogenous factors such as demand for the services or a change in macroeconomic conditions. There have been many studies related to the determination of new or greenfield PPP projects using this approach. Most of these are based on financial techniques such as expected NPV, NPV-at-risk or payback period. For example, Ye and Tiong [17] provided a conceptual framework for determining the duration of a new BOT project using a risk-return trade-off technique. Shen and Li [18] used expected investment return to determine the payback period of a PPP project. Researchers such as Ye and Tiong [19], Miller [20], Zhang [3], and Yu and Lam [21] also explicitly relied on PPP financial models based on the discounted cash flow (DCF) method. Ng *et al.* [22] proposed a more advanced method, using a simulated model for optimizing PPP concession periods.

However, in some circumstances and when permitted by law, the concession duration may be determined endogenously. For example, if the Least-Present-Value-of-Revenue (LPVR) is used as an award criterion, the contract will last until the winning private partner receives the LPVR it submitted [6]. Another endogenous approach was proposed by Shen *et al.* [23], who used game theory for determination of contract duration.

To date, studies concerned with the duration of a renewed concession in a PPP are quite limited. Many of those that exist have focused on lease renewal in real estate markets (e.g., [24, 25]). Relevant to this research is a study by Contreras and Angulo [26], who proposed an option-pricing model for valuing the impact on the public budget arising from extension options embedded in a build-operate-finance-transfer (BOFT) arrangement. As for research on revenue sharing mechanisms, there are several currently focused on new greenfield PPP projects. For example, a recent study by Wang and Liu [27] used principal-agent (P-A) models to determine the excess revenue sharing ratios in PPP projects. Moreover, a number of articles have focused on the revenue risk management of a PPP using real options analysis. Examples of these studies include Chiara et al. [28], Ashuri et al. [29], and Kokkaew and Chiara [30].

3. Determination of Contract Duration

In this paper, we will adopt the exogenous approach to the determination of the concession duration. This method can be applied for both new contracts and contracts to be renewed. Accordingly, we will study and

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compare the results between two alternatives (see Fig. 1):

A1: contract renewal
A2: management under public agency's responsibility

Once the contract duration is exogenously determined, the optimal revenue sharing mechanism can be established. It should be noted that, for the sake of comparison between the options to renew or not to renew the concession, option *A3* (Retendering process) is not included in our analysis. However, if the decision arrived at is alternative *A2*, then the contracting authority may use the expected benefits as a benchmark price for a new competitive retendering process to provide value for money or VfM.

As for determination of the optimal revenue sharing rate, it should be the one at which the concessionaire's required rate of return on equity cash flow (ECF) is close to zero. It should be noted that *the right to make the decision to renew or to end the contract rests solely with the contracting authority*. To make an objective decision, the contracting authority, therefore, must compare the present worth of net benefits associated with each alternative. In addition, the discount rate for each stream of future revenues must be appropriately calculated. This is mainly because different cash flows are subject to different levels of risk, and they should be discounted with appropriate discount rates to compensate for the risk of the undertaking. We acknowledge that the choice of discount rates is a contentious topic; however, simply ignoring this fact could give rise to misleading results.

To determine the financial viability of a PPP project, discounted cash flow (DCF) methods such as net present value (NPV) are commonly employed by PPP analysts. In the DCF analysis, future cash flow must be discounted using an appropriate discount rate to compensate for the risk exposure from the undertaking. In addition, to determine an appropriate concession duration for each PPP project, risk factors such as product prices, market demand, and the like should be incorporated into the financial analysis [31]. Initial investments such as construction or rehabilitation and renovation cost will be estimated; so too will the future stream of project revenues and operation and maintenance (O&M) costs.

By using the minimum required rate of return as a discount rate (r), the net present value (NPV) of the project's cash flows can be calculated. For example, adapted from Zhang [2], the net present value (NPV) of a PPP road project may be computed by

$$NPV = \sum_{t=0}^{t=N} \frac{-I_t + (T_t \times \alpha_t) - (\gamma_t \times T_t)}{(1+r)^t} \quad (1)$$

where I_t is initial investment made in year t ; T_t is traffic volume in year t ; α_t is average toll rate in year t ; γ_t is average unit operation and maintenance cost in year t ; r is required rate of return or cost of capital using weighted average cost of capital or WACC, and N is the number of concession years.

Based on Eq. (1), the number of concession years should be the length of time (N) at which the project's net present value (NPV) is zero. This approach to the determination of concession period may be called a deterministic approach, and its result a predetermined period.

In reality, construction costs, operating revenues, and O&M costs will certainly be different from initial estimates. One can think of these variables as a set of risk factors influencing a financially optimal concession period, which could be either shorter or longer than originally estimated. As a result, some researchers such as Engel *et al.* [6] and Vassallo [32] have suggested that the concession period, which is unknown at the outset of the contract, should be a function of future revenue, and that the concession shall end when the present value of future revenue covers the cost of construction and operation, plus a sufficient amount of business profit for the private concessionaire. This approach to the determination of concession period can be called a flexible approach, and its result a stochastic concession period.

As for the determination of the number of years (M) to be specified in a new contract, the same principle as that mentioned above can be applied. It should be noted that if operating revenues are to be shared by the contracting authority, the expected concessionaire's NPV can be modified as

$$NPV = \sum_{t=0}^{t=M} \frac{-R_t + (T_t \times \alpha_t) \times (1-\lambda) - (\gamma_t \times T_t) - DS_t - Tax_t}{(1+r_E)^t} \quad (2)$$

where λ is revenue sharing rate; DS_t is debt service in year t ; Tax_t is tax payment in year t , and r_E is the required rate of return on equity.

4. Computational Framework

In general, there are three players who benefit financially from the operation of PPP road projects. The first is the concessionaire (denoted as *C*), who collects toll revenues and who retains operating cash flows after deduction of the revenue share, debt service, and tax payments. The second entity is the contracting authority (denoted as *A*), who may receive a revenue share from the concession at an agreed sharing rate. Finally, the government (denoted as *G*) benefits from tax collection, both in terms of goods and services tax or value added tax (VAT), and corporate tax.

4.1. Decision Making Process of Contracting Authority

A decision tree can be employed to model how the contracting authority reaches a decision at the end of concession contract (i.e., to renew or to end the contract), as depicted in Fig. 2.

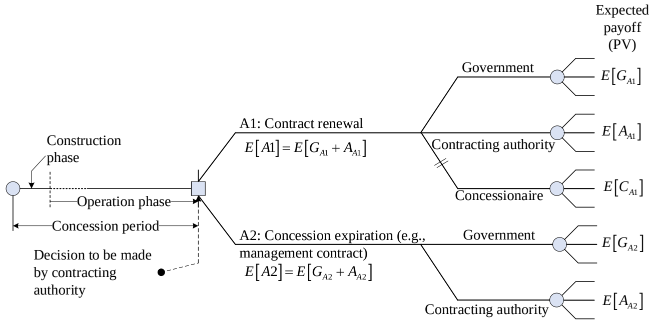

Fig. 2. Decision tree representing the comparison of alternatives *A1* and *A2* at the end of a PPP concession contract.

As can be seen in Fig. 2, in theory, the decision to renew or not to renew should be analytically made by comparing the expected net present value (NPV) of *A1* (Contract renewal) and that of *A2* (Contract expiration). If the expected net present value (NPV) of *A1* is greater than that of *A2* (Contract expiration), the contracting authority should renew the concession ($E[A1] > E[A2]$); otherwise, the contracting authority should take over the management of the project.

Key assumptions used in this study include:

(1) the revenue sharing rate is fixed over the contract duration, and

(2) the contract has early termination clauses to provide the contracting authority an exit from the obligation in the case of concessionaire's performance failure.

Details about how to compute expected net benefits associated with each alternative are as follows.

4.2. Modelling of Future Project Cash Flow

4.2.1. Alternative *A1*: Contract Renewal

The cash flow waterfall shown in Fig. 3 can be used to demonstrate how cash flow will be distributed between the concessionaire and the government, as a tax collector.

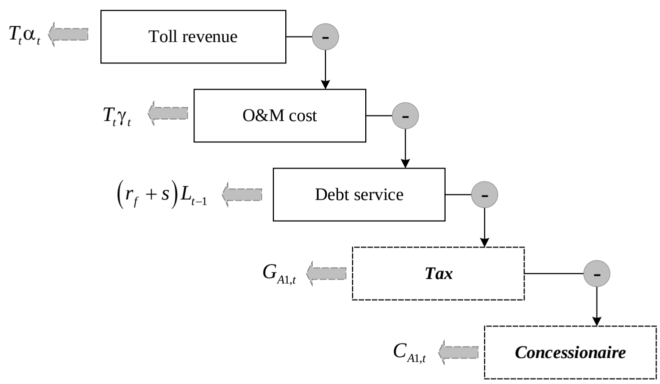

Fig. 3. Cash flow waterfall of alternatives *A1*: Contract Renewal without revenue share.

As shown in Fig. 3, if the decision of the contracting authority is to renew the concession contract "without revenue share," expected annual net revenue for year t of a PPP toll road concessionaire (denoted as $E\left[C_{A1,t}\right]$ or $\hat{C}_{A1,t}$) during the concession period can be computed, after rearranging the equation, as

$$\hat{C}_{A1,t} = [1-c]\left[(\hat{\alpha}_t - \hat{\gamma}_t)\hat{T}_t - (r_f + s)L_{t-1} - \frac{R}{n}\right] \tag{3}$$

where $\hat{C}_{A1,t}$ is expected annual net revenue of the concessionaire in year t; c is corporate tax rate; $\hat{\alpha}_t$ and $\hat{\gamma}_t$ is average toll price and unit O&M cost in year t, respectively; $\hat{T}_t$ is expected traffic in year t; r_f and s is the risk free rate and credit spread charged by lenders; L_{t-1} is outstanding debt in year $t-1$; R is total construction or rehabilitation cost, and n is the number of operation years (i.e., R/n is yearly depreciation).

As for the government, expected annual cash flow ($\hat{G}_{A1,t}$) to be received from the concessionaire in a form of tax revenues is given by

$$\hat{G}_{A1,t} = c\left[(\hat{\alpha}_t - \hat{\gamma}_t)\hat{T}_t - (r_f + s)L_{t-1} - \frac{R}{n}\right] \tag{4}$$

However, in some projects, such as PPP toll roads in Thailand, toll revenues must be shared with the contracting authority. Therefore, Eq. (3) and Eq. (4) can be modified to account for shared revenues. Accordingly, the value of net benefits to be received by the contracting authority under alternative *A1* ($A_{A1,t}$) can be computed as

$$A_{A1,t} = \lambda\left[(\alpha_t)T_t - V_{A1,t}\right] \tag{5}$$

where λ is revenue sharing rate for the contracting authority, and $V_{A1,t}$ is value added tax (VAT) in year t, which can be computed as

$$V_{A1,t} = (\alpha_t)T_t - \frac{(\alpha_t)T_t}{(1+v)} \tag{6}$$

where v is the VAT rate (e.g., the current VAT rate in Thailand is 7%).

Annual corporate tax revenue ($G_{A1,t}$) in year t and net revenue for the concessionaire ($C_{A1,t}$) are estimated by the following equations

$$C_{A1,t} = \left[(\alpha_t T_t - V_t)[1-\lambda] - \gamma_t T_t - (r_f + s)L_{t-1} - G_t\right] \tag{7}$$

where

$$G_{A1,t} = c \times \left[(\alpha_t T_t - V_t)[1-\lambda] - \gamma_t T_t - (r_f + s)L_{t-1} - \frac{R}{n}\right] \tag{8}$$

Therefore, the upper bound of revenue sharing rate (λ_u) can be calculated as

$$NPV\left(C_{A1,t};\lambda_u,r_E\right)=0 \tag{9}$$

where NPV is a function of one variable, namely, $C_{A1,t}$, and two parameters: λ_u and r_E.

4.2.2. Alternative *A2*: Public Authority Own Management

If the contracting agency decides to let the PPP contract expire so that it can operate the project itself or through a management contract, tolled revenue in year t (Y_t) can be estimated by

$$Y_t=\left(\alpha_t\right)T_t \tag{10}$$

If value added tax (VAT) is included in the tolled price, the total amount of VAT (V_t) for each year can be computed using Eq. (6). Therefore, the annual income of the contracting authority ($A_{A2,t}$) is calculated as

$$A_{A2,t}=\left[\alpha_t-\gamma_t-\left(\alpha_t-\frac{\alpha_t}{1+v}\right)\right]T_t, \tag{11}$$

where γ_t is average unit O&M cost in year t.

4.3. Proposed Computational Framework

Once the projected cash flow associated with each alternative is modelled, the net present value of each alternative must be compared using either (1) a risk premium approach (i.e., risky cash flow discounted using risk-adjusted interest rate), or (2) a certainty equivalent approach [33]. In this study, we adopt a risk premium approach to determine the risk-adjusted discount rate associated with each stream of cash flow. The computational framework proposed in this study is shown in Fig. 4.

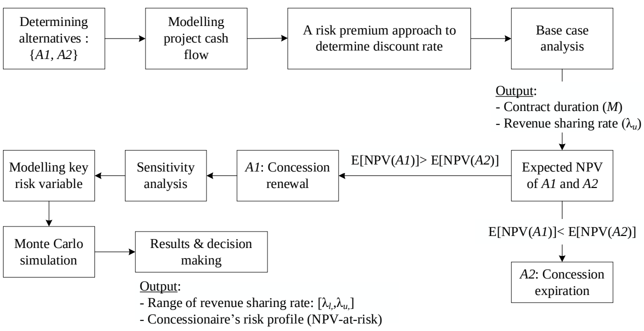

Fig. 4. Computational framework of the determination of revenue sharing rate using a risk premium and Monte Carlo approach.

5. Risk Analysis Using Monte Carlo Simulation

5.1. Monte Carlo Simulation

Once the computational framework is completed, Monte Carlo (MC) simulation can be employed to perform risk analysis. A basic process of MC simulation for risk analysis is shown in Fig. 5.

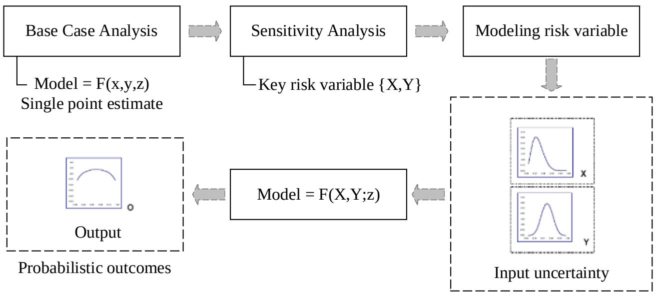

Fig. 5. Risk analysis using Monte Carlo simulation.

5.2. A Risk Premium Approach

The level of risk associated with each entity's stream of future cash flow can be determined using a risk premium approach. The sequence of how toll revenue will be distributed for each alternative is depicted in Fig. 6 and 7.

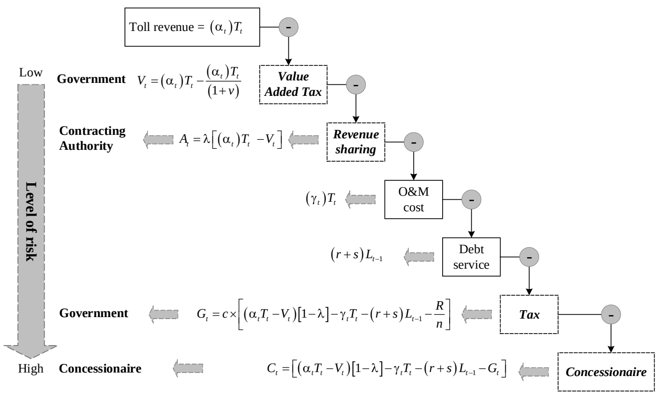

Fig. 6. Cash flow modelling of *A1* (Contract renewal).

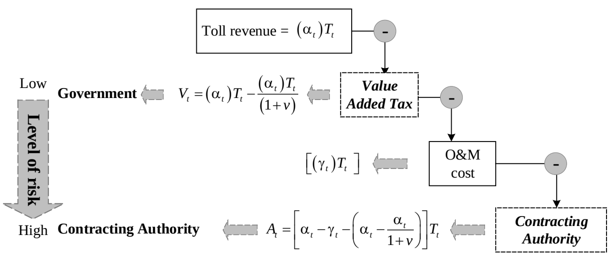

Fig. 7. Cash flow modelling of *A2* (Contract expiration).

Present value (PV) of benefits to be received by the contracting authority for each alternative can be mathematically modelled as

$$PV[A1] = f\left(V_{A1,t}, A_{A1,t}, G_{A1,t}; r_f, r_m\right) \quad (12)$$

$$PV[A2] = f\left(V_{A2,t}, A_{A2,t}; r_f, r_m\right) \quad (13)$$

where PV for each alternative is a function of variables $V, A,$ and G, and a set of two parameters: r_f (risk-free rate) and r_m (expected market risk).

It should be noted that the duration (M) for the new contract should be the time that makes $PV[A1]$ greater than $PV[A2]$ to ensure that the contracting agency will benefit from PPP contract renewal. As for the appropriate revenue sharing rate (λ), theoretically, it is the rate at which the net present value (NPV) of concessionaire discounted by cost of equity (r_E) is equal to zero.

However, since substantial operational risks will be transferred to the concessionaire, this calculated revenue sharing rate will need to be adjusted to a level to which both the contracting agency and the concessionaire, through negotiation, can agree. Therefore, in this study, we proposed using a risk premium approach and Monte Carlo simulation for determining the revenue sharing rate that provides the contracting agency with a possible range for the revenue sharing rate. The results of such analysis may help the agency negotiate effectively with the incumbent concessionaire.

6. Risk Premium Calculation

As mentioned earlier, increased efficiency of PPPs may help governments provide services at lower cost than would be possible with public sector delivery [9]. Therefore, one of the most important criteria for assessing a PPP project is whether the cost to the government will be less with a PPP than with conventional public provision. This comparison must be based on present value, which requires identification and selection of an appropriate discount rate.

The choice of discount rate to be used in this sort of analysis is controversial. Many researchers have taken the view that the discount rate used to evaluate public projects should be less than that used to assess a PPP [8]. The main argument of this view is that the public sector has risk pooling capacity; therefore, public projects should be assessed using lower discount rates. However, in practice, public infrastructure is usually operated independently by a responsible public agency, so the assumption of risk pooling capacity may not be accurate, and the use of a lower discount rate for the public project may lead to an overestimation of future benefits [34, 35]. However, a study by Grout [8] showed that the discount rates used for the public sector should be lower than those used for the private sector. His main argument was that the failure to do so suggests that private provision is less efficient than public management of service since the present value of private provision will be overestimated relative to public provision. Accordingly, the choice of discount rate should not be treated as trivial, especially for long life cycle undertakings such as transportation projects.

In general, the cost of capital (debt plus equity) is often used as the discount rate for a PPP. If the capital structure (e.g., debt-to-equity ratio) is known, then the cost of capital may be computed using the weighted sum of the cost of the debt and the cost of the equity, formally known as weighted average cost of capital (WACC). For an infrastructure project, WACC should be used for the cash flow available for debt service (CADS) or free cash flow (FCF). However, for infrastructure investment, the capital structure will change over time since debt service will reduce the amount of outstanding debt. For this reason, Esty [36] argued that a PPP project should be assessed through equity cash flow using cost of equity, which remains constant over time. Cost of capital can be estimated using a method called the Capital Asset Pricing Model or CAPM [37]. For PPP infrastructure projects, the cost of capital for equity cash flow (ECF) can be computed by the following equation

$$r_E = r_f + \beta_e \times (r_m - r_f) + Crp \quad (14)$$

where r_E is cost of equity; r_f is risk-free rate; r_m is expected market risk; β_e is the equity beta of the project, and Crp is country risk premium [38]. The country risk premium reflects the potential volatility of investments in a given country due to defaults associated with political or other events [38]. Estache and Pinglo [38] estimated that the country risk premium is around 5-8%. For example, for an upper-middle income country, country risk premium is about 6%. Therefore, if the average annual interest rate on government bonds over a 5-year period is used, the risk-free rate is set at 4%. Further, if the market risk for transportation infrastructure projects is, on average, 7.4%, and the equity beta of the project is set at 1.1%, then the cost of equity is calculated to be 13.74%.

7. Numerical Example Using Case Study Project

7.1. Project Setting and Arrangement

In this study, we employed the Second Stage Expressway System, a built-transfer-operate (BTO) toll road in Bangkok, as the case study. The Bangkok Expressway and Metro (BEM) Public Company (Concessionaire) was granted, by the Expressway Authority of Thailand (Contracting Authority), the right to build and operate the project for 30 years, from 1990 to 2020. The project comprises 4 sections (Sections A to D) with a total distance of 38.5 kilometers (see Fig. 8). In addition, the contractual arrangement is depicted in Fig. 9.

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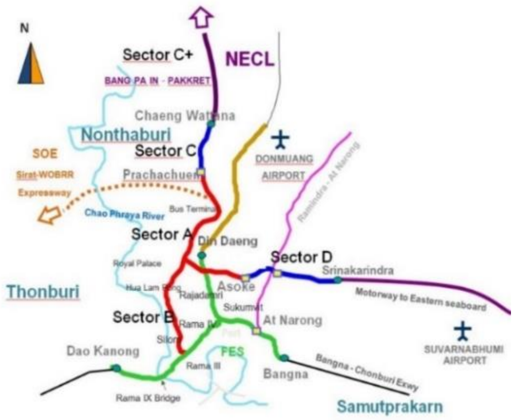

Fig. 8. Map of the Second Stage Expressway System in Bangkok. (Source: BEM Plc.)

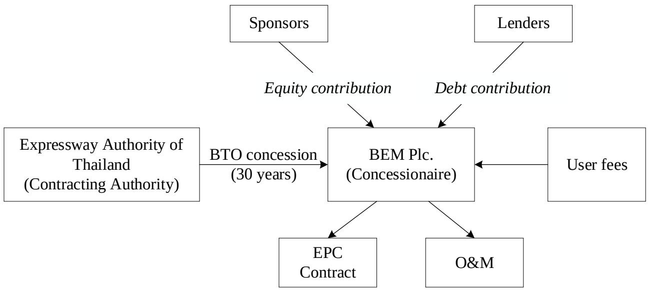

Fig. 9. Contractual arrangement of the case study project.

7.2. Base case analysis

In this case study, rehabilitation required at the outset of the contract is expected to cost about 6,450 million Thai baht (THB). The VAT rate (v) and corporate tax rate (c) are fixed at 7% and 20%, respectively. For *Alternative A1*, we assume that the concessionaire will finance the required rehabilitation cost by utilizing 50% debt and 50% equity. The cost of lending ($r_D = r_f + s$) is assumed to be about 7%. Other parameters such as expected annual traffic volume ($\hat{\tau}_t$), toll rate ($\hat{\alpha}_t$), and unit operation cost ($\hat{\gamma}_t$) of the case study project and toll rate are presented in Table 1, and are graphically depicted in Fig. 10 and 11.

Table 1. Projected traffic volume, toll rate, and unit O&M cost (THB).

Year	Traffic Volume	Average Toll Price	Average Unit O&M Cost
1	259,035,640	32.55	11.83
2	264,863,120	32.47	10.64
3	270,690,600	32.39	10.82
4	276,518,080	32.34	11.03
5	280,428,560	32.32	9.87
6	283,016,880	33.84	9.92
7	285,605,200	34.46	10.05
8	288,193,520	34.47	12.17
9	290,781,840	34.50	12.09
10	293,370,160	34.52	12.59
11	295,958,480	35.98	16.79
12	298,546,800	36.57	12.33
13	301,135,120	36.59	13.02
14	303,723,440	36.62	13.68
15	306,311,760	36.64	16.12
16	308,900,080	38.43	15.46
17	311,471,360	39.15	15.83
18	312,896,520	39.27	16.59
19	314,321,680	39.40	16.32
20	315,746,840	39.52	16.75
21	316,080,000	41.17	22.35
22	316,080,000	41.81	20.76
23	316,080,000	41.81	21.15
24	316,080,000	41.82	22.48
25	316,080,000	41.83	23.72
26	316,080,000	43.45	23.76
27	316,080,000	44.09	24.99
28	316,080,000	44.10	26.51
29	316,080,000	44.10	30.71
30	316,080,000	44.10	31.45

Source: Expressway Authority of Thailand, EXAT [39].

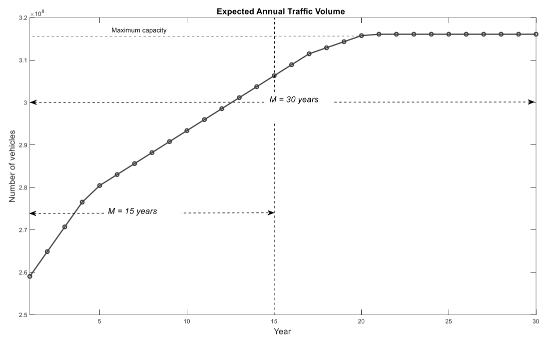

Fig. 10. Expected annual traffic volume of the case study project.

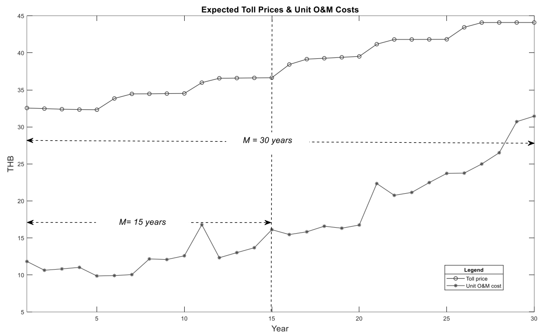

Fig. 11. Expected average toll rates ($\hat{\alpha}_t$) and average unit O&M costs ($\hat{\gamma}_t$) of the case study project.

Based on the equations presented in the previous section, the new revenue sharing rate (λ_u) can be determined using Eq. (9), which is the rate at which the NPV of concessionaire equals zero. The appropriate discount rate for each stream of cash flow can be computed using Eq. (14). For the case study project, the risk-free rate (r_f) is 4%, market risk (r_m) is 7.4%, and $\beta_e = 1.1$ (we used the beta of the company operating the project as a proxy for project beta). From Eq. (14), $r_E = 13.74$ (Crp is omitted since the project is a brownfield with recorded performance). An example of the financial analysis of *Alternative A1* with a 30-year contract is presented in Table 2.

Table 2. Example of financial analysis of Alternative A1 with a 30-year contract.

Yr.	Toll Revenue	$V_{A1,t}$	$A_{A1,t}$	DS_t	Interest payment	Principal payment	Remaining balance	R/M	$G_{A1,t}$	$C_{A1,t}$
0							3,225			-3,225
1	8,431	552	4,058	-277	-226	-51	3,174	215	63	416
2	8,600	563	4,139	-277	-222	-55	3,119	215	129	675
3	8,768	574	4,220	-277	-218	-58	3,061	215	122	646
4	8,942	585	4,304	-277	-214	-62	2,999	215	115	612
5	9,063	593	4,362	-277	-210	-67	2,932	215	183	880
6	9,577	627	4,609	-277	-205	-72	2,860	215	223	1,034
7	9,842	644	4,737	-277	-200	-77	2,784	215	235	1,078
8	9,935	650	4,782	-277	-195	-82	2,702	215	117	603
9	10,032	656	4,829	-277	-189	-88	2,614	215	126	631
10	10,127	663	4,874	-277	-183	-94	2,521	215	100	520
11	10,648	697	5,125	-277	-176	-100	2,420	215	-	-418
12	10,919	714	5,255	-277	-169	-107	2,313	215	177	816
13	11,019	721	5,303	-277	-162	-115	2,198	215	139	657
14	11,123	728	5,353	-277	-154	-123	2,075	215	103	505
15	11,224	734	5,402	-277	-145	-131	1,944	215	-	-125
16	11,870	777	5,713	-277	-136	-141	1,803	215	51	278
17	12,195	798	5,870	-277	-126	-151	1,652	215	51	269
18	12,288	804	5,914	-277	-116	-161	1,491	215	9	92
19	12,385	810	5,961	-277	-104	-172	1,319	215	33	174
20	12,479	816	6,006	-277	-92	-184	1,135	215	12	78
21	13,012	851	6,263	-277	-79	-197	937	215	-	-1,443
22	13,216	865	6,361	-277	-66	-211	726	215	-	-850
23	13,216	865	6,361	-277	-51	-226	500	215	-	-970
24	13,220	865	6,363	-277	-35	-242	259	215	-	-1,389
25	13,221	865	6,364	-277	-18	-259	0	215	-	-1,782
26	13,733	898	6,610					215	-	-1,286
27	13,936	912	6,708					215	-	-1,582
28	13,938	912	6,708					215	-	-2,061
29	13,939	912	6,709					215	-	-3,390
30	13,940	912	6,710					215	-	-3,623

**Unit in million THB*

Table 3. Expected present value ($E[NPV]$) of each alternative (million Thai baht).

Entity	**A1: Contract renewal (30-year)**	**A2: Contract expiration (30-year)**	**A1: Contract renewal (15-year)**	**A2: Contract expiration (15-year)**
Government (Value Added Tax)	12,322	12,322	7,075	7,075
Contracting Authority (*A*)	59,951	56,443	41,052	40,562
Government (Corporate Tax)	1,466	0	1,123	0
Concessionaire (*C*)	0	0	0	0
Revenue sharing rate	51.5%	-	51.5%	-
Total	**73,739**	**68,765**	**49,250**	**47,637**

In Table 2, when the duration of the contract is assumed to be 30 years, the revenue sharing rate (λ_u) can be determined by making the net present value of the concessionaire's benefits equal to zero (i.e., $E[NPV(C_{A1,t};\lambda_u,r_E)]=0$). The upper bound of revenue sharing rate in the case of *Alternative A1* with a 30-year contract is therefore about 51.5%.

Expected net present value ($E[NPV]$) associated with each party for all remaining alternatives can be estimated as presented in Table 3.

Based on the comparison of NPV shown in Table 3, the contracting authority may opt to negotiate a 30-year contract (of course, only with an exit clause included) because the increased benefit of the PPP renewal (i.e., the difference between NPV[*A1*] and NPV[*A2*]) is about 7% for a 30-year period, compared with just 3% for a 15-year contract.

7.3. Sensitivity Analysis

The base case analysis implies that a 30-year PPP contract may, in theory, benefit the contracting agency more than would a 15-year contract (see Table 2). Therefore, we will use the case of a 30-year contract for the sensitivity analysis in order to determine which input has the greatest impact on the concessionaire's NPV, based on Eq. (7). As shown in Eq. (7), key risk variables include traffic demand (T_t), toll prices (α_t), and average unit operation costs ($\hat{\gamma}_t$). As for credit spread charged by lenders (s), in this study, this variable was not included in the sensitivity analysis because interest rates are expected to remain low and the principal of the loan will be repaid over a loan period of 25 years, which can help reduce the risk of interest fluctuation. The assumptions and results of this sensitivity analysis are shown in Table 4 and Fig. 12.

Table 4. Inputs and percentage of sensitivity.

Input	Base case	% Sensitivity	Low	High
Realized traffic demand	$\hat{T}_t$	30%	$0.7\hat{T}_t$	$1.3\hat{T}_t$
Average toll price	$\hat{\alpha}_t$	20%	$0.8\hat{\alpha}_t$	$1.2\hat{\alpha}_t$
Average unit operating cost	$\hat{\gamma}_t$	20%	$0.8\gamma_t$	$1.2\gamma_t$

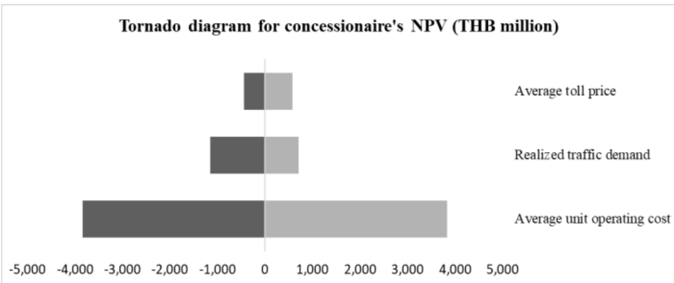

Fig. 12. Tornado diagram for concessionaire's NPV.

As can be seen in Fig. 12, unit operating cost (λ_t) is the input that has the greatest impact on the concessionaire's NPV. This input variable will then be used as the risk variable for risk analysis using Monte Carlo simulation.

7.4. Monte Carlo simulation

To determine the possible range of a concessionaire's NPV resulting from uncertainty of operating cost, a Monte Carlo simulation is performed where the unit operating cost is assumed to follow a normal distribution with a mean of $\hat{\gamma}_t$ and a coefficient of variation of 20%. Therefore, the stochastic variable unit operating cost is modelled as

$$X_t = N\left(\mu_X = \hat{\gamma}_t, \sigma = 0.2\mu_X\right) \tag{15}$$

For example, for year 1 and year 2 the unit operating costs are modelled as

$$X_{t=1} = N\left(\mu_X = 11.83, \sigma = 2.37\right)$$

$$X_{t=2} = N\left(\mu_X = 10.64, \sigma = 2.13\right)$$

Probability density of $X_{t=1}$ is shown in Fig. 13.

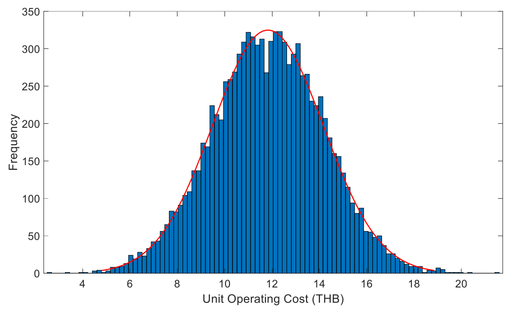

Fig. 13. Probability density of unit operating costs for year 1 ($X_{t=1}$).

7.5. Results of the Analysis

The results of 10,000 simulations using MATLAB are presented in Fig. 13.

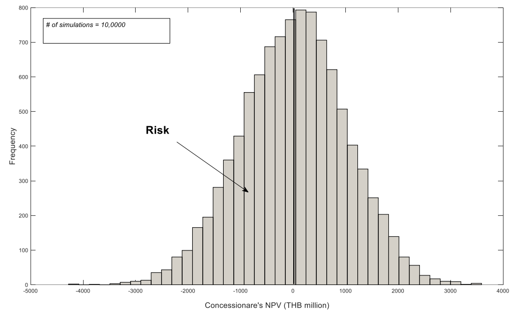

Fig. 14. Simulation of concessionaire's risk profile.

As illustrated in Fig. 14, by using a revenue sharing rate of 51.5% ($\lambda = 0.515$), the expected NPV of the concessionaire is consistent with the theoretical value. However, there is a high risk that the concessionaire's NPV will be negative. Therefore, concessionaire is likely to negotiate to reduce the level of risk. With our proposed model, the concessionaire's NPV and risk profile associated with a revenue sharing rate (λ) can be determined; the results are shown graphically in Fig. 15.

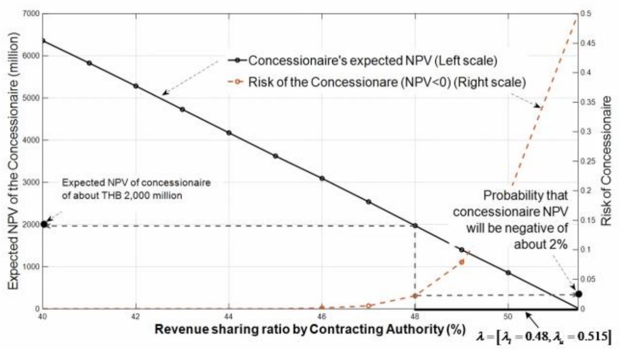

Fig. 15. Concessionaire's risk profile associated with each revenue sharing rate (λ).

Based on the results shown in Fig. 15, the range of revenue sharing rate, i.e., $[\lambda_l, \lambda_u]$ may be specified as $[\lambda_l = 0.48, \lambda_u = 0.515]$. As can be seen in Fig. 15, the concessionaire's NPV-at-risk at a revenue sharing rate of 48% ($\lambda_l = 0.48$) is about THB 2,000 million, with the probability of having negative NPV of about 2%. However, if the contracting authority were to increase its revenue share from the lower bound of 48% to the upper bound of 51.5% ($\lambda_u = 0.515$), the concessionaire's NPV-at-risk would be reduced from about THB 2,000 million to 0 million, with the probability of having negative NPV of about 50%.

8. Conclusions

PPP arrangements are undoubtedly increasing in popularity. Obviously, in the future, the concession contracts of these PPP projects will expire. Therefore, a decision about whether to renew or to end each contract -- that is, whether to renew the concession contract with the incumbent concessionaire for a certain period of years or to let the concession expire -- must be made by the responsible contracting agency. In this paper, we have proposed a computational framework based on a Monte Carlo simulation and risk premium approach for determining the contract duration and optimal revenue sharing rate. Our proposed model makes use of sensitivity analysis and Monte Carlo simulation with the aim of providing the expected NPV-at-risk of the concessionaire and the risk profile of the renewed contract based on different revenue sharing rates so as to bracket an appropriate range for revenue shares, i.e., $[\lambda_l, \lambda_u]$, which can be employed by the contracting agency in negotiating with the incumbent.

We then applied the proposed model to the SSES project, a BTO elevated road located in Bangkok, Thailand. Based on the results of the study, which used the proposed method for the case project, it was shown that the contracting authority should renew the concession contract *only when the revenue sharing rate is at least* 48%.

However, in case of PPP infrastructure projects, the first and greenfield concession period is rather long, i.e., 30 years in our case. Therefore, at the concession expiration, the project may have almost reached its maximum level of services, thereby capping maximum revenues, while operation and maintenance costs are increasingly significant risk factors since the project will be more costly to operate. Therefore, we suggest that a longer-term contract should be used *only* with an *early termination clause* that may be exercised when the concessionaire seriously fails to meet output performance. For example, the contract may include a 5-year re-evaluation for performance in order for the contract to be continued. It is our hope that the proposed model presented in this study will be used by governments as an additional tool for analyzing concession duration and revenue sharing rates so that they can negotiate effectively with incumbents or establish a fair price when a competitive retendering process is considered by the contracting authority.

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