



# A royalty negotiation model for BOT (build–operate–transfer) projects: The operational revenue-based model

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## ABSTRACT

Whilst few studies have explored royalty negotiations for build, operate and transfer (BOT) projects, some works have proposed numerous royalty formulas to evaluate royalty amounts or franchise fees for a BOT project. Despite this, the royalty negotiation process is one of the many critical negotiation items of a concession contract. This study not only developed a royalty negotiation model for BOT projects, but also developed the iterative algorithm for the BLP problem for the government and the private sector. In addition, the factors incorporated into the iterative algorithm for the BLP problem include the concession rate, learning rate, and the time value discount rate for both parties. Moreover, this paper conducted a case study of the Taipei Port Container Logistic BOT Project using LINGO and MATLAB programming. The results show that the two parties involved completed royalty negotiation at the sixth negotiation. The objective function value for lower-level programming was 1.062 and the government finance recovery rate for higher-level programming was 11.832. The findings show that the government can receive the royalty, which is calculated by using 0.012% of the operating revenue of this BOT project, from the concessionaire. Therefore, the royalty negotiation model based on the operating revenue developed herein; could be employed to explain the negotiation behavior.

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## 1. Introduction

The Build, Operate and Transfer (BOT) is a project financing approach in which a private entity receives a concession from the private or public sector to finance, design, contract, and operate a facility for a specific period, often as long as 20 or 30 years. After the concession periods ends, the ownership is transferred back to the granting entity. During the concession period the project proponent is allowed to charge the users of the facility appropriate tolls, fees, rentals, and charges stated in the concession contract [1,2]. This enables the project proponent to recover its investment, operating and maintenance expenses in the project. The BOT approach has been widely employed to implement infrastructure projects, including rail, port, telecommunications, toll road, and highway, etc., in many developed and developing countries around the world [1]. Some BOT cases are the 80 km elevated toll expressway in metropolitan Bangkok in Thailand; the 1200 MW Hab River Project in Pakistan; the 300 MW coal-fired projects in the Philippines; Mexico's 5400 km BOT road-building project; and the Europe Disneyland project, and so on [1].

The royalty should be written in the BOT agreement through the negotiation by both parties [3]. Obviously, it is a revenue sharing scheme between the government and private sectors through the bargaining process for a BOT concession contract. The government or private sector can adopt many methods for royalty computation, such as pre-tax profit-based royalty,

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total revenue-based royalty, lump-sum royalty, patronage-based royalty and so on [4]. In Taiwan, many infrastructure projects, including the High Speed Rail Project (HSRBOT) and Taipei Port Container Logistic BOT Project, have also been carried out using the BOT approach according to the Act for Facilitation of Private Participation in Infrastructure Projects (AFPPIP) enacted by the Ministry of Transportation and Communications (MOTC). The lump-sum royalty levied is NT\$ 30 billion which is calculated according to the fixed royalty method of the 101 Skyscraper BOT Project in 1998. The royalty, which includes 10% of the pre-tax of annual operation benefit for the High Speed Rail BOT project of concessionaire, should be paid to the government [4,5].

Many issues relevant to risk-sharing or revenue-sharing, for BOT projects should be investigated from the negotiation viewpoint. Some issues are, for instance, determining the concession period, identifying the price and production level, and taking over a BOT project, etc. Shen et al. [6], Xing and Wu [7], Yang and Meng [8] have investigated these issues from the negotiation perspective. Recently, although some researches have pointed out many royalty models from the viewpoints of the government or private sectors [3,9]. The research of Chiou and Lan [3] does not fully reflect the bargaining behavior for two parties from the negotiation perspective. Thus, this study extends the researches of Chiou and Lan [3] and Kang et al. [9, 10] to make a case study for analyzing the royalty determination in application in the BOT case. Therefore, the purpose of this paper is to construct the royalty negotiation model from the negotiation viewpoint and to determine the royalty for a BOT project. The remainder of the paper is structured as follows: Section 2 is a literature review. Section 3 describes the research problem. Section 4 constructs a royalty negotiation model and solution algorithm. Section 5 presents a numerical example. Finally, a discussion is presented and conclusions are drawn.

## 2. Literature review

Many researches have been conducted in risk evaluation, risk management and financing viability in BOT projects to allocate risk for a BOT project [1,2]. For example, Ranasinghe [11] used the NPV index to analyze the financial viability of private-sector participation in new infrastructure. Chang and Chen [12] simulated the financial viability changes for the High Speed Rail BOT project in Taiwan with the royalty as a given variable. Farrell [13] introduced many financial engineering methods to measure the financial ability for BOT projects. The uncertainty of demand was incorporated into a bi-level programming model which Chen et al. [14] have developed to assess the financial feasibility of a BOT project. On the other hand, Kang et al. [2] used the utility theory to develop the dynamic utility programming model to assess risk and to identify risk factors among the uncertainty from the decision-making group perspective.

Recently, some researches constructed royalty formulas using mathematical programming, fuzzy mathematical programming, simulation, or financial engineering methods for a BOT project. For instance, Chiou, and Lan [3] developed a royalty model using mathematical programming and fuzzy mathematical programming models for analyzing different types of royalty formulas which are pre-tax profit-based, total revenue-based, and patronage-based. Moreover, Kang et al. [9,10] constructed royalty models for a BOT project using mathematical programming and financial cash flow from the government and private sector's viewpoints, respectively. Kang et al. [9,10] have pointed that the royalty model is one of revenue-sharing and risk-sharing policies of a BOT concession contract. Governments use the royalty amount to recover their investment on a BOT project in order to share risk with the other party. Their findings reveal that royalty exists in the upper and lower bounded value from the viewpoints of the two parties. And the royalty amount for determining for a BOT project should be negotiated for two parties during the negotiation phase. However, the authors ignored the royalty negotiation issue for private and public sectors although Chiou and Lan [3] and Kang et al. [9] have proposed many different royalty models.

A number of researches have been undertaken on the negotiation or bargain modeling to determine the price (toll charge) and the operation quantity level, or to identify the concession period of a BOT project [6–8]. For instance, Xing and Wu [7] used bi-level programming to construct the Stackelberg game model for determining the price and production quantity of a power utility in a BOT project. Yang and Meng [8] explored toll scheme of a highway network using bi-level programming under the highway Build–Operation–Transfer mechanism. Lin and Chang [15] presented the negotiating process of BOT projects using the Cross model [16] to establish mathematical models for concession contract negotiation. Moreover, Chen and Subprason [17] incorporated demand uncertainty into the BOT network design problem that have provided the stochastic bi-level programming formulation using the genetic algorithm (GA) procedure to maximize the expected profit for the government and private sectors and to minimize the inequality of benefit among the road users. Additionally, Shen et al. [6] used the bargaining game theory to identify a concession period of a BOT project. The authors proposed a build–operate–transfer concession model (BOTCM) to identify a specific concession period which takes into account the bargaining behavior of the two concerned parties in engaging a BOT contract. In this paper, we utilize the bi-level programming approach to formulate royalty negotiation model and to determine royalty in a BOT scheme from the negotiation perspectives. A case study of the Taipei seaport BOT project in Taiwan is used as an example.

## 3. Problem description

### 3.1. Assumptions of the model development

These theories, including the game theory, bargaining theory, or bi-level programming (BLP), have been widely applied to analyze resource allocation, price determining, wage determining, Stackelberg duopoly model for economic policy or

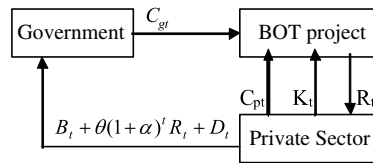


Fig. 1. Concept of an annual royalty in a BOT project, the operational revenue-based case.

BOT project and so on [18–20]. Based on researches on the bargaining-game or BLP above, the authors have made some assumptions about their models on the number of players, competent information, rational behavior, bargaining cost, and time value and so on. Hence, following the above-mentioned research, we made some assumptions for the development model as follows:

- (1) Two parties, the government concerned and the private investor commit a BOT contract with rational behavior during the negotiation. The rational behavior means that both parties will calculate and compare adequately all the possible outcomes to protect their own interests and pursue their own profit.
- (2) The two parties share the full and same information about the BOT project concerned to ensure that they can respond to each other clearly.
- (3) This study assumes that the concession period of a BOT project contains the construction period ( $t = 0 \sim n$ ) and the operation period ( $t = n + 1 \sim N$ ). We also assume that the government has no affiliated business income, no joint-development income, no subsidies to the private sector, and the salvage value of the fixed asset of the BOT project is not considered. After the concession period expires, the facilities of the BOT project should be returned to the government unconditionally. Moreover, we assume that the government investment is totally capitalized by debt and the planning cost of the government is not considered. And we also assume that the royalty is not tax-deductible. The annual royalty of government is received from the concessionaire at the  $h$ th year of the operation period; where  $h$  is the first year for royalty-collection. The capital cost of the BOT project is evaluated by the Weighted Average Cost of Capital (WACC) method.

### 3.2. The concept of financing BOT projects

The concept of financing a project proposed by Kang et al. [9,10] is utilized to describe the relationship of the annual royalty between the government investment and private investment. The concept is shown in Fig. 1.

Fig. 1 indicates that the fund resource for both construction and operation in a BOT project comes from the concessionaire and the government [9,10]. The construction cost of the project comprises  $C_{gt}$  and  $C_{pt}$ ; where  $C_{gt}$  and  $C_{pt}$  represent the government investment cost and the private investment cost at time  $t$  during the construction period, respectively; and  $K_t$  is the nominal operation cost at time  $t$  during the operation period. As Fig. 1 depicted, the term  $B_t + \theta(1 + \alpha)^t R_t + D_t$  is the sum of land-used rent, royalty, and tax. The  $\theta(1 + \alpha)^t R_t$  term is the royalty amount, it varies by  $R_t$ ,  $t$ ,  $\alpha$ , and  $\theta$ ; where  $\theta$  is the proportion of the operational revenue of the BOT project at time  $t$ . Thus, the  $B_t + \theta(1 + \alpha)^t R_t + D_t$  term indicates the concessionaire should pay the land-used rent, and operational revenue to the government.

## 4. Methodology

### 4.1. The model

As shown in Fig. 1, a causal relationship exists between royalty, government investment, private sector investment, and the government finance recovery ratio in the cash flow for BOT projects. The government finance recovery ratio for the operating revenue of a BOT project in which the royalty is calculated was defined as [9,10].

$$\Pi_{g,R}(k) = \frac{1}{C_g} [r_g + \theta(k) \times f_{g,R}] \tag{1}$$

where  $r_g = \sum_{t=0}^N \frac{B_t + D_t}{(1+i)^t}$ ;  $f_{g,R} = \sum_{t=h}^N \frac{(1+\alpha)^{t-h} R_t}{(1+d)^t}$  is a discount factor of royalty for the project;  $P_C = \frac{C_p}{C} = \frac{C_p}{C_g + C_p}$ ;  $h$  is the first year for royalty-collection;  $P_C$  is the rate of the concessionaire’s investment cost;  $C$  is the sum of the present value of construction costs which is discounted to the first year of the construction period;  $C_g$  is the sum of the present value of construction costs financed by government investment, and the cost is discounted to the first year of the construction period;  $C_p$  is the sum of the present value of construction costs financed by private investment, and the cost is discounted to the first year of the construction period; and  $i$  is the interest rate of government bonds.

Eq. (1) represents the government finance recovery ratio  $\Pi_{g,R}(k)$  at the  $k$ th negotiation. There exists a positive relationship between  $\Pi_{g,R}(k)$  and  $(r_g + \theta(k) \times f_{g,R})$ . That is, the more in royalty, tax, and land-used rent for the government, the higher the  $\Pi_{g,R}(k)$ . Thus,  $\Pi_{g,R}(k)$  goes up when variables of  $r_g$ ,  $\theta(k)$ , and  $f_{g,R}$  increase. Conversely,  $\Pi_{g,R}(k)$  decreases as  $P_C$  increases or variables of  $r_g$ ,  $\theta(k)$ , and  $f_{g,R}$  decrease.

Furthermore, let  $\Pi_{p,R}(k)$  be the profit index of the concessionaire.

$$\Pi_{p,R}(k) = \frac{N_I - \theta(k) \times f_{p,R}}{P_C \times C} \tag{2}$$

where  $N_I = \sum_{t=n+1}^N \frac{R_t - C_t - B_t - D_t}{(1+d)^t}$ ,  $N_I$  is the total revenue of the BOT project, which includes operation revenue and non-operational revenue;  $f_{p,R} = \sum_{t=h}^N \frac{(1+\alpha)^{t-h} R_t}{(1+d)^t}$ ,  $d$  is the risk adjusted discount ratio after tax of the concessionaire, where  $d > i$ . It can be estimated by the WACC with corporate tax as:

$$d = d_B \times (1 - T_c)' \times \left( \frac{B}{S + B} \right) + d_S \times \left( \frac{S}{S + B} \right) \tag{3}$$

where  $d_B$  is the cost of long-term debt of the BOT project for the private firm;  $d_S$  is the cost of equity of the BOT project for the private firm;  $B$  is the market value of the debt of the BOT project for the private firm;  $T_c$  is the marginal tax ratio of the BOT project; and  $S$  is the market value of the equity of the BOT project for the private firm.

The numerator of (2) is the net operation income minus royalty at the  $k$ th negotiation, and the denominator of (2) is the investment cost of the concessionaire. Eq. (2) stands for the profitability of private sector at the  $k$ th negotiation. It indicates that the concessionaire pursues its maximum financial profit at the  $k$ th negotiation if the private sector is a rational decision-maker.

According to Wen and Hsu [20], the authors have pointed that the BLP is a Stackelberg game associated with the leader and follower conception. This model can illustrate a sequential decision for two players who pursue their own maximized aims that are subject to another decision-making strategy. The government can be regarded as the higher-level problem of the BLP because the royalty was first announced by the government in the BOT tender document. Then, the private sector will negotiate with the government regarding the royalty. Hence, the private sector can be regarded as the lower-level problem of the BLP. The bi-level programming problem was formulated as

[Higher-level problem]:

$$\text{Max}_{\{g_u(k)\}} \Pi_{g,R}(k) = \frac{1}{C_g} [r_g + \theta(k) \times f_{g,R}] \tag{4}$$

$$\text{s.t. } \theta(k) \times f_g + C \times \Pi_{G0} \times P_C \geq C \times \Pi_{G0} - r_g \tag{5}$$

$$\theta(k) \leq (N_I - P_C \times C) / f_{p,R} \tag{6}$$

$$\theta(k) \geq \theta_\ell(k) \tag{7}$$

$$\theta(k) \leq \theta_u(k) \tag{8}$$

$$f_{g,R} = \sum_{t=h}^N \frac{(1 + \alpha)^{t-h} R_t}{(1 + i)^t} \tag{9}$$

$$f_{p,R} = \sum_{t=h}^N \frac{(1 + \alpha)^{t-h} R_t}{(1 + d)^t} \tag{10}$$

[Lower-level problem]:

$$\text{Max}_{\{g_\ell(k)\}} \Pi_{p,R}(k) = \frac{N_I - \theta(k) \times f_{p,R}}{P_C \times C} \tag{11}$$

$$\text{s.t. } \theta(k) \times f_{g,R} + C \times \Pi_{G0} \times P_C \geq C \times \Pi_{G0} - r_g \tag{12}$$

$$\theta(k) \leq (N_I - P_C \times C) / f_{p,R} \tag{13}$$

$$\theta(k) \geq \theta_\ell(k) \tag{14}$$

$$\theta(k) \leq \theta_u(k) \tag{15}$$

$$f_{g,R} = \sum_{t=h}^N \frac{(1 + \alpha)^{t-h} R_t}{(1 + i)^t} \tag{16}$$

$$f_{p,R} = \sum_{t=h}^N \frac{(1 + \alpha)^{t-h} R_t}{(1 + d)^t} \tag{17}$$

where  $\theta_\ell(k)$  is the lower bounded value of the feasible solution at the  $k$ th negotiation for the lower-level problem;  $\theta_u(k)$  is the upper bounded value of the feasible solution at the  $k$ th negotiation for the higher-level problem;  $\theta(k)$  is decision variable of the BLP problem.

Eq. (4) is the objective function of the higher-level problem. It illustrates that the government maximizes his financial recovery rate for joining a BOT project. Furthermore, Eq. (4) shows that the higher the royalty amount collected by the government is, the higher the  $\Pi_{g,R}(k)$  index is. These are the constraints of the higher-level problem from Eqs. (5)–(8). Eq. (5) shows that the host utility should collect the above minimum royalty level from the concessionaire in order to meet the minimum financial recovery rate  $\Pi_{G0}$ . Moreover, let  $\Pi_{G0}$  be a constant value. Eq. (6) describes that the royalty has been delivered by the private sector to the government which has upper bounded values for avoiding the deficit in operation.  $((N_I - P_C \times C)/f_{p,R}) \geq 0$  is held, because  $\theta(k)$  is a non-negative value. Eqs. (7) and (8) are the upper and lower bounded solutions for the higher-level problem, respectively.

Eq. (11) is the objective function of the lower-level problem, it illustrates that the private sector hopes to reduce the royalty to be paid, and to maximize its profit for each negotiation. These are constraints of the lower-level problem from Eqs. (12)–(17); and the meanings of Eqs. (12) and (13) are the same as those of Eqs. (5) and (6); and the illustrations of Eqs. (14) and (15) are also the same as those of Eqs. (7) and (8). Eqs. (16) and (17) are the discount factors of the decision variables for the higher-level and lower-level problems, respectively.

#### 4.2. Algorithm for BLP

A number of global optimization have been proposed including the vertex enumerate, the Kth-best algorithm, cutting planes or domain partition, Kuhn–Tucker transformation approach, branch and bound etc. to handle the nonconvexity programs [18,19]. The vertex enumeration approach is based on the simplex algorithm to find a feasible solution for the higher-level problem of the BLP problem, while the Kuhn–Tucker transformation approach converts the objective function of the lower-level problem into constraints of the higher-level problem [19–21]. Recently, the most recent development on heuristics for solving bi-level programs including genetic algorithms (GA), Tabu search, and simulated annealing approaches. It is likely that Chen and Subprasom [17] used the GA approach for solving the optimization in toll charge for BOT project. Calvete et al. [22] have also proposed an algorithm which combined classical extreme point enumeration techniques and genetic algorithms for solving linear bi-level problems.

From the above-mentioned studies, both of those solving techniques for bi-level problems are used to handle nonconvexity programs and to find global optimization. It means that the global or local optimization of BLP does not have a tolerance of error in the theory perspective. However, in a real royalty negotiation environment, the royalty determination represents the “comprisal solution” of two parties regarding the royalty negotiation. The “comprisal solution” implies that a minor error or tolerance of error of the negotiation exists. Therefore, the royalty determination is influenced by the tolerance of error that two parties can accept. Thus, we develop an “iterative algorithm” for the BLP problem. The steps of the iterative algorithm are as follows:

Step 0: Let  $k = 0$  and  $k = k + 1$ .

Step 1: Find a feasible solution for the higher-level problem.

Step 2: Find a feasible solution for the lower-level problem.

Step 3: Converge the test for these feasible solutions for the BLP problem. If all solutions converge, then the comprisal solution exists; otherwise, go to Step 4.

In this step, we set the convergence test based on the differences in the royalty amount the government and the private sector are willing to pay being smaller than the level of error tolerated. The condition is defined as:

$$\left| \frac{\theta(k) - \theta_\ell(k)}{\theta_\ell(k)} \right| \leq \delta \quad \text{and} \quad \left| \frac{\theta(k) - \theta_u(k)}{\theta_u(k)} \right| \leq \delta \tag{18}$$

where  $\delta$  is the error tolerated; for illustration, we assumed  $\delta = 0.01$ . If the solutions of BLP satisfy the convergence test condition, then the royalty negotiation is ceased.

Step 4: Set initial concession rates for the two parties, and let  $k \neq 0$ . Substitute concession rates into Eqs. (19) and (20), and find  $\theta_\ell(k + 1)$  and  $\theta_u(k + 1)$ .

Step 5: Find the concession rates at the next negotiation,  $\theta_u(k + 1)$  and  $\theta_\ell(k + 1)$ .

Step 6: Repeat Steps 0–5. The solution of the BLP problem will be obtained if the solution from convergence testing holds, if not, there is no solution, and thus stop the algorithm.

Although Xing and Wu [6], Yang and Meng [7] utilized the bi-level programming model for determining the price (or toll) and capacity using different algorithms under the BOT scheme, they do not explore the effect of learning effect, concession rate and time value discount of players changes. Nevertheless, these factors which are regarded as factors of bargaining cost, addressed by Cross [16], are very important impact factors for the bargaining process. Thus, these factors of a bargaining cost have incorporated into the BOT bargaining model studies (Shen et al. [5]; Lin and Chaing [15]).

Following the concept of Cross [16] and Lin and Chaing [15], values of the concession rate for two parties were shown in Eqs. (19) and (20), respectively [15,16].

$$r_u(k) = \frac{(buvr_\ell(k - 1) + (ab(1 - \frac{v}{2})(1 + \frac{u}{2}) - uv)r_u(k - 1))}{(ab(1 + \frac{u}{2})(1 + \frac{v}{2}) - uv)} \tag{19}$$

$$r_\ell(k) = \frac{(\text{auvr}_u(k-1) + (ab(1 - \frac{\mu}{2})(1 + \frac{\nu}{2}) - uv)r_\ell(k-1))}{(ab(1 + \frac{\mu}{2})(1 + \frac{\nu}{2}) - uv)} \quad (20)$$

where  $r_u(k)$  and  $r_\ell(k)$  are concession rates at the  $k$ th negotiation for the higher-level and lower-level programming problems, respectively; similarly,  $r_u(k-1)$  and  $r_\ell(k-1)$  are the concession rates at the  $(k-1)$ th negotiation. Variables of  $a$  and  $b$  are the time value discounts of the higher-level and lower-level programming problems, respectively. Let  $a$  and  $b$  be constant values. Let  $\mu$  and  $\nu$  be the learning rates for the higher-level and lower-level programming problems, respectively. Assume  $\mu$  and  $\nu$  are constant. Eqs. (19) and (20) were proposed by Lin and Chaing [15] which are based on the assumptions by Cross [16]. For illustration, this study uses Eqs. (19) and (20) to find the reaction of concession rate for two parties. As noted, Eqs. (19) and (20) should be reexamined and modified for future study.

Eq. (19) demonstrates that the concession rate at the  $k$ th negotiation for the higher-level programming problems were affected by  $r_\ell(k-1)$ ,  $r_u(k-1)$ ,  $u$ ,  $v$ ,  $a$ , and  $b$ . Similarly,  $r_\ell(k)$  in Eq. (20) it was affected by  $r_\ell(k-1)$ ,  $r_u(k-1)$ ,  $u$ ,  $v$ ,  $a$ , and  $b$ . This implies that the royalty negotiation between the government or concessionaire was reflected by the concession rate of both parties. Then, Eqs. (19) and (20) were substituted into (21)–(24) and  $\theta_u(k+1)$  and  $\theta_\ell(k+1)$  of the higher-level and the lower-level programming were modified, respectively.

$$\theta_u(k+1) = \theta_u(k) - \theta_u(k) \times r_u(k) \quad (21)$$

$$\theta_\ell(k+1) = \theta_\ell(k) + \theta_\ell(k) \times r_u(k) \quad (22)$$

$$\theta_u(k+1) = \theta_u(k) - \theta_u(k) \times r_\ell(k) \quad (23)$$

$$\theta_\ell(k+1) = \theta_\ell(k) + \theta_\ell(k) \times r_\ell(k) \quad (24)$$

where  $\theta_u(k)$  and  $\theta_\ell(k)$  are the upper and lower bounded value at the  $k$ th negotiation for the higher-level and the lower-level programming, respectively.  $\theta_u(k+1)$  and  $\theta_\ell(k+1)$  are the upper and lower bounded value at the  $(k+1)$ th negotiation, respectively.

## 5. Case study

### 5.1. Taipei port container logistic BOT project

A case study using the financial data from the Container Terminal in Taipei Port BOT Project was conducted to illustrate the applicability of the proposed model. According to the Terms of Reference (TOR) of Concessions of the Container Terminal in Taipei Port issued by the Keelung Harbor Bureau in 2000 [23], some of the key points of this project are described as follows:

- (a) The scope of this BOT project includes seven wharves in the container terminal.
- (b) The duration of the concession period of this project is 50 years. The construction period would be from 2001 to 2010. According to the TOR of this BOT project, the concessionaire will construct seven wharves, among which wharves 6 and 7 (W6 and W7) would be completed first at the end of 2004 and commence operation in the beginning of 2005. W6–W9 and the container yard would be completed at the end of 2007. All the other wharves, W10–W12, would be completed by the end of 2010 and commence operation in 2011.
- (c) The annual container handling volume of W6 and W7 from 2005 to 2006 is assumed to be 500,000 TEUs. By 2008, the assumed annual container handling volume for four wharves would be 1,000,000 TEUs. From 2011 until 2050, the end of the concession period, the seven wharves would maintain 1,750,000 TEUs.
- (d) The basic corporate income tax rate is 25%; however, according to the AFPPIP, the concessionaire could have corporate income tax exemption for up to 5 years. Therefore, it was assumed that the tax exemption period would be between 2005 and 2009.
- (e) The interest rate of government bonds was assumed to be 8%. The inflation rate was assumed to be 3.5%.

Some of the items and assumptions of this BOT project are summarized in Table 1.

According to Table 1, the construction period is from 2001 to 2004 ( $n = 3$ ), and the operating period is from 2005 to 2050 during which royalty collection begins in 2011; hence  $h = 10$ . According to the TOR of this BOT project, the private sector investment rate of the total investment is 94% and the government investment rate of the total investment is 6%. On the other hand, the government investment items such as construction of access roads, land acquisition, and basic utility infrastructures are assumed to account for 10% of the total cost of this project, which is approximately NT\$ 653 million,  $L = 653$ ; where  $L$  is the sum of the present value of the part of construction cost which the government agrees to pay. Moreover, it was assumed that the discount rate is 10%,  $d = 10\%$ , and the annual cash flow occurs at the end of each year.

As for the concession rate, although Cross [16] proposed the concession rate formula, however, in application of the bargaining model, he assumed the concession rate of the player I and player II are given. Following concept of Cross [16, pp. 92–93], Chaing and Lin [15] have also assumed the concession rate values of government and private sectors are constant. For illustration, we followed the concept of Cross [16] and assumed the initial concession rate of government and private firms are 20% and 17%, respectively because the concession rate of the government and private firm cannot be inquired using a questionnaire or other investigative methodologies during the negotiation period. Furthermore, we also assumed the time value discount and the learning rate are the same in two parties. That is  $a = b = 0.2$  and  $\mu = \nu = 0.1$  [15,16].

**Table 1**  
Summary of TOR of container terminal in Taipei port BOT project.

Item	Summary
Concession period	50 years
Implementation schedule	Contract negotiation phase: 2001, Construction period: 2001–2007, Operating period: 2005–2050
No. of wharves	7
Total project installation cost (Including government-related costs)	\$US332.14 million (2001 currency)
Project phase and scales	a. 2005–06, for 2 wharves: 0.5 million TEU/year b. 2007, for 3 wharves: 0.8 million TEU/year c. 2008, for 4 wharves: 1.0 million TEU/year d. 2011–2050, for 7 wharves: 1.75 million TEU/year
Concession scope	a. 7 wharves and storage yard with exclusive operation rights and land superficies b. Operation scope: vessel berthing, container loading/unloading, transshipping, transportation, warehouse and storage, and container repair business
Interest rate of government bonds	8%
Corporate income tax exemption	Maximum of 5 years, exemption period 2005–2009 corporate income tax rate is 25%
Subsidy	No subsidy

Sources: Terms of Reference (TOR) of “Concessions of container terminal in Taipei port”.

**Table 2**  
Result of simulated royalty negotiation.

No. of negotiations	$r_u(k)$	$r_l(k)$	$\theta_u(k)$	$\theta_l(k)$	$\Pi_{G,R}(k)$	$\Pi_{P,R}(k)$
$k = 0$	0.200	0.170	0.032	0.006	13.252	1.082
$k = 1$	0.185	0.161	0.025	0.007	12.790	1.078
$k = 2$	0.172	0.152	0.021	0.008	12.447	1.075
$k = 3$	0.160	0.143	0.017	0.009	12.187	1.071
$k = 4$	0.148	0.135	0.014	0.011	11.988	1.067
$k = 5$	0.138	0.127	0.012	0.012	11.832	1.062

## 5.2. Results of model application

The financial data of this BOT project were substituted into the BLP problem and the algorithm was implemented; both LINGO and MATLAB programming were used, which involve the iterative algorithm and concession rates, to simulate the bargaining process for royalty negotiation for both parties.

The initial solution of higher-level programming is  $\theta_u(k = 0) = 0.032$  whilst that of the lower-level programming is  $\theta_l(k = 0) = 0.006$ .  $\theta_u(k = 0) = 0.032$  illustrates that the government first wants to receive the royalty from 0.032% of the operation revenue during the period from the concessionaire according to the announced TOR of this project. However,  $\theta_l(k = 0) = 0.006$ , which shows that the private firm pays only the 0.006% of the operating revenue to the government. The convergence test is not held. Then, substitute the assumed concession rates of  $r_u(k = 0) = 20\%$  and  $r_l(k = 0) = 17\%$ , time value discount rates of  $a = 0.2$  and  $b = 0.2$ , and learning rates of  $\mu = 0.1$  and  $\nu = 0.1$  into Eqs. (19)–(24) to modify the concession rate the next negotiation for two parties. Steps 0–5 of the iterative algorithm were repeated. Results are shown in Table 2.

As reported in Table 2, the solutions are  $\theta_u(k = 5) = 0.012$  and  $\theta_l(k = 5) = 0.012$  for higher-level programming and lower-level programming, respectively. As shown, the convergence test solution for the BLP problem was held. It reflects that the royalty negotiation for the two parties finished at  $k = 5$ . The solutions  $\theta_u(k) = 0.012$  and  $\theta_l(k) = 0.012$  for higher-level programming and lower-level programming are obtained, respectively. Thus, we find  $\theta(k = 5) = 0.012$  for the BLP. As a consequence, results reveal that the government can charge a royalty which is calculated as 0.012% of the operational revenue of this BOT project from the concessionaire. In addition, the objective function values,  $\Pi_{G,R}(k = 5) = 11.832$  and  $\Pi_{P,R}(k = 5) = 1.062$ , for the two parties can also be found, respectively. It demonstrates that the government can get the finance recovery ratio 11.832 times of its investment cost and the concessionaire has an operational benefit of 1.062 based on the royalty negotiation.

As shown in Table 2, we can clearly find that changes in the concession rates of two parties affect the number of the negotiation. At the same time, those concession rates of two parties impact in their objective functions. In addition, results of case study indicate the relationship between royalty and number of negotiations. Clearly, it shows that  $\Pi_{G,R}(k)$  decreases from 13.252 to 11.832 when the number of negotiations increases. Similarly,  $\Pi_{P,R}(k)$  decreases from 1.082 to 1.062 as  $k$  increases. Therefore, Table 2 reveals that the decrease in the concession rates of the two parties contribute to successful royalty negotiations.

**Table 3**  
Result of sensitivity analysis for the operational revenue-based royalty model.

Items	$k$	$\theta_u(k)$	$\theta_l(k)$	$\Pi_{G,R}(k)$	$\Pi_{P,R}(k)$
$r_u(k) = 0.2, r_l(k) = 0.04$	8	0.00941	0.00924	11.6261	1.0721
$r_u(k) = 0.2, r_l(k) = 0.07$	7	0.01000	0.00988	11.6770	1.0695
$r_u(k) = 0.2, r_l(k) = 0.11$	6	0.01100	0.01080	11.7441	1.0664
$r_u(k) = 0.2, r_l(k) = 0.17$	5	0.01220	0.01210	11.8324	1.0621
$r_u(k) = 0.2, r_l(k) = 0.25$	4	0.01400	0.01370	11.9583	1.0581
$r_u(k) = 0.2, r_l(k) = 0.42$	3	0.01620	0.01590	12.1268	1.0506

Note: the case of fixed  $r_u(k)$  and changed  $r_l(k)$ .

**Table 4**  
Result of sensitivity analysis for the operational revenue-based royalty model.

Items	$k$	$\theta_u(k)$	$\theta_l(k)$	$\Pi_{G,R}(k)$	$\Pi_{P,R}(k)$
$r_u(k) = 0.04, r_l(k) = 0.17$	11	0.0183	0.01810	12.2857	1.0435
$r_u(k) = 0.09, r_l(k) = 0.17$	8	0.0160	0.01570	12.1038	1.0516
$r_u(k) = 0.12, r_l(k) = 0.17$	7	0.0146	0.01450	12.0030	1.0547
$r_u(k) = 0.2, r_l(k) = 0.17$	5	0.0122	0.01210	11.8324	1.0621
$r_u(k) = 0.26, r_l(k) = 0.17$	4	0.0111	0.01090	11.7541	1.0661
$r_u(k) = 0.36, r_l(k) = 0.17$	3	0.0096	0.00959	11.6423	1.0702

Note: the case of varying  $r_u(k)$  and fixing  $r_l(k)$ .

In summary, findings of the case study illustrate that the royalty which the government is concerned about decreases as the number of negotiations increase. This means that the concessionaire is willing to pay more when the number of negotiations increase. Thus, it clearly shows that changes in the concession rates of two parties affect the number of the negotiations. At the same time, the concession rates of two parties affect change in the objective functions for these models.

### 5.3. Sensitivity analysis

As reported in Table 2, changes in the concession rate of both parties will lead to variations in  $\Pi_{G,R}(k)$ ,  $\Pi_{P,R}(k)$ ,  $\theta_u(k)$  and  $\theta_l(k)$ . Therefore, in this section, a sensitivity analysis among  $r_u(k)$ ,  $r_l(k)$ ,  $\Pi_{G,R}(k)$ ,  $\Pi_{P,R}(k)$ ,  $\theta_u(k)$  and  $\theta_l(k)$  was conducted. Two cases are considered: firstly, where  $r_u(k)$  is fixed but  $r_l(k)$  varies; and secondly where  $r_u(k)$  varies whilst  $r_l(k)$  remains fixed.

Case(1)  $r_u(k)$  is fixed whilst  $r_l(k)$  varies.

Tables 3 and 4 indicate that both  $\theta_u(k)$  and  $\theta_l(k)$  will decrease, when  $r_l(k)$  changes with  $r_u(k)$  kept constant. Thus,  $\Pi_{P,R}(k)$  decreased from 1.0721 to 1.0506 whilst  $r_l(k)$  increased from 0.04 to 0.42 as  $\Pi_{G,R}(k)$  increased from 11.6261 to 12.1268. On the other hand, as indicated in Table 4,  $\Pi_{P,R}(k)$  increased from 1.0435 to 1.0702 whilst  $\Pi_{G,R}(k)$  decreased from 12.2857 to 11.6423 as  $r_u(k)$  increased from 0.04 to 0.36. In addition, Tables 3 and 4 show that a decrease in  $r_u(k)$  with  $r_l(k)$  kept constant will also increase the number of negotiations  $k$ . However, an increase in  $r_u(k)$  with  $r_l(k)$  kept constant will decrease as the number of negotiation  $k$  decreases. At the same time,  $\Pi_{G,R}(k)$  decreased when the  $r_u(k)$  increased rapidly; but  $\Pi_{P,R}(k)$  increased when the  $r_u(k)$  increased.

Case(2)  $r_u(k)$  varies whilst  $r_l(k)$  is fixed.

Similarly, we investigate the sensitivity analysis as  $r_u(k)$  is changed but  $r_l(k)$  is fixed. This case can also be classified into two conditions, decreasing and increasing in  $r_u(k)$  and  $r_l(k)$  is fixed. Results of this analysis were summarized as Table 4. As Table 4 indicates, for a decrease in  $r_u(k)$  and  $r_l(k)$  fixed, the number of negotiation  $k$  increases when the variable  $r_u(k)$  decreases; while the number of negotiation  $k$  decreases when variable  $r_u(k)$  increases. At the same time,  $\Pi_{G,R}(k)$  decreases as  $r_u(k)$  increases rapidly; but  $\Pi_{P,R}(k)$  increases as  $r_u(k)$  increases. Results of Table 4 show  $\Pi_{P,R}(k)$  will increase from 1.0435 to 1.0702 as  $r_u(k)$  increases from 0.04 to 0.36; however,  $\Pi_{G,R}(k)$  decreases from 12.2857 to 11.6423.

From the previous sensitivity analysis, we realize clearly that changes in the concession rate for both parties affect the number of negotiations. In other words, if either party keeps the concession rate constant, the negotiation for royalty will not be easily settled, and the number of negotiations required will increase.

### 5.4. Discussion and implications

As analyzed in Sections 4.2 and 5.3, the objective function values, results of this study demonstrate that the model development for royalty determining by BLP could be applied to investigate or simulate the negotiation process for two parties. However, some issues are discussed as follows:

- (1) Many algorithms, GA, Tabu search or other algorithms, can be used to solve the BLP problem (Bard [19]; Calvete et al., [22]). The previous algorithms provide research to find the global optimization of BLP. But, in this article, the



solution of the BLP using the developed “iterative algorithm” represents the “compromising solution” of two parties. It is different from global optimization, obtained by GA or other optimization algorithms.

- (2) In contrast to traditional negotiation and bargaining theories, the concession rate, learning effect, time value are regarded as factors of the bargaining process which were addressed by Cross [16]. Shen et al. [5], Lin and Chaing [15] have also adopted the concept of Cross [16] to investigate the concession period and revenue-sharing determining for a BOT project. Similarly, we also used the concept and formulas by Cross [16] and Lin and Chaing [15] to analyze the royalty determining for a BOT project. Unlike Shen et al. [5] using the Rubinstein model and Lin and Chaing [15] adopting the Cross model, this study adopts the BLP approach. However, values of concession rates, time value discount rate and learning effect are given in this study, research can use the questionnaire method to get the information of the investigating negotiators’ learning, concession rate, and time value discount rate for each bargaining. On the other hand, factors of the negotiators’ risk attitude and negotiation cost could also be incorporated into the concession rate formulas as Eqs. (17) and (18) for the further study.
- (3) As for managerial implications, this paper proposes a royalty negotiation analysis framework for a BOT project. It can be applied to analyze other methods which are lump-sum, quantity-based etc. to determine the royalty amount for the government or private sectors. Also some alternative royalty methods that government and private sectors are concerned about for a BOT project can be compared using this analytical analysis on this model and algorithm. The proposal model could be extended to analyze royalty determination for multiple issues royalty-determining for mixed royalty strategy which government is concerned.

## 6. Conclusions and suggestions

Whilst few studies have explored royalty negotiations for BOT projects, some works have proposed numerous royalty formulas to evaluate royalty amounts or franchise fees for a BOT project. Despite this, the royalty negotiation process is one of the many critical negotiation items of a concession contract. This study not only developed a royalty negotiation model for BOT projects, but also developed a heuristic algorithm for the BLP problem for the government and the private sector. In addition, the factors incorporated into the heuristic algorithm for the BLP problem include the concession rate, learning rate, and the time value discount rate for both parties. This paper also presented a case study with data from the Taipei Port Container Logistic BOT Project.

The results of this study, using the LINGO package and MATLAB programming, show that the two parties involved finish the concession negotiation at the sixth negotiation, that is  $k = 5$ , the profit index of concessionaire is 1.062,  $\Pi_{P,R}(k = 5) = 1.062$  and the government finance recovery rate is 11.832,  $\Pi_{G,R}(k = 5) = 11.832$ . The government can receive the royalty which is calculated by the 0.012% of the operating revenue of this BOT project from the concessionaire. It reveals that the government can receive the government finance recovery ratio at 11.832 times of its investment cost and the concessionaire has operation benefits based on the royalty negotiation process for the BOT project. In addition, variables of the concession rate, learning rate, and time value discount rate of the two parties also affect the algorithm of the BLP problem. It shows that the royalty negotiation model developed herein could be employed to explain behavior during negotiations.

Below are some of the issues found in this study which can be further explored in future studies: (1) some assumptions of this model can be substituted to modify the proposed model. In addition, the concession rate, learning rate, and time value discount rate of this model can be reexamined. Moreover, the assumption of tolerance of error for the “iterative algorithm” could be reexamined. (2) The royalty negotiation issue for the two parties, the multiple issues of the bargain model and multi-level programming problem can be developed in future research in order to explore multiple parties and multiple negotiation issues for BOT projects. (3) The mixed royalty negotiation model, including fixed and flexible royalty model, can be investigated in future research.

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## References

- [1] C. Walker, A.J. Smith, *Privatized Infrastructure: The Build Operate Transfer Approach*, Thomas Telford Publication, 1996.
- [2] C.C. Kang, C.M. Feng, A.Khan. Haider, Risk assessment for build-operate-transfer projects: a dynamic multi-objective programming approach, *Computers and Operations Research* 32 (6) (2005) 1633–1654.
- [3] L.K. Tiong, J. Alum, Final negotiation in competitive BOT tender, *Journal of Construction Engineering and Management* 123 (1) (1997) 6–10.
- [4] Y.C. Chiou, W.L. Lan, The royalty models for transport infrastructure BOT projects, *Transportmetrica* 2 (3) (2006) 175–197.
- [5] Public Construction Commission, Report of Financial Planning of the Private Participation in Infrastructure, Department of Public Construction Commission, 2001.
- [6] L.Y. Shen, H.J. Bao, W.S. Lu, Using bargaining-game theory for negotiating concession period for BOT-type contract, *Journal of Construction Engineering and Management* 133 (5) (2007) 385–392.
- [7] W. Xing, F.F. Wu, A game-theoretical model of private power production, *Electric Power and Energy Systems* 23 (2001) 213–218.
- [8] H. Yang, Q. Meng, Highway pricing and capacity in a road network under a build-operate-transfer scheme, *Transportation Research Part A* 34 (2000) 207–222.

- [9] C.C. Kang, C.M. Feng, S.C. Huang, The new finance model of BOT projects, *Journal of the Eastern Asia Society for Transportation Studies* 5 (2003) 2920–2931.
- [10] C.C. Kang, C.M. Feng, S.C. Huang, A new financial engineering model for analyzing the royalty of BOT projects: the Taiwan case. CD-ROMP, in: *IEEE International Conference on Industrial Engineering and Engineering Management*, Singapore, 2007, pp. 277–281.
- [11] M. Ranasinghe, Private sector participation in infrastructure projects: a methodology to analyze viability of BOT, *Construction Management and Economics* 17 (1999) 613–623.
- [12] L.M. Chang, P.H. Chen, BOT financial model: Taiwan high speed rail case, *Journal of Construction Engineering and Management* 127 (3) (2001) 214–222.
- [13] M. Farrell, Financial engineering in project management, *Project Management Journal* 33 (1) (2001) 27–36.
- [14] A. Chen, K. Subprasom, P. Chootinan, Assessing financial feasibility of build-operate-transfer project under uncertain demand, *Transportation Research Record* 1771 (2001) 124–131.
- [15] Y.S. Lin, Y.H. Chang, A study of nonlinear negotiation model for build-operate-transfer infrastructure projects: the case of negative utility resource distribution, *Journal of the Chinese Institute of Transportation* 17 (1) (2005) 27–64 (in Chinese).
- [16] J.G. Cross, A theory of the bargaining process, *American Economic Review* 55 (1) (1965) 67–94.
- [17] A. Chen, K. Subprasom, Analysis of regulation and policy of private toll roads in a build-operate-transfer scheme under demand uncertainty, *Transportation Research Part A* 41 (2007) 537–558.
- [18] H. Houba, The policy bargaining model, *Journal of Mathematical Economics* 28 (1997) 1–27.
- [19] J.F. Bard, *Practical Bilevel Optimization Algorithms and Application*, Kluwer Academic Publishers, 2002.
- [20] U.P. Wen, S.T. Hsu, Linear bi-level programming problem: a review, *Journal of the Operational Research Society* 42 (2) (1991) 125–135.
- [21] Y.H. Liu, M.H. Stephen, Characterizing an optimal solution to the linear bi-level programming problem, *European Journal of Operational Research* 73 (1) (1994) 164–166.
- [22] H.I. Calvete, C. Gale, P.M. Mateo, A new approach for solving linear bi-level problems using genetic algorithm, *European Journal of Operation Research* 188 (2008) 14–28.
- [23] Terms of Reference (TOR) of Concessions of the Container Terminal in Taipei Port issued by Keelung Harbor Bureau in 2000, MOTC, Taipei, 2000.