IDENTIFICATION AND QUANTIFICATION OF INCREMENTAL MARKET RISK USING ALTERNATE VALUATION METHODS

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1. INTRODUCTION

The most widely used method for mineral project evaluation has been the discounted cash flow analysis, where the cash flows are discounted by an appropriate discount rate to obtain the present value. Any increment in perceived risk usually results in a higher risk adjusted rate which eventually results in undervaluing the project value. Another, commonly used method is Option Pricing Model (Black and Scholes 1973) which may result in overvaluing the project, especially in cases where prices are volatile. None of the above methods offer any operational flexibility. The authors in this research project developed an Expert System as an alternative method for evaluation of natural resource. This method attributed to more closely approximate the decision making behavior of an investor while offering operational flexibility.

In this paper, an investment simulation was developed using a gold mine as an example with stochastic output price. Using historical data base in the simulation, gold prices were forecasted, and cash flows derived using several input parameters. Cash flows were derived using (a) conventional revenues and cost figures, and (b) Expert Systems. Comparisons of the two methods along with Option Pricing model is done and results are reported. Using the results the incremental market risk is identified and quantified.

2. REVIEW OF VALUATION METHODS

2.1. THE TRADITIONAL DISCOUNTED CASH FLOW ANALYSIS

The most widely used method for evaluation of natural resources, is the discounted cash flow (DCF) analysis. In this method, future cash flows are discounted to determine their present value and cumulated to determine the worth of the project. The net present value (NPV) of an investment is the present value of its future net cash inflows minus the initial capital expenditure

(Neveu. 1975). The simple decision rule that is used for investment is to invest in the project with a positive net present value and reject the one with a negative net present value.

The main criticisms for DCF analysis has is that it is static in nature and it does not consider the role of operational flexibility by management to make or revise a decision in the future (i.e. option to produce, to suspend, or to relinquish the project). DCF analysis also overlooks the strategic option value of a project resulting from a project's interdependence on future and subsequent investments. Theoretically, DCF analysis violates risk assumption. A decision undertaken with DCF is considered irreversible, and significantly reduces the variety of choices which could be possible in the future.

2.2. OPTION PRICING MODEL VALUATION

Another method used for natural resources valuation is the Option Pricing model. An option is a contract, which provides its owner with the right to buy or sell a specified commodity at a specified price by a specified date.

The analogy between a mine and stock option is to take the production cost of a mine as the exercise price and price of the ore as the stock price (Lehman, 1991; Brennan and Schwartz, 1985, and Paddock, Siegal, and Smith, 1987). At the time, if the price of the ore is greater than its production cost, the owner will operate the mine thus exercises his option. However, if the price of ore is less than the production cost, the owner will not operate the mine, or exercises his option. The return on investment depends on the market price of the commodity.

Table 1, further illustrates the five basic factors that affect the price of call options and their direction of influence. It also provides a comparative analysis of variables for pricing models of stock "call" options and undeveloped natural reserves. This method may provide more flexibility in investment decision making compared to DCF, however it could overvalue the worth of a given project if the output price is highly volatile.

Table 1: Comparison for Pricing Models of Stock Call Options and Undeveloped Reserves

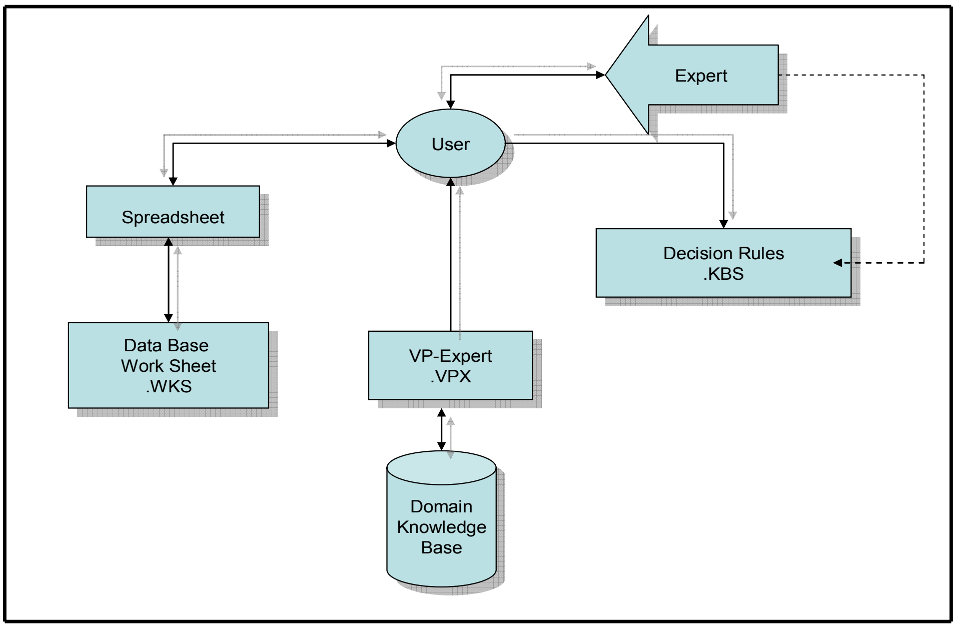
+	Stock price (S)	Current value of Reserve
+	Variance of rate of rate return on stock	Variance of rate of change in the value of developed reserve
-	Exercise value (E)	Development cost
+	Time to expiration (T)	Relinquishment requirement
+	Risk-free interest rate (Rf)	Risk less rate of return

Source: Siegal, D.R., J. L. Smith and J. L. Paddock, " Valuing off shore Oil Properties with Option Pricing Models," P. 23

2.3. VALUATION USING EXPERT SYSTEMS

In their research project, these authors developed Expert Systems to determine the value of natural resources. Using VP Expert, as an Expert System development tool, and fundamental principles of economics and finance, rules were written for making investment and operation decisions rules. Figure 1 displays the architecture of the Expert System that was developed. Although this is not an optimization method, it is based on a combination of optimal financing and economic principles using the investment and operation rules. This method closely approximates the actions of the investors and producers, provides flexibility for strategic decision making, and may result in higher monetary values for the project. It provides opportunity for active management involvement, and serves both as an investment and operational decision making tool. It can indicate all possible solutions to the established goal, explain how the solution was derived, and calculate a quantitative measure for each solution.

Figure 1: The Architecture of the Expert System for the Project



3. METHODOLOGY

3.1. THE MODEL

An investment in a small gold mine project is used as an example. The objective function for this project is to:

Maximize $$NPV = \sum_{t=1}^{t=10} (1-\delta)^1 \; [(P_t \, q_t) - Cv_t \, q_t] - I_o$$

Subject to $R_t = q_t$, …….. Investment method

given $R_o, q_t \geq 0$

Where:

NPV expected net present value,

P_t exogenous gold price

q_t gold output per year,

Cv_t extraction cost

Io initial capital expenditure,

R_o original stock of ore

δ discount rate

3.2. THE INVESTMENT PROJECT AND PROJECT CYCLES

The life of this investment project is assumed to be ten years, $\ell = 10$. As it is illustrated in figure 2, there are ten individual project cycles Pc_j, j = 1 to 10. Net present value of each project cycle (NPV_{Pcj}) is determine as

$$NPV_{Pcj} = \int_1^n [(P - V)\, Q]^{-rt} \quad - I_{o,} \qquad \text{for} \qquad j = 1 \text{ to } 10$$

Where

ℓ the life of this gold mine project is assumed to be ten years

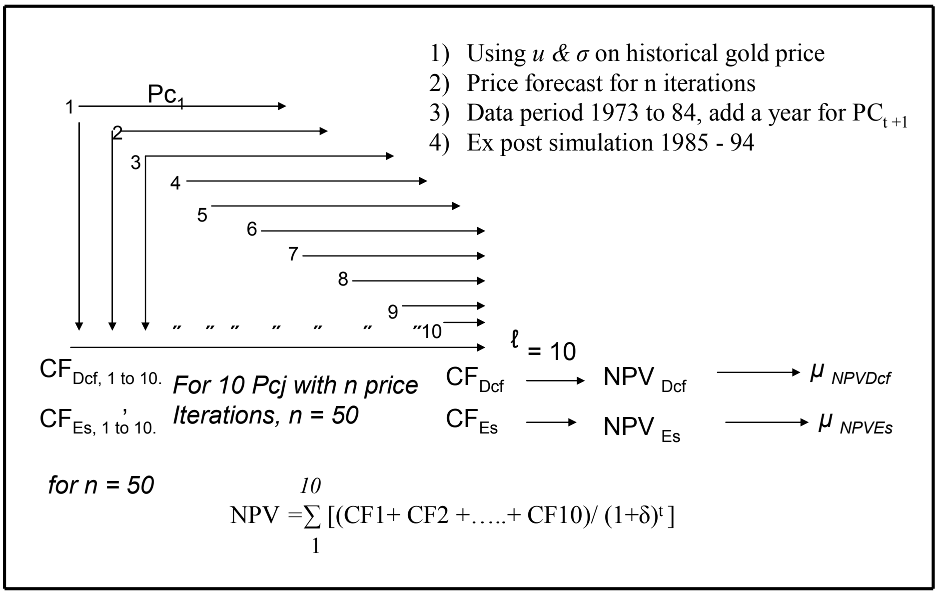
Pc_j j = 10 is the number of individual project cycles, i.e. jth project cycle

Each individual project cycle Pc_j has a life cycle of n.

For j = 1 to 6, n = 5.

For j = 7 to 10, n = 11 – j.

Figure 2: Process of Gold Mine Evaluation for 10 Project Cycles



3.3. PRICE SIMULATION

An investment simulation was developed using a gold mine as an example, with stochastic output price. Actual gold prices from 1973 to 1984 were used as the historical data base in the simulation. Using the mean and standard deviation of historical data on gold prices, the expected gold prices were generated for each project cycle during the period from 1985 to 1994 to test the behavior of the simulation, and compare the performances of the DCF and Expert System.

For example, at the initial year t_0, the historical data on gold prices on annual bases from initial data base year, t_{0-11} to year t_0 are used to solve for the mean and the variance on gold price. Using the resulting mean and variance, the expected prices for each year of project cycle is generated for life of the project on a random basis.

The first project cycle Pc_1 is supposed to begin at year t_1 for n periods. At the end of year t_1, the data set is updated by addition of that year's price value, which now includes data from years $t_{0-}11$ to t_1. Again, the mean and the variance on gold price are updated with recent information and recalculated to generate a new set of prices for the next project cycle Pc_2, which is scheduled to start at year t_2. This process continued until terminal state at project cycle number ten (Pc_{10}).

The expected gold prices for n price iterations were generated by using @ Risk software, and assuming normal distribution for output prices. The selection of price values from probability distribution is referred to as sampling, and regeneration of gold prices on a work sheet is referred to as iteration. For each project cycle there were one hundred price iterations. However, only fifty iterations were utilized, since the results of the comparative study converged at n = 50 price iterations.

3.4 CASH FLOWS AND NET PRESENT VALUES

From the simulated gold prices two sets of cash flows were generated. One set of cash flows were conventional cash flows for each project cycle, calculated using basic economic principles of revenue and cost. Another set of cash flows were obtained using Expert Systems. These cash flows were a result and a function of a set of investment and operational decisions rules arrived at during consultation with Expert Systems.

The first year cash flows from each project cycle, represent the actual (although still simulated) cash flow in that particular project cycle. Therefore, from each project cycle the first year cash flows for both the above cases, DCF and Expert System, are stored for final determination of project's value. Net Present Value for each set of cash flows is calculated. For calculating the Net Present Value in case of conventional cash flows, risk adjusted discount rate of 14% is assigned, while for calculating the NPV in case of Expert System cash flows, risk free rate of 9% is assigned as the discount rate.

In determination of risk adjusted discount rate the capital asset pricing method (CAPM) was utilized as illustrated below

$$
\begin{aligned}
r' &= r + \beta\,(r_m - r)\\
&= 9\% + \beta\,(14\% - 9\%)\\
&= 14\%
\end{aligned}
$$

Where the risk free rate (r) of 9% is determined using interest returns on short-term U.S. government securities for early 1980s. The return in the market (r_m) is expected to approximate the historical rate of return of 14% on gold investment for 1974 – 1984. The beta coefficient is 1, and is approximated from historical volatility on the rate of return on gold for the Newmont mining company (Tinsley, **1985, P. 89).**

4. RESULTS AND ANALYSIS

4.1 COMPARATIVE VALUATION OF DIFFERENT METHODS

Table 1 show the value of the project determined by using three alternative methods, DCF, Expert Systems, and OPM. The Expert System valuation resulted in a higher value for this project than the DCF and a lower value than the OPM. As discussed earlier in this paper, the DCF has been criticized for undervaluing the projects by assuming higher discount rate to compensate for risky investment. The OPM on the other hand overvalues an investment project with high volatile output price. The Expert System has flexibility to make operational decision based on anticipated cash flows and can influence the investment value much more closely to that of a human decision maker.

Table 1: Alternative Value of the Project (Millions $)

	n = 30	n = 40	n = 50
μ_{Dcf}	7.96	9.10	9.30
μ_{Es}	12.24	13.50	13.90
OPM	22.30	22.30	22.30

Values with Discounted Cash Flow (μ_{Dcf}) analysis, Expert System (μ_{Es}) and Option Valuation (OPM).

Table 2 shows the simulation results for NPVs and convergence test for 50 price iterations. It appears that the valuation with the Expert System more closely approximates the actions of investors and management, provides operational flexibility and results in a consistent value at different price samplings.

Table 2: Convergence test for the expected NPVs (Millions $)

Methods	Sample Size	Values	% Change
μ_{Dcf}	30	7.70	
μ_{Es}	30	12.20	
μ_{Dcf}	40	9.10	0.14
μ_{Es}	40	13.50	0.10
μ_{Dcf}	50	9.30	0.01
μ_{Es}	50	13.90	0.02

The comparative statistical analysis shown on Table 3. It indicates that there is no possibility of losses with Expert System, because the operational decisions result in stopping the losses before they occur.

Table 3:Statistical comparison for NPV s with alternative valuation methods

Items	μ_{Es}	μ_{Dcf}
Minimum	3.60	-2.50
Maximum	26.41	21.95
Expected value	13.97	9.26
Standard Deviation	6.10	5.50
Coefficient of Variation (Cvar)	0.43	0.60
P ($\mu < 0$)	0.00	5%

4.2 Identifying Incremental Market Risk.

The Expert System enabling operational flexibility influences investment decisions and therefore reduces the risk of financial loss. Application of this method for valuation also can capture incremental market risk. Market risk can be from unexpected changes in output price and it has two segments: 1) price fluctuations which cause fluctuation in profits even there are no losses; this segment of market risk is still a systematic risk, and 2) combined operational decisions which must be able to react to price fluctuation to prevent losses, thus providing unsystematic character for this segment of market risk. The application of Expert System in this case provided mechanism to capture this segment of market risk through operation flexibility. The approach to quantify the incremental market risk is shown below

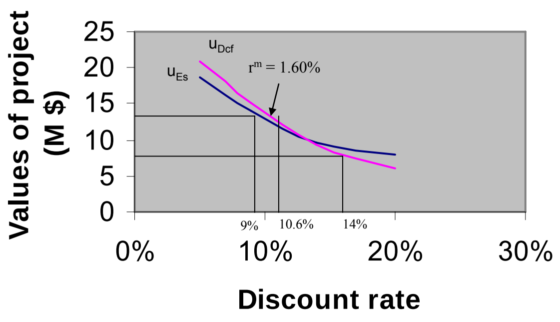
r^m	*market risk increment*
r^a	*market risk increment due to other risk elements*
r	*risk free discount rate*
$\acute{r}$	*risk adjusted discount rate*

Where

$$r' = r + r^m + r^a$$

The expected net present value for the gold mine project amounting to $10.61 million was calculated with conventional discounted cash flow analysis (μ_{NPVc}) at 14% risk adjusted discount rate. The expected net present value for the gold mine project amounting to $13.97 million was calculated using cash flows obtained with expert system (μ_{NPVe}) at 9% risk free rate of return. The discount rate *(r*)* which equates μ_{NPVc} to μ_{NPVe} at risk-free discount rate r = 9%, was obtained. This amounts to 10.6%. This difference represents the value of incremental market risk ($r^m = r^* - r$) that is removed through operational flexibility using expert system technology for project evaluation.

Figure 3: Estimated market risk increment



Therefore application of expert system for project evaluation allows management to identify portion of the market risk through operational flexibility. This rate is 1.60% and it is quantified as

$$r^{m} = r^{*} - r = 1.60\%$$

Where r^{m} represent the market risk increment that is captured through operational flexibility using the expert system.

5. Conclusions

The objective of this study was to design an evaluation method for a mineral investment project that provides more flexibility for the manager using Expert System with simulation. The review of the project evaluation models available revealed that all of them were deficient in various ways. Specifically, the traditional discounted cash flow (DCF) analysis, failed to capture the true value of the project.

An alternative method for DCF analysis recommended for natural resource evaluation has been the option valuation method (OPM). The option valuation method provides some degree of flexibility for investment decision making. However, OPM could overvalue the worth of a given project if the output price is highly volatile. Since it is possible that DCF analysis can undervalue, and OPM can overvalue a risky project with a high volatile output price, we developed an alternative evaluation method.

After a careful review of the available methods and their deficiencies, it was determined that a more realistic project evaluation method was needed. An alternative method using Expert System for mineral project evaluation was developed. The Expert System more closely approximated the actions of investors and producers, provided flexibility for strategic decision making and may result in higher values for the project.

In this paper, using gold mine project as an example, we simulated the mine investment and operation decision making under uncertainty using historical data of gold prices. Resulting analysis showed that the expert system served as both an investment and operation decision making tool providing an opportunity for active management involvement. Although, it is not an optimization method the investment and operational rules of the expert system are based on combination of optimal financing and economic principles. The Expert System technology can provide all possible solutions to the established goal, describe how the solutions were found, and give a quantitative measure for each solution.

The Expert System captures the knowledge of an expert and can apply the expertise to similar project evaluations at no additional cost. The operational flexibility provided by the expert system allows it to circumvent price risks, and from strategic perspective prevent losses before they occur. Using this aspect further, we quantify this element of the operational risk as the incremental market risk and show how it can be measured using expert system.

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Summary

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This paper will explore the practical importance of the value of flexibility in resources assessment by evaluating investment in a gold mine project using simulation and expert system. Historically the most prominent techniques for asset valuation have been discounted cash flow analysis (DCF). The major weakness of DCF is it does not theoretically recognize risk. Siegal, Smith and Paddock (1992, p. 22) argued that the application of DCF analysis for project valuation becomes difficult for investment opportunity which provides various operational options.
Another method as an alternative for discounted cash flow analysis (Pam et. Al 1986 and Gibson, 1991) is the Option Pricing Model (OPM) which provides more flexibility for management in investment decision making. However, this method could overvalue the worth of a given project if the output price is highly volatile. Recently, these authors developed an alternative valuation method by using a rule based Expert Systems that provided operational flexibility.
In this paper, by using simulated cash flows, the performance of the Expert System is compared to discounted cash flow analysis DCF and OPM. The result indicated that Expert System more closely approximated the actions of investors and producers, provided managerial flexibility, resulted in a lower coefficient of variations, and minimized possible losses in the operation process. Furthermore, analysis of result indicated how Expert System can identify and capture the incremental market risk.