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An investment decision for a developing country, Türkiye: Real Option Analysis for Large Nuclear Power Plants and Small Modular Reactors

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1. Introduction

Nuclear Power Plants are capital-intensive projects, they are viewed as risky projects by all investors, regardless of their economic situation. Developing-country investors, on the other hand, should consider their limited resources. In order to make nuclear power facilities economically viable, technology developers have recently focused on developing small modular reactors (SMRs). SMRs, which draw the interest of developing countries with restricted budgets, are being studied to determine if this technology are more profitable than Large Nuclear Reactors (LRs) [1]. Although the classic NPV technique may determine if an investment is profitable or not, it is inflexible since it does not account for future uncertainties, and therefore the investor is unable to make a strategic decision. Real option analysis, which is a more dynamic and flexible approach to investment decision-making, would be a stronger method in terms of that [2]. This methodology has been applied to Türkiye' s nuclear energy investment decisions.

2. Methods and Results

Calculation methods that have been assumed for valuing investments are presented in this section: Net Present Value Analysis, Strategic Real Option Analysis with binomial valuation and Monte Carlo Simulation Method in @Risk software, and lastly, Trigger Value Calculation.

By using these approaches, two different nuclear options are compared; LRs and SMRs, which is calculated as FOAK and NOAK of SMRs, separately. To analyze these techniques, we have used values taken from historical data, many academic papers, or the assumptions of specialists.

2.1. Net Present Value Analysis

The first step for Real Option Analysis is to calculate the Net Present Value (NPV) of the project by using the traditional DCF approach. It estimates the project's potential future cash flows and discounts them to present value using a project-specific discount rate. However, the possible change in the risk profile of the project over time is ignored in this analysis. The disadvantages of this approach push the investor to make a real option analysis, which can also be called an expanded net present valuation. The input parameters used in this work is presented in Table I.

	LRs	SMRs Foak	SMRs Noak
Capacity [MW]	1400	300	300
Capacity Factor [%]	90%	93%	95%
TCIC [$/KWh]	10,076,000	7,312,000	3,165,000
Construction Time [Years]	7	5	3
Operating years [Years]	60	60	60

Table I: Input parameters of NPV Analysis [8]

Both NPV calculations for LRs and SMRs use the same electricity prediction. Since revenues are highly dependent on the electricity price, its prediction should be reasonable.

To be able to forecast the electricity price in Türkiye, we chose to use Geometric Brownian Motion (GBM) as a stochastic price model by using Time Series of the @Risk Program. GBM is the most appropriate stochastic process in terms of forecasting electricity prices. Because the logarithm of random values follows a Brownian Motion, it is useful for processes that can never take on negative values, such as the price of electricity.

2.2 Real Option Analysis with Binomial Valuation and Delay Option Model in Excel Software

As already mentioned in the previous section, Strategic Real Option Analysis can be considered as an expanded NPV analysis. Unlike NPV analysis, investment decisions can be evaluated in a flexible manner in this methodology.

In particular, energy investments have numerous uncertainties and risks, such as electricity prices, fuel costs, construction costs and time, interest rates, and exchange rates, and these parameters need to be managed in a dynamic way, not in a technique employing a static approach.

We only consider the deferral option among several options since investors can postpone the investment decision until a more suitable time. Firstly, we will present a real option approach by calculating binomial trees to show it visually more clearly and more understandable. We will use another two approaches to present real option valuation in the next sections which we used in our research.

Formulas for binomial trees, simply are shown in the given small part of excel calculation in Fig. 2. As for the estimation of the variance of the present value of the project (the initial value of the option valuation), the standard deviation of the simulated probability distribution for the rate of return is calculated. Because the standard deviation and mean of the returns can determine the lognormal distribution of the project's value, without options, the present value of the project is the project's market value (as if the project were a traded asset).

The Monte Carlo simulation of the returns of the project provides the standard deviation of the returns, or the volatility of the project.

In the final step, a binomial tree can be created to model the stochastic process underlying the project value.

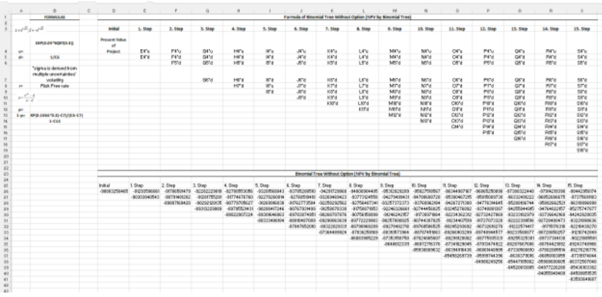

Fig. 1. Real Option Valuation by using Binomial Tree [3]

The competitiveness of both technologies is assessed based on the outcome of Real Option Valuation.

Also we could compared results by calculating in an excel model for delay option before calculating it via @Risk software model.

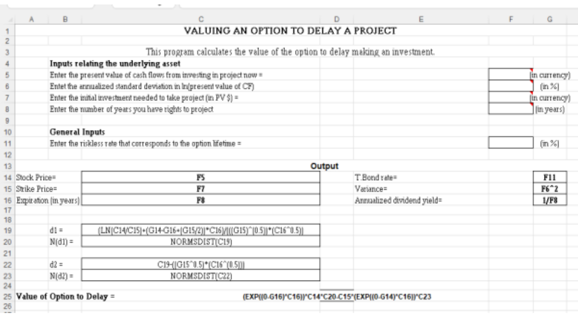

Fig. 2. Delay Option Valuation by using an Excel Model [7]

2.3 Monte Carlo Simulation Method in @Risk software

The second valuation approach is the @Risk Program. We can see a similar result with the binomial tree method. The @Risk program evaluates project outcomes using the Monte Carlo method as one of its functions, giving more accurate results.

The simulation of Monte Carlo can be viewed as a supplement to the binomial tree approach discussed above for valuing options. It can be applied to high-dimensional issues, whereas the other approach is applied to problems with low dimensions.

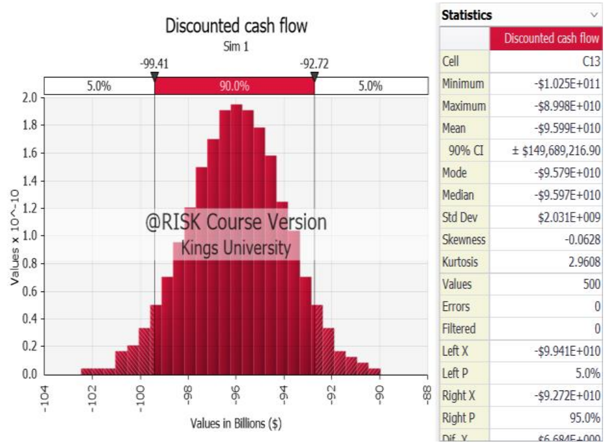

Fig. 3. DCF distribution by using MCS at @Risk Program

Sensitivity analysis is essential in order to identify the critical aspects of the investment after real option valuation. In addition, it enables decision-makers to identify areas for future improvement.

Sensitivity Analysis may also investigate many parameters, such as the impact of varying interest rates on the option's value. TopRank program, which is designed to analyze spreadsheet models, can be used for this purpose in our future research.

2.4 Trigger Value Calculation

The last approach is the calculation of trigger values that allow investors to specify the critical point regarding the decision to invest or not. Based on the results, we can analyze more clearly which is the better investment decision: LRs or SMRs?

	A	B	C	D	E
1		SMR	LRs	Formulas (For SMR)	Formulas (For LRs)
2	(FCF) Net Revenues (R*) per year				
3	Volatility of Net Revenues				
4	Discount Rate				
5	γ			0,5*(1+SQRT(1+(8*B4/(B3^2))))	0,5*(1+SQRT(1+(8*C4/(C3^2))))
6	W (size of the plant)				
7	Risk Premium			B4/(B5-1)	C4/(C5-1)
8	Trigger Value for Investment (T*)			(((B5-1)*B2)/(B5*B4))	(((C5-1)*C2)/(C5*C4))
9	Trigger Value for Construction Cost (K*)			(B8/B6)	(C8/C6)

Fig. 4. Calculation of Trigger Values for LRs and SMRs [2]

If trigger value for investment is higher than the actual value of investment, investor should ahead with the investment. Because this means that project did not exceed the critical point for investment costs.

3. Conclusions

In this research, we demonstrated that there are several methods for calculating the value of investment options. Decision-makers are able to select the optimal methodology for their needs.

In addition to that, we also presented the idea of applying these methodologies separately to LRs and SMRs and which investment might be more productive for a developing country. In future research, we will expand on this concept by comparing and evaluating the outcomes of nuclear power investment decisions for LRs and SMRs in Türkiye.

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REFERENCES

[1] Ahmed Abdulla, M. Granger Morgan, Nuclear Power for the Developing World, Vol. XXXI, No. 2, Winter 2015

[2] Olga Sokolova and Peter Zerek, The Power of Real Options-Evaluating nuclear energy investments in Ontorio, Industrial and Financial Economics Master Thesis No. 2006:5

[3] Burhan Toptaş, Rüzgar Enerjisi Santrali (RES) yatırımlarının değerlemesinde Reel Opsiyon Yaklaşımı ve Örnek bir Uygulama Yüksek Lisans Tezi, TC. Balıkesir Üniversitesi Sosyal Bilimler Enstitüsü İşletme Anabilim Dalı Muhasebe ve Finansman Bilim Dalı, Balıkesir, 2016.

[4] Robert T. Clemen, Terence Reilly, Making Hard Decisions with DecisionTools

[5] UKEssays. (November 2018). Comparing Binomial Tree, Monte Carlo Simulation And Finite.

[6] Sabuhi Safarov, Yatırım Projelerinin değerlendirilmesinde Reel Opsiyon Yöntemi ve Enerji Sektöründe bir Uygulama Yüksek Lisans Tezi, TC. Dokuz Eylül Üniversitesi Üniversitesi Sosyal Bilimler Enstitüsü İşletme Anabilim Dalı Finansman Programı, 2009

[7] Aswath Damodaran, (2022, August 20), Damodaran Online, https://pages.stern.nyu.edu/~adamodar/

[8] Giorgio Locatelli, Mauro Mancini, Giovanni Lotti, A simple-to-implement real options method for the energy sector, Energy, Volume 197, 15 April 2020, 117226

[9] Jonathan Mun, Real Option Analysis Tools and Techniques for Valuing Strategic Investments and Decisions