MINE PROJECT EVALUATION TECHNIQUES

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ABSTRACT
Mining industry was always considered as risky business. Uncertainties about ore body, volatile commodity prices, exchange rates, environmental issues, political/legislation risks make a capital investment puzzle for every decision maker throughout the industry. Major challenge of project evaluation is how to deal those risks/uncertainties. Several methods including Discounted Cash Flow (DCF), Decision Trees (DT) and Monte Carlo Simulations (MCS) are commonly used for evaluation of mining projects. This paper briefly outlines and summarizes application of those methods.

АБСТРАКТ
Рударската индустрија одсекогаш се сметала за ризичен бизнис. Неодоволната истраженосст и непознавање на природните услови, променливите цени на металите на берзите, флуктуација на девизните курсеви, проблеми со животната средина, политички и законски ризици, ги прават инвестциите во нови проекти загатка за секој инвеститор во оваа индуструја. Главниот предизвик на евалуацијата на проектот е да ги дефинира и вклучи влијанијата на ризиците. Неколку методи на анализа вклучувајчи ги DCF, DT и MCS вообиачено се користат во еваулацијата на рударските проекти. Овој труд накратко ги сумира и објаснува овие методи и нивната примена.

1. INTRODUCTION

Selection and proper application of project evaluation techniques is of crucial importance for mining industry due to fact that this industry is extremely capital intensive, require years of production period before a positive cash flow commences, and requires longer project life compared to other industries. The major challenge for a valuation technique is to be able to consider the project risk, effect of time and management of flexibility in the valuation (Torries, 1998).

The risk associated with a mining project can be classified as internal and external (sources). Internal sources of uncertainties relate to the ore body model and grade distributions, as much as technical mining specifications (ground condition, equipment capacities, workforce and management). The external sources consist of commodity price, political/country risk, environmental conditions, legislation and government policy.

According to the results of a Canadian Mineral Economics Society survey, where respondents were asked to rank a list of mining project risks, the highest risk comes from mineral reserves and ore grade, then political, social and environmental, metal price, profitability/operating cost, location, capital cost, management and so on (Smith, 2002). Lilford and Minnitt (2005) studied project valuation methodologies for mineral deposits. At the end of the study, it was concluded that the selection of the valuation methodology depends on the ability to correctly interpret all of the available information and fundamental factors (commodity prices, exchange rate, technical information, economic information, comparative transactions, uncertainty risk) required for each valuation methodology in order to guide selection process.

The purpose of this paper is to present available mine project evaluation methods and more specifically Discounted Cash Flow (DCF), Decision Trees (DT) and Monte Carlo Simulations (MCS) and subsequently apply them to a mine project using different discount rates. The example of DCF method is also presented stressing knowledge about the input parameters and handling the time value of money concept.

2. MINE PROJECT EVALUATION METHODS

2.1 Discounted Cash-Flow analysis

One of the most common methods to evaluate a mining project is the DCF method. In 1995, Bhappu and Guzman surveyed 20 mining companies located in the USA, Canada, Mexico, Australia, and Great Britain and obtained the results shown in Table 1(Bhappu and Guzman, 1995).

Table 1. Priorities of 20 selected mining companies for investment decisions

Priority	NPV	IRR	Payback-period	Other methods
Primary	8	11	3	3
Secondary	5	3	6	0
Tertiary	0	1	2	0

DCF is a valuation method used to estimate the attractiveness of an investment opportunity through future free cash flow projections and discounts them (most often using the weighted average cost of capital) to arrive at a present value, which is used to evaluate the potential for investment. If the value arrived at through DCF analysis is higher than the current cost of the investment, the opportunity may be a good one.

$$DCF = \frac{CF_1}{(1+r)^1} + \frac{CF_2}{(1+r)^2} + \cdots + \frac{CF_n}{(1+r)^n}$$

where: *CF* – projected cash flow
r- discount rate

There are many variations when it comes to what you can use for your cash flows and discount rate in a DCF analysis.

This method include the effects of risk and time by adjusting or discounting the project net cash flow. The greater the projects risk, the higher the discount rate should be. Under this method, Net Present Value (NPV) and Internal Rate of Return (IRR) are the most common methods for evaluating a mining project.

Net Present Value (NPV)

It is the difference between the present value of cash inflows and the present value of cash outflows. NPV analysis is sensitive to the reliability of future cash inflows that an investment or project will yield.

$PV_n=FV_n/(1+interest)^n$

where:

PVn - present value for year n
FVn - future value for year n
interest – interest rate used for discounting

In addition to the formula, net present value can often be calculated using tables, and spreadsheets such as Microsoft Excel. If the NPV of a prospective project is positive, it should be accepted. However, if NPV is negative, the project should probably be rejected because cash flows will also be negative.

Internal Rate of Return (IRR)

The discount rate often used in capital budgeting that makes the net present value of all cash flows from a particular project equal to zero. Generally speaking, the higher a project's internal rate of return, the more desirable it is to undertake the project. As such, IRR can be used to rank several prospective projects a firm is considering. Assuming all other factors are equal among the various projects, the project with the highest IRR would probably be considered the best and undertaken first.

Since there is no clear analytical solution of IRR standard tray/error or iterative methods are used.

IRR is sometimes referred to as "economic rate of return"(ERR) as the rate of growth a project is expected to generate. While the actual rate of return that a given project ends up generating will often differ from its estimated IRR rate, a project with a substantially higher IRR value than other available options would still provide a much better chance of strong growth.

IRRs can also be compared against prevailing rates of return in the securities market. If a firm can't find any projects with IRRs greater than the returns that can be generated in the financial markets, it may simply choose to invest its retained earnings into the market.

2.2 The Decision Tree (DT) method

Decision Tree analysis is a method which comes from operations research and game theory. The method estimates the probability of possible outcomes of a project by generating appropriate decision branches that have probabilities of their likelihood of occurrence. It is simply a flowchart or diagram representing a classification of a system or a probabilistic model (Clemen, 1995).

The tree is structured as a series of simple questions. The answers to these questions generate a path down the tree. The values are determined for each of the possible outcomes in the analysis. In order to construct the decision tree, all the appropriate decision nodes and probabilities of occurrence must be determined (Moore et al., 2001).

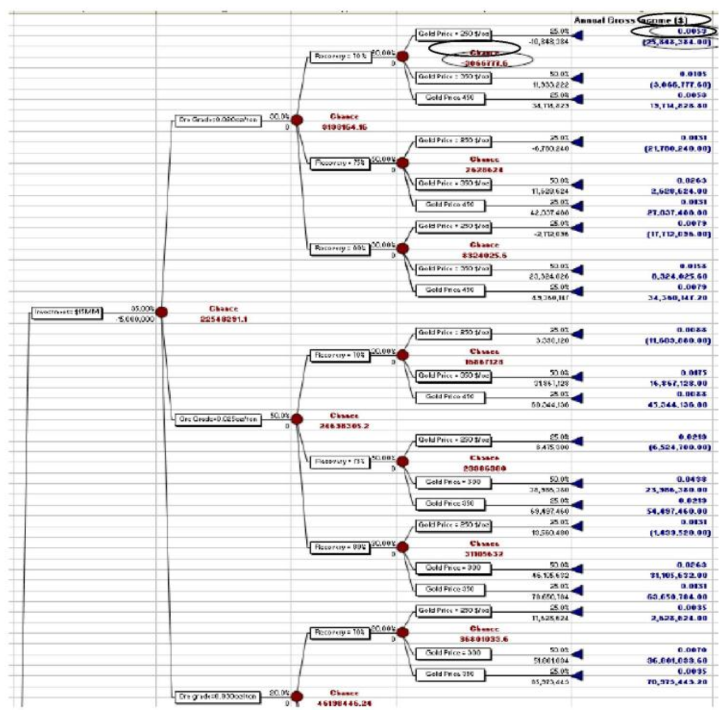


Fig.1 Decision tree sample

A decision tree consists of nodes and branches. There are two types of nodes: decision nodes, represented by squares, i.e., whether to make the investment or not, and uncertain event nodes, represented by circles, i.e., ore grade, commodity price, project investment, ore recovery. Branches are straight lines that emanate from the nodes. At the end of each branch the generated NPV is denoted.

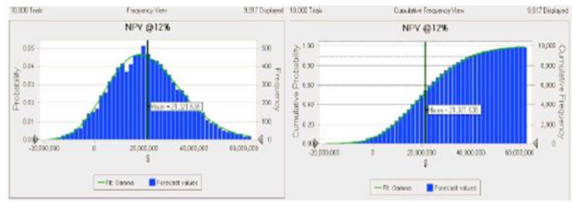
The DT allows for the decision maker to break down a large, complicated problem into a series of smaller, simple problems. The decision maker can see the whole picture of the project and the outcomes of the possible routes with respect to NPV. Also, sensitivity analysis can be generated from the outcomes to see which variables i.e., price, ore grade, production cost, impact more on the expected NPV of the project.

DT method is mostly utilized in the probabilistic analysis of mining projects.

2.3 Monte Carlo Simulation (MCS) methods

The MCS technique has been used increasingly as an important tool for analyzing projects with uncertainty because of the development of computer technology. In order to perform a MCS, the first step is to develop an analytical model to evaluate. The second step is to generate a probability distribution from subjective or historical data for each variable (not defined) in the model (Degarmo et al., 1997). MCS calculates the outcome of the project by using the marginal distribution of all the parameters appearing in the NPV equation. The method simply uses statistical distributions, such as normal, lognormal, triangular, and uniform, to evaluate the uncertainty in the parameters within the project. In every simulation, the values are selected randomly from each parameter distribution for every time period and substituted into the NPV equation in order to generate one possible outcome of the project (Galli et al., 1999). This process repeated hundreds or thousands of times will calculate an average or expected NPV of the project.

Fig. 2 MCS sofware snapshoot



of the project will be (Walls, 1999). In most cases, to make the calculation easier, the variables are assumed to be independent from one another. In reality, most of the variables are correlated. For example, in mining, ore grades are positively correlated with ore recovery. In other words, the higher the ore grade, the higher the recovery. Also, it is shown that the commodity prices are correlated between time periods.

The method not only can be used as an important tool for the project uncertainty analysis, but with any other evaluation method together also.

3. ABOUT THE METHODS

Three methods (DCF, DT, MCS) use the traditional discount rate whereas RO uses a risk free rate in order to consider the time value of money in the evaluation of the project. The selection of the correct discount rate crucially affects the outcome of the projects in these three methods. In most circumstances, discount rate is the most sensitive variable and the most difficult variable to correctly quantify. The value of the selected discount rate reflects both time value of the money and the riskiness of the project.

DCF methods have been used in 75% of the mining companies. It can be calculated easily and does not require a deep knowledge of the economy. DT can also be calculated easily but as the number of the possibilities increases, the tree grows exponentially. This makes the calculations harder. There are sophisticated packages such as Crystal Ball and @ Risk available for the calculation of MCS methods.

An ‘ideal’ mining project evaluation method needs to answer the following questions for the decision maker. First, “when to make the investment and development of the project”? Second, “how much to produce annually”? Although all methods present here (DCF, DT, MCS) can be used in investment analysis, there is no single method that can be entirely adequate for the evaluation of mining project.

Although DCF methods do not allow for managerial flexibility, all the input parameters are known with certainty for the entire life of the project, decisions must be made on a ‘now or never’ basis and usage of appropriate discount rate is crucially important , it is easy to calculate.

DT analyses different managerial strategies and shows all the outcomes (expected NPV) from these strategies. It is helpful to see the whole picture of the project, but it can be misleading when the discrete probability of the variable is not estimated correctly. Also, the DT method can easily get complex when the number of variables increases. Decision tree method is mostly utilised in the probabilistic analysis of mining projects.

4. SAMPLE DCF

A better understanding of most frequent methodology used can be gained through a sample DCF analysis of polymetalic underground mine expansion investment. In order to simplify calculation the analysis period is reduced to 5 years. The DCF analysis in general comprises following steps:

- cash flow analysis
- cumulative money flow
- calculation of indicators
    - payback period
    - NPV
    - IRR

First and crucial step for successful application is costs calculation and as real as possible investment schedule (project start, development and production phase). In deep knowledge and understanding all technicalities regarding the planed activities is essential for proper costs calculation and definition of cost/income distribution throughout the period of analysis. This is a basis for cash flow analysis.

Table 3. Costs/Income distribution in the analysis period.

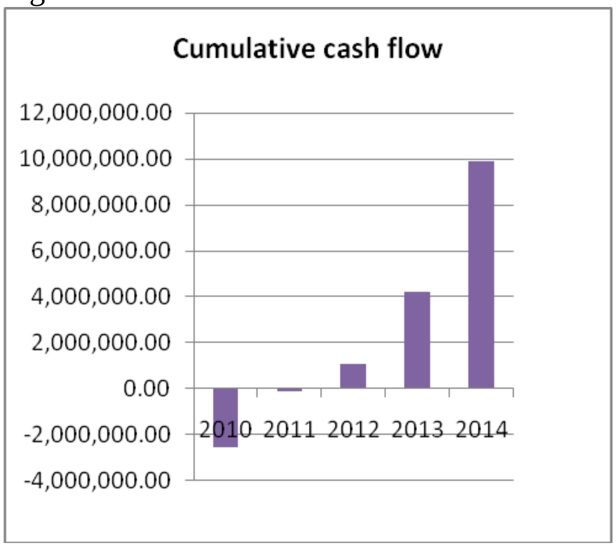
Cost distribution 2010-2014					
	2010	2011	2012	2013	2014
Total costs per year	**2.551.291,35**	**3.605.700,00**	**5.850.100,00**	**8.790.040,00**	**15.717.340,00**
Incomes distribution 2010-2014					
	2010	2011	2012	2013	2014
Income per year	**0,00**	**3.474.400,00**	**6.948.800,00**	**13.029.000,00**	**25.623.700,00**

Based on costs/income distribution cumulative cash flow is calculated in table 4.

Table 4. Cumulative cash flow

Year	2010	2011	2012	2013	2014	Total
Total incomes	0,00	3.474.400,00	6.948.800,00	13.029.000,00	25.623.700,00	49.075.900,00
Total cost	2.551.291,35	3.605.700,00	5.850.100,00	8.790.040,00	15.717.340,00	36.514.471,35
CFF	-2.551.291,35	-131.300,00	1.098.700,00	4.238.960,00	9.906.360,00	12.561.428,65

Fig 3. CCF chart



Based on this and using simple spreadsheet calculation Payback period and IRR are calculated as follow:

Tab.5 Payback and IRR fr 5 years

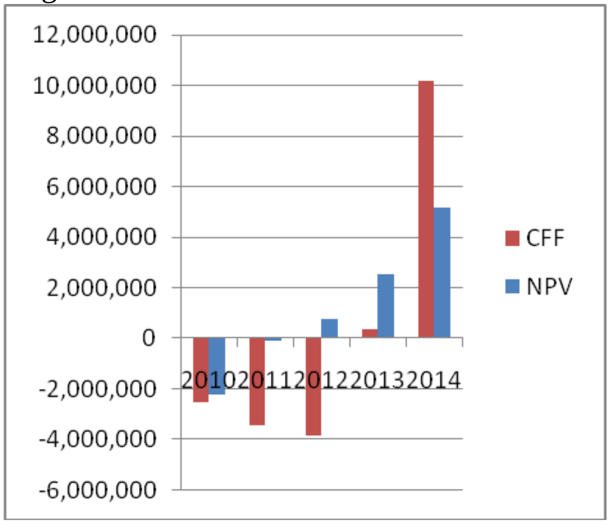
Payback period	3.4 years
IRR for %5 year period	34 %

Discounted cash flow with 14 % interest rate is calculated in table/chart below;

Tab.6 Discounted cash flow

Interest rate (0 - 100%)		14			
	2010	20112	2012	2013	2014
CFF	**-2.551.291,35**	**-131.300,00**	**1.098.700,00**	**4.238.960,00**	**9.906.360,00**
		Discounted cash flow (NPV)			
	-2.237.975,00	**-101,031,00**	**741.591,00**	**2.509.805,00**	**5.145.053,00**

Fig 4. NPV chart



5. INSTEAD CONLCSUIONS

The paper try to show importance of economic evaluation techniques for mineral deposits in their early stages as a screening device to make "go/no go" decisions. It's obvious that DCF methodology is currently „industrial standard"due to easy application. But decisions based only on DCF should acknowledge their limitations and wider analysis and alternative methods usage (like DT) are highly recommendable. Some risk assessment program can be also very supportive in any decision for further investments.

REFRENCES

Bhappu, R.R. and Guzman, J. (1995) 'Mineral investment decision making', Engineering and Mining Journal, pp.36–38. Black, F. and Scholes, M. (1973) 'The pricing of options and corporate liabilities', Journal of Political Economy, pp.637–654. Blais, V. and Poulin, R. (2004) 'Stochastic pricing of real options', 13th Annual Conference of the Mineral Economics and Management Society (MEMS), Toronto, Canada, pp.6–9.

Brennan, M.J. and Schwartz, E.S. (1985) 'Evaluating natural resource investments', Journal of Business, Vol. 58, No. 2, pp.135–157. Clemen, R.T. (1995) Making Hard Decisions, Fugue School of Business Duke University, Duxbury Press, CA, USA. Colwell, D., Henker, T., Ho, J. and Fonk, K. (2003) 'Real option valuation of Australian gold mines and mining companies', The Journal of Alternative Investments, pp.23–38.

Degarmo, P.E., Sullivan, G.W., Bontadelli, J.A. and Wicks, E.M. (1997) Engineering Economy, 10th ed., Prentice–Hall, New Jersey, pp.546–563.

TOPUZ,1977, "Assessing the value of mining investment proposals under multiple objectives", PhD dissertation, Virginia Tech, Dept. of Mining and Minerals Engineering, Blacksburg,VA,

WALLS, M.R.; EGGERT,R.G.1996, "Managerial Risk-Taking: A Study of Mining CEOs", Mining Engineering, March:61-67.