A Study on the Economic Analysis for Overseas Project of New Nuclear Power Plant Using Binomial Option Pricing Model and Monte Carlo Simulation

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1. Abstract

Nuclear power plant (NPP) project has a long term construction period and huge investment compared to other construction projects. In addition, oversea nuclear power plant construction project has large uncertainties according to target countries. So we should analyze the risks of target countries and evaluate their marketability and possibility with deliberation when we evaluate the economic assessment of project.

Nowadays real option analysis (ROA) which makes up weakness of discounted cash flow (DCF) has been widely used in analysis of various projects.

The purpose of this study is to help decision-makers in the decision-making by applying real option analysis to evaluate the feasibility of overseas project for new nuclear power plant in target countries. So cash flow models for investment and operation are established based on Monte Carlo simulation and apply volatility to show uncertainties of target countries.

As a result, when the real option analysis is applied, the project value with uncertainties is expected to be higher than DCF method.

2. Introduction

The value evaluations involved with nuclear power are very uncertain. This is because of a long period of construction as well as the cost uncertainties of decommissioning and nuclear waste management. Even more elements should be considered in new nuclear power valuation, including the uncertainty from the technology, operating costs, the potential risk of radiation, electricity mechanism and climate policy [1].

In this respect, a traditional method such as discounted cash flow (DCF) can't fully catch the impacts of these uncertainties on nuclear power investment. So it is necessary to develop a proper method to handle such kinds of uncertainties to evaluate the new deployment of nuclear power plants.

Meanwhile, overseas construction projects which are required capital investment, localization by target countries are increasing in these days. These elements may influence the uncertainty of project too. So evaluation method should be developed to analyze marketability and expansion of target countries reasonably [2].

Real options approach is suitable for evaluation of large-scale investment project with great uncertainties. Takizawa and Omori (2001) introduced a real option approach to calculate electricity price for economic feasibility [3]. Rothwell (2006) modeled the net present value (NPV) of building an ABWR in Texas using ROA to determine the risk premium associated with net revenue uncertainty [4]. W.C Yoon (2006) evaluated nuclear power plant construction value using DCF and ROA with sensitivity analysis [5]. Also, Fan and Zhu (2011) has discussed the investment evaluation of third-generation nuclear power using least square Monte Carlo simulation [1].

3. Valuation model of real option

3.1 Discounted cash flow method and its limitations.

The discounted cash flow (DCF) method is used most commonly to analyze project values for decision making of specific project as one of typical methods.

$$Project\ Value = \sum_{t=1}^{T} \frac{CF_t}{(1+WACC)} \quad (1)$$

CF_t =Future Cash Flow expected at T time period

WACC = Weighted Average Cost of Capital

Here, project value is the current value earned by discounting the total of cash flow obtained during presumption period as the company destroys its asset. Discount rate in this method uses weighted average cost of capital (WACC) which is earned through weighted average of cost of equity capital and cost of borrowed capital. But this method has limitation.

Commonly, the uncertainties of future cash flow are originated by market changing or decision-making of board of directors. But traditional value evaluation method is possible to overestimate or underestimate project and company value due to not enough reflecting of future cash flow as well as passing over strategic or variable characteristics of project.

In addition, this method can't reflect decision-maker's flexibility which can apply or change follow-up decision making in response to unpredictable change of market condition in value evaluation because it assumes that project can't be changed after establishing project plan [6].

3.2 The basic concept of real option

In financial industry, options are contracts that give one party the right buy or sell share, other financial instruments or commodities from another party within a given time and at a given price. In a narrow sense, the real options approach is the extension of financial option theory to options on non-financial assets including R&Ds, large scaled projects. While financial options are detailed in the contract, real options embedded in strategic investments are identified and specified. Moving from financial options to real options requires a way of thinking, one that brings the discipline of the financial markets to internal strategic investment decisions.

Like financial options, these strategic investments can give companies the option to capture benefits from future market conditions. The real options way of thinking has three components that are useful to decision-makers.

First, options are contingent decision. An option is the opportunity to make a decision after events unfold. On the decision date, if events have turned out well, decision-maker will make one decision, but if they have turned out poorly, decision-maker will make another. This means that the payoff to an option is nonlinear: it depends on decision-maker's choice.

Second, option valuations are aligned with financial market valuations. The real options approach uses financial market inputs and concepts to value financial complex payoffs across all type of real assets. So the result can be compared with managerial options, financial market alternatives, and internal investment opportunities and transaction opportunities, such as joint ventures, technology, licenses, and acquisitions.

Third, options thinking can be used to design and manage strategic investments proactively.

NPV which considers the real option reflecting the flexibility of management is expressed by the following expression.

$$NPV\ with\ Real\ Option = Existing\ NPV + Real\ Option\ Value$$

3.3 The types of real option [7]

There are six types of real option for executives.

1) Option to defer: Management holds a lease on valuable land or project. Decision-maker can wait x years to see if output prices justify constructing a building or a plant or developing a field. Although, it is unusual in overseas business, we need to consider it since global market is changing rapidly, we need to consider it.

2) Time-to-build option: Staging investment as a series of outlays creates the option to abandon the enterprise in midstream if new information is unfavorable. Each stage can be viewed as an option on the value of subsequent stages and valued as a compound option.

3) Option to alter operation scale: If market conditions are more favorable than expected, the firm can expand the scale of production or accelerate resource utilization. On the other hand, if conditions are less favorable than expected, it can reduce the scale of operation. In extreme cases, production may be halted and restarted.

4) Option to abandon: If market conditions decline severely, management can abandon current operations permanently and realize the resale value of capital equipment and other assets on secondhand markets.

5) Option to switch: If price or demand change, management can change the output mix of the facility (product flexibility). Alternatively, the same outputs can be produced using different types of inputs.

6) Option to grow: An early investment is a prerequisite or a link in a chain of interrelated projects, opening up future growth opportunities

3.4 Black-Sholes model and its limitation

The derivation of Black-Sholes model rests on the concept of risk-free hedge portfolio. It is a model to valuate European option which uses stock as underlying asset. An option is valued by the value of the underlying asset at the expiration thus to valuate an option a portfolio composed of the risk-free asset and underlying asset that has the same value as the option being valued is needed. As various factor affect the value of the option, to compose model for the option several changes were needed to be made. Black-Sholes model is as follows [8].

$$C_0 = S_0 N(d_1) - X e^{-r_f T} N(d_2) \quad (2)$$

S_0 = Present price of underlying asset
X = Exercise price of the option
r_f = Annual risk-free interest rate
T = Time remaining until expiration
$N(d_1)$ = Probability of value being lower than d_1 from cumulative standard normal distribution
$N(d_2)$ = Probability of value being lower than d_2 from cumulative standard normal distribution
e = Vase of natural logarithm

$d_1 = \frac{\ln\left(\frac{S}{X}\right) + r_f T}{\sigma\sqrt{T}} + \frac{1}{2}\sigma\sqrt{T}$

$d_2 = d_1 - \sigma\sqrt{T}$

Black-Sholes model is European option model which does not pay dividends until the expiration date. On the other hands, American option pays dividends any time during the life of contract. If dividends is lower than the interest of exercise price from the payout to expiration day the model is applied without modification. In the case of payout of dividend or exercise of right before expiration date, model need to be modified before application.

But there are limitations of this model. First, Black-Sholes Model is based on Black-Sholes assumptions. Second, stock price (S_0), exercise price (X), expiration time (T) and interest rate (r) are observed precisely but standard deviation (σ) of rate of return of stock is estimated based on historical rate of return of stock. As mentioned above, the first parameter is solved to some degree by modifying the model but the there are no alternatives for the second one.

3.5 Binomial option pricing model [9]

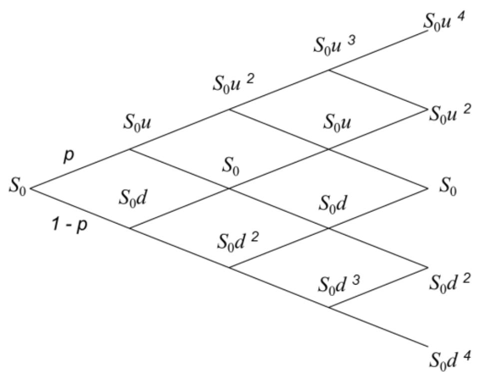
To valuate binomial option pricing model for several period, the valuation has to proceed iteratively starting with the expiration date and moving backwards in time until the current point in time. In each time, portfolio to replicate the option is composed. Through this formulation, the value of the option is calculated. This value of the option is called replication portfolio and it is expressed with stock of underlying asset and borrowing/lending (risk-free interest rate application). This binomial option pricing model formula is as follows;

$$Call\ option\ value = S_0 \times borrowed\ \ money\ to\ replicate\ option \quad (3)$$

S_0 = Current value of the underlying asset
Option δ = the number of purchased underlying asset

The binomial option pricing model is based upon a simple formulation of the underlying asset price process in which the asset, in any time period, can either increase or decrease moving in one of two ways. S is the price of present stock. The rate of increase to *Su* is p_1 and S has possibility of decrease to *Sd.*

Fig. 1. The binomial tree structure [10]



The objective in a replicating portfolio is to use a combination of the underlying asset and risk-free asset (borrowing/lending with risk-free interest rate) to create a portfolio that has the same cash flows as the option being valued. Under the principles of arbitrage the value of the option must be equal to the value of the replicating portfolio. Therefore, where stock prices can either move up to *Su* or down to *Sd* in certain time period, the replicating portfolio will involve borrowing money and acquiring δ of the underlying asset.

δ = Number of units of the underlying asset bought

$$\delta = \frac{Cu - Cd}{Su - Sd} \quad (4)$$

Cu = Value of call option if the stock price goes to Su
Cd = Value of call option if the stock price goes to Sd

The binomial option pricing model determines the value of the option and provides intuitive insight into the determinants. The value of the option applies logic of arbitrage trading and is determined by its current price which reflects expectations of the future.

While the binomial option pricing model provides easy understanding logically, but it require a large number of inputs to calculate expected future prices at each period. Black-Sholes model is used in case of extreme binomial distribution reducing the number of data needed.

4. Empirical analysis

4.1 The introduction of empirical analysis for project

The subject of this empirical analysis is the overseas project for new nuclear power plant. This project needs investment costs (I_t) to construct and produce electrical power after finishing construction, generating costs (G_t). It also makes profits during operation period, sale price (P_t).

For a more realistic analysis, this study assumes that a utility company “K” in South Korea which had an experience in the nuclear power plant project closes a contract for their new nuclear power plant, APR+, in Vietnam.

The APR+ is developing for exporting and will get a certification until 2015 [4]. It has several advantages compared to other third-generation nuclear power plants such as EPR, AP1000 and Advanced Gen III+.

As stated above, the continued growth of industry and gradual increase of people’s living standards in developing countries have speed up the demand of nuclear energy. Among developing countries, Asia has become the largest market for nuclear energy after remarkable growth has emerged to its economies in the last decade.

Especially, Vietnamese government has considered establishing nuclear power generation since 1995, and firm proposals surfaced in 2006. As a result, Russia has agreed to finance and build 2000MWe of nuclear capacity and Japan has agreed similarly for another 2000MWe. Also, the Vietnam and South Korean presidents have approved a jointly-prepared plan on nuclear power plant construction, and agreed to "use the plan as a basis for future cooperation projects to be undertaken in accordance with agreement between the two countries". Both governments agreed to cooperate further on the development project [17, 23]. So this study selects Vietnam as a target country.

Prior to this, this study assumes a BOO (Build-Own-Operate) contract under Vietnamese government guarantee for income of operation.

A turnkey is traditional in nuclear industry even though there are many contract types.

But Rusatom Overseas, which is a subsidiary of Russia’s State Atomic Energy Corporation, has arranged to use a BOO model to build Turkey’s first NPP, based at Akkuyu in southern Turkey. Although this contract type is unusual, it will be a new way to introduce the first nuclear power plant in developing countries which have poor capital condition.

Meanwhile, the construction period of APR+ set up 48 months in technical report. But it can be changed by the impact of demographic, economic, and political preconditions of a country [13]. So we apply scaling factor (α_{cp}) for construction period.

Also, the interest during construction has been omitted for simplification of model.

Table I: The basic assumptions of project

Item	*Contents*
Country	Vietnam
Reactor type	APR+, 2 Units
Capacity	1500MWe * 2
Contract type	Build-Own-Operate
Construction period	48 month
Scaling factor	1.2
Operation period	60 years

4.2 Model description and parameter setting

As stated above, APR+ project in Vietnam has been chosen for analysis object, the model established here is based on real option theory with Monte Carlo method. The value evaluation in this study includes the new nuclear power plant construction and operation period. As a large-scaled investment project, it will take time to complete nuclear power investment.

And the power generation company has basically the right to exercise the abandon option to terminate the nuclear project in the investment stage. So the company "K" can re-evaluate the nuclear project to decide whether to continue or abandon the investment at each step of the investment stage before starting at the beginning of operation (t=5). This model considers the case that future cash flow during construction is not enough to get economic feasibility of total project. In this case, the company can save investment costs which produce after construction stopped.

Assuming the total period for nuclear power construction and operation is T years, for the purpose of valuation we divide the T years into N periods. So $\Delta t = T/N$.

4.2.1 Modeling investment

At nuclear power-plant construction period, we apply a controlled diffusion process to describe the uncertainty of new nuclear power investment. K_{Nu} is the expected total investment cost for power generation company to deploy new nuclear power technology and total deployment investment remaining at period t_i is $K_{Nu}(t_i)$. Assume that K_{Nu} follows the controlled diffusion process [1].

$$K_{Nu}(t_{i+1}) = K_{Nu}(t_i) - I_{Nu}(t_i)\Delta t + \beta[I_{Nu}(t_i)K_{Nu}(t_i)]^{\frac{1}{2}}(\Delta t)^{\frac{1}{2}}\varepsilon_x \quad (5)$$

Where β is a scale parameter representing the uncertainty around K_{Nu} ; ε_x is a normally distributed random variable with mean of 0 and standard deviation equivalent to 1.

4.2.2 Modeling operation

At nuclear power plant operation period, it should be needed to calculate the cash flow during nuclear power operation. Assuming at any period t_n, the generating capacity of new nuclear power is $Q_{Elec}(t_n)$, and all the electricity generated by nuclear power can be sold to grid. If we assume that the possibility of nuclear accident is zero, the cash flow $CF(t_i)$ earned by the power company through electricity selling from nuclear power at t_i period should be; [1]

$$CF_{Nu}(t_i) = [P_{Nu}(t_i) - C_{Nu}(t_i)] \cdot Q_{Elec}(t_i) \cdot (1 - Tax) \quad (6)$$

Where $P_{Nu}(t_i)$ is electricity price; $C_{Nu}(t_i)$ is the nuclear generating cost; Tax denotes the income tax for power generation company in Vietnam.

During nuclear power plant operation period, we have considered generating cost (uranium fuel price) uncertainty, and unexpected events with small possibility on the nuclear power plant operating cash flow and value. So we can assume nuclear generating cost following a geometric Brownian motion [1].

$$C_{Nu}(t_{i+1}) = C_{Nu}(t_i) exp\left(\alpha_c \Delta t + \sigma_c (\Delta t)^{\frac{1}{2}} \varepsilon_c\right) \quad (7)$$

Where ε_c is a normally distributed random variable with mean of 0 and standard deviation equivalent to 1; and α_c and σ_c represent the drift and variance parameter of the nuclear generating cost, respectively.

4.3 Model parameter

Table II: The model parameters for analysis

Parameter	*Symbol*	*Value*
Generation Capacity	Q_{Elec}	1500MWe * 2
Total investment cost	K_{Nu}	$8,200 million
Initial annual Investment cost	I_{Nu}	$1,640 million
Technology uncertainty	β	0.5
Generating cost	C_{Nu}	0.046 USD/kWh
Generating cost drift rate	α_c	0.01/year
Generating cost standard deviation rate	σ_c	7.27%/year
Electricity price	P_{Nu}	0.08 USD/kWh
Electricity price drift rate	α_p	0.01/year
Electricity price standard deviation rate	σ_p	5%/year

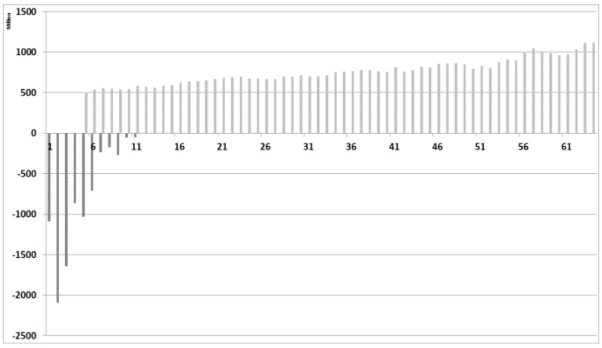
Each parameter values are rationally configured refer to technical reports, Vietnam's economic condition and MIT report [1, 11, 14, 15, 18].

5. The analysis of result

5.1 The financial feasibility analysis: NPV using DCF

Based on above models and parameters, cash flow simulations (out of 1000) were made using Monte Carlo simulation with Crystal ball and Microsoft excel.

Fig. 2. The result of cash flow simulation



The net present value (NPV) is defined as the sum of the present values (PVs) of the individual cash flows of the same entity. In this analysis, we apply a discount rate of 6% since 2020. Ideally, discount rate in revenue should be considered risk-adjusted rate which is risk-free rate with proper risk premium and investment should be considered risk-free rate. But we assume that both cases consider risk-free rate [16]. Therefore, the NPV can be calculated as below based on estimated cash flow in Fig. 2.

$$NPV = \sum_{i=1}^{N} \frac{CF_{Nu}(t_i)}{(1+r)^i} - K_{Nu}(t_i) \quad (8)$$

When the discount rate is 6%, the NPV of this project is $1,135 million. If the discount rate changes 5%, 10%, the NPV also change $2,920 million and -$2,676 million. As a result, it can be seen that the net present value goes down as the discount rate increased.

5.2 Economic analysis using real option model

A traditional calculation of NPV, which discounts projected costs and revenues into present value, examines the project as a whole and concludes it is a no-go. But a real option analysis breaks it into stages and concludes it makes sense to fund at least the first stage. Real option analysis rewards flexibility and that is what makes it better than NPV method. In this study, we apply binomial option pricing model to evaluate the feasibility of this project. Binomial option pricing model is suitable for evaluation because it can grasp the flow of cost-benefit more clearly than Black-Scholes model.

5.2.1 The parameters for binomial option pricing model

In real option approaches, the volatility of underlying asset is the most important factor. The volatility means the size of the fluctuations of underlying asset and the boundary of future underlying asset depends on the change of volatility. Kodukula and Papudesu (2006) defined volatility in ROA as the standard deviation of natural logarithm for cash flow return. [17]

$$\sigma = \sqrt{\frac{1}{n-1}\sum(R_t - \overline{R_t})^2} \quad (6)$$

$\sigma = Volatility\ of\ underlying\ asset$

$R_t = \ln S_t / S_{t-1}$

$S_t = Value\ of\ underlying\ asset\ at\ t$

Therefore, the calculation of volatility is very important. W.C, Yoon (2006) set annual volatility using monthly BLMP (Base Load Margin Price) data. [6] B.I**,** Kim (2009) developed volatility estimation model of overseas construction project using GDP and the price index of stocks. [3] In this study, we define the volatility as combined GDP and sale price of nuclear energy in South Korea.

$$\sigma_{ijx} = \alpha_n \times V.of\ GDP_{ij} + \beta_n \times V.of\ SP_{jx} \quad (9)$$

$\sigma_{ijx} = Volatility\ if\ x\ advance\ i\ in\ j\ year$

$V.of\ GDP_{ij} = GDP\ volatility\ of\ i\ in\ j\ year$

$V.of\ SP_{jx} = Sale\ price\ volatility\ of\ x\ in\ j\ year$

$\alpha_n = National\ risk\ weight\ value\ due\ to\ national\ development$

$\beta_n = Company\ risk\ weight\ value\ due\ to\ national\ development$

If we apply the above model, total volatility is 33.3 × 0.4958 + 7.27 × 0.5042 = 20.1757. We assume that risk-free rate is 5% and time step size is 1year. Also, we calculate up factor, $u = e^{\sigma}$ when value increases and down factor, $d = e^{-\sigma}$ when value decreases in given time interval. Risk neutral probability is calculated by this formula, $p = (e^r - d)/(u - d)$.

Here are parameters for calculating of option value.

Table III: The parameters for binomial option pricing model

Parameter	*Symbol*	*Value*
Underlying asset price	*S*	$ 9,335 million
Exercise price	*X*	$ 8,200 million
Total volatility	*σ*	20.18
Risk-free rate	*R*	5%
Investment period	*T*	5 year
Time step size	*t*	1year
Up factor	*u*	1.2236
Down factor	*d*	0.8173
Risk Neutral Probability	*p*	0.5759

Using these parameters stated above, we draw a basic model for binomial option pricing model.

Table IV: The basic binomial price tree model

(Unit: $ Million)

Option value	t=1	t=2	t=3	t=4	t=5
9,335	11,422	13,976	17,101	20,925	25,604
	7,626	9,335	11,423	13,977	17,102
		6,236	7,630	9,336	11,423
			5,096	6,236	7,630
				4,165	5,097
					3,404

5.2.2 Option to time-to-build

The company re-evaluates the nuclear project to decide whether to continue or abandon the investment at each step of the investment stage before starting at the beginning of operation (t=5). In case of project that has uncertainty due to high volatility, if expected future cash flow won't be realized as circumstance worsen, option to abandon the project gains value excluding the possibility to abandon the project and obtain more value that the project itself before finishing construction [6]. It can be indicate the put option or compound call option types. The form of option is as follows.

$$V_{n,j}^{c} = MAX[S_{n,j} - X, 0], j = 0 \sim n \quad (10)$$
$$V_{n,j}^{c} = MAX[e^{-r\Delta t}(pV_{i+1,j}^{c} + (1-p)V_{i+1,j+1}^{c} - X), 0],$$
$$0 \le i \le n-1, 0 \le j \le i \quad (11)$$

Table V: Option to abandon construction

(Unit: $ Million)

Option value	t=1	t=2	t=3	t=4	t=5
3,338	4,874	6,957	9,682	13,126	17,404
	1,657	2,634	4,096	6,177	8,902
		530	967	1,766	3,223
			0	0	0
				0	0
					0

Refer to Table V, the option value which is applied the abandon option during construction or after construction is calculated by recursive backward iteration. As a result, the option value is $3,338 million and total value of project is $4,473 million.

This value is very similar with option calculated with Black-Sholes model ($3,333 million). In other words, the result of calculation is reasonable.

5.2.3 Option to defer

Although known as option to defer is included in most of the projects, option exercise is commonly limited in overseas construction project. The reasons are that the size of construction doesn't change rapidly in short time and the sales capacity and technology are almost same as the former. But option to defer becomes more important because the global market is in crisis and change rapidly [3].

Nuclear projects are usually deferred by regulation enactment and financing and so on. So we assume that we should wait x years to see if the option value justify constructing a plant.

In this option, we consider investment cost rising as much as discount rate. In other words, we calculate the option value on condition that investment cost change whenever the time of project is deferred.

$$V_{n,j}^{c} = MAX[S_{n,j} - X(1+r), 0], j = 0 \sim n \quad (12)$$
$$V_{n,j}^{c} = e^{-r\Delta t}(pV_{i+1,j}^{c} + (1-p)V_{i+1,j+1}^{c}),$$
$$0 \le i \le n-1, 0 \le j \le i \quad (13)$$
$$V_{0,0} = \frac{V_{1,0}}{(1+r)^{d}} \quad (14)$$

Table VI: Option to defer construction for a 1year

(Unit: $ Million)

t=0	t=1	t=2	t=3	t=4	t=5	t=6
6,038	6,340	8,539	11,260	14,517	18,307	22,719
		3,354	4,843	6,837	9,369	12,316
			1,332	2,135	3,399	5,368
				241	418	726
					0	0
						0

Table VII: Option to defer construction for a 2year

(Unit: $ Million)

t=0	t=2	t=3	t=4	t=5	t=6	t=7
8,247	9,092	11,894	15,272	19,257	23,896	29,294
		5,288	7,307	9,861	12,959	16,565
			2,546	3,838	5,654	8,063
				791	1,373	2,383
					0	0
						0

In case of the option to defer construction 1 year and 2 year, the total value of project for each case is $ 7,773 million and $ 9,382 million. As a result, the total value of project increase as deferred the beginning of project.

6. Conclusions

Up to now, we studied both of the discounted cash flow method and real option method considering uncertainties for overseas nuclear power plant project.

Especially, real option method can handle the risks for future project because it evaluates the uncertainties with volatility for time period.

In this study, we apply binomial option pricing method and consider option to abandon construction and option to defer which can be assumed in nuclear projects.

Moreover, the uncertainties of cash flow about the new nuclear power plant which does not have been constructed were modeled by Monte Carlo simulation. And the uncertainties of construction period and increasing period were assumed by applying the reasonable factors for target countries which were based on B.I Kim [2].

In regard to the setting of the volatility of the underlying asset, this study applied the nuclear energy sales price in South Korea from 2007 to now which is based on W.C Yoon (2006) that applied BLMP of South Korea. Also, the future GDP changes of the target countries was forecasted by applying various objective data and model factors which were based on B.I Kim (2009) were applied in this study. Finally, the combined volatility was defined and applied to the underlying asset.

As a result, the total value of project increases $4,473 million in abandon option and it also increases $7,773 and $9,382 million in deferred option compared to NPV.

It means that we can find advanced value of project when we consider the uncertainties. Moreover, we apply the Black-Sholes model to compare the result for abandon option.

This is because the real option valuation method recognizes uncertainty and irreversibility as the new investment value and highly evaluates their value but the discounted cash flow method recognizes them as risk elements and underestimates investment value.

Also, this study suggests that project which has negative NPV in discounted cash flow method can be re-evaluate as the feasible project which has positive NPV in real option method.

In other words, considering flexibility of decision-making and uncertainty of future market will show the new economic value of project and it will be helpful to decision-makers.

However, several assumptions used in modeling and case analysis will impede the application of the framework used as it stands. The binomial option pricing model needs many assumptions. Those assumptions limit the boundary of real option application and the input variable of those models can't capture all intangible benefits of this project. To be specific, in binomial option pricing model, nuclear waste disposal cost, damage of small or serious accidents and additional business expenses are not included in the estimated cash flow. Besides, the volatility is assumed to be constant for all stages, but the volatility can be changed any time.

It is recommended that future research in the area of real options be focused on demonstrating how real option can fit into the existing evaluation models and improve them. Rather than developing mathematical models, effort should be allocated to develop an integrated real options approach to investigate implicit opportunities in overseas project of new nuclear power plant. Also, sensitivity analysis should be carried out for analyzing the effect of each factors in project based on objective data.

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