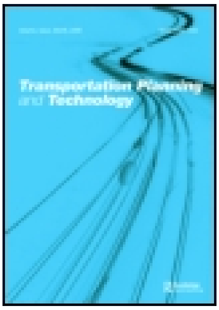

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Using bi-level programming to analyze the royalty for private-public partnership projects: the operational quantity-based model

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This paper develops a royalty negotiation model based on the operating quantity of Build, Operate, and Transfer (BOT) projects for both government and the private sector using a bi-level programming (BLP) approach. The royalty negotiation is one of many critical negotiation items of a concession contract. This study develops a royalty negotiation model to simulate the negotiation behavior of two parties, and derives the heuristic algorithm for the BLP problem. A number of factors are incorporated into this algorithm including the concession rate, the time value discount rate, the learning rate, and the number of negotiations. The paper includes a case study of the Taipei Port Container Logistic BOT Project. The results show that the two parties involved completed royalty negotiation at the sixth negotiation stage. The findings show that the government can receive a royalty from the concessionaire, calculated at 0.00386% of the operating quantity of this BOT project. Therefore, the royalty negotiation model developed here could be employed to explain negotiation behavior.

Keywords: BOT project; royalty; negotiation; bi-level programming

1. Introduction

This paper develops a royalty negotiation model using the bi-level programming (BLP) approach and derives an algorithm for determining the royalty fee for a Build, Operate, and Transfer (BOT) project from a game theory perspective. BOT is an approach the private sector utilizes to obtain a granted concession for completing a specific project independently. However, the ownership of the project must be returned to the public sector once it is completed (Hwang 1995, Kang *et al.* 2005). This has been widely employed to implement infrastructure projects in many developed and developing countries. For example, the 80 km elevated toll expressway in metropolitan Bangkok in Thailand; the 300 MW coal-fired power station projects in the Philippines; and the 5400 km road-building project in Mexico (Walker and Smith 1996). In addition, 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.

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The host utility uses the royalty from the concessionaire to cover their investment in the BOT project. It is obvious that the royalty or franchise is a revenue sharing scheme between the host utility and private sector (Tiong and Alum 1997). Tiong and Alum (1997) pointed out that the royalty amount should be included in the BOT agreement through negotiations by both parties. For instance, the franchise fee in the Dulles Greenway BOT Project in Virginia is about US$4.3 million, and the royalty amount for the M2 Motorway BOT Project in Australia for the host utility was about AU$7 million (Walker and Smith 1996). In 1998, the lump sum royalty levied for the 101 Skyscraper BOT Project in Taiwan was NT$ 30 billion which was calculated according to the fixed royalty method. The royalty, which includes 10% of the pre-tax amount of annual operational benefit for the High Speed Rail BOT Project of the concession, is paid to the government (Public Construction Commission 2001).

Previously, many researchers have conducted risk evaluation, risk management, and financing viability in BOT projects for allocating risk (Walker and Smith 1996, Chang and Chen 2001, Chen *et al.* 2002, Kang *et al.* 2005). In recent years, some studies have adopted game theory or BLP approaches to determine the price, the operating quantity level, or to identify the concession period of a BOT project. For example, Yang and Meng (2000) explored the toll scheme of highway networks using BLP under the BOT mechanism. Xing and Wu (2001) used BLP to construct a Stackelberg game model for determining the price and production quantity of a power utility in a BOT project. Shen *et al.* (2007) used Bargaining Game Theory to identify the concession period of a BOT project. They proposed a BOT concession model to identify a specific concession period which takes into account the bargaining behavior of the two parties engaged in a BOT contract.

As seen, the price, the determination of operational quantity, or the identification of the concession period should be written into the franchise contract through the negotiations between both parties under the BOT mechanism. However, those factors, including the concession rate, the time value discount rate, and the learning rate, have not been incorporated into their models. Conversely, during the negotiation process, those factors will actually affect the determination of price, production quantity, or the identification of the concession period of a BOT project.

As for royalty formulae, some studies have used mathematical programming, simulation, or for the case of BOT projects, financial engineering models. For instance, Chiou and Lan (2006) constructed a royalty model using fuzzy programming for analyzing different types of royalty formulae which were pre-tax profit based, total revenue based, and patronage based under uncertain demand. Moreover, Kang *et al.* (2003, 2004, 2007) constructed royalty models for a BOT project using mathematical programming and financial cash flow from the viewpoint of the government and the private sector, respectively. The contributions of Kang *et al.* (2003, 2004, 2007) for the determination of royalty amounts for BOT projects are from the perspective of the government and private sectors, respectively. Furthermore, their study describes the royalty at the lower boundary and the upper boundary for the two parties. However, those studies lack the exploration of the royalty negotiation issue for private and public sectors. Although Kang *et al.* (2003, 2004, 2007) as well as Chiou and Lan (2006) have proposed many different royalty models, nevertheless, it is worth analyzing royalty negotiations for both parties because few studies have explored this issue in sufficient depth.

The purpose of this paper is to construct a royalty negotiation model and to investigate royalty negotiation for a BOT project. The remainder of the paper is structured as follows: Section 2 describes the assumptions of the developed model; Section 3 constructs a royalty negotiation model and a solution algorithm; Section 4 presents a numerical example; and finally, a discussion of findings is presented and conclusions are drawn.

2. Assumptions used in model development

Theories, including game theory, bargaining theory, or BLP, have been widely employed to analyze resource allocation, price determination, wage determination, Stackelberg's Duopoly Model for economic policies or BOT projects, and other problems (Wen and Hsu 1991, Adams *et al.* 1996, Houba 1997, Lim 1999, Strand 2000, Xing and Wu 2001, Aloysius 2002). According to previous research on bargaining theory or BLP mentioned above, these authors have made some assumptions about their models in terms of number of players, competent information, rational behavior, bargaining cost, and time value. Hence, based on the above mentioned studies, the following assumptions for developing the model were made:

(1) Two parties, the government concerned and the private investor, establish contractual relations with a BOT contract through appropriate negotiations conducted with rational behavior. Assuming rational behavior means that both parties will calculate and adequately compare all the possible outcomes for protecting their own interests and profit-making objectives.
(2) The two parties are both entitled to the same full and frank disclosure of relevant information in regards to the BOT project concerned. Furthermore, parties should endeavor to ensure they communicate to each other clearly and effectively.

3. Methodology

3.1. Concept of financing BOT projects

The concept of financing projects proposed by Kang *et al.* (2003, 2004) was utilized to describe the annual royalty relationship between government and private investments. The concept is shown in Figure 1.

Figure 1 indicates that the fund resource for both construction and operation in a BOT project comes from the concessionaire and the government (Finnerty 1996). The construction cost of the project comprises C_{gt} and C_{pt}; where C_{gt} and C_{pt}

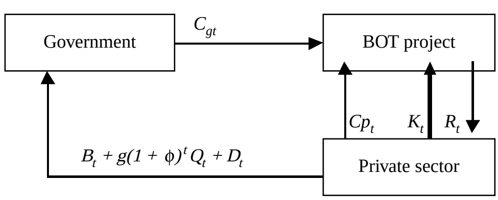

Figure 1. Concept of annual royalty of BOT projects, the operational quantity-based case.

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. The concessionaire pays $B_t + g(1+\phi)^t Q_t + D_t$ to the government according to the product quantity and affiliated business income, where B_t is the land-use rent at time t, Q_t is the product quantity at time t, and D_t is the tax at time t. The term $B_t + g(1+\phi)^t Q_t + D_t$ in Figure 1 is the sum of the land-use rent, royalty, and tax. Let g be the proportion of the product quantity of BOT project during the operating period, and let ϕ be the annual growth rate of g.

3.2. The model

To develop the royalty negotiation model, this study assumes that the concession period of a BOT project is made up of both 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 given to the private sector, and the salvage value of the fixed asset component 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. Further, we assume that the government investment is entirely capitalized by debt and the planning cost of government is not considered. Additionally, we assume that the royalty is not tax deductible. Finally, the capital cost of the BOT project was evaluated using the Weighted Average Cost of Capital (WACC) method.

As shown in Figure 1, a causal relationship exists between royalty, government investment, private-sector investment, and the government finance recovery ratio in cash flow for BOT projects. The government finance recovery ratio for the operating quantity of a BOT project for which the royalty is calculated has been defined by Kang *et al.* (2004, 2007) as:

$$\Pi_{g,Q}(k) = \frac{1}{C_g}[r_g + g_u(k) \times f_g] = \frac{1}{C(1 - P_c)}[r_g + g_u(k) \times f_g] \tag{1}$$

where $r_g = \sum_{t=0}^{N} \frac{B_t + D_t}{(1+i)^t}$; $f_g = \sum_{t=h}^{N} \frac{(1+\phi)^{t-h} Q_t}{(1+i)^t}$ 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.

Equation (1) represents the government finance recovery ratio $\Pi_{g,Q}(k)$ at the kth negotiation. There exists a positive relationship between $\Pi_{g,Q}(k)$ and $(r_g + g_u(k) \times f_g)$. That is, the more in royalty, tax, and land-use rent for the host utilities, the higher the value of $\Pi_{g,Q}(k)$. Thus, $\Pi_{g,Q}(k)$ goes up when variables of r_g, $g_u(k)$, and f_g increase.

Conversely, $\Pi_{g,Q}(k)$ decreases as P_C increases or variables of r_g, $g_u(k)$, and f_g decrease.

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

$$\Pi_{p,Q}(k) = \frac{N_I - g_\ell(k) \times f_p}{P_C \times C} \tag{2}$$

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 operational and non-operational revenues; $f_p = \sum_{t=h}^{N} \frac{(1+\phi)^{t-h} Q_t}{(1+d)^t}$, d is the risk-adjusted discount ratio after tax of the concessionaire, where $d > i$; it can be estimated using the WACC with corporate tax that:

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

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 Eq. (2) is the net operating income minus its royalty at the kth negotiation, and the denominator is the investment cost of the concessionaire. Equation (2) is the profitability of the private sector at the kth negotiation. It indicates that the concessionaire pursues its maximum financial profit at the kth negotiation if the private sector is a rational decision-maker.

According to Wen and Hsu (1991), the BLP is a Stackelberg game associated with a leader and follower. This model can illustrate a sequential decision for two players who pursue the objective of maximizing their own aims subject to another decision-making strategy. The host utility can be regarded as the higher-level problem of BLP because the royalty was first announced by the government in the BOT tender document. Then, the private sector will negotiate with the host utility regarding the royalty. Hence, the private sector can be regarded as the lower-level problem of the BLP. The two problem levels are formulated as follows.

Higher-level problem,

$$\max_{\{g_u(k)\}} \Pi_{g,Q}(k) = \frac{1}{C_g}[r_g + g_u \times f_g] = \frac{1}{C(1-P_C)}[r_g + g_u(k) \times f_g] \tag{4}$$

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

$$g_u(k) \leq (N_I - P_C \times C)/f_p \tag{6}$$

$$g_u(k) \geq V_\ell(k) \tag{7}$$

$$g_u(k) \leq W_u(k) \tag{8}$$

$$f_g = \sum_{t=h}^{N} \frac{(1+\phi)^{t-h} Q_t}{(1+i)^t} \tag{9}$$

$$f_p = \sum_{t=h}^{N} \frac{(1+\phi)^{t-h} Q_t}{(1+d)^t}. \tag{10}$$

Lower-level problem,

$$\max_{\{g_l(k)\}} \Pi_{p,Q}(k) = \frac{N_I - g_l(k) \times f_p}{P_C \times C} \tag{11}$$

$$\text{s.t. } g_\ell(k) \times f_g + C \times \Pi_{G0} \times P_C \geq C \times \Pi_{G0} - r_g \tag{12}$$

$$g_\ell(k) \leq (N_I - P_C \times C)/f_p \tag{13}$$

$$g_\ell(k) \geq V_\ell(k) \tag{14}$$

$$g_\ell(k) \leq W_u(k) \tag{15}$$

$$f_g = \sum_{t=h}^{N} \frac{(1+\phi)^{t-h} Q_t}{(1+i)^t} \tag{16}$$

$$f_p = \sum_{t=h}^{N} \frac{(1+\phi)^{t-h} Q_t}{(1+d)^t} \tag{17}$$

where $V_l(k)$ is the lower-bounded value of the feasible solution at the kth negotiation for the lower-level problem; $W_u(k)$ is the upper-bounded value of the feasible solution at the kth negotiation for the higher-level problem; and $g_l(k)$ and $g_u(k)$ are decision variables of the BLP problem.

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

Equation (11) is the objective function of the lower-level problem, illustrating 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) to (17); and the meanings of Eqs. (12) and (13) are the same as those of Eqs. (5) and (6); and the illustration of Eqs. (14) and (15) is also the same as those of Eqs. (7) and (8). Equations (16) and (17) are the discount factors of the decision variables for the higher-level and lower-level problems, respectively.

3.3. Algorithm for bi-level programming (BLP)

Many algorithms for the BLP problem – including the vertex enumeration or the Kuhn–Tucker transformation approach – have been proposed for finding the optimal solution (Wen and Hsu 1991, Liu and Stephen 1994). The vertex enumeration approach involves the simplex algorithm for finding the feasible solution for the higher-level problem of the BLP problem, whilst the Kuhn–Tucker transformation approach converts the objective function of the lower-level problem into constraints of the higher-level problem. However, to find the comprisal solution for the level of royalty, a heuristic algorithm was developed. The steps of the heuristic algorithm are shown as follows:

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

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

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

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

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

$$\left|\frac{g_u(k)^*f_g - g_\ell(k)^*f_p}{g_\ell(k)^*f_p}\right| \le \delta \text{ and } \left|\frac{g_u(k)^*f_g - g_\ell(k)^*f_p}{g_u(k)^*f_g}\right| \le \delta \tag{18}$$

where δ is the error tolerated; and $\delta=0.01$. If the solutions of BLP satisfy the convergence test condition, then the royalty negotiation was ceased.

Step 4: Set initial concession rates for the two parties, and let $k\neq 0$. Substitute concession rates into Eqs. (17)–(20), and find $V_l(k+1)$ and $W_u(k+1)$.

Step 5: Find the concession rates at the next negotiation, $r_u(k+1)$, $r_l(k+1)$, and find $g_l(k+1)$ and $g_u(k+1)$.

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.

The learning effect, concession rate and time value discount of players are very important impact factors for the bargaining process (Cross 1965). These factors have been introduced into studies of the BOT bargaining model (Lin and Chiang 2005, Shen *et al.* 2007). Following the concept of Cross (1965), we defined the concession rate of the government and the private firm, respectively. The concession rates for both parties are shown in Eqs. (19) and (20), respectively.

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

$$r_\ell(k) = \frac{(auvr_u(k-1) + (ab(1-\frac{u}{2})(1+\frac{v}{2}) - uv)r_\ell(k-1))}{(ab(1+\frac{u}{2})(1+\frac{v}{2}) - uv)} \tag{20}$$

Where $r_u(k)$ and $r_l(k)$ are concession rates at the kth negotiation for higher-level and lower-level programming problems, respectively; similarly, $r_u(k–1)$ and $r_l(k–1)$ 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 μ and ν to be the learning rates for higher-level and lower-level programming problems, respectively. Assume μ and ν are constant.

Equation (19) demonstrates that the concession rate at the kth negotiation for the higher-level programming problems were affected by $r_l(k–1)$, $r_u(k–1)$, u, v, a, and b. Similarly, $r_l(k)$ in Eq. (20) it was affected by $r_l(k–1)$, $r_u(k–1)$, u, v, a, and b. This implies that the royalty negotiation between the host utility and concessionaire was reflected by the concession rate of both parties. Then, Eqs. (19) and (20) were substituted into Eqs. (21)–(24) and $W_u(k+1)$ and $V_l(k+1)$ of higher-level and the lower-level programming were modified, respectively.

$$W_u(k+1) = W_u(k) - W_u(k) \times r_u(k) \tag{21}$$

$$V_\ell(k+1) = V_\ell(k) + V_\ell(k) \times r_u(k) \tag{22}$$

$$W_u(k+1) = W_u(k) - W_u(k) \times r_\ell(k) \tag{23}$$

$$V_\ell(k+1) = V_\ell(k) + V_\ell(k) \times r_\ell(k) \tag{24}$$

Where $W_u(k)$ and $V_l(k)$ are the upper- and lower-bounded value at the kth negotiation for higher-level and the lower-level programming, respectively. $W_u(k+1)$ and $V_l(k+1)$ are the upper- and lower-bounded value at the $(k+1)$th negotiation, respectively.

4. Case study

4.1. Background of Taipei Port Container Logistic BOT Project

A case study using financial data from the Container Terminal in Taipei Port BOT Project was conducted to illustrate the application 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, 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 twenty-foot equivalent units (TEUs) containers. By 2008, the assumed annual container handling volume for four wharves would be 1,000,000 TEUs. From 2011 to 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 is assumed to be 8%. The annual inflation rate is assumed to be 3.5%.
(f) 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 $h=0$. 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

Table 1. Summary of TOR of Container Terminal in Taipei Port BOT Project.

Items	Summary
Concession period	50 years
Implementation schedule	Contract negotiation phase: 2001, construction period: 2001–2007, operating period: 2005–2050
Wharves	7 wharves
Total project installation cost (including government-related costs)	$US332.14 million (2001 currency)
Project volume	a. 2005–2006, 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. Seven wharves and storage yard with exclusive operation rights and land superficies b. Operation scope: vessel berthing, container loading/unloading, trans-shipping, 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.’

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, when Cross (1965) proposed the Concession Rate Formula, he assumed that the concession rate of players I and II is given in an application of the bargaining model. Following the concept of Cross (1965) and Lin and Chiang (2005), it was also assumed that the concession-rate values of both government and private sectors are constant. Hence, it was assumed that the initial concession rate of the government and the private firm are 20% and 17%, respectively. Furthermore, it was assumed that the time value discount rate and the learning rate are the same for both parties – that is, $a = b = 0.2$ and $\mu = \nu = 0.1$ (Cross 1965, Lin and Chiang 2005).

4.2. 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 involved the heuristic algorithm, to simulate the bargaining process for royalty negotiation for both parties.

The initial solution of the higher-level programming is $g_u(k = 0) = 0.0001$ whilst that of the lower-level programming is $g_l(k = 0) = 0.0019\%$. The $g_u(k = 0) = 0.0001$ value illustrates that the government first wants to receive the royalty from 0.01% of the operation quantity during the period from the concessionaire according to the announced TOR of this project. However, $g_l(k = 0) = 0.0019\%$, which shows that the private firm pays only 0.0019% of the operating quantity to the government. The convergence test is not held because $\left|\dfrac{0.01\% \times f_g - 0.0019\% \times f_p}{0.0019\% \times f_p}\right| > 0.01$ and $\left|\dfrac{0.01\% \times f_g - 0.0019\% \times f_p}{0.01\% \times f_g}\right| > 0.01$. 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. (17)–(22) to modify the concession rate the next negotiation for two parties. Steps 0–5 of the algorithm were repeated. Results are shown in Table 2.

As reported in Table 2, the solutions are $g_u(k = 5) = 0.0000386$ and $g_l(k = 5) = 0.0000386$ for the higher-level and lower-level programming, respectively. As shown, the convergence test solution for the BLP problem was held. Therefore, the

Table 2. Result of simulated royalty negotiation.

Number of negotiation	$r_u(k)$	$r_l(k)$	$g_u(k)$	$g_l(k)$	$\Pi_{G,Q}(k)$	$\Pi_{P,Q}(k)$
$k = 0$	0.2000	0.1700	0.001	0.000019	12.7976	1.0843
$k = 1$	0.1853	0.1608	0.00008	0.0000222	12.4258	1.0815
$k = 2$	0.1719	0.1520	0.0000652	0.0000258	12.1503	1.0784
$k = 3$	0.1596	0.1432	0.000054	0.0000297	11.9420	1.0750
$k = 4$	0.1484	0.1350	0.0000454	0.000340	11.7878	1.0714
$k = 5$	0.1380	0.1270	0.0000386	0.0000386	11.6567	1.0675

royalty negotiation for the two parties finished at $k=5$. The results obtained imply that the government and the private firm make a compromise royalty solution. As a consequence, the government can collect the royalty which is computed by 0.00386% of the operating quantity of this BOT project from the concessionaire. At the same time, the objective function values, $\Pi_{G,Q}(k=5)=11.6567$ and $\Pi_{P,Q}(k=5)=1.0675$, for the two parties were found, respectively. Results show that the government can get the government finance recovery ratio 11.6567 times of its investment cost and the concessionaire has an operational benefit of 1.0675 based on the royalty negotiation process for BOT projects. In addition, the concession rates of $r_u(k=5)=0.1380$ and $r_l(k=5)=0.1270$ for the government and the private firm were also obtained, respectively. It reveals that the decrease in the concession rates of the two parties contributes to successful royalty negotiations.

In addition, Table 2 indicates the relationship between the royalty and the number of negotiations. $\Pi_{G,Q}(k)$ decreased from 12.7976 to 11.6567 when the number of negotiations increases. Similarly, $\Pi_{P,Q}(k)$ decreased from 1.0843 to 1.0675 as k increased. It shows that the royalty for the host utility decreases as the number of negotiations increases. In contrast, the royalty the concessionaire is willing to pay increases when the number of negotiations increases. Clearly, we are able to conclude that changes in the concession rates of two parties affect the number of negotiations necessary. At the same time, those concession rates of the two parties affect change in $\Pi_{G,Q}(k)$ and $\Pi_{P,Q}(k)$. Furthermore, it can be shown that the royalty of concern to the host utility decreases when the number of negotiations increases. Conversely, the royalty the concessionaire is willing to pay increases when the number of negotiations increases. In addition, Table 2 shows that changes in concession rates of both parties affect the number of negotiations. At the same time, the concession rates of both parties affect changes in $\Pi_{G,Q}(k)$ and $\Pi_{P,Q}(k)$.

4.3. Sensitivity analysis

As reported in Table 2, changes in the concession rate of both parties will lead to variations in $\Pi_{G,Q}(k)$, $\Pi_{P,Q}(k)$, $g_u(k)$, and $g_l(k)$. Therefore, in this section, a sensitivity analysis among $r_u(k)$, $r_l(k)$, $\Pi_{G,Q}(k)$, $\Pi_{P,Q}(k)$, $g_u(k)$, and $g_l(k)$ 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.

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

As Table 3 indicates, a change in $r_l(k)$ can be classified into two conditions: a decrease and a subsequent increase in $r_l(k)$ whilst $r_u(k)$ remains constant. A decrease in $r_l(k)$ with $r_u(k)$ kept constant will increase the number of negotiations k for the royalty game. Conversely, increasing $r_l(k)$ whilst $r_u(k)$ is kept constant will decrease the number of negotiations k. If the concession rate of the private firm decreases rapidly, $\Pi_{G,Q}(k)$ will increase. However, both $g_u(k)$ and $g_l(k)$ will decrease, when $r_l(k)$ changes with $r_u(k)$ kept constant. $\Pi_{P,Q}(k)$ decreased from 1.0760 to 1.0576 whilst $r_l(k)$ increased from 0.04 to 0.42 as the $\Pi_{G,Q}(k)$ increased from 11.4910 to 11.8933.

Table 3. Result of sensitivity analysis for the case of fixed $r_u(k)$ and changed $r_l(k)$.

Items	k	$g_u(k)$	$g_l(k)$	$\Pi_{G,Q}(k)$	$\Pi_{P,Q}(k)$
$r_u(k)=0.2$, $r_l(k)=0.04$	9	0.0000293	0.0000289	11.4910	1.0760
$r_u(k)=0.2$, $r_l(k)=0.07$	8	0.0000319	0.0000314	11.5319	1.0738
$r_u(k)=0.2$, $r_l(k)=0.11$	7	0.0000348	0.0000342	11.5858	1.0711
$r_u(k)=0.2$, $r_l(k)=0.17$	6	0.0000386	0.0000386	11.6567	1.0675
$r_u(k)=0.2$, $r_l(k)=0.25$	5	0.0000436	0.0000429	11.7579	1.0641
$r_u(k)=0.2$, $r_l(k)=0.42$	4	0.0000510	0.0000501	11.8933	1.0576

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

Similarly, sensitivity analysis was conducted as $r_u(k)$ varies whilst $r_l(k)$ is kept constant. This case can also be classified into two conditions, manipulating $r_u(k)$ by increasing and decreasing it as $r_l(k)$ remains constant. Results of this analysis are summarized in Table 4. Table 4 shows that a decrease in $r_u(k)$ with $r_l(k)$ kept constant will increase the number of negotiations k. However, an increase in $r_u(k)$ with $r_l(k)$ kept constant will decrease the number of negotiation k decreases. At the same time, $\Pi_{G,Q}(k)$ decreased when the $r_u(k)$ increased rapidly; but $\Pi_{P,Q}(k)$ increased when the $r_u(k)$ increased. Results of Table 4 show that $\Pi_{P,Q}(k)$ increased from 1.0515 to 1.0745 whilst $\Pi_{G,Q}(k)$ decreased from 12.0209 to 11.5040 as $r_u(k)$ increased from 0.04 to 0.36.

As shown above, 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. Conclusions

Whilst few studies have explored royalty negotiations for BOT projects, some research has proposed a variety of royalty formulae 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 paper has not only developed a royalty negotiation model for BOT projects, but also developed the 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

Table 4. Result of sensitivity analysis for the case of varying $r_u(k)$ and fixing $r_l(k)$.

Items	k	$g_u(k)$	$g_l(k)$	$\Pi_{G,Q}(k)$	$\Pi_{P,Q}(k)$
$r_u(k)=0.04$, $r_l(k)=0.17$	12	0.0000582	0.0000572	12.0209	1.0515
$r_u(k)=0.09$, $r_l(k)=0.17$	9	0.0000502	0.0000493	11.8748	1.0584
$r_u(k)=0.12$, $r_l(k)=0.17$	8	0.0000460	0.0000459	11.7939	1.0611
$r_u(k)=0.2$, $r_l(k)=0.17$	6	0.0000386	0.0000386	11.6567	1.0675
$r_u(k)=0.26$, $r_l(k)=0.17$	5	0.0000352	0.0000346	11.5938	1.0709
$r_u(k)=0.36$, $r_l(k)=0.17$	4	0.0000304	0.0000304	11.5040	1.0745

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 showed that the two parties involved finish the concession negotiation at the sixth negotiation, that is $k=5$, the profit index of the concessionaire is 1.0675, $\Pi_{P,Q}(k=5)=1.0675$ and the government finance recovery rate is 11.6567, $\Pi_{G,Q}(k=5)=11.6567$. The government can receive the royalty which is calculated as 0.00386% of the operating quantity of this BOT project from the concessionaire. It reveals that the government can receive the government finance recovery ratio at 11.6567 times of its investment cost and the concessionaire has operation benefit based on the royalty negotiation process for the BOT project. In addition, variations in 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 here could be employed to explain behavior during negotiations.

There are three issues found in this study which need to 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 re-examined; (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 order to explore multiple parties and multiple negotiation issues for BOT projects; and (3) the mixed royalty negotiation model, including both fixed and flexible royalty model, is also worthy of investigation.

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References

Adams, G., Rausser, G., and Simon, L., 1996. Modeling multilateral negotiations: an application to California water policy. *Journal of Economics Behavior & Organization*, 30, 97–111.

Aloysius, J.A., 2002. Research joint ventures: a cooperative game for competitors. *European Journal of Operational Research*, 136, 591–602.

Chang, L.M. and Chen, P.H., 2001. BOT financial model: Taiwan high speed rail case. *Journal of Construction Engineering and Management*, 127 (3), 214–222.

Chen, A., Subprasom, K., and Chootinan, P., 2002. Assessing financial feasibility of a build-operate-transfer project under uncertain demand. *Transportation Research Record*, 1771, 124–131.

Chiou, Y.C. and Lan, L.W., 2006. The royalty models for transport infrastructure BOT projects. *Transpormetrica*, 2 (3), 175–197.

Cross, J.G., 1965. A theory of the bargaining process. *The America Economic Review*, 55 (1), 67–94.

Finnerty, J.D., 1996. *Project financing: asset-based financial engineering*. Toronto, OT: John Wiley.

Houba, H., 1997. The policy bargaining model. *Journal of Mathematical Economics*, 28, 1–27.

Hwang, Y.L., 1995. *Project and policy analysis of build-operate-transfer infrastructure development.* Thesis (PhD). Department of Civil Engineering, University of California at Berkeley.

Kang, C.C., Feng, C.M., and Huang, S.C., 2003. The new finance model of BOT projects. *Journal of the Eastern Asia Society for Transportation Studies*, 5, 2920–2931.

Kang, C.C., Feng, C.M., and Huang, S.C., 2004. The royalty model for BOT projects. *Journal of Financial Studies*, 12 (3), 1–31. (In Chinese)
Kang, C.C., Feng, C.M., and Huang, S.C., 2007. A new financial engineering model for analyzing the royalty of BOT projects: the Taiwan case. *In*: *Proceedings of the IEEE international conference on industrial engineering and engineering management,* 2–5 December 2007. Singapore: World Scientific, 277–281.
Kang, C.C., Feng, C.M., and Khan, H.A., 2005. Risk assessment for build-operate-transfer projects: a dynamic multi-objective programming approach. *Computers & Operations Research*, 32 (7), 1633–1654.
Lim, J.L.H., 1999. Multi-stage negotiation support: a conceptual framework. *Information and Software Technology*, 41, 249–255.
Lin, Y.S. and Chiang, Y.H., 2005. 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), 27–64. (In Chinese)
Liu, Y.H. and Stephen, M.H., 1994. Characterizing an optimal solution to the linear bi-level programming problem. *European Journal of Operational Research*, 73 (1), 164–166.
Public Construction Commission, 2001. *Report of financial planning of the private participation in infrastructure*. Taipei.
Shen, L.Y., Bao, H.J., and Lu, W.S., 2007. Using bargaining-game theory for negotiating concession period for BOT-type contract. *Journal of Construction Engineering and Management*, 133 (5), 385–392.
Strand, J., 2000. Wage bargaining and turnover costs with heterogeneous labor and asymmetric information. *Labor Economics*, 7, 95–116.
Tiong, R.L.K. and Alum, J., 1997. Final negotiation in competitive BOT tender. *Journal of Construction Engineering and Management*, 123 (1), 6–10.
Keelung Harbor Bureau, 2000. *Terms of reference (TOR) of 'Concessions of the container terminal in Taipei port'*. Taipei: Ministry of Transportation and Communication.
Walker, C. and Smith, A.J., 1996. *Privatized infrastructure: the build operate transfer approach*. London: Thomas Telford.
Wen, U.P. and Hsu, S.T., 1991. Linear bi-level programming problem – a review. *Journal of the Operational Research Society*, 42 (2), 125–135.
Xing, W. and Wu, F.F., 2001. A game-theoretical model of private power production. *Electrical Power and Energy System*, 23, 213–221.
Yang, H. and Meng, Q., 2000. Highway pricing and capacity in a road network under a build-operate-transfer scheme. *Transportation Research Part A*, 34, 207–222.