A Study on the Decision Making of New Construction Technology information Services Development Project Using Real Option Model

Seong-Yun Jeong

Abstract—**In this paper, the Construction Technology Digital Library Service (CODIL) system is operated as part of the project to build the construction technology information distribution system aimed at improving the technology competitiveness of the construction industry. With the recent migration of the database that had so far been serviced by the CODIL system to other systems, the overall usage of the system is expected to fall. We are planning a new construction technology information services development to raise the usage of the system with a limited budget. This study evaluated the economic feasibility of this project using the real option model (ROM) method to enhance the implied payoff of the system. The results of this study are expected to provide the necessary information to decision makers, which is required for the strategic decision making on the new services development project by considering the uncertainty of the future.**

Index Terms—**Real option model, construction technology digital library system, economic analysis, decision making.**

I. Introduction

The construction industry of South Korea began to be exposed to an increasingly competitive environment both in the domestic and overseas construction markets when it joined Uruguay Round and WTO in the mid-1990s. To survive in the increasingly competitive markets, the industry was required to change its business practices from being highly labor-intensive in the past to being technology-intensive. Having arrived at the conclusion that the technological competitiveness of the domestic industry should be markedly strengthened for a smooth transition of the business practices to those that are technology-intensive, the South Korean Government enacted Article 18 of the Construction Technology Promotion Act. This provision specifies that a construction technology information distribution system should be established so that construction engineers would be able to access the rich store of construction technology information anywhere and anytime.

According to this provision, the Korea Institute of Civil and Building Construction Technology (KICT) was commissioned by the Ministry of Land, Infrastructure, and Transport (MOLIT) to push forward with the project of establishing a construction technology information distribution system. Thus, beginning in 2001, KICT started to collect the construction technology-related materials and literature published by the MOLIT and affiliated public organizations to construct the database (DB), and has been running the Construction Technology Digital Library (CODIL) system to allow the people to access the DB for free. KICT, however, is planning to implement the migration of the construction-related standards DB and overseas construction technology information DB currently being serviced by CODIL system to other service systems. Upon the completion of the migration of these DB, the usage rate of CODIL system is expected to drop by more than 30%. While the budget allocated for the construction of a DB is dwindling every year, additional cost would be incurred by the development of new services.

Therefore, some strategic decision making was required to provide the new construction technology information services with a limited budget.

The most popular among the many methods employed to determine whether to push forward with a new project is economic feasibility analysis. In economic feasibility analysis, each business is determined to be economically feasible or not by calculating the difference from the investment cost to the return on investment through net present value (NPV) analysis based on the discounted cash flow (DCF) method, which is the most popular analysis method. DCF-based economic feasibility analysis signifies that the future cash inflow and cash outflow are fixed, assuming that no change would occur in the internal or external situations in the course of implementing the project

And, the economic feasibility of the project is calculated with the difference between the cash inflow and the cash outflow. Therefore, the calculation process is simple. In practice, however, the future cash flow may fluctuate anytime due to the uncertainty of the future, such as inflation and the occurrence of changes in the government's economic policies.

To supplement such shortcoming of DCF-based economic feasibility analysis, the real option model (ROM) can be employed. In the ROM method, the implied payoff of a specific project is estimated through a flexible decision making process depending on the cause of a given uncertainty. The implied payoff here can be called "option value." We are planning the project to construct the construction-technology-related academic information and latest technology trend information as a DB, and to provide the constructed DB services through the CODIL system. ROM was used as a strategic decision making tool for increasing the payoff that can be get with a flexible response to the uncertainty that may be experienced while implementing this project.

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In this study, the volatility of the underlying asset value was estimated by performing Monte Carlo simulation using the historical data on the number of literature downloads to analyze the economic feasibility of the new service development project. The average 10-year government bonds rate of return of 5.15% as of 2006 was applied as the risk-free interest rate. And time to expiration of option was set up by considering the period of basic plan for the construction project informatization in South Korea, including the CODIL system. The option value was estimated by applying ROM to some potential delay in the investment timing or to the potential downsizing of the DB's scale that may occurs while implementing a project, in an attempt to perform empirical analysis of the application of ROM to the service development project. It is believed that the results of this study may provide decision makers sufficient information on the optimal investment timing and investment scale, which are essential for the strategic decision making required to raise the expected profit from the investment in the project by considering the future uncertainty. Finally, the limitations of this study were described.

II. Summary of the Construction Technology Digital Library Establishment Project

A. Introduction of the CODIL System

KICT is constructing a DB by collecting the various construction technology literature and materials and by creating metadata to improve the technological competitiveness of the construction industry. Also, the CODIL system is being managed to be able to use the system to anyone for free [1]. CODIL system is divided mainly into the domestic and overseas construction technology information services as shown in Fig. 1.

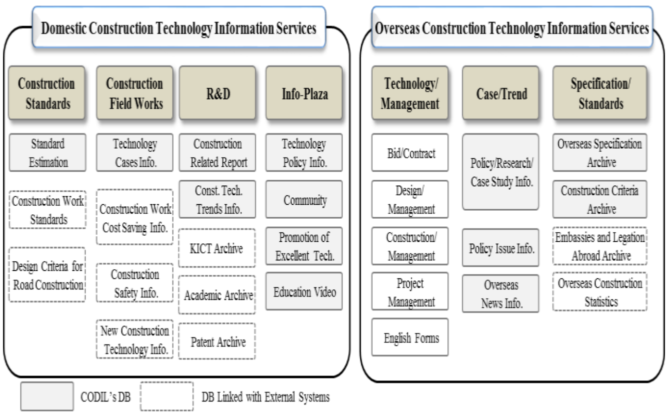

Fig. 1. Configuration of information services system offered by CODIL.

The domestic construction technology information services are composed mainly of the applicable construction standards that should be complied with while performing domestic construction projects, technology cases information that can be referred to in each construction site, construction technology development and R&D related reports, as well as other construction-related information serviced by external affiliated systems.

The overseas construction technology information services are composed mainly of the information of Korea's construction companies are required to enter the foreign construction markets, the information necessary to conduct business for companies involved in the construction markets, and the overseas construction-related statistical information serviced by external affiliated systems.

On the basis of 2015, some 70,000 people have accessed CODIL system per month on average and literature were downloaded to the monthly average of 66,400.

B. Need for the New Service Development Project

The Korea Construction Standards Center developed the construction standards information services system that provides the various construction standards in August 2015, and plans to construct the construction engineering information system by key overseas region in June this year, jointly with the International Construction Association of Korea and KICT. Accordingly, the construction-related standards DB and overseas construction technology-related DB that is being serviced by CODIL system will be migrated to the newly developed systems to consolidate all the related information services. Once the migration of the aforementioned DBs is complete, the usage rate of CODIL system is feared to drop by more than 30%.

To raise the usage rate of CODIL system pursuant to the purpose of Article 18 of the Construction Technology Promotion Act, a new DB that would replace the migrated DBs would be required. To satisfy such need, we were planning to embark on a new service development project that would construct a DB consisting of construction-technology-related academic information and latest technology trend information, and service it via CODIL system. Additional cost would inevitably be incurred to push forward with the new service construction, but the budget allocated for DB construction is dwindling every year.

Therefore, strategic decision making that would improve the profitability became necessary to implement the new service development project with a limited budget.

III. Analysis of Economic Feasibility Using ROM

A. Comparison of the DCF- and ROM-based Economic Feasibility Analyses

The monetary value of cost and profit may change over time due to inflation, etc. For an accurate analysis of economic feasibility, the cost and profit should be converted simultaneously to the monetary value as of the same reference point. At this time, the discount rate is applied.

As the DCF method assesses the economic feasibility simply with the difference between the discounted costs and discounted profit, its calculation is very simple, which is why DCF is used in most economic feasibility analyses.

As DCF analyzes the economic feasibility assuming that the cost and profit never change on the process of performing the project. But In reality, the cost and profit will continue to change according to the uncertainty of the future.

ROM can be used to make up for such limitation of DCF. In fact, if the decision is made at an appropriate time in the future after a resolution of the uncertainty rather than proceeding as planned with the future uncertainty, one can expect more payoff than in the case of DCF.

ROM is used to estimate the implied payoff in a project by exercising flexible decision making according to the uncertainly. The expected profit via ROM equals the DCF-based NPV plus option value.

The option is called a "call option" when the buyer of the option assumes the right to buy the underlying asset, and a "put option" when the buyer of the option assumes the right to sell the underlying asset. Meanwhile, the options are divided into the European option, in which the option can be exercised only upon its expiration time, and the American option, in which the option can be exercised before its expiration time.

ROM also allows the selection of an appropriate option type depending on the cause of the uncertainty. There are many option types depending on the type and characteristic of the actual assets. Among the types of options, options such as postpone, abandonment, expansion, and reduction are used most frequently [2], [3].

B. Calculation of the Option Value using ROM

The ROMs that are used to calculate the option value are the Black-Scholes (BS) model, which uses the time-series-data-based continuous model, and the binominal option (BS) model, which uses a discrete model [4]. Whereas the BS model can be applied only to the European option, the BO model can also be applied to the American option [5].

To calculate the option value using the aforementioned models, the following parameters are basically used: the value of the underlying asset (S), exercise price (X), volatility (σ), risk-free interest rate of return (r_f), and time to expiration (T).

For instance, the BO model is used to calculate the value of the underlying asset, which goes up and down discretely according to the ascent and descent rates, respectively.

The value of underlying asset until the expiration time of the option is calculated by applying (1) and (2).

The calculation of rolling forward iteration is applied differently depending on the call (C) or put (P) option. For instance, in the case of the call (C) option, the highest value of the underlying asset is assumed as shown in (2) at the expiration time of the option (t=T).

$$
\begin{aligned}
& u = \exp(\sigma), \quad d = \exp(-\sigma) = \frac{1}{u}, \\
& S = \frac{pSu + (1-p)Sd}{1+r_f}, \; 1+r_f = pu + (1-p)d, \\
& p = \frac{(1+r_f) - d}{u-d}, \; q = 1 - p = \frac{u-1-r_f}{u-d}
\end{aligned} \tag{1}
$$

where, u is the ascent rate, d is the descent rate, p is the risk-neutral probability in the event of an ascent, and q is the risk-neutral probability in the event of a descent.

$$
\begin{aligned}
If\ t = T, \quad C(u) &= Max[S(u) - X, 0], \\
C(d) &= Max[S(d) - X, 0]
\end{aligned} \tag{2}
$$

where $C(u)$ and $C(d)$ each signifies the expected value of S depending on the call option when S rises or falls given that t=T.

Next, recursive backward iteration is performed beginning from the expiration date (t=T) of the option to calculate the expected value of the underlying assets as shown in (3).

Such recursive backward iteration is performed up to the first time (t=0), first time (t=0) becomes the ROM-based NPV including the option value [5].

$$
\begin{aligned}
If\ t = T-1, \quad C(u) &= Max[\frac{pC(u) + qC(d)}{1+r_f}, \; S(u) - X], \\
C(d) &= Max[\frac{pC(u) + qC(d)}{1+r_f}, \; S(d) - X]
\end{aligned} \tag{3}
$$

where, C(u) and C(d) each signifies the expected value of the call option at a specific point when S rises or falls, whereas C is the expected value of the call option (S) within a short period.

C. Estimation of a New Service Construction Cost

As the service construction cost varies depending on the type of data, work elements, and skill level of staff, it was estimated by consulting the DB Construction Pay Standard Guidelines published by the National Information Society Agency of Korea. Table I shows the number of construction technology information DBs that have been established from 2013 to 2015 as well as the corresponding construction costs. Within the period, a total of 2,652 overseas construction technology-related DBs and 331 construction-related standards DBs were constructed. Moreover, US$220,000 per year on average was invested in DB construction, and an additional US$1,100,000 is estimated to be required in the coming five years to construct a new service based on these DB construction results.

TABLE I: NO. OF ANNUAL DB CONSTRUCTION AND CONSTRUCTION COSTS

Criteria	2013	2014	2015
No. of DB construction projects	1,948	1,323	1,743
DB construction costs (US$)	570,000	236,000	302,000

D. Estimation of the Value of the Underlying Asset

As the construction technology information service is a non-market goods, no market price can be slapped on the service. Furthermore, no direct profit from the project investment can be estimated because the service is given for free. As the method of estimating the value of such non-market goods, the contingent valuation method (CVM) is used most frequently. CVM assumes an imaginary universal market trading situation and estimates the value of non-market goods by collecting the maximum amount that the users of non-market goods are willing to pay (WTP), and then processes them via quantitative statistical processing [6].

In this study, the WTP for the satisfaction of the construction technology literature service was surveyed in July 2015 based on the 320 samples selected from the members of CODIL system [7]. The correlation coefficient between the statistical value of satisfaction to the construction technology literature service and the other variables that affect the satisfaction levels were statistically processed to estimate the average WTP of per literature service as US$38. Therefore, the total revenue is calculated by multiplying the average WTP by the number of literature downloads. Such revenue is assumed as the value of the underlying asset that can be earned from the DB construction project. Next, the annual average value of the underlying asset was estimated as with US$260,000 by considering the ratio of the overseas construction technology-related DB and the construction-related standards DB in all the DBs, and by excluding the repeat downloads of the same literature. Meanwhile, construction or product development projects can earn profit from the completed facilities or the products that were made after the investment is completed. On the contrary, the DB construction project can expect to earn profit as soon as its construction is completed. Therefore, the value of the underlying asset was calculated by assuming that the cost and profit are generated at the same time.

E. Estimation of the Volatility of the Underlying Asset Value

The volatility in the value of the underlying asset is estimated using the historical data on those factors that affect the value of the underlying asset. As explained earlier, it was estimated based on the average WTP of a single literature service and the number of downloads. As the WTP was estimated from the survey process, it is difficult to obtain historical data. On the contrary, the number of downloads is stored as historical data because it is registered in the log file. In this study, therefore, the volatility in the underlying asset value was calculated via the process shown below, using the number of downloads.

First, the historical data on the number of downloads from 2006 to 2015 was analyzed as shown in Table II.

TABLE II: ANNUAL NUMBER OF LITERATURE DOWNLOADS

Years	2006	2007	2008	2009	2010
Downloads	2,049,445	1,387,324	771,305	1,439,775	1,302,927
Years	2011	2012	2013	2014	2015
Downloads	1,280,285	1,108,704	1,206,062	1,235,770	796,685

Next, Monte Carlo simulation was performed to prevent the left-skewing of the volatility and to ensure the objective estimation of the volatility.

The probabilistic distribution of the literature downloads was used as an input value. The confidence level was set at ±95%, and random numbers were generated 10,000 times. For the distribution model, the lognormal distribution was applied. The lognormal distribution has a value larger than "0" and is used mainly to calculate the probabilistic distribution of continuous data such as stock prices. Fig. 2 shows the distribution style and statistical values of the assumption in Monte Carlo simulation. As is obvious in Fig. 2, the input values skewed left from the center and the graph demonstrate substantial deviation on the right side.

Meanwhile, a total of 46,600 literatures were constructed as a DB beginning in 2001. Assuming that a new DB whose scale matches those of the construction-related standards DB and overseas construction technology-related DB shall be constructed, the values obtained from Monte Carlo simulation were adjusted. The volatility for the estimated income, which was obtained by multiplying the average WTP by the adjusted values, was estimated as the volatility of the underlying asset value. The volatility was calculated as 22.74%.

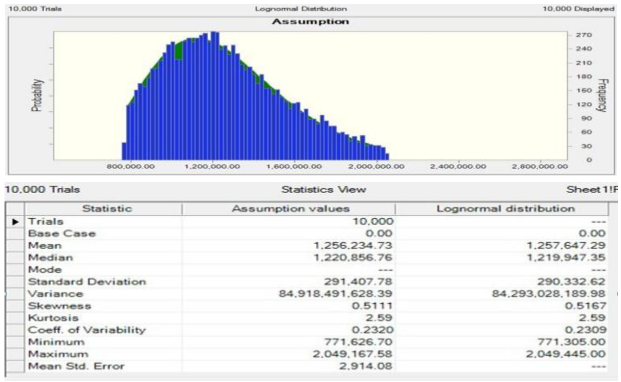

Fig. 2. Examples of the input value for Monte Carlo simulation.

F. Setting of Risk-Free Interest Rate

As the cost and profit that may occur in the future may change over time in terms of its monetary value, the interest rate should be multiplied to convert them to the present monetary value. As the interest rates quoted in the financial market may change at any time, it is practically impossible to apply an accurate interest rate. Therefore, ROM reflects the discount rate considering the future uncertainty and risks by assuming that the change in the underlying asset value follows the risk-neutral probability curve. The discount rate applied here is called "risk-free interest rate (r_f)." As CODIL system does not require similar alternative securities to calculate the risk-free interest rate, the yield to average of the treasury bonds is assumed as the risk-free interest rate. In this study, the 10-year yield to average of the treasury bonds (5.15%) was assumed as the risk-free interest rate.

G. Setting the Expiration Time of the Option

The "expiration time of the option" signifies the final point when one can purchase the underlying asset or abandon the option exercise. In general, the time value goes up and the opportunity for advantageous decision making becomes plenty the longer the option period, and a higher option value can be expected. One may lose an investment opportunity, however, if the expiration time of the option is too long. In this study, the expiration time of the option was set at after 5 years as the Korea's Construction Project Informatization Basic Plan, which includes CODIL system, is re-established every five years.

IV. EMPIRICAL TESTING

A. Setting of the Value of the Used Parameters of the ROM

In this study, the option value was calculated using the BO model, which allows the exercise of an option right before the expiration time whenever one obtains some useful information that may resolve the future uncertainty. Table III shows the value of the parameters used in the BO model.

Next, the causes of uncertainty may vary depending on the characteristics of the business, thereby also changing the type of decision making. In this study, the expected values of the delay and reduction options that can be realized with a potential delay of the investment timing and the reduction of the DB scale that may occur during the project implementation period were calculated.

TABLE III: VALUES OF THE USED PARAMETERS

Parameters	Description	Setting values
S	Profit from service development	US$1,300,000
X	Cost required for service development	US$1,100,000
T	Expiration time of the option	5 years
σ	Volatility of the underlying asset	22.74%
ϒ	Risk-free interest rate	5.15%

B. Estimation of the Option Value Arising from the Delay of Investment Timing

Assuming that it is unclear whether the budget required for the new service development project would be allocated, it would be desirable to postpone the project, and deciding whether to restart the project sometime in the future, after acquiring the information required to secure the budget, would be desirable rather than pushing forward with the plan with an uncertain future. The delay option is used in such cases.

As the buyer of the option may exercise its delay option whenever he/she deems it beneficial to the project, it has the characteristics of the American call option.

To calculate the option value, the annual value of the underlying asset was calculated until t=5 via the rolling forward process, as shown in (1) and (2). Table IV shows the annual value of the underlying asset represented with the binomial option lattice.

TABLE IV: THE BINOMINAL OPTION LATTICE OF THE ALTERNATIVE INVESTMENT

	t=0	t=1	t=2	t=3	t=4	t=5
s=0	1,300,000	1,631,931	2,048,616	2,571,693	3,228,328	4,052,623
s=1		1,035,583	1,300,000	1,631,931	2,048,616	2,571,693
s=2			824,947	1,035,583	1,300,000	1,631,931
s=3				657,155	824,947	1,035,583
s=4					523,491	657,155
s=5						417,014

Next, the value of the underlying asset was calculated using (3). For instance, when t=5, s=0, the ROM-based NPV was calculated as $C(u)=\max(S(u^5)-X\times(1+r_f)^5, 0)$=US$2,638,656. The same method was used to calculate the ROM-based NPV beginning from the t=5 point to the remaining conditions (s).

Next, the expected value of S when t=0, s=0 was calculated using the recursive backward iteration, as shown in (3). For instance, when t=4, s=0, the value of the option is $E(u^4)=S(u^4)-X\times(1+r_f)^4$ when the delay option is exercised.

The value of the option when it was open was $O(u^4)=((p\times V(u^5)+(1-p)\times V(u^4d))/(1+r_f)$. Therefore, the ROM-based NPV when t=4, s=0 became $V(u^4)=\max(E(u^4), O(u^4))=E(u^4)$=1,883,614, where "open(*O*)" signifies that it would be desirable to delay the decision making until some useful information is obtained than delaying or processing as planned at the option exercise time (t).

As such, the ROM-based NPV eventually became US$356,934 when t=0, s=0, using the recursive backward iteration, and the option value amounting to US$156,934 is the option value that can be calculated by subtracting the original DCF-based NPV. Therefore, one can expect a profit that is higher by 12.07% than the DCF-based NPV if he/she exercises the delay option.

C. Estimation of the Option Value Arising from the Reduction of the DB Scale

Assuming that the service usage rate that was initially assumed is forecasted to drop considerably as another institution announced a plan to develop the academic information service system while pushing forward with the service development project, it would be advised that the investment loss be minimized by scaling back the scale of the DB rather than sticking with the original plan. Assuming that the profit would drop by 50% with a 40% reduction in the scale of the DB, the buyer of the option possesses an American put (*P*) option, which allows him to scale back the project well before the expiration date whenever he/she obtains some advantageous information.

Under the aforementioned assumption, the expected value of the underlying asset from exercising the reduction option was calculated.

First, the annual value of the underlying asset was calculated via the rolling forward process, as shown in Table IV.

Next, the expected value of S in the case where the original plan was maintained until t=0 by applying the recursive backward iteration using (3), and another value of S in the case where the plan was reduced, were compared with the larger value eventually taken. For instance, when t=3, s=0, the expected value of S is $S(u^3)$ when the original plan is maintained, and when the plan was reduced, the expected value of S became $E(u^3)=0.5\times S(u^3)+0.6\times X\times(1+r_f)^3$. Further, when it was open, its expected value became $O(u^3)=((p\times V(u^4)+(1-p)\times V(u^3d))/(1+r_f)$.

Therefore, the expected value of S when t=3, s=0 became $V(u^3)=\max(S(u^3), E(u^3), O(u^3))=O(u^3)$=US$2,577,481.

Recursive backward iteration was applied as such, earning the value of the underlying asset when the reduction option was exercised when t=0, s=0. Therefore, the value of the option became US$130,623 when the DCF-based NPV was subtracted from US$1,430,623, thereby making it possible to expect a profit 10.05% higher than the DCF-based NPV.

Fig. 3. Sensitivity analysis according to the change in the risk-free interest rate.

D. Sensitivity Analysis

As the economic feasibility analysis of the ROM is performed by anticipating the future changes in a situation, uncertainty is also inevitable for the economic feasibility analysis.

In this study, the volatility and risk-free interest rate values affecting the value of the underlying asset were converted by a certain ratio, and the sensitivity to the reduction option was analyzed to determine the risk of the project arising from the uncertainty of the future. Fig. 3 and 4 each shows the change against the ROM-based NPV by performing sensitivity analysis.

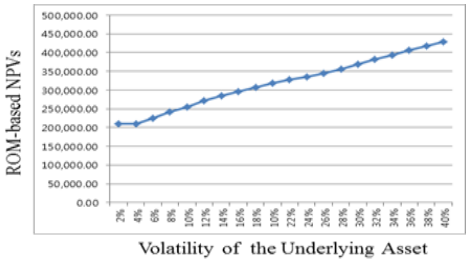

Fig. 4. Sensitivity analysis according to the change in the volatility.

As shown in Fig. 3 and 4, the ROM-based NPV goes up if the volatility goes up to a certain rate in the case of the service development project, whereas it goes up the lower the risk-free interest rate falls. It was therefore judged that the profitability of the service development project may be improved in the case where the volatility is high but the risk-free interest rate is low.

V. Conclusions

KICT constructed a construction technology-related information database and has been running the service system beginning in 2001, pursuant to Article 18 of the Construction Technology Promotion Act. In this study, the new construction-technology-related service development project was being planned to replace the existing DB as the construction-related standards DB and the overseas construction technology–related DB currently in service shall be migrated to other systems. Given the limited budget, a strategic decision making system was required to effectively develop the new service. In this study, the economic feasibility of the new service project was analyzed using ROM to maximize the payoff of the investment. DCF-based methods are used in most economic feasibility analyses thanks to its simple calculation process, but it tends to assess the future uncertainty rather negatively. On the contrary, ROM utilizes uncertainty as a strategic tool to raise the economic value of the investment.

In this study, ROM in the event when the investment timing was delayed and the DB scale was reduced, and DCF in the event when the project was implemented according to the original plan, were compared for their respective economic feasibility analysis results. It was determined that an additional 10% profit can be expected when exercising the delay and reduction options, respectively, rather than the DCF-based NPV.

Finally, the following limitations are expected when ROM is used in the project to expand the construction technology-related service. As mentioned by [3], the economic feasibility analysis result obtained by ROM is only theoretical and may not be identical with the reality. For instance, it assumed that the same volatility and interest rate would be maintained during the expiration of the option, but in reality, it can change unexpectedly. Therefore, it is advised that ROM be used only as a supplementary tool for DCF-based economic feasibility analysis, considering the uncertainty that may arise during the project implementation.

Second, the key factors that may affect the payoff of the service expansion may include direct/indirect factors such as the reduced time and the construction quality as well as the WTP and the number of literature downloads. Therefore, it is advised that the historical data of such factors be accumulated to accurately estimate the volatility of profit.

Third, some additional researches may be required on the correlation between the factors leading to the occurrence of uncertainty and the factors related with strategic decision making.

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