Model for Evaluating the Financial Viability of the BOT Project for Highway Service Areas in South Korea

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Abstract: Evaluating the financial viability of a build-operate-transfer project for highway service areas (HSA BOT project) in South Korea is very important for the private sector because it does not have a risk-allocation agreement with the public sector, such as the minimum revenue guarantee. In this study, a model to evaluate the financial viability of a HSA BOT project is developed based on the discounted cash flow analysis and the real option valuation. The developed model can evaluate the financial viability of the HSA BOT project more robustly and comprehensively than existing methods by considering the characteristics of the HSA BOT project as well as the value of the HSA BOT projects due to the future uncertainty that the existing methods cannot consider. The case study shows that compared to the result from the existing methods, the result from the developed model is close to the actual results of the case project. It is expected that the private sector can use the developed model to determine the investment decision for HSA BOT projects. **DOI: 10.1061/(ASCE)ME.1943-5479.0000396.** *© 2015 American Society of Civil Engineers.*

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Introduction

The public sector (i.e., the government) has invested the public finance to build various types of infrastructures for improving people's lives. As most infrastructure projects have the characteristics of large-scale investment and long payback period, the public finance used for developing infrastructures has become a fiscal burden on the government. The public-private partnerships (PPPs) have been provided as solutions to reduce the government's fiscal burdens by encouraging private-sector participation in the financing, construction, operation, and maintenance of infrastructures (Liu et al. 2014; Zhang 2004). PPPs come in many forms, such as build-transfer, build-transfer-lease, build-transfer-operate, and build-operate-transfer (BOT) (Miller 2000). Of the various forms of PPPs, BOT agreement is based on the idea that infrastructures are constructed by using the private finance instead of the public finance (Shen and Wu 2005) and that the public sector will guarantee the private sector the ownership of the infrastructures and the minimum revenue guarantee (MRG) during the concession period. For this reason, BOT agreement has generally been applied to the development of profitable infrastructures, such as toll-road projects. In BOT projects, to provide the various services, the private sector is organized as a consortium or joint venture consisting of various stakeholders, such as investors, lenders, architects, engineers, and contractors (Schaufelberger and Wipadapisut 2003). As the stakeholders aim to earn profits, the evaluation of the financial viability of BOT projects is very important for the stakeholders.

Discounted cash flow (DCF) analysis is a well-established technique that has been successfully used in evaluating projects for several decades (Kodukula and Paoudesu 2006). Therefore, the financial viability of BOT projects has been evaluated based on the net present value (NPV), internal rate of return (IRR), or debt service coverage ratio, which are calculated by DCF analysis (Zhang 2005). DCF analysis, which is the deterministic assessment, evaluates the financial viability of BOT projects with static assumptions about demand projection, operating revenue, debt-equity ratio, financing cost, operating cost, and construction and concession period. That is, all the parameter values are assumed fixed in DCF analysis. Thus, it is necessary to set the reasonable variables for DCF analysis to obtain reliable results. In addition, DCF analysis cannot consider the value of BOT projects due to the future uncertainty (Amram and Kulatilaka 1999; Kodukula and Papudesu 2006; Trigeorgis 1996). For instance, although the adjustments, which the project managers can make after starting a BOT project, may have effects on the values of the project, DCF analysis does not account for these values. These limitations of DCF analysis decrease the reliability of the result (Cheah and Garvin 2009; Kodukula and Papudesu 2006).

The financial option is a contract in which the buyer is given the right to buy or sell an underlying asset or stock at a specified strike price on or before a specified date, and the buyer pays a premium as option value to the seller for this right (Black and Scholes 1973; Cox et al. 1979). A real option, which is based on the financial option, is a right to take certain actions in the uncertain future (Copeland and Antikarov 2001) and is carried out with decision tree where the option to expand, delay, or abandon the project are taken into account deliberately (Supriyadi 2013). For instance, in the case of a poor market situation, such as a decrease in demand, the project manager may reduce the size of the investment or delay the investment to minimize the downside loss. On the other hand, if the market performs well, the project manager may expand the investment size to increase the profit. Therefore, real option

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valuation (ROV) can evaluate the value of a real estate project based on the project manager's opportunity to revise the initial investment strategy in the future (Shockley 2007). That is, ROV can evaluate the value of the project due to the future uncertainty. As ROV can make up for the limitations of DCF analysis, ROV has been considered an alternative to the conventional DCF analysis and has been used to evaluate the financial viability of BOT projects (Chiara et al. 2007; Collan et al. 2009; Ford et al. 2002; Garvin 2005; Garvin and Cheah 2004; Grenadier 1996; Ho and Liu 2002; Liao and Ho 2010; Panayi and Trigeorgis 1998; Yeo and Qiu 2003; Zhao et al. 2004).

Meanwhile, over 170 highway service areas (HSAs), which include restaurants, convenience stores, restrooms, and gas stations, are being operated in South Korea. Most of the HSAs were leased to private operators after planning and construction by Expressway Corporation, which is a public enterprise. Recently, BOT agreement has been applied to the development of HSA. According to Expressway Corporation, 28 HSA projects had been delivered through BOT agreement until 2011 (Expressway Corporation 2011). In addition, BOT projects for HSA (HSA BOT projects) tend to increase.

The characteristics of HSA BOT projects are different from those of the conventional BOT projects. In HSA BOT projects, the private sectors are not provided with MRG from Expressway Corporation, but even they have to pay land-use fees (LUF), which are calculated by applying the land-use fee rate (LUFR) to revenue, to the expressway corporation (Kim and Lee 2013). LUFR, which is determined at the bidding stage, was in a range of 5–15% in South Korea. Getting the stable revenue during the concession period is an important consideration to both private and public. Therefore, Expressway Corporation controls that HSAs are established with a certain distance on the highway instead of not providing the private sector with MRG and getting LUF from the private sector (Expressway Corporation 2011). Meanwhile, HSA BOT projects may be planned in a multiphased development according to the change in profit circumstances or the financing plan. A number of studies have developed the evaluation models for the conventional BOT projects, but there have been few research works that targeted the HSA BOT projects. As HSA BOT projects have to pay LUF without the guarantee of MRG, unlike conventional BOT projects, their financial viability evaluation may be incorrect if using the existing methods, which were developed for targeting the conventional BOT projects. In particular, as the private sector in HSA BOT projects is exposed on more risky condition than those in conventional BOT projects, it is necessary to provide a method that targets the financial viability evaluation of HSA BOT projects.

This study aims to develop a model for evaluating the financial viability of an HSA BOT project. The developed model can consider not only expected cash flow of an HSA BOT project but the value of the project due to the future uncertainty using DCF analysis and ROV. Also, Monte Carlo simulation (MCS) is applied to the model to consider the variability of the variables.

Evaluation Model of HSA BOT Projects

In this study, a model for evaluating the financial viability of an HSA BOT project was developed so as to support the decision-making process of the private sector that participates in an HSA BOT project. As shown in Fig. 1, the developed model consists of three parts: (1) the calculation of NPV through DCF analysis, (2) the calculation of the option value (OV) through the revised binomial lattice model, and (3) the calculation of the expanded NPV (ENPV) by integrating NPV and OV. In addition, using MCS, the developed model presents the range of ENPV by considering the variability of the variables, which are applied to the evaluation of the financial viability for an HSA BOT project.

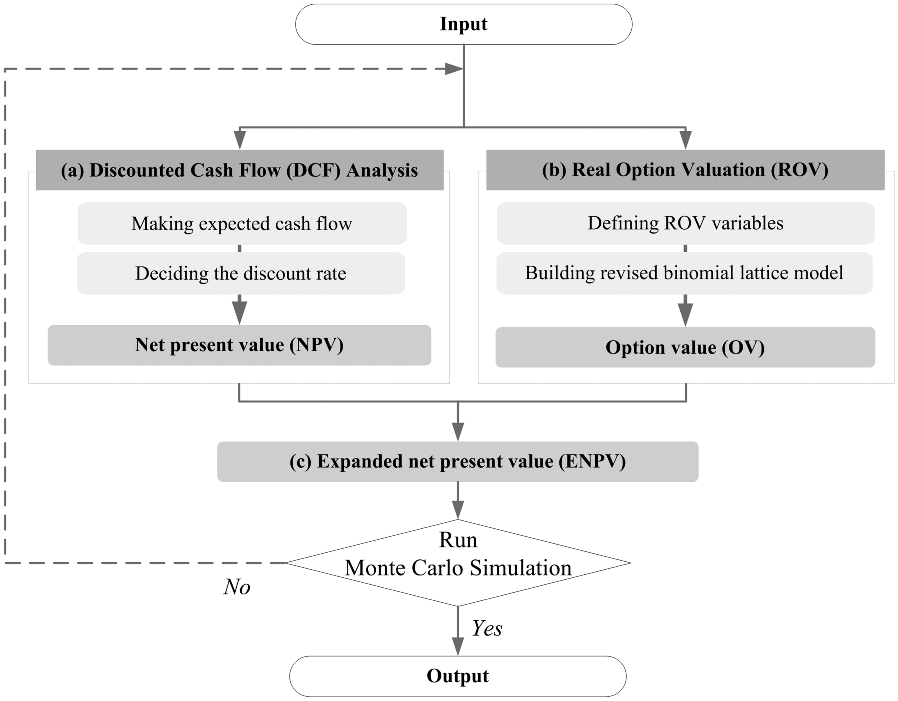


Fig. 1. Framework of model for evaluating financial viability of HSA BOT projects: (a) discounted cash flow analysis; (b) real option valuation; (c) expanded net present value

DCF Analysis of HSA BOT Projects

In the first phase of the evaluation of the financial variability, the NPV of an HSA BOT project is calculated based on the expected cash flow based on the private sector's business plan. Generally, NPV of a conventional BOT project can be calculated by Eq. (1). As mentioned above, the private sector in HSA BOT projects should consider LUF, which should be paid to Expressway Corporation. Thus, NPV of an HSA BOT project can be calculated by Eq. (2). In addition, HSA BOT projects may be planned in a multiphased development according to the change in profit circumstances or the financing plan. Eventually, reflecting such characteristics of HSA BOT projects in South Korea, the NPV of an HSA BOT project can be calculated using Eq. (4).

Meanwhile, as an HSA BOT project includes the long-term concession period, the discount rate is especially important in evaluating the financial viability of the project. The valuation of infrastructure projects often used to employ the weighted average cost of capital (WACC), which is the risk-adjusted discount rate method focusing on the determination of discount rates under uncertainties (Garvin and Cheah 2004; Ho and Liu 2002; Ye and Tiong 2000). Therefore, WACC from Eq. (5) can be used to evaluate the financial viability of an HSA BOT project (Park 2012)

$$\mathrm{NPV} = \sum_{j=n+1}^{T} \frac{(OR_j - OC_j)}{(1+r_w)^j} - \sum_{i=0}^{n} \frac{CC_i}{(1+r_w)^i} \tag{1}$$

$$\mathrm{NPV} = \sum_{j=n+1}^{T} \frac{(OR_j - OC_j - \mathrm{LUF}_j)}{(1+r_w)^j} - \sum_{i=0}^{n} \frac{CC_i}{(1+r_w)^i} \tag{2}$$

$$\mathrm{LUF}_j = OR_j \times \mathrm{LUFR}_j \tag{3}$$

$$\begin{aligned}\mathrm{NPV} &= \sum_{k=1}^{m} \mathrm{NPV}_k \\ &= \sum_{k=1}^{m} \left[\sum_{j=n+1}^{T} \frac{(OR_j - OC_j - \mathrm{LUF}_j)}{(1+r_w)^j} - \sum_{i=0}^{n} \frac{CC_i}{(1+r_w)^i} \right]\end{aligned} \tag{4}$$

$$\mathrm{WACC} = W_d \times C_d \times (1 - \mathrm{tax}) + W_e \times C_e + W_p \times C_p \tag{5}$$

where n = length of the construction period in years; T = concession period; r_w = WACC on the project as the discount rate; OR_j = expected annual operating revenue from operating HSA in year j; OC_j = expected annual operating cost, including the maintenance and operating cost, debt and tax service in year j; CC_i = annual construction cost in year i under construction; LUF_j = expected annual total land-use fee provided to the government based on the OR_j in year j; LUFR_j = land-use fee rate in year j; k = first phase of development; m = total phase of development; W_d = ratio of the debt; C_d = cost of the debt; W_e = ratio of the common equity; C_e = cost of the common equity; W_p = ratio of the preferred stock; and C_p = cost of the preferred stock.

Real Option Valuation of HSA BOT Projects

The NPV calculated via DCF analysis shows the value of an HSA BOT project under the assumption that the actual income and expenses generated in the concession period are identical to the expected cash flow. It is very probable, however, that the real cash flow of an HSA BOT project is different from the expected cash flow due to the uncertainty of the market condition and the demand. In the second phase, ROV shows the value of the uncertainty of the market condition during the concession period.

The Black–Scholes and binomial lattice models are two of the most representative ROV models. The Black–Scholes model, which is a continuous model, started as a financial option pricing model proposed by Fischer Black and Myron Scholes in the early 1970s (Black and Scholes 1973). The Black–Scholes model expressed in a partial differential equation is based on the following preconditions: (1) it assumes a lognormal distribution of the underlying asset value; (2) it assumes that the increase in the underlying asset value is continuous, as dictated by its volatility, and does not account for drastic ups and downs; and (3) it allows only one strike price for the option, which can change for a real option during its life (Kodukula and Papudesu 2006). The Black–Scholes model can be applied to the European option, which only is exercised on expiry time and does not have dividends until maturity.

The binomial lattice model is a discrete model, which simplifies the Black–Scholes model structurally based on the assumption of the risk-neutral probability approach. That is, the binomial lattice model is with assumption that an underlying asset rises or falls within limited conditions (Cox et al. 1979). The binomial lattice model can be freely reconstructed by the evaluator by considering the various project conditions, so it can be applied to the American option, which may be exercised on any time on or before expiry time, as well as the European option.

In BOT projects, as the underlying asset value may differ by the uncertainty during the concession period, the distribution of the underlying asset value should not be restricted to the lognormal distribution, which is one of the preconditions of the Black–Scholes model. Due to these characteristics of BOT projects, many previous studies have used the binomial lattice model for the ROV of BOT projects (Alonso-Conde et al. 2007; Ashuri et al. 2012; Garvin and Cheah 2004; Ho and Liu 2002; Liao and Ho 2010). As HSA BOT projects also have similar characteristics to the conventional BOT projects, it is also reasonable to use the binomial lattice model for the ROV of an HSA BOT project.

The ROV of an HSA BOT project is calculated as the following steps: (1) the definition of the variables required for ROV; (2) the construction of the revised binomial lattice model up to the expiry time; and (3) the calculation of the OV at the evaluation period through backward iteration.

In Step 1, the variables required for calculating the OV of an HSA BOT project by using the binomial lattice model are defined (Guma 2008; Yeo and Qiu 2003). As shown in Table 1, current stock price (S) means the present value of expected operating assets

Table 1. Variables for Real Option Valuation of HSA BOT Projects

Financial option	Real option	Symbol
Current stock price	Present value of the operating assets expected to be acquired (i.e., underlying asset value)	S
Strike price	Expenditure required to acquire the project assets (i.e., initial investment cost)	X
Risk-free interest rate	—	R
Volatility of returns on stock	Volatility of returns of the underlying asset	Σ
Expiry time	—	T
Time period	—	Δt
Upturn coefficient	—	U
Downturn coefficient	—	D
Risk-neutral probability	—	P

to be acquired, which is expressed as the underlying asset value in this study. Strike price (X) is the initial investment cost, signifying the expenditure required to acquire the project assets. Risk-free interest rate (r) signifies the theoretical rate of return of an investment with no risk of financial loss. The short-dated government bond is normally perceived as a good proxy for the risk-free interest rate because there is by definition no risk of default; the bond is a form of government obligation (Tobin and Golub 1998). As three-year, five-year, and 10-year government bonds are officially distributed in South Korea, a three-year government bond rate is used as the risk-free interest rate in this study. Volatility (σ) shows the level of uncertainty on the underlying assets. In the financial option, either stock based on the time or the change in the bond price can be directly used as the volatility. In the real option, however, depending on what kind of underlying assets are considered, the factors that can explain their volatility can be different, so the proxy variables can be chosen to explain the volatility of different underlying assets in ROV. For example, the historical price data of fuel can be used as the proxy variable of the volatility in a power plant facility (Piesse and Putte 2004), whereas the expected annual average traffic can be used as the proxy variable of volatility in a toll road project (Ashuri et al. 2012; Garvin 2005). In South Korea, the highway daily average traffic (HDAT) volume has turned out to be a variable affecting mainly the revenue of an HSA BOT project (Kim and Lee 2013). Therefore, in this study, the volatility of an HSA BOT project is calculated by using the historical data of the HDAT volume obtained from the traffic monitoring system (TMS) in South Korea, as shown in Eq. (6). The upturn coefficient (u), downturn coefficient (d), and risk-neutral probability (p), which signify the degree of change of the underlying asset value, are calculated using Eqs. (7)–(9) (Shockley 2007; Guma 2008; Yeo and Qiu 2003)

$$\sigma = \sqrt{\frac{1}{(n-1)}\sum (o_t - \bar{o})^2}, \qquad o_t = \ln(\mathrm{HDAT}_t/\mathrm{HDAT}_{t-1}) \tag{6}$$

$$u = e^{\sigma\sqrt{\Delta t}} \tag{7}$$

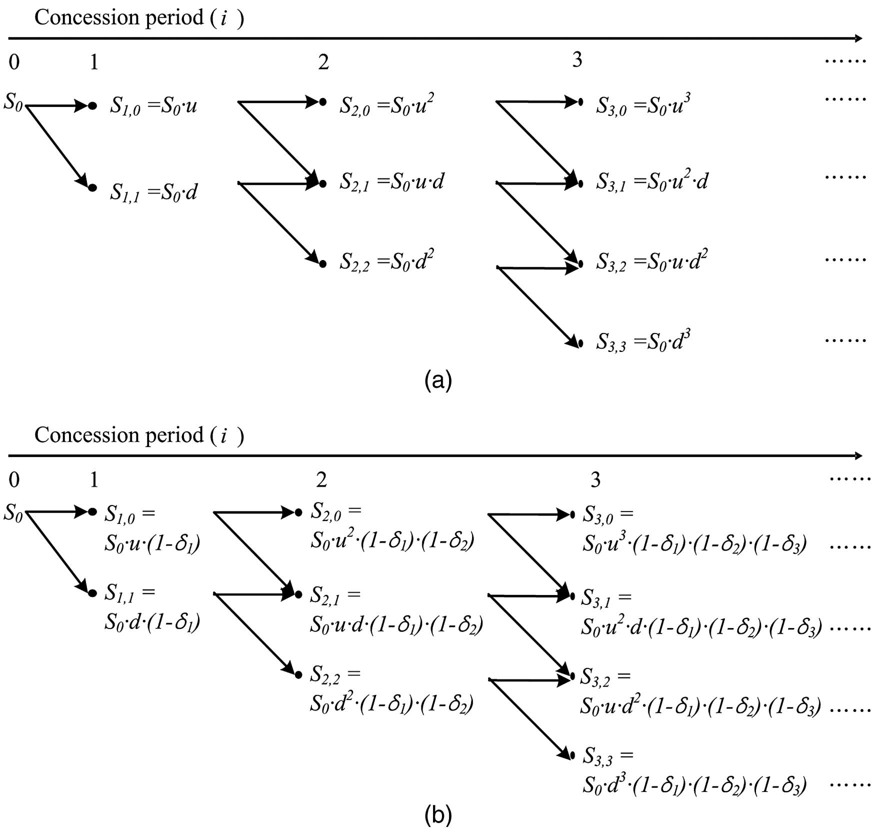
$$d = e^{-\sigma\sqrt{\Delta t}} \tag{8}$$

$$p = \frac{e^{r\Delta t} - d}{u - d} \tag{9}$$

where σ = volatility of the underlying asset; n = number of the historical HDAT data cases; o_t = change rate of the HDAT volume; $\bar{o}$ = mean value of o_t; u = upturn coefficient; Δt = time period (generally one year); d = downturn coefficient; p = risk-neutral probability; and r = risk-free interest rate.

In Step 2, the revised binomial lattice model is established. The original binomial lattice model calculates the underlying asset value that changes discretely based on the upturn coefficient (u) and downturn coefficient (d) during the concession period. In the original binomial lattice model, for example, if the underlying asset value at the starting point is S_0, the underlying asset value in the following period becomes $S_0 \cdot u$ (for the top node) or $S_0 \cdot d$ (for the bottom node) [Fig. 2(a)].

Depending on the financing or market condition, the investment may be delayed or may be planned in a multiphased development after dividing into smaller projects. As an HSA BOT project generates profit during the operation period, no profit will be gained if the project is being delayed. Accordingly, for an HSA BOT project



(a)

(b)

Fig. 2. Difference between the original and revised binomial lattice models: (a) original binomial lattice model; (b) revised binomial lattice model

that includes the delayed investment or that is planned in a multiphased development, the binomial lattice model should be reconstructed with the consideration of the profit loss.

In an HSA BOT project, as the end of the concession period is fixed, the operating duration of the project may be shortened if the investment is delayed. In addition, the shortened operating duration may lead to the decrease of operating revenue. Therefore, the decreasing operating revenue should be considered to calculate the OV for HSA BOT project. Meanwhile, as the profit may differ in each year during the concession period, the profit loss due to the delay of the project should also be considered differently depending on different years. Therefore, the profit loss can be reflected on the binomial lattice model by using the leakage rate, which signifies the ratio of the profits decreased due to the delay of the project. That is, this study proposed the revised binomial lattice model, which can consider profit loss due to the delayed investment by including the revised binomial lattice model.

The leakage rate can be calculated using Eq. (10). The underlying asset value of an HSA BOT project with the delayed investment can be calculated by applying the leakage rate to the original underlying asset value, as shown in Eqs. (11) and (12). For example, if an HSA BOT project with S_0 of the underlying asset value at the starting point is delayed for one year, the underlying asset value after one year can be estimated to be $S_0 \cdot u \cdot (1-\delta_1)$ or $S_0 \cdot d \cdot (1-\delta_1)$ [Fig. 2(b)]. As a result, the revised binomial lattice model is established, as shown in Fig. 2(b). In addition, the underlying asset value ($S_{T,j}$) at the expiry time (T) can be calculated using Eq. (11), and the underlying asset value ($S_{i,j}$) at a specific point in time (i) can be calculated using Eq. (12)

$$\delta_j = \frac{\frac{OR_j - OC_j - \mathrm{LUF}_j}{(1+r_w)^j}}{\sum_j^T \frac{(OR_j - OC_j - \mathrm{LUF}_j)}{(1+r_w)^j}} \times 100 \qquad (10)$$

$$S_{T,j} = S_0 u^{T-j} d^j (1-\delta_T)(1-\delta_{T-1})(1-\delta_{T-2}) \cdots (1-\delta_2)(1-\delta_1), \quad j = 0,1,2,\ldots,T \qquad (11)$$

$$S_{i,j} = S_0 u^{i-j} d^j (1-\delta_i)(1-\delta_{i-1})(1-\delta_{i-2}) \cdots (1-\delta_2)(1-\delta_1), \quad i = 1,2,3,\ldots,T, \qquad j = 0,1,2,\ldots,i \qquad (12)$$

where δ_j = leakage rate in year j occurring through the exercise of the option to delay; OR_j = expected annual operating revenue from operating HSA in year j; OC_j = expected annual operating cost, including the annual sales, maintenance and operating cost, and tax service, when the accumulated earnings indicate a surplus in year j; LUF_j = expected annual total land-use fee paid to the government based on OR_j in year j; r_w = WACC on the project as the discount rate; T = concession period; S_0 = original underlying asset; and $S_{j,k}$ = underlying asset at node k in year j.

In Step 3, the OV of an HSA BOT project is calculated via backward iteration. In an HSA BOT project with expiry time (T), the OV ($V_{T,j}$) at the expiry time (T) should first be calculated to get the OV of the project ($V_{0,0}$) at the date of evaluation (0). As shown in Eq. (13), $V_{T,j}$ is calculated by deducting the initial investment cost (X) from the underlying asset value ($S_{T,j}$) at the expiry time (T) (Cox et al. 1979). When the concession period is t, the number of OVs is $t+1$. For example, as shown in Fig. 3, for a three-year project, four OVs—$V_{3,0}$, $V_{3,1}$, $V_{3,2}$, and $V_{3,3}$—are calculated at the expiry time. In addition, the OV ($V_{i,j}$) of an HSA BOT project at

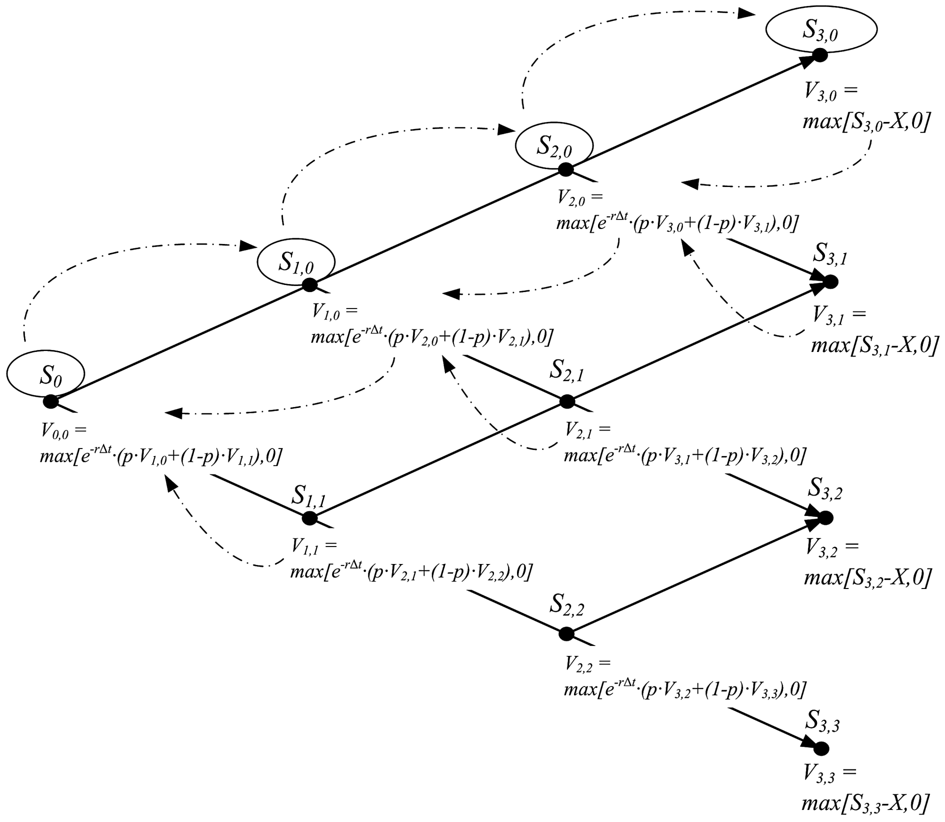


Fig. 3. Option value calculation process on binomial lattice model

time (i) on node (j) can be calculated using Eq. (13) (Cox et al. 1979). For example, as shown in Fig. 3, the OV ($V_{2,0}$), which means OV at second year on node 0, is calculated based on $V_{3,0}$ and $V_{3,1}$. By repeating backward iteration in this way, eventually, the OV at the date of evaluation ($V_{0,0}$) is calculated based on $V_{1,0}$ and $V_{1,1}$

$$V_{T,j} = \max(S_{T,j} - X, 0), \qquad j = 0,1,2,\ldots,T \tag{13}$$

$$V_{i,j} = \max\{e^{-r\Delta t}[pV_{i+1,j} + (1-p)V_{i+1,j+1}], 0\}, \quad (0 \le i \le T-1, 0 \le j \le i) \tag{14}$$

where $V_{T,j}$ = option value at expiry time T on node j; $S_{T,j}$ = underlying asset at expiry time T on node j; X = present value of initial investment cost; j = node number; $V_{i,j}$ = option value at time i on node j; r = risk-free interest rate; p = risk-neutral probability; and Δt = time period (generally yearly basis).

Meanwhile, as mentioned above, an HSA BOT project may be divided into smaller projects and planned as multiphased development according to the changes in market condition or the financing plan. If an HSA BOT project is planned as multiphased development, the investment cost and concession period for each phase will also change. Thus, the OV of an HSA BOT project that consists of several phased subprojects cannot be calculated by the aforementioned single model. This study developed a parallel revised binomial lattice model to calculate the OV of an HSA BOT project that consists of several phased subprojects. In the parallel model, two or more revised binomial lattice models, which consist of one independent and several dependent binomial lattice models, are available at the same time. The duration of the independent binomial lattice model is longer than or equal to the dependent model (Kodukula and Papudesu 2006). For instance, if two phased developments are planned, both first and second phase developments are maintained until the end of the concession period, whereas first-phase development should be started before second-phase development. In addition, both of two phased developments have the option to delay.

Fig. 4 shows how the OV of an HSA BOT project of which second-phase development starts one year after the first-phase development is calculated. The initial investment cost (X) should be separated into each phase to calculate the OV at the starting point ($V_{0,0}$). As shown in Fig. 4, the concession period of the first-phase development is three years, and therefore, $V^1_{3,0}$ is calculated by deducting the initial investment cost of the first-phase development (X^1) from the underlying asset value of the project at the expiry time ($S_{3,0}$). As the concession period of the second-phase development is one year shorter than that (i.e., three years) of the first-phase development, the initial investment cost of the second-phase development (X^2) should be considered at second year. Namely, $V^2_{2,0}$ can be calculated by deducting X^2 from $V^1_{2,0}$, which is calculated via backward iteration based on $V^1_{3,0}$ and $V^1_{3,1}$. The OV at the starting point ($V^2_{0,0}$), which considering both of the first-phase and second-phase projects, is calculated via backward iteration based on $V^2_{2,j}$. The OV of a project divided into m phases ($V^m_{0,0}$) can also be calculated using the same method. The calculation of Fig. 4 can be expressed in Eqs. (15)–(18)

$$V^1_{T,j} = \max(S_{T,j} - X^1, 0), \qquad j = 0,1,2,\ldots,T \tag{15}$$

$$V^1_{i,j} = \max\{e^{-r\Delta t}[pV^1_{i+1,j} + (1-p)V^1_{i+1,j+1}], 0\}, \quad (0 \le i \le T-1, 0 \le j \le i) \tag{16}$$

$$V^m_{T-q^m,j} = \max(V^{m-1}_{T-q^m,j} - X^m, 0), \qquad j = 0,1,2,\ldots,(T-q^m) \tag{17}$$

$$V^m_{i,j} = \max\{e^{-r\Delta t}[pV^m_{i+1,j} + (1-p)V^m_{i+1,j+1}], 0\}, \quad (0 \le i \le T-q, 0 \le j \le i) \tag{18}$$

where $V^1_{T,j}$ = option value of a project at the expiry time T with node j when only the first-phase development is considered; $S_{T,j}$ = total underlying asset value at the expiry time T on node j; X^1 = present value of the initial investment cost for the first-phase development; $V^1_{i,j}$ = option value at time i on node j in the concession period when only the first-phase development is considered; p = risk-neutral probability; $T - q^m$ = expiry time of the mth-phase development; q^m = time gap between the $(m-1)$th-phase and mth-phase developments; $V^{mm}_{T-q,j}$ = option value of a project at the expiry time $(T - q^m)$ on node j when the investment for the first-phase to mth-phase developments is considered; X^m = present value of the investment on the mth-phase development; and $V^m_{i,j}$ = option value of a project at time i on node j in the concession period when the investment for the first-phase to mth-phase developments is considered.

Expanded NPV of HSA BOT Projects

The NPV calculated by the conventional DCF analysis signifies the static value of an HSA BOT project based on the expected cash flow whereas the OV calculated by the revised binomial lattice model signifies the strategic value of an HSA BOT project based on uncertainty of future. Trigeorgis (2005) proposed ENPV, which combined NPV and OV to complement the conventional DCF analysis, as shown in Eq. (17) (Trigeorgis 2005). The developed model also evaluates the financial viability of an HSA BOT project by proposing ENPV

$$\text{Expanded NPV (ENPV)} = \text{NPV} + OV \tag{19}$$

where NPV = net present value based on the static cash flow through DCF analysis; and OV = option value through ROV.

Monte Carlo Simulation

The investment cost, annual operating revenue, and risk-free interest rate are the variables that affect ENPV, but the aforementioned model is based on the static value of the variables and presents the deterministic results, which fail to reflect the variability of these variables. This study applied the MCS to the model so as to consider the variability of the variables. As many MCS tools have been developed, it is possible to apply one of these tools to the developed model. For MCS, this study used the *@Risk 5.5* tool by Palisade Corporation among many MCS tools.

For MCS, the distribution of uncertain variables should be defined. The distribution of the investment cost, the annual operating revenue, and the risk-free interest rate can be set using the data-fitting function of the *@Risk 5.5* tool. The possibility of fluctuation on the initial investment cost of HSA BOT projects can be assumed based on the ratio of contract cost to completion cost of the project that the contractor has carried out in the past. Therefore, the distribution of the expected investment cost can be defined by using the ratio of contract cost to completion cost as a proxy variable. As mentioned above, the annual operating revenue is mainly affected by the HDAT volume (Kim and Lee 2013). Thus, the distribution of the annual operating revenue can be set using the fluctuation rate of the HDAT volume yearly as a proxy variable. The distribution of

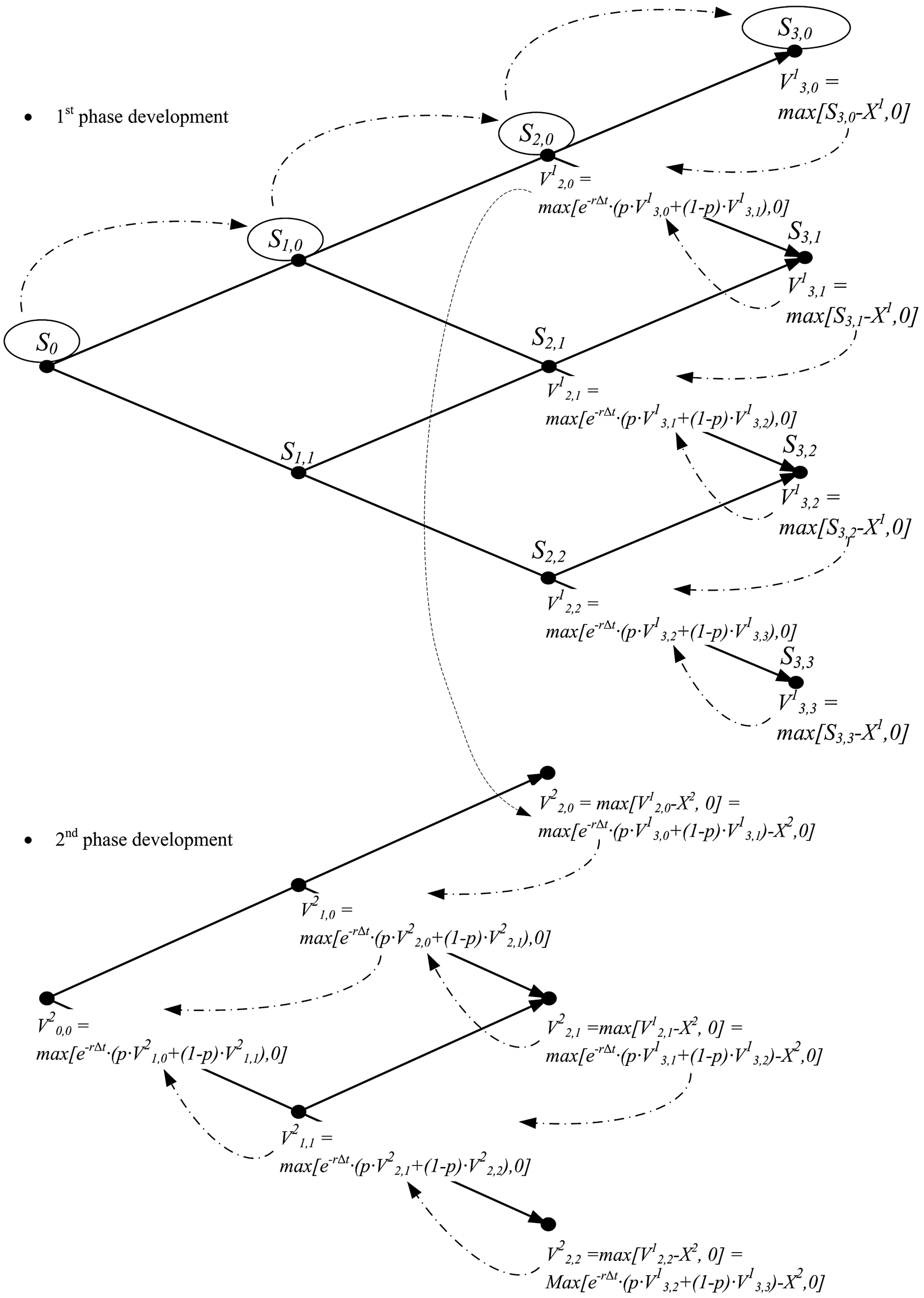


Fig. 4. Calculation process on revised binomial lattice model with parallel option

the risk-free interest rate can be set based on the time series data of the three-year government bond rate. Also, some variables are defined as linkage variables related to the uncertain variables. WACC is affected by the risk-free interest rate, and land-use fee; leakage rate and annual operating cost are affected by annual operating revenue. The annual operating cost consists of the fixed and variable cost. The costs for debt service, insurance, and depreciation are the fixed cost. As the fixed costs have a little relationship with annual operating revenue, another proxy variable should be considered for the fixed operating cost instead of the annual operating revenue. However, the fixed operating costs for debt service, insurance, and depreciation are less than 10% of total operating cost for general HSAs in South Korea (Expressway Corporation 2011). Therefore, this study considered the operating cost as the variable cost instead of considering the fixed cost separately.

Thus, WACC can be set identically to the distribution of the risk-free interest rate while the land-use fee, leakage rate, and annual operating cost can be set equally to the distribution of the annual operating revenue. Table 2 shows the distribution of variables.

Table 2. Distribution of Variables

Variable	Distribution	Type
Investment cost	Log-logistic	Uncertain variable
Annual operating revenue	Logistic	Uncertain variable
Risk-free interest rate	Triangular	Uncertain variable
Annual operating cost	Logistic	Linkage variable
WACC	Triangular	Linkage variable
Land-use fee	Logistic	Linkage variable
Leakage rate	Logistic	Linkage variable

Table 3. Development Scenario in Each Phase

Category	Program	Area (m^2)	Construction	Concession	Scenarios
First-phase development	HSA on direction to Seoul	5,266	‘05~’06	‘07~’29	1
Second-phase development	HSA on direction to Gangneung	2,668	‘08~’09	‘10~’29	2
Third-phase development	Sports attractions (e.g., driving range with par 3 golf course)	22,853	‘11~’12	‘13~’29	3

Note: S#1 = Scenario 1 including only first-phase development; S#2 = Scenario 2 including first-phase and second-phase developments; and S#3 = Scenario 3 including all-phases developments.

Case Study

To demonstrate the usability of the developed model, a case study was conducted based on “A” HSA BOT project located in South Korea. The case project was planned as mixed-use HSA, which includes restaurants, convenience stores, restrooms, gas stations, specialized leisure facilities, such as a shopping mall, spa, driving range, par-3 golf course, and its access roads to cover both directions on Yongdong Highway. The gross area of the case project was 23,000 m^2. Of $66 million of investment for the whole development of the case project, the special purpose company, which represents this project, planned that $20 million would be invested as equity from a parent company and the remaining $46 million would be invested as a loan. The case project had been constructed in 2006. For the case project, the public sector guaranteed the private sector a 23-year concession period from 2007 to 2029.

Because the end of the concession period is fixed in a BOT project, completing the investment at the early stage is the way to maximize the operating revenue. However, a multiphased development may be the alternative for risk hedging because investment timing can be controlled after observing the market condition. In the case project, the private sector established the investment plan consisting of three phases (2006, 2008, and 2011) as shown in Table 3, by considering the financing plan and operating efficiency. Scenario 1 means only the first-phase development while Scenarios 2 and 3 include the first-phase and second-phase developments or up to the third-phase development, respectively. The detail information of the case project is described in Tables 3–5. The land-use fee rate of the case project was set to 11.19%, which was based on (1) the competition among the bidders, and (2) the negotiation with the public sector.

NPV of the Case Project

Using the Eqs. (2)–(5), the NPV of the case project was calculated. Table 4 shows the investment plan of each development phase. In the case project, WACC was calculated to be at 7.73%$\{= [(46.17 \div 65.96) \times 8.0\%] \times (1 - 27.5\%) + [(19.79/65.96) \times 10.5\%]\}$, based on Eq. (5). Table 5 shows the expected cash flow of the case project that is based on the private sector’s business plan and the NPV of the case project calculated using Eq. (4). As shown in Table 5, the NPV of the case project based on Scenario 3 (including the first-phase, second-phase, and third-phase development) was −\$4.87 million $(= -1.89 + 0.75 + -3.72)$ while that of Scenario 2 (including the first-phase and second-phase development) and Scenario 1 (including only the first-phase development) was −\$1.14 million $(= -1.89 + 0.75)$ and −\$1.89 million, respectively. Thus, the calculated NPV showed that the investment in the case project was inappropriate.

ROV of the Case Project

The NPV through DCF analysis did not consider the value of uncertainty that could occur within the 23-year concession period. The case study conducted ROV to calculate the values of the case project due to the future uncertainty. Table 6 shows the defined variables for ROV.

The underlying asset value and initial investment cost in Table 6 are the present values that were converted as of 2006, the start date of the first-phased development. The expiry time signified the end of the concession period and all development phases had the same expiry time. As the second-phase development was planned to start three years later, and the third-phase was planned to start six years later than the first-phase, the concession period of the second-phase and third-phase development were 20 and 17 years, respectively. As mentioned above, the risk-free interest rate was set based on the three-year government bond rate, as presented by Korean statistical information service (KOSIS). The risk-free interest rate in the case study was 4.88%, which was the average of the three-year government bond rate between 2001 and 2005, just before the case project started (KOSIS 2013). Due to the international monetary fund (IMF) crisis in 1997, the interest rate including government bonds in South Korea was abnormally high until 2000. For this reason, the government bond rate before 2000 was disregarded. The volatility was calculated by applying the historical data of the HDAT volume from 1995 to 2005, obtained from TMS, to Eq. (6) (TMS 2012). The upturn and downturn coefficients and the risk-neutral probability were calculated by applying the time period, risk-free interest rate, and volatility, all of which were previously determined, to Eqs. (7)–(9). The leakage rate was calculated using Eq. (10), and the applied leakage rate to Scenario 1 was shown in Table 7.

Using the variables in Table 6, the revised binomial lattice model for three scenarios was established. In Scenario 1, the model is a single option to delay in a single binomial structure whereas in Scenarios 2 and 3, the model is a parallel option to delay in a double or triple binomial structure. Table 7 shows the revised binomial lattice model of the underlying asset in Scenario 1. Table 8 shows the process of calculating the OV of the case project through backward iteration based on the revised binomial lattice model in Table 7.

Table 4. Investment Plan

	Investment cost (million USD)					
Category	Total	First-phase development	Second-phase development	Third-phase development	Interest rate (%)	Tax rate (%)
Equity	19.79	8.38	4.86	6.55	8.00	−27.5
Loan	46.17	19.55	11.34	15.28	10.50	
WACC	7.73%	—	—	—	—	—

Table 5. Expected Cash Flow of Case Project

	Cash flow (million USD)											
	First-phase development				Second-phase development				Third-phase development			
Year	Invest	Revenue	Cost	NPV	Invest	Revenue	Cost	NPV	Invest	Revenue	Cost	NPV
2006	27.93	—	—	−4.87	—	—	—	0.75	—	—	—	−3.72
2007	—	6.74	6.48	—	—	—	—	—	—	—	—	—
2008	—	10.42	9.44	—	4.40	—	—	—	—	—	—	—
2009	—	12.16	10.82	—	11.81	—	—	—	—	—	—	—
2010	—	14.55	12.64	—	—	9.04	7.85	—	—	—	—	—
2011	—	16.51	14.63	—	—	9.47	8.39	—	5.38	—	—	—
2012	—	17.59	16.04	—	—	9.69	8.84	—	16.44	—	—	—
2013	—	18.38	16.84	—	—	10.26	9.40	—	—	8.14	7.07	—
2014	—	19.12	17.47	—	—	10.95	10.00	—	—	8.52	7.39	—
2015	—	20.12	18.46	—	—	11.46	10.52	—	—	8.72	7.70	—
2016	—	21.04	19.23	—	—	12.11	11.06	—	—	9.23	8.06	—
2017	—	22.15	20.15	—	—	12.66	11.52	—	—	9.85	8.44	—
2018	—	23.17	20.99	—	—	13.38	12.12	—	—	10.31	8.83	—
2019	—	24.38	21.99	—	—	14.00	12.63	—	—	10.90	9.24	—
2020	—	25.50	22.90	—	—	14.79	13.29	—	—	11.40	9.65	—
2021	—	26.82	23.34	—	—	15.49	13.47	—	—	12.04	10.10	—
2022	—	28.07	23.69	—	—	16.36	13.81	—	—	12.60	10.56	—
2023	—	29.52	25.38	—	—	17.13	14.55	—	—	13.32	11.05	—
2024	—	30.88	25.51	—	—	18.10	14.95	—	—	13.94	11.55	—
2025	—	32.47	27.29	—	—	18.96	15.93	—	—	14.72	12.09	—
2026	—	34.13	28.07	—	—	19.87	16.35	—	—	15.42	13.02	—
2027	—	35.71	28.78	—	—	20.99	16.92	—	—	16.29	13.64	—
2028	—	37.53	29.68	—	—	22.01	17.40	—	—	17.06	14.27	—
2029	—	39.43	26.18	—	—	23.08	14.98	—	—	17.89	12.92	—

Table 6. Variables for ROV of Case Project

Variables	Symbol	First-phase development	Second-phase development	Third-phase development
Underlying asset value (million USD)	S	26.04	13.98	10.51
Initial investment cost (million USD)	X	27.93	13.24	14.23
Expiry time (year)	T	23	20	17
Time unit (year)	Δt	1	1	1
Risk-free interest rate	r	4.88%	4.88%	4.88%
Volatility	σ	7.64%	7.64%	7.64%
Upturn coefficient	u	1.0794	1.0794	1.0794
Downturn coefficient	d	0.9265	0.9265	0.9265
Risk-neutral probability	p	0.8079	0.8079	0.8079
Leakage rate[a]	δ	0.9~9.2%	0.6~9.6%	0.6~8.0%

[a]Leakage rate is different from every year during concession period.

For example, the upturn and downturn underlying asset values of Scenario 1 after one year were $27.85\{= 26.04 \times 1.0794 \times (1 - 0.009)$ and $23.91[= 26.04 \times 0.9265 \times (1 - 0.009)]\}$, respectively. Also, as shown in Table 8, the OV ($V^1_{23,0}$) of Scenario 1 at the end of the concession period is $25.73\ \{= \max[(53.66 - 27.93), 0]\}$. After 23 times repeated backward iteration considering the 23-year concession period, OV ($V^1_{0,0}$) at the date of the evaluation of Scenario 1 was finally calculated at $1.37[= \max(\{e^{-0.0488}[0.8079 \times 1.60 + (1 - 0.8079) \times 0.73], 0\})$. Table 9 shows the OVs of the case project in the three development scenarios.

The OVs of the case project could be changed depending on the risk-free interest rate and volatility. To compare with the calculated OV in Table 9, the average of the five-year and 10-year government bond rate in same period for the risk-free interest rate, 80% and 120% of the volatility calculated based on HDAT were applied. Table 10 shows how OVs can be changed depending on the risk-free interest rate and volatility. Because ROV is the method for measuring the value of uncertainty, OV with 120% of volatility was higher than others. As long-term bonds have more uncertainty than short-term bonds, long-term government bonds have higher interest rates than the three-year one. Thus, the OV with three-year government bond rate was lower than OVs with five-year or 10-year government bond rates, as shown in Table 10. In addition, Table 10 shows that it is necessary to consider the variability of the variables through stochastic approach like MCS because it is important to determine the appropriate risk-free interest rate and volatility for ROV.

ENPV of the Case Project through MCS

The ENPV of the case project was calculated by integrating the NPV in Table 5 and the OV in Table 9. The NPV and OV in Tables 5 and 9, however, did not consider the variability of the variables, such as the investment cost, operating cost, and revenue for each year, and the risk-free interest rate. Accordingly, the ENPV was calculated by considering the variability of these variables through

Table 7. Revised Binomial Lattice Model Based on Scenario 1

Upturn coefficient	Downturn coefficient	Underlying asset value (million USD) 0 year (0%)[a]	1 year (0.9%)	2 year (3.3%)	3 year (4.1%)	. . .	23 year (9.2%)
1.0794	0.9265	26.04	27.85[b]	29.07	30.08	. . .	53.66
		—	23.91[c]	24.95	25.82	. . .	46.06
		—	—	21.42	22.36	. . .	42.13
		—	—	—	19.02	. . .	34.88
		—	—	—	—	. . .	29.85
		—	—	—	—	. . .	⋮
		—	—	—	—	—	1.60

[a] The percentages in brackets mean the leakage rates.
[b] $27.85 = 26.04 \times 1.0794 \times (1 - 0.009)$.
[c] $23.91 = 26.04 \times 0.9265 \times (1 - 0.009)$.

Table 8. Process of Calculating OV Based on Scenario 1

Risk-free interest rate	Risk-neutral probability	Option value (million USD) 0 year	1 year	2 year	3 year	. . .	23 year
4.88%	0.8079	1.37[a]	1.60	1.87	2.18	. . .	25.73[b]
		—	0.73	0.87	1.04	. . .	18.13
		—	—	0.31	0.38	. . .	14.20
		—	—	—	0.09	. . .	6.95
		—	—	—	—	. . .	1.92
		—	—	—	—	. . .	⋮
		—	—	—	—	—	0

[a] $1.37 = \max\{e^{-0.0488}[0.8079 \times 1.60 + (1 - 0.8079) \times 0.73], 0\}$.
[b] $25.73 = \max[(53.66 - 27.93), 0]$.

Table 9. OV of Case Project under Three Development Scenarios

Scenario	Option value (million USD)	Leakage rate (%)
Number 1 (first-phase development only)	1.37	0.9~9.2
Number 2 (first-phase and second-phase development)	2.00	0.6~9.6
Number 3 (first-phase, second-phase, and third-phase development)	1.25	0.6~8.0

Table 10. OV Variations on Scenario 2 by Risk-Free Interest Rate and Volatility

Government bond (year)	Risk-free interest rate (%)	Volatility (%)	Option value (million USD)
3	4.88	6.11 (80%)	1.45 (72.5%)
		7.64 (original)	2.00 (100%)
		9.16 (120%)	2.44 (121.6%)
5	5.22	6.11 (80%)	1.97 (98.3%)
		7.64 (original)	2.56 (127.9%)
		9.16 (120%)	2.95 (147.4%)
10	5.64	6.11 (80%)	2.67 (133.1%)
		7.64 (original)	3.33 (166.2%)
		9.16 (120%)	3.66 (182.7%)

Note: The percentages in brackets mean the ratio to original value.

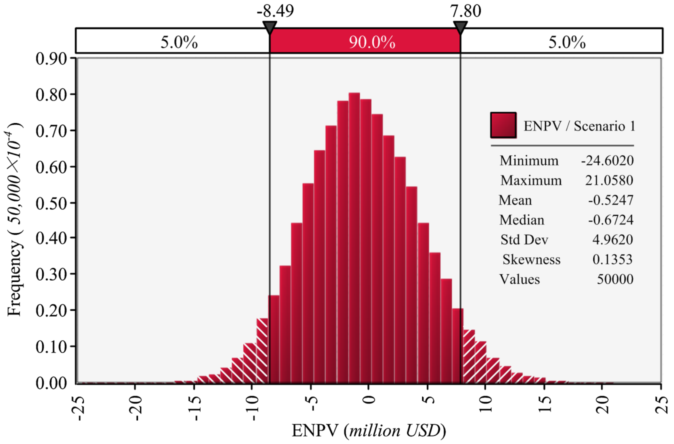


Fig. 5. ENPV results on Scenario 1 using MCS

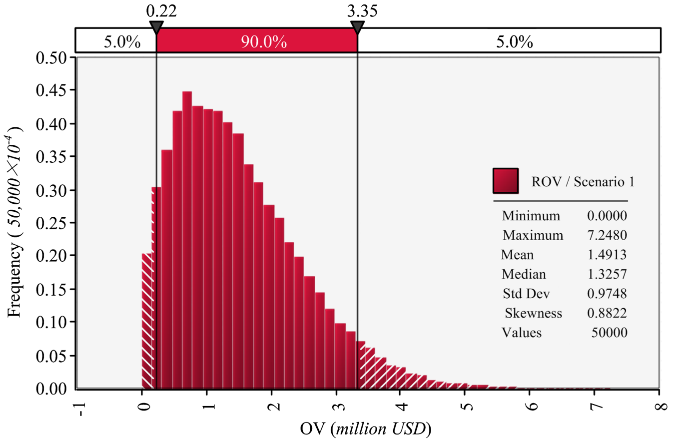


Fig. 6. OV results on Scenario 1 using MCS

MCS. Using the *@Risk 5.5* tool, 50,000 simulations were performed in the case study.

First, the variables for MCS were defined as in Table 2. According to the data fitting based on the ratio data of contract cost to completion cost (90.9–117.2%) of the 18 infrastructure projects that the contractor of the case project had completed between 2000 and 2005, the investment cost was defined as a log-logistic distribution. Similarly, according to the data fitting based on the fluctuation rate of the HDAT volume between 1995 and 2005 (84.7–109.8%), the annual operating revenue was defined as a logistic distribution. The distribution of the risk-free interest rate was set based on the three-year government bond rate during 2001–2005. Generally, if enough historical data are not available, triangular distribution can be used (Back et al. 2000; Hong and Hastak 2006, 2007; Sukumaran et al. 2006). Therefore, the three-year government bond rate data were defined as stochastic values expressed by triangular distribution (minimum 4.11%, maximum 5.78%, most likely 4.88%). As mentioned above, WACC was defined as a triangular distribution while the land-use fee, annual operating cost, and leakage rate were defined as a logistic distribution.

Fig. 5 shows the ENPV of Scenario 1 based on MCS. Within the 90% confidence interval, ENPV shows the −\$8.49 to 7.80 million distribution. The ENPV distribution is right-skewed due to the effect of the distribution of OV, as shown in Fig. 6, so that the mean value was shown to be higher than the median value. As opposed to the normal distribution, it is reasonable to present the median value, not the mean value, as the primary value in the skewed distribution (Sheskin 2003). Therefore, this case study presented the median value of 50,000 simulations as the final result.

Table 11. Results of Case Study

	Result (million USD)		
Scenario	NPV	OV	ENPV
1	−2.16	1.49	−0.67
2	−1.28	2.04	0.76
3	−5.12	1.28	−3.79

Results and Discussions

This study developed a model that is capable of evaluating the financial viability of an HSA BOT project. The developed model presents the ENPV of an HSA BOT project by considering the OV as well as the NPV of the project. To determine the usefulness and validity of the developed model, this study conducted a case application to the three scenarios in an HSA BOT project in South Korea. Table 11 shows the NPV, OV, and ENPV of the three scenarios in the case project presented by the developed model. As the results in Table 11 reflected the variability of variables using MCS, they are different from the sum of the NPV in Table 5 and the OV in Table 9. In addition, Fig. 7 shows the cumulative distribution function (CDF) to the ENPV of the three scenarios produced by 50,000 simulations. According to Fig. 7, the probability that the ENPV of Scenario 2 is larger than 0 was 55.3%, whereas those of Scenarios 1 and 3 were 44.7% and 25.2%, respectively. Namely, Fig. 7 shows that the probability of obtaining positive profit through Scenario 1, 2, or 3 is 44.7%, 55.3%, or 25.2%, respectively.

Generally, the valuation of the financial viability of a BOT project considers only the NPV based on DCF analysis. As shown in Table 11, if the financial viability of the case project was evaluated based only on the NPV, the investment of the case project should be stopped because the NPVs of the three scenarios were all negative values. However, the OVs of the case project in the three scenarios were positive. Consequently, the ENPV of the case project in Scenario 2 was turned to a positive value, as shown in Table 11. It is reasonable to invest the case project throughout Scenario 2 if the financial viability of the case project is evaluated based on the ENPV in Table 11.

To determine the validity of the developed model, the actual condition of operation of the case project was analyzed. Fig. 8 shows the expected and actual value of revenue, investment cost, and cumulative cash flow during seven years of operation (i.e., from 2006 to 2013). The expected value in Fig. 8 was from the expected cash flow of Scenario 2 (Table 5). The actual revenues are significantly improved from the expected value, and there were minor investments for improving facilities due to the additional revenues. Total cumulative cash flow is still negative owing to initial investments, but it has been continuously improved more than the expectation. The various changes by the project managers during the actual operation duration made the cash flow of the case project better than the expectation. The developed model could consider the improved value of the case project due to these changes whereas the existing methods do not. Although it is too early to judge whether the ENPV from the developed model can evaluate the financial viability of the HSA BOT project because there are still lots of remaining concession periods, it is clear that the ENPV results in the case project are closer to actual conditions of the case project compared to the result from DCF analysis.

The developed model considers the characteristics of HSA BOT projects different from those of conventional BOT projects. In addition, the developed model evaluates the financial viability of HSA BOT projects more comprehensively by considering the value of the HSA BOT projects due to uncertainty through the ROV, which existing methods did not consider. These make the developed model to evaluate the financial viability of HSA BOT projects and present the robust and comprehensive results compared with existing DCF methods. It means that the developed model can support

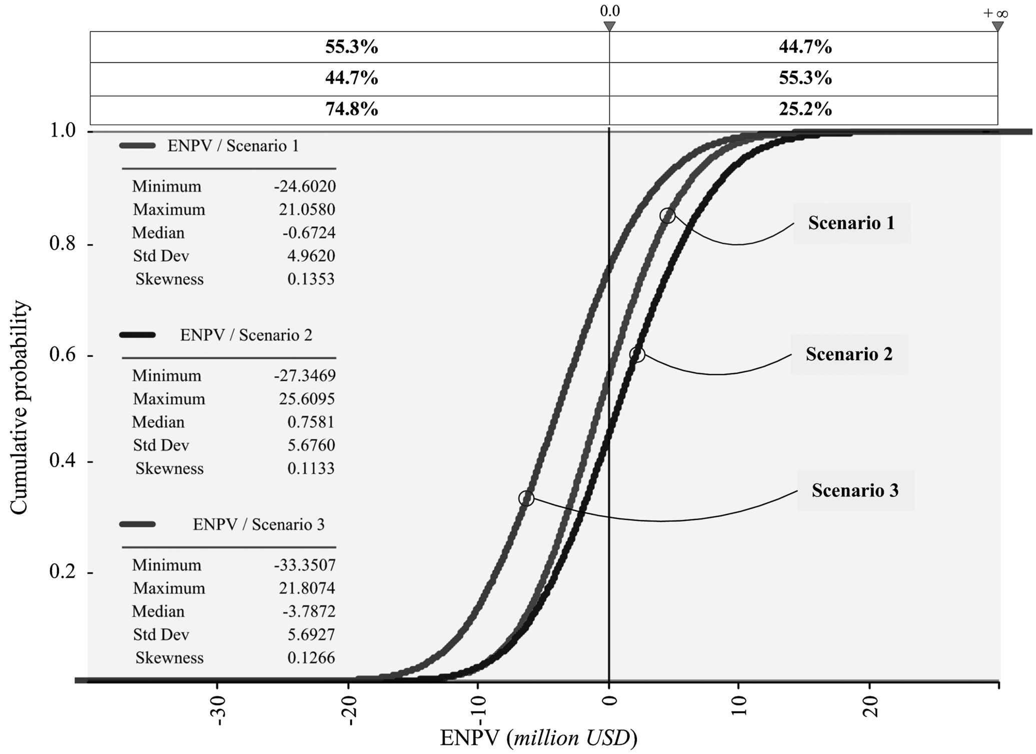


Fig. 7. Cumulative distribution function of the ENPV of Scenarios 1, 2, and 3

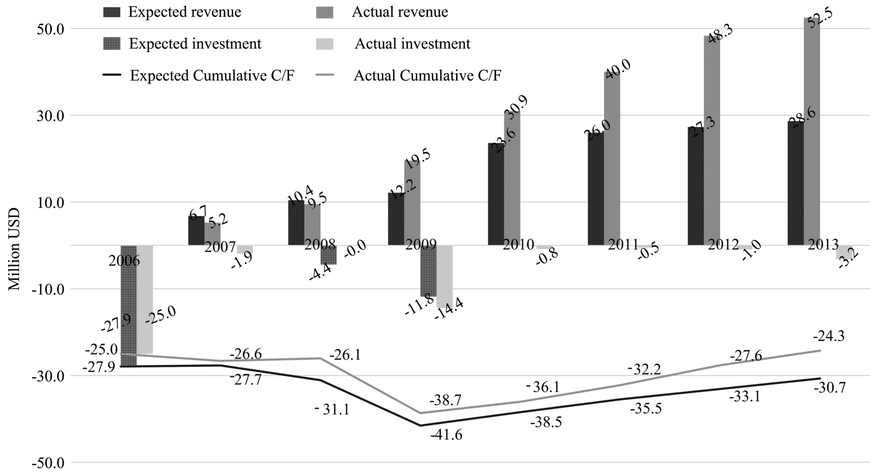


Fig. 8. Comparison between expected and actual cash flow of the case project in Scenario 2

the private sectors to make more reasonable decision making by evaluating the financial viability of HSA BOT projects.

Conclusions

The conventional DCF analysis is widely used for the valuation of construction projects. However, a BOT project has the uncertainty of a long-term concession period. Furthermore, since an HSA BOT project in South Korea, as opposed to a conventional BOT project, has a peculiar characteristic that the private sector should pay LUF to the public sector instead of receiving MRG from the public sector, the financial viability evaluation of an HSA BOT project is more important for the private sector. For this reason, the existing methods that previous studies have proposed to evaluate the financial viability of a BOT project are inappropriate for evaluating the financial viability of an HSA BOT project. Therefore, this study developed a more appropriate model for evaluating the financial viability of an HSA BOT project.

The developed model has the following characteristics: (1) as opposed to the existing methods considering only NPV, the developed model can more comprehensively evaluate the financial viability of an HSA BOT project by considering not only NPV but also the value of an HSA BOT project due to future uncertainty throughout the ROV; (2) the developed model can calculate more accurately the NPV of an HSA BOT project by considering the LUF, which is one of the characteristics of HSA BOT projects; (3) the developed model can calculate more accurately the OV for an HSA BOT project through the revised binomial lattice model. When the private sector decides the option to delay the investment for an HSA BOT project, the operating revenue may decrease due to the shortened duration of operating the project. As opposed to the binomial lattice model, the revised binomial lattice model, which was developed in this study, considers the leakage rate to reflect these characteristics of an HSA BOT project. As the original binomial lattice model overlooks the decreasing operating revenues due to the delayed investment, the OV of an HSA BOT project can be overestimated when the original binomial lattice model is used; and (4) as the variables, such as the initial investment cost, annual revenue and operating cost, risk-free interest rate, and WACC, are not static values, a deterministic result may include errors. The developed model can present a result considering the variability of the variables by using MCS.

In this study, a case study was conducted to verify the usability of the developed model. The evaluation of the three development scenarios showed that the ENPV proposed by the developed model provides a more positive value than the NPV proposed by DCF analysis because the developed model considers not only the NPV but the OV based on the uncertainty of future in the HSA BOT project. The ENPV proposed by the developed model results from the consideration of the characteristics of an HSA BOT project as well as the uncertainty of the variables, and therefore, it is more comprehensive than NPV. In particular, the results of the case study demonstrated that the developed model can more accurately evaluate the financial viability of an HSA BOT project compared to the conventional DCF analysis. Therefore, it is reasonable for the private sector to use the developed model for evaluating the financial viability of an HSA BOT project so that it can determine its investment decision.

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