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Valuation of Mining Investment Projects by the Real Option Approach
- A Case Study of Uzbekistan's Copper Mining Industry -

Mumin Sh. MAKHKAMOV[1] and Dong-Hwan KIM[2]

실물옵션평가방법에 의한 광산투자의 가치평가
-우즈베키스탄 구리광산업의 사례연구를 중심으로-

무민 마카모브[1*], 김동환[2]

Abstract "To invest or not to invest?" Most business leaders are frequently faced with this question on new and ongoing projects. The challenge lies in deciding what projects to choose, expand, contract, defer, or abandon. The project valuation tools used in this process are vital to making the right decisions. Traditional tools such as discounted cash flow (DCF)/net present value (NPV) assume a "fixed"path ahead, but real world projects face uncertainties, forcing us to change the path often.
Comparing to other traditional valuation methods, the real options approach captures the flexibility inherent to investment decisions. The use of real options has gained wide acceptance among practitioners in a number of several industries during the last few decades. Even though the options are present in all types of business decisions, it is still not considered as a proper method of valuation in some industries. Mining has been comparably slow to adopt new valuation techniques over the years. The reason for this is not entirely clear. One possible reason is the level and types of risks in mining. Not only are these risks high, but they are also more numerous and involve natural risks compared with other industries. That is why the purpose of this study is to deal with a more practical approach to project valuation, known as real options analysis in mining industry. This paper provides a case study approach to the copper mining industry using a real options analysis. It shows how companies can minimize investment risks, exercise flexibility in decision making and maximize returns.

Key words : Sensitivity Analysis, Monte Carlo Stimulation, DTA, CAPM, ROV, and AMMC.

요 약 대부분의 기업경영자들은 새로운 투자와 현재의 진행 중인 투자 안에 대해서조차도 "투자를 할 것인가, 안 할 것인가?" 라는 문제에 자주 직면하게 된다. 이러한 도전은 어떤 투자안의 선택과 이의 확장과 축소, 투자지연과 포기 등을 결정하는데 놓여진다. 본 연구의 진행과정에서 사용된 투자평가 방법은 올바른 투자의사결정을 하는 데 있어서 매우 중요하다. 할인현금흐름법(DCF)/순현재가치법(NPV) 등과 같은 기존의 전통적인 가치평가방법들은 미리 확정된 경로를 가정하고 있다. 그러나 실제적인 투자계획안들은 불확실성에 직면하고 있음으로 경영자들로 하여금 평가의 경로를 수시로 변경시키도록 하게 만든다. 실물옵션 가치평가 접근방법은 다른 전통적인 가치평가방법들과비교하여볼 때 투자의사결정에 고유한 특성인 가변적인 융통성을 함축하고 있다. 실물옵션의 활용은 최근 몇십년 동안에 많은 산업들의 투자 실무자들 중에서 폭넓게 수용되어져 왔다. 비록 옵션이란 자체가 기업의사결정의 모든 형태에 상존하는 것임에도 불구하고, 아직까지도 몇몇 산업들에서는 적절한 투자가치 평가방법으로 고려되지 않고 있다.
광산업은 특히 수년 동안에 걸쳐 새로운 투자평가 기법을 채택하는데 상대적으로 둔감하였다. 이에 대한 이유의 근거는 명확하지 않다. 하나의 가능한 이유는 광산업종에 있어서 위험의 수준과 위험 형태의 문제이다. 광산업의 위험은 매우 높을 뿐만 아니라, 다른 여타산업과 비교하여 볼 때, 다양한 자연의 위험을 내재하고 있다는 점이다.
따라서 본 논문의 연구의 목적은 광산업에 있어서 실물옵션 분석방법으로 알려진 보다 실적인 투자방법을 통하여 실증적으로 고찰해보고자 하는 것이다. 본논문은 실물옵션분석모형을 이용하여 구리광산업의 투자가치평가 사례분석방법을 제시한다. 본 연구는 어떻게 기업들이 투자위험을 최소화 할 수 있고, 투자 의사결정에서 가변적 융통성을 행사하며, 기업의 성과를 극대화 시킬 수 있는가를, 여러 가지 기존의 방법들 중 실증적 비교 분석을 통하여 실물옵션 평가방법의 우수성을 보여준다.

[1]Ph.D., Business Administration, Hoseo University, Korea.
E-mail: swiftstaruz@yahoo.com
[2]Professor School ofBusiness and Economics, Hoseo University, Korea. E-mail: dhkim@office.hoseoac.kr

1. Introduction

If a firm is willing to invest on any project or sell the project, it should correctly define the true value of it. Defining the true value of a project is not an easy task for an investor. The problem is to figure out which valuation method can suit better for forecasting the value of a project. There are several capital budgeting techniques currently used in practice for making optimal investment decisions. Each technique has its own pros and cons. That' s why while the using different project valuation methods corporate managers try to figure out which methods are proper for their project analysis.

As the practice shows in some cases traditional methods fail to capture, even they are considered the most secure methods, the real value of a project. Especially this is truewhen the project has high uncertainty. The mining industry is one of them, where most of the risk is hedgeable, diversible or avoidable. For example, when the principal uncertainty is price the mine managers have some degree of operating flexibility in managing the outcome of their projects. When the price is falling to an unacceptable level usually the mine managers are mothballing the mine until conditions improve [1]. That' s why we think that in the presence of multiple sources of uncertainty, with different risk characteristics, it is inappropriate to use a uniform discount rate to adjust for the combination of factors.

2. Objective and Scope of the Study

The similarity between real and financial decision making has been recognized for at least two decades, when researches such as Tourinho, Brennan and Schwartz, and McDonald and Siegel extended the financial options theories of Black-Scholes and Merton to encompass irreversible real investment such as investment in mining [2-5]. Nevertheless, in contrast to financial decision makers, few mining industry practitioners have been persuaded to adopt real options methods. It is therefore natural to ask if the problems that they face are more complex. One way to address this question is to collect the most reliable data that are available to industry decision makers and use those data to assess the problems which are associated with real investment decisions.

Accounting to that,that mining has unique characteristics, which are not available in other industries; the great attention was given for implementation of ROV method for evaluating of a copper mining project' s value in the example of Uzbekistan' s mining company. We set following objectives from the implementation of ROV method:

1. To find out, when the use of ROV is proper? And which method of ROV is the best for the mining investment project analysis in Uzbekistan?
2. Compare the results of ROV with other traditional methods.
3. Compare the results of analysis with other previous empirical researches in the mining industry.

According to our investigations there wasn' t any ROV application practice found within the territory of the republic of Uzbekistan. That' s why we were interested to perform an analysis of the ROV method in the example of copper mining industry of Uzbekistan.

The scope of the study includes evaluation process of a copper mining project by using traditional and advanced method - ROV. The unit of analysis in this study is a case study taken from the current projects of Almalyk Mining and Metallurgical Complex (AMMC).

3. Methods and Materials

In the present study, several data collection methods were used. The main source of data collection methods were documents, interviews, archives and direct observations. Generally speaking we divided our research into two parts. First, the primary source of data collection, which is intended to study the use of project appraisal methods in the mining industry, and it also, considers the selection of the sole copper producer. After identifying the sole producer, the secondary source of data collection method was carried out with the purpose of selecting one of the current upcoming projects. A selected project (a case) has been analyzed by using ROV method and the results of this method have been compared with other methods.

3.1 Characteristics of the Mining Industry

We considered several mines in Uzbekistan and tried to learn their nature. Learning the nature of the mines mainly based on these two questions: "What are the main characteristics of the copper mining industry in Uzbekistan?" and "What kind of risks does the mining industry have?" We were deeply concerned about these two questions a lot because they should reveal us atrue nature of copper mining industry and pave us the right way for our project evaluation process. According to our investigations we gathered following information:

Mining has specific characteristics different from other industries:

1. Non renewable resources
2. Resources are located in areas with specific geophysical characteristics
3. High risk(exploration success rate is very low)
4. Slow yielding
5. Capital intensive
6. Technological innovations are slow
7. Mine sites are located in rural areas with minimal infrastructure

Mining business considered as inherently risky by most of the producers because:

1. Commodity price fluctuation
2. Competition risk
3. Government regulatory and policy risk
4. Exploration risk
5. Scarcity of reserves risk
6. Foreign exchange and monetary risk
7. Global economy risk

3.2 Current Mining Industry Appraisal Practice in Uzbekistan

With the purpose of knowing how the mining companies evaluate projects an informal survey was conducted in Uzbekistan in 2006. Interviews with vice presidents in charge of corporate development or other strategic management departments in charge led us to conclude that, although there is considerable variation across firms, certain practices emerge as central tendencies. The following facts were gathered based to our interviews:

- Virtually all firms use some form of DCF calculation to evaluate projects. The base calculation is often supplemented with sensitivity analysis for key parameters such as price. Some analysts use Monte Carlo techniques internally, but they often do not present results to senior management.
- Most firms use a long-run commodity price. In other words, they replace the random variable with its expected value. A possible reason for this is that most large companies acquire forecasting services of governmental agencies such as Agency of External Economic Activities of the Republic of Uzbekistan.
- Most firms adjust for risk by using a hurdle rate, which is an inflated discount rate. Although this hurdle varies across firms and across projects within firms, the most common rate is around 15%. Rates are usually changed according to economical and political instability within the country.
- Very few project decision makers had heard of real options theory and none had used it.

Some of the governmental banks that help to finance mining projects also undertake appraisals. Like producers, they use a standard DCF analysis that utilizes parameters that were obtained in a prior technical review. The principal difference is theway they utilize the risk. Most banks do not increase the discount rate to reflect greater risk. Instead, they use the bank' s cost of money for the discount rate and adjust the protection or coverage ratio. Finally, banks are often willing to accept price risk, which they can hedge, but are less willing to assume any technical risk.

4. Application of Traditional Methods and ROV Project Evaluation Method Using DCF

AMMC in Uzbekistan is considering the new project with the initial investment cost $58,000,000. The new copper project is estimated to have a lifetime of 10 years. Company is not sure about the project attractiveness and that is why wondering to start the development and production process or not. Project seems to be very risky because of not stable market prices for copper and unpredictable expenses involved within the project. AMMC has predicted some future expenses and amount of production for a lifetime of the project, which will be the source for our calculations and predictions for the attractiveness of the project [6].

As the free cash flows already defined by the companywe have to determine the risk-adjusted discount rate to calculate the NPV of the project. As the cash flow streams are influenced by the market risk in our project, the appropriate method for finding the risk-adjusted discount rate will be the CAPM.

$$r_a = r_f + \beta_a (r_m - r_f)$$

Where r_a = expected return of security a

r_f = risk-free rate of return, which is approximately 6%

r_m = expected market return (normally based on All-Share Index), 11%

$(r_m - r_f)$ = market risk premium, (11%-6%) = 5%

β_a = beta of security a, this is a measure of risk specific to the security

Since the beta is not available for a project, the idea is to find market proxy and calculate the beta using regression analysis. After doing some research analysis we found the market proxy which represents general market risk for copper industry. A company proxy, South Copper Corporation, is believed to have the same risk as its expected cash flow profiles are the same as AMMC project cash flows. For finding the beta we conducted regression analysis using Microsoft Excel. According to our findings the beta for AMMC is equal to 2.804699, approximately 2.8. Findings show that the stocks of AMMC are more volatile than the average market risk 2.8>1.0, which means the new undertaken project is highly risky. Using the beta value we can calculate the expected return for the CAPM.

$$r_a = 6\% + 2.8(11\% - 6\%) = 20\% \text{ or } 0.2$$

This expected return is considered to represent the risk associated with the project and is, therefore, used as the risk-adjusted discount rate to discount the project cash flows. Table 1 presents the steps involved in calculating the project NPV using DCF method and summarizes the results. According to our calculations the NPV of the new copper project is less than zero ($70,392)<0, which means the project is not financially attractive and should be rejected.

Table 1. Discounted Cash Flow Calculations for AMMC in Uzbekistan

	Year					
	2006	2007	2008	2009	2010	2011
Price of copper per ton		$2,930	$2,930	$2,930	$2,930	$2,930
Amount of production		10,000	15,000	16,000	17,000	18,000
Gross revenue		$29,300,000	$43,950,000	$46,880,000	$49,810,000	$52,740,000
Variable cost		$9,816,000	$14,650,000	$16,350,000	$18,050,000	$19,750,000
Fixed cost		$7,325,000	$7,325,000	$7,325,000	$7,325,000	$7,325,000
Total cost		$17,141,000	$21,975,000	$23,675,000	$25,375,000	$27,075,000
Gross profit		$12,159,000	$21,975,000	$23,205,000	$24,435,000	$25,665,000
Depreciation cost		$2,442,000	$2,442,000	$2,442,000	$2,442,000	$2,442,000
Earnings before interest and taxes (EBIT)		$9,717,000	$19,533,000	$20,763,000	$21,993,000	$23,223,000
Tax rate		40%	40%	40%	40%	40%
Less taxes		$3,886,800	$7,813,200	$8,305,200	$8,797,200	$9,289,200
Earnings after taxes		$5,830,200	$11,719,800	$12,457,800	$13,195,800	$13,933,800
Plus depreciation		$2,442,000	$2,442,000	$2,442,000	$2,442,000	$2,442,000
Free cash flows		$8,272,200	$14,161,800	$14,899,800	$15,637,800	$16,375,800
Risk-adjusted discount		20%	20%	20%	20%	20%
PV of cash flows		$6,893,500	$9,834,583	$8,622,569	$7,541,377	$6,581,913
PV of all cash flows	$57,929,608					
Project investment	$58,000,000					
Project NPV	($70,392)					

4.2 Sensitivity Analysis of the NPV to Key Parameters

With the purpose of gaining better insights into the DCF results we are going to conduct sensitivity analysis to our project. Sensitivity analysis should help us to identify sensitive variables/parameters within the project which have considerable affect on the NPV. To conduct sensitive analysis we varied initial investment, discount rate, peak variable cost, peak variable revenue, and a copper price for +20% and −20% compared to their "average" estimate. Table 2presents the results and Figure 1 shows the impact of input variables on the NPV in the form of "tornado" diagram. (A tornado diagram graphically shows the ranges

Table 2. Discounted Cash Flow Sensitivity Analysis for AMMC

	Variable		NPV	% NPV Change
Investment cost	Base	$58,000,000	($70,392)	
	20%	$69,600,000	($11,670,392)	-16479%
	-20%	$46,400,000	$11,529,608	16279%
Discount rate	Base	20%	($70,392)	
	20%	24%	($7,650,376)	-10768%
	-20%	16%	$9,424,187	13288%
Peak gross revenue	Base	$55,670,000	($70,392)	
	20%	$66,804,000	$2,158,316	2966%
	-20%	$44,536,000	($2,316,188)	-3190%
Peak variable cost	Base	$21,450,000	($70,392)	
	20%	$25,740,000	($940,963)	-1236%
	-20%	$17,160,000	$783,091	1012%
Copper price	Base	$2,930	($70,392)	
	20%	$3,516	$22,292,216	31568%
	-20%	$2,344	($22,450,088)	-31792%

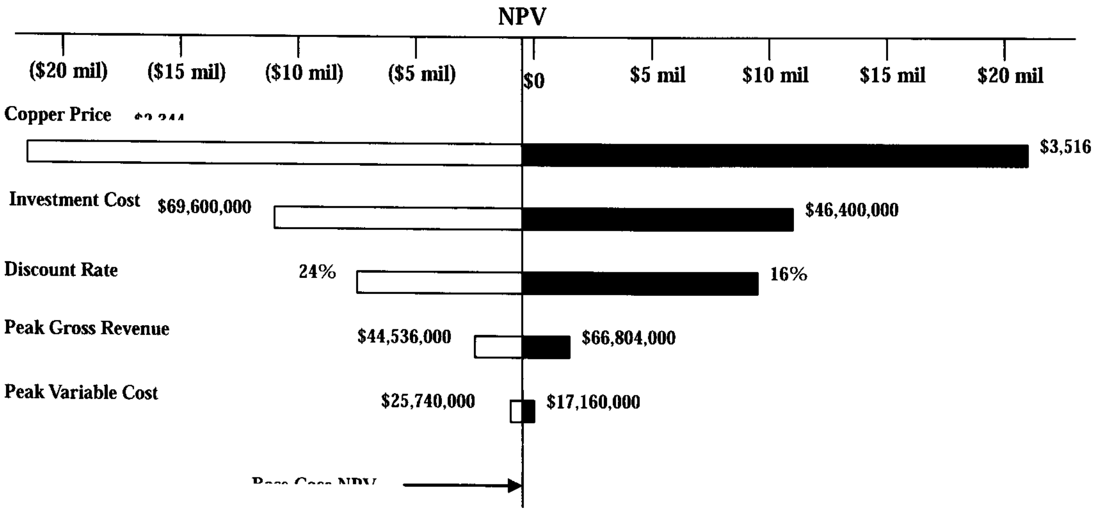

Figure 1. Tornado Diagram: Effect of Input Variables on NPV

of NPVs in descending order).

Even with +20% and −20% change in the input variables compared to their "average" estimates, AMMC' s project NPV in most of the cases is still a negative number, showing that the project is probably is not a good investment. The sensitivity analysis also shows that the copper price has the highest impact on the final NPV.

To gain further insight into the problem, we also conducted a scenario analysis where best and worst cases were evaluated and compared with the average case. The best and worst scenarios represented 150% = $86,894,412 and 50% = $28,964,804 of the expected total net annual revenues of the baseline case $57,929,608, respectively. Accounting for the investment cost of $58,000,000, the project NPV would be ($70,392), $28,894,412 and ($29,035,196) for average, best, and worst cases, respectively.

To approach better results of scenario analysis we should use more sophisticated tools involving computer software. One of such tool is called Monte Carlo Simulation.

4.3 Monte Carlo Simulation for NPV of the Project

To start with our simulation analysis we used all the data from the previous sensitivity

analysis results for five input variables. We took two basic steps before starting the calculations.

1. We defined the probability distribution of each input variable (max and min probabilities from sensitivity analysis) that dictates the free cash flows by identifying its average value and standard deviation of the distribution.
2. We defined NPV as a forecast parameter in our analysis.

Using a commercially available software Crystal Ball [7] we got results for probability and cumulative distributions of project NPVs. Figure 2 presents the probability distribution of the final NPVs calculated from the simulation, whereas the cumulative probability distribution is presented in Figure 3.

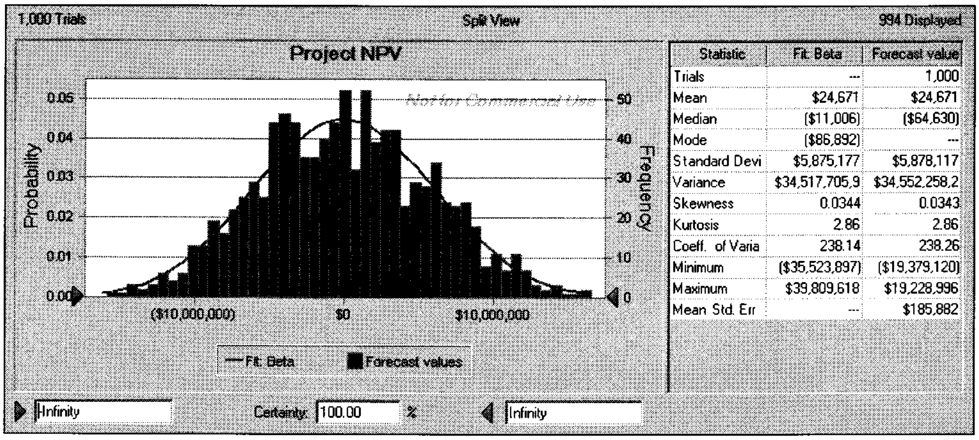

Figure 2. Probability Distribution of Project NPVs Based on Monte Carlo Simulation

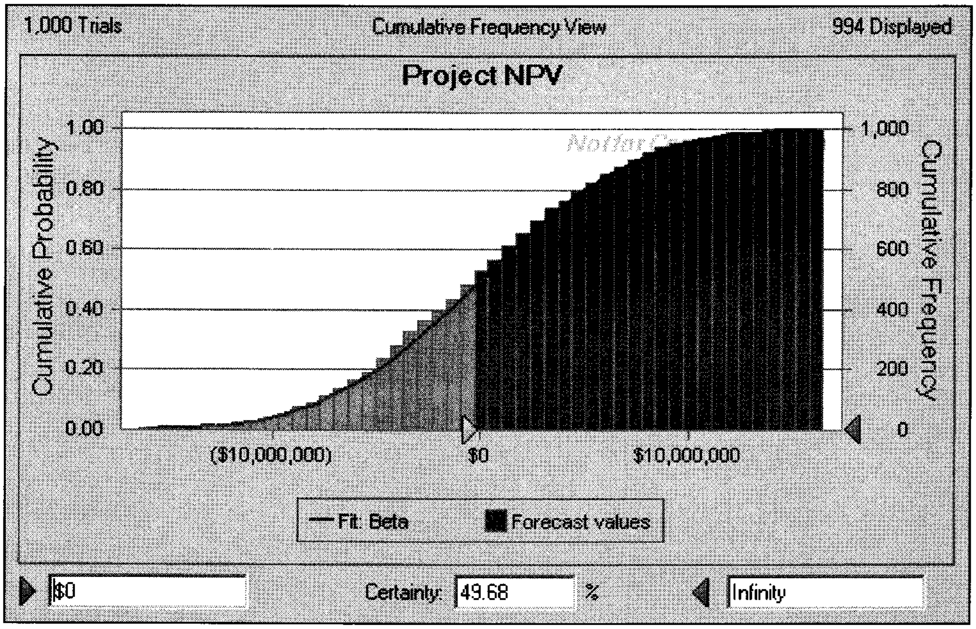

Figure 3. Cumulative Probability Distribution of Project NPVs Based on Monte Carlo Simulation

Statistical data shows that max forecast value of NPVis $19,228,996 and min is ($19,379,120). The second figure shows that the probability that the project NPV is greater than zero is 49.68%. Such information is extremely valuable for us as it tells us the merit of a given project; according to it we should reject the project.

4.4 Project Evaluation Method Using DTA

It is not clear yet whether the mine will turn out to be grade A-(rich), grade B-(middle), or grade C-(poor). To reduce the risk of its decision, the company can get more information about the new mine by doing some geological studies at the cost of $100,000. Geological studies are expected to disclose the geological characteristics of the mine. If the mine has "sub-surface structure", the pit expected to yield less copper as opposed to the "open-pit structure". Figure 4presents decision tree for this problem depicting decision points, decision alternatives, cost of the decisions, possible

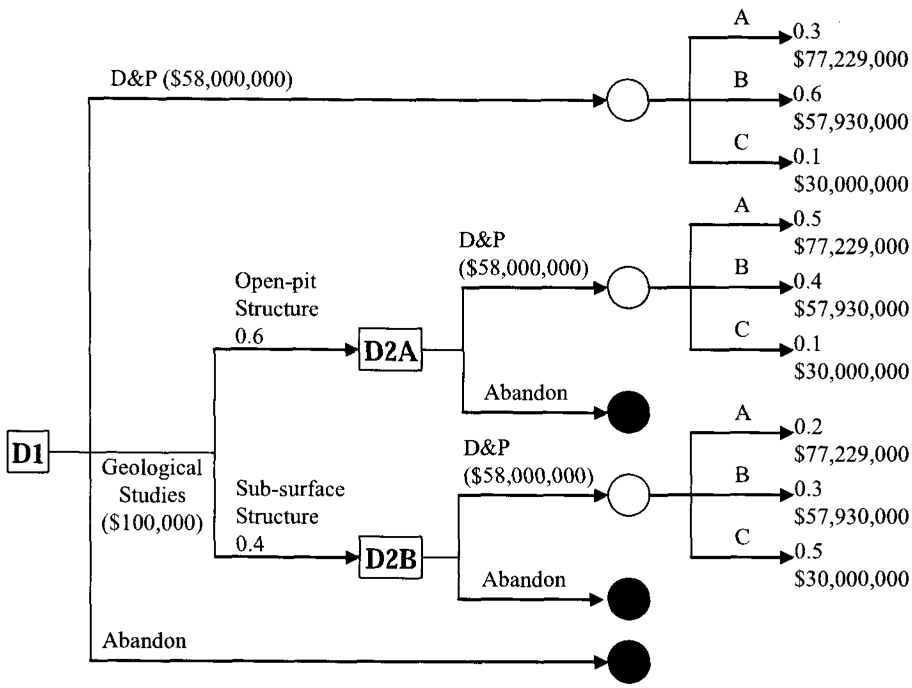

Figure 4. DecisionTree for AMMC

outcomes, probabilities of the outcomes, and the payoff related to each outcome.

Table 3 summarizes the results and the calculations involved in solving the decision tree. The solution to the decision tree involves calculation of "expected value" (EV) at each decision point and folding of the EVs from the extreme right of the decision tree into the preceding decision point and on toward to left.

The solution suggests that AMMC should first conduct initial geological studies before D&P, because the expected NPV of the geological studies decision at this point is higher than that of the D&P or abandon alternative. If the studies show an open-pit structure, the decision would be D&P because of its higher expected NPV compared to its abandon counterpart. In the case of a sub-surface structure, however, the expected NPV of the abandon decision is higher than the D&P alternative; therefore abandoning the project would be the right decision.

Using the decision tree results, we can also gain further insight by considering the best,

Table 3. Decision Tree Calculations for AMMC

Decision Point	Alternatives	Expected NPV Calculations	Expected NPV	Choice
D2A	D&P	0.5*$77,229,000 + 0.4*$57,930,000 + 0.1*$30,000,000 - $58,000,000	$6,786,500	D&P
	Abandon	$0	$0	
D2B	D&P	0.2*$77,229,000 + 0.3*$57,930,000 + 0.5*$30,000,000 - $58,000,000	($10,175,200)	Abandon
	Abandon	$0	$0	
D1	D&P	0.3*$77,229,000 + 0.6*$57,930,000 + 0.1*$30,000,000 - $58,000,000	$2,926,700	Geological Studies
	Abandon	$0	$0	
	Geological Studies	0.6*$6,786,500 + 0.4*$0 - $100,000	$3,971,900	

Table 4. Expected NPV: Best, Worst and Most Likely Case Scenarios for AMMC in DTA

Scenario	Expected NPV Calculations	Expected NPV
Best	$77,229,000 - $58,000,000 - $100,000	$19,129,000
Worst	$30,000,000 - $58,000,000 - $100,000	($28,100,000)
Most likely	[0.5*$77,229,000 + 0.4*$57,930,000 + 0.1*$30,000,000- $58,000,000]*0.6 + 0.4*$0 - $100,000	$3,971,900

worst, and most likely case scenarios for the project. It should give us a perspective on the relative upside and downside to the project. The results from the analysis are summarized in Table 4.

From the scenario analysis we see that most likely NPV is close to the best case than to the worst, which means there is an excellent chance of success by undertaking the project.

4.5 Project Evaluation Method Using ROV

Before conducting ROV analysis we evaluatedthe project characteristics to determine whether the project has high option value and deserves further consideration. A screening test has been used to determine the ROV potential of a project [8]. According to the assessment tool results our project has significant real options value, which indicates high enough potential to use ROV.

There are three kinds of optionvaluation techniques in practice, and each technique has its own specific methods to calculate options values. The Black-Scholes and binomial methods are by far the most commonly used, followed by simulations. In our project analysis we are intended to employ both the binomial and Black-Scholes methods. In the binomial method input parameters such as the strike price and volatility can be changed easily over the option life. Jumps and leakage also can be accommodated without any complex changes and the results of analysis can be easily explained using the illustrative tools. That is why we think binomial method can give us more realistic results in identifying the option values of our project and Black-Scholes method can be used as a tool to verify those results.

4.5.1 Binominal Method

First step in estimating the option value of the project, using the binominal method,is to identify the input parameters. Almost all parameters are known except one, volatility.

S_0(current asset value) = $57,929,608
X(strike price or investment cost)
= $58,000,000
r (risk free rate) = 6%
T (time to expiration) = 5 years
δ t (incremental time step) = 1 year
σ (volatility)

Since the volatility factor is not available in the given input parameters, the idea is to use the Logarithmic Cash Flow Returns Method. We selected the logarithmic cash flow return method because this method provides a volatility factor that is based on the variability of the same cash flow estimates that are used in calculating the underlying asset value itself; therefore, it is most representative of the volatility of the asset value. Table 5 presents a calculation of the volatility factor estimation, where the annual volatility factor equals to 21%.

After identifying all the input parameters we should calculate the option parameters, which are the up (u) and down (d) factors and the risk-neutral probability (p):

$$u = \exp(\sigma\sqrt{\delta t}) = \exp(0.21*\sqrt{1}) = 1.233$$

$$d = 1/u = 1/1.233 = 0.811$$

$$p = \frac{\exp(r\delta t) - d}{u-d} = [\exp(0.06*1) - 0.811]/(1.233-0.811) = 0.251/0.422 = 0.595$$

Table 5. Volatility Factor Estimation: Logarithmic Cash Flow Returns Approach[3]

Year	Cash Flow (S_t)	Return(R_t)[4] $R_t=S_t/S_{t-1}$	ln R_t	Deviation (ln R_t - Average ln R)	Square of Deviation (ln R_t - Average ln R)^2
2007	$8,272,200	-	-	-	-
2008	$14,161,800	1.711975	0.537648	0.506713314	0.256758382
2009	$14,899,800	1.052112	0.0508	0.019865202	0.000394626
2010	$15,637,800	1.049531	0.048343	0.04834327	0.002337072
2011	$16,375,800	1.047193	0.046114	0.046113575	0.002126462
2012	$17,113,800	1.045067	0.044081	0.04408052	0.001943092
2013	$16,375,800	0.956877	-0.04408	-0.04408052	0.001943092
2014	$15,637,800	0.954933	-0.04611	-0.046113575	0.002126462
2015	$14,161,800	0.905613	-0.09914	-0.099142861	0.009829307
2016	$10,927,800	0.771639	-0.25924	-0.259238198	0.067204443
Average ln R			**0.03093**		
Total of squares of deviation					**0.344662939**

Now we can build the binominal tree and calculate the asset values at each node of the tree. The binominal tree is shown in Figure 5using one-year time intervals for five years.

4.5.2 Black-Scholes Method

With the purpose of verifying our binominal method results we are intended to use Black-Scholes method. Identifyingthe input parameters within the equation and calculating option parameters we got:

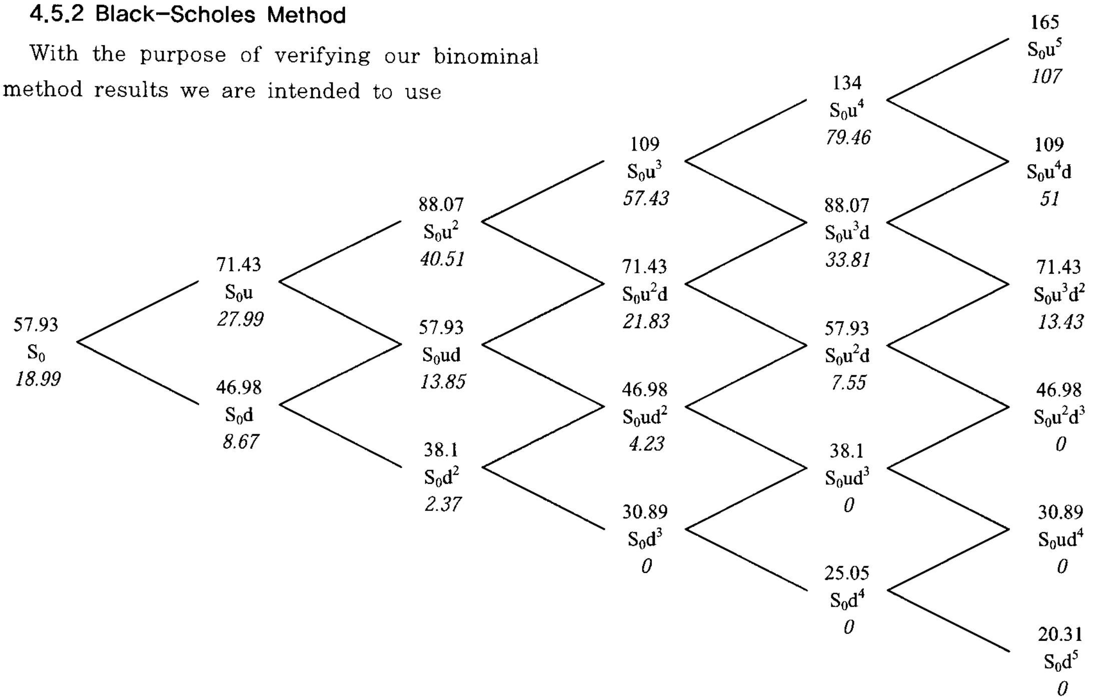

Figure 5. Option Valuation Binomial Tree for AMMC in Uzbekistan[5]

3 Volatility factor is the square root of (total of squares of deviation/n - 1), where n is the number of values included = square root [0.344/(9-1)] = 0.21

4 $R_t=S_t/S_{t-1}$

5 All numbers are in $ million. Top numbers are asset values. Bottom italicized numbers are option values. Option to invest is exercised at nodes where the option value is not zero.

S_0 (current asset value) = \$57,929,608
X (strike price or investment cost)
= \$58,000,000
r (risk free rate) = 6%
T (time to expiration) = 5 years
σ (volatility) = 21%

$$d_1 = \frac{\ln(\frac{S_0}{X}) + (r + \frac{1}{2}\sigma^2)(T)}{\sigma\sqrt{T}}$$

$$= \frac{\ln(\frac{\$57,929,608}{\$58,000,000}) + (0.06 + \frac{1}{2}0.21^2)(5)}{0.21\sqrt{5}} = 0.871$$

$$d_2 = d_1 - \sigma\sqrt{T} = 0.871 - 0.21\sqrt{5} = 0.401$$

N(d_1) and N(d_2) are the values of the standard normal distribution at d_1 and d_2 (available in Microsoft Excel as a function).

N(d_1) = 0.808 (from Microsoft Excel)
N(d_2) = 0.656 (from Microsoft Excel)

When all parameters are found we can easily solve the Black-Scholes equation for ROV:

$C = N(d_1)S_0 - N(d_2)X \exp(-rT) = \$46,807,123 - \$38,048,000 * \exp(-0.3) = \$18,620,471$

The ROVs for the new copper project based on the two methods used are:

- Binominal = \$18,990,000
- Black-Scholes = \$18,620,471

Given the margins of error for the estimated input parameters, the above values can be considered to be virtually the same.

4.6 Summary

The results of our analysis can be summarized in Table 6, where the outcomes of traditional techniques and ROV method are compared.

Let' s compare the decisions we would make strictly based on DCF results versus ROV result. The DCF method, using a risk-adjusted discount rate, shows a payoff of \$57,929,608 for the project, which is expected to cost \$58,000,000 for development and production. This means the NPV of the project is (\$70,392) = (\$57,929,608 - \$58,000,000), which does not favor the investment.

Strictly based on the DCF alone, our decision may be not to invest in this project. However, the project has an ROV of approximately \$18 million created by the option characteristics of the project related to the high uncertainty. The additional value created by the option is the difference between the ROV of \$18 million and the DCF-based NPV of (\$70,392), which equals to \$18,070,392.

With such substantial additional value created by the option, AMMC may want to explore alternatives other than abandonment of the project at this time.

Table 6. Comparative Results of Traditional Techniques and ROV.

Methods	Project's NPV	Decisions Concerning to Project
DCF	(\$70,392)	Reject
Sensitivity Analysis	Key parameters were changed to +20% and -20% compared to their "average" estimates. Parameter - copper price has the highest impact on the final NPV.	Reject the project as the current copper price is low.
Monte Carlo Simulation	The probability of upcoming project's NPV>0 is 49.68%.	Reject
DTA	\$3,971,900	Conduct Geological Studies. If the mine has "open-pit structure" accept the project and if it has "sub-surface structure" reject the project.
ROV: Binominal	\$18,990,000	Accept
ROV: Black-Scholes	\$18,620,471	Accept

For example, it may simply wait until the market uncertainty clears by itself (passive learning), at which time it would re-estimate the project payoff. If the payoff is unfavorable, it may still continue to wait or abandon the project idea altogether. If, on the other hand, the conditions are favorable with high expected payoff, it may invest in the project. Alternatively, AMMC may decide to conduct geological test of the copper from the terrain to clear the uncertainty (active learning) ‑instead of waiting for the uncertainty to resolve itself. As the uncertainty is resolved, AMMC may produce the copper anytime during the option life. The life of the new project is assumed to be fixed irrespective of when it is introduced within the option lifetime of five years. Therefore, the payoff does not vary based on when the investment is made. In other words, there is no "leakage" in the asset value because of waiting.

It should be evident from the foregoing calculations and discussion that ROV is a supplement to rather than an alternative to the DCF-based NPV. If AMMC' s candidate project has either an extremely high positive or extremely high negative NPV, the project may be accepted or rejected for investment, respectively, irrespective of the option value. Since the NPV is not highly negative and the project has a high option value, management may want to consider alternative decisions related to passive or active learning and keep the project "alive".

DTA suggests us to conduct geological studies before starting development and production. Because the value attached to geological studies is higher than that of the development and production or abandonment alternative (D&P=$2,926,700; abandon=$0; geological studies=$3,971,900). According to DTA if the studies show an open-pit structure, the decision would be development and production because of its higher expected NPV compared to its abandon counterpart (D&P= $6,786,500; abandon=$0). In the case of a sub-surface structure, however, the expected NPV of the abandon decision is higher than the development and production alternative (D&P=-$10.175200; abandon=$0); therefore abandoning the project would be the right decision.

As we can see ROV and DTA gives us positive NPV, because of contingent decisions in our project, while DCF gives us negative NPV suggesting to abandon the project as it not takes into account contingent decisions. Sensitivity analysis of the NPV to key parameters in DCF also clearly mentioned that copper price has the highest impact on the result of NPV because of its high volatility nature. That is why the price of the copper is an important variable which involves the market risk associated with project and dictates to exercise or abandon the project.

5. Conclusions

We can conclude following facts (findings) about our project analysis:

1. In our project analysis additional value was created by using ROV method, which is equal to $18,070,392. This value has been created because of high uncertainty involved into the project. Considerable difference between the calculated values of traditional methods and ROV, made ROV superior to them as it presented positive value. ROV took into account all contingent decisions within the project, and that is why we think it should be selected as a standard method for evaluating mining investment projects.
2. ROV is most valuable when there is high uncertainty with the underlying asset value and management has significant flexibility to change the course of the project in a favorable direction and is willing to exercise the options. When there is little uncertainty and not much room for managerial flexibility,

the real options approach offers little value. Our analysis shows that ROV does not provide much value in investment decisions on projects with very high or very low NPVs. Real options offer the greatest value on projects with an NPV close to zero (either positive or negative).

3. By using ROV method we were able not only to identify the value of the mining project but we also gained a lot of insights about the project and strategic choices available to the management. In other words, ROV revealed us other opportunities concerning the project. We are sure that such abilities of ROV make it special among other evaluation methods.
4. DTA method showed positive NPV taking into account contingent decisions. DTA is one of the proven methods in practice but it has limitations. When contingent decisions appear to be a lot it is not useful, because it can't account for all of them and starts to become much more complicated than usual for solving project decisions. In such situations ROV stands to be superior (Black-Scholes model).
5. In AMMC view of strategy, risk is perceived as a negative factor. The same applies to capital budgeting, where high risk isreflected in high discount rates. However, in order to create new business opportunities, companies have to assume certain risks. Thus risk becomes a positive factor. The ROV approach helps to bridge this gap.
6. ROV is now more than 30 years old, but it still has not made its own way into the mining industry of Uzbekistan. Currently it is an approach still too theoretical and mathematical for the companies. Majority managers in mining companies don' t know the power of ROV in project evaluation process and they think that it is much too complicated for understanding and use. Although the actual decision makers can avoid mathematical complexity by choosing an appropriate framework, they still need to understand ROV concept. That is why we think that ROV method needs a time to be approved as a standard set of decision making tool like DCF.

Even though the findings from this study reinforce results from previous research certain contribution points should be mentioned:

1. In fact, most of the previous studies provedthe dominance of ROV by comparing it with traditional methods. They concluded that ROV is an alternative to traditional methods. But our findings conclude that ROV is a supplement to traditional methods not an alternative. In other words, it is an extended form of DCF. According to our findings traditional methods like DCF assess whether a project has a significant real option value or not. That is why we suggest always using DCF at the initial stage of project evaluation process, and then ROV (when a project investment is equal or almost equal to the present value of net payoff).
2. While previous studies were mostly conducted taking into account only market or private risks, in this study both (market and private risk) were considered separately. In doing sowe gained a lot of insights about our project and strategic choices available to management. We think that not taking into account both types of risks decrease the probability of finding the true value of a project.

6. Limitations and Future Research

Despite its potential for broad-based application, the real options framework has been applied to a limited extent in our present study. Herein, we can count several limitation points and their extensions for future research:

1. Because the data in the presentstudy were gathered from the single producer deep observation was possible, but at the same

time the ability to generalize the findings may have suffered. For a broader analysis of project evaluation one can conduct research of several projects in the mining industry using ROV. An empirical research conducted using several projects could be a great extension of this study.

2. For evaluating the mining investment project's value we used option to wait, where the simple scenario has been presented. As an extension of our analysis other types of advanced options can be utilized. Real options solutions can be presented with more complex project scenario such as with compound or rainbow options where volatility of the asset value changes during the option life.
3. We separated the study of private and market risks using DTA and ROV separately. Perhaps the most interesting extension, and the most demanding, would be to integrate DTA and ROV in order to account for both market and private risks in the same time.

We learn from this study that the real options could be very valuable in the mining industry, and these results cannot be derived by applying the traditional methods alone. The results of this study also demonstrate the power of the real options approach for evaluating different projects where contingent decisions are involved. It goes without saying that ROV method could also be applied into other types of commodities such as gold, oil, and zinc etc.

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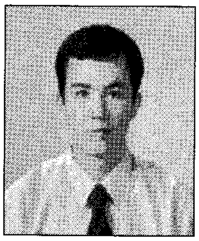
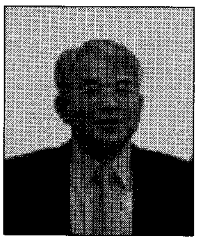
Mumin Sh. Makhkamov [Regular Member]



- July-1999 :BachelorDiploma in B.A., Tashkent State Economics University, Uzbekistan
- June-2001:MBA, TSEU,Uzbekistan
- Dec-2003: Techno- MBA in The Graduate School of Venture Business, Hoseo University
- Aug.-2007 Ph.D. in Finance, Hoseo University.

<Field of Major > : Valuation of IT related Industry, Financial Management, Investments, Business Analysis, M & Aetc.

Dong-Hwan Kim [Permanent Member]



- Aug.-1979 : MBA, Korea University
- Feb.-1989년: Ph.D. in Finance, Korea University
- March-1983 to Present : Prof., Hoseo University.

Field of Major : The Firm's Valuation, Financial Management, Investments, Business Analysis, Financial Institution, Securities Markets, Financial Derivative Assets, M & Aetc.