VALUATION METHODOLOGY FOR VALMIN

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ABSTRACT

This paper examines the methodologies commonly used in the valuation of mineral properties. A methodological context is developed by presenting the general framework for asset valuation provided by multidimensional utility theory. It is shown how utility theory provides the theoretical basis for a number of forms of discounted cash flow analysis including the net present value of expected cash flow and the utility appraisal of the probability distribution of net present value based on a utility function, stochastic dominance criteria, or intuitive judgement. Modern portfolio theory and the capital asset pricing model are also presented.

The subject literature suggests that the most controversial questions asked about mineral property valuation are:

- is it legitimate to extend the application of discounted cash flow analysis to the valuation of mineral properties characterised by very imprecise data and thus remove the historical reliance on theoretically unsound methods of valuation based on inference and scoring of subjective judgements?

- can risk be treated satisfactorily by adding a risk premium to the discount rate (either judgementally, on the basis of returns historically demanded by investors, or on the basis of the Capital Asset Pricing Model) or should risk be treated explicitly in a Monte-Carlo simulation analysis?

This paper concludes that:

- discounted cash flow analysis can be extended to properties characterised by imprecise data but mining analysts must first become more comfortable with the use of subjective probabilities. This requires an abandonment of the old distinction between risk and uncertainty inasmuch as it considers uncertainty fundamentally unamenable to quantification and the only respectable definition of probability is an objectivist one based on relative frequency;

- the Capital Asset Pricing Model is relevant to mineral property valuations, provided its underlying assumptions are satisfied and the model is properly applied in a methodological rigorous way; and

- project specific risks can be treated explicitly using Monte-Carlo simulation.

INTRODUCTION

This paper, parts of which are based upon Sorentino and Weston, 1996, reviews the most commonly used mineral valuation methodologies as they are reported in the specialised literature and more particularly those outlined in a previous MICA Seminar (VALMIN 1994).

It is the outside of the scope of this paper to discuss the inappropriate use of these methods (see Lawrence and Dewar, 1999, for a discussion of these aspects).

It is important at the outset to determine whether the valuation of mineral assets is especially different from the valuation of any other asset. According to Runge *risk ... differentiates mining from other business enterprises*. It is of course true that mining is characterised by risk especially in relation to the size and grade of mineral deposits and also with respect to commodity prices, but it is by no means unique in this regard.

Hydroelectric power, irrigation and water supply projects often proceed on the basis of imprecisely quantified hydrology and then experience fluctuations in output due to natural inflow variability. Significant risk also attends agricultural production - plants and livestock being susceptible to drought and disease, and prices for output being subject to great variation.

It would be wrong then for the mining industry to think certain kinds of mineral property are so special that they require special valuation methodologies different to those used to value others kinds of projects.

Lawrence (1994) provides a fourfold classification of mineral properties -

- grass roots exploration areas,
- advanced exploration properties,
- predevelopment projects and developing mines, and
- operating mines.

For properties with well defined resources and operating mines, most valuers agree that discounted cash flow (DCF) analysis should be the primary valuation method. For other mineral properties they object to its use and indicate a preference for other non-theoretically based methods. It is contended in this paper that discounted cash flow analysis could be extended in its application to the valuation of these other properties if mining analysts and valuers were more inclined to accept the notion of subjective probability.

If precise data could always be obtained on asset characteristics and performance, and there was subsequently no risk associated with the attainment of projected cash flows, asset valuation would be a less controversial subject than it is. For it is in the treatment of imprecise data and risk, that valuers differ in their opinions of what method is appropriate for particular valuations.

This paper will set out to show that a general valuation methodology, which is able to capture investors' preferences for risk and timing of payments, is available in the form of multidimensional utility theory.

The information requirements of this general approach are perceived as prohibitive and therefore seldom used. Two courses of action are left to valuers:

- The first one is to retain the theoretical basis of the utility approach but to reduce its information requirements by making reasonable assumptions about investors' preferences.

- The second approach, which seem overwhelmingly adopted by valuers, is to ignore the theoretical approach on the grounds that data is too imprecise to warrant its application, and to resort to *inferential* methods (e.g. rely on data generated by Comparable Sales, buy-in terms for Joint Ventures, and past history of Exploration Expenditure; or to use *scoring* methods, such as the Geoscience Rating method) which seek to impose some rigour on the quantification of subjective judgements.

Although the literature points out the many logical and practical problems associated with these non-theoretical methods, and few if any valuers believe them to be entirely satisfactory, most remain reticent about extending DCF to the evaluation of properties characterised by imprecise data.

It is suggested that the problem lies in a rejection of the notion of *subjective probability*: Most mineral property valuers tend to accept Knight's (1921) old distinction between risk and uncertainty which Dasgupta and Pearce (1972) express as follows: *if there is sufficient information to justify the assignment of probabilities to outcomes the situation is risky, if there is not enough information the situation is uncertain*.

While accepting that the use of subjective probabilities remains controversial, it is important to point out that many modern economic authors have departed from Knight's distinction. For instance, Levy and Sarnat (1984) in their text on investment and portfolio selection, use uncertainty and risk interchangeably on the ground that *in financial investment probability beliefs are almost invariably subjective*. Basically the market will make a judgement where the analyst and valuer may hesitate.

A favourable reconsideration of the notion of subjective probability would prepare the way for DCF analysis to enter the kinds of valuation where the less satisfactory inferential and scoring methods are presently applied. It scarcely needs pointing out that these methods do not escape the necessity of making subjective judgements. The Geoscience Rating method for instance is a good candidate for replacement by a subjective probability method.

Whether the precision of data warrants the application of DCF analysis is a major issue mentioned in the literature. Other issues of concern is how to carry out a DCF analysis, how to include in it the valuation of managerial flexibility, and the question of whether using an appropriate discount rate can adequately treat risk or whether one should treat risk explicitly in a Monte-Carlo simulation.

The widespread availability of powerful microcomputers and software packages to carry out the required analysis, renders the Monte-Carlo simulation approach practical and worthwhile. It is also suggested that this simulation approach is well suited to the analysis of managerial flexibility.

AN OVERVIEW OF VALUATION THEORY
MULTIDIMENSIONAL UTILITY THEORY

A general theory of valuation must take into account the beliefs and preferences of investors. This is done by modern utility theory.

The origin of modern utility theory is associated with Daniel Bernoulli (1738) who in the early eighteenth century presented a solution to the famous St Petersburg paradox. The paradox concerned the limited amounts people are prepared to pay to play a simple coin-tossing game with an infinite expected return. Bernoulli's solution involved the postulation of a logarithmic utility function descriptive of risk aversion. Two centuries later the axiomatic basis of utility was formalised by von Neumann and Morgenstern (1953) who showed that if a decision maker fulfils a number of reasonable consistency requirements, the expected utility hypothesis results in optimality under conditions of uncertainty.

In developing a general valuation theory it is necessary to allow for investors' preferences with respect to the risk and timing of cash flows to be totally general. It is supposed that the object of valuation is an asset and that a valuation is made by, or on behalf of an investor.

The physical nature of the asset is considered unimportant and it is assumed that the investor values the asset for no other property than the financial return it provides.

The form of this return is a risky cash flow and the purpose of valuation is so that the investor can determine whether the return associated with one asset is preferable to the return associated with other assets - a choice among risky cash flows.

While a choice between risky cash flows need not entail an absolute valuation, that is to say, it is only necessary to establish a relative preference ranking, an investor's valuation of a risky cash flow is the certainty equivalent he places upon it - i.e. the amount of money he will presently exchange for it.

Harrington (1987) defines value as *the fair price that an investor would be willing to pay for a firm, or a portion of a firm, or any other asset. Value is determined by three factors*

- *the size of the anticipated return*
- *the date that these returns will be received*
- *the risk that the investor takes to obtain these return.*

In valuation two subjective elements are involved - *beliefs* and *preferences*:

- *Beliefs* are involved in the evaluation (quantification) of risk. Although influenced by the opinions of others (especially those regarded to be experts), and the past performance of similar assets, the investor will form a view (have a belief) as to the riskiness of the returns, and this will be a subjective view differing from the views of other investors.
- The second subjective element is *preferences*. These are of two kinds: one relating to the timing of the returns, the other to the riskiness of the returns.

A valuation is made when an investor combines his beliefs and preferences to indicate a preference for one risky cash flow over other risky cash flows or a certainty equivalent.

The general theory of valuation is rooted in utility theory. This theory postulates that *an investor's preferences can be described by a utility function, which maps a risky cash flow onto a scalar value*. In general term the investors time and risk preferences for cash flows are described by a multidimensional utility function.

A stochastic process can generate a series of risky cash flow. The utility of a ***k*** year risky cash flow is given by the expected utility theorem:

$$U = E[U(x_1 .. x_k)] = \int .. \int U(x_1 .. x_k)\, P(x_1 .. x_k)\, dx_1 .. dx_k \qquad [1]$$

where:

U	is the scalar utility value;
E	is the expectation operator;
$x_1 .. x_k$	denotes cash flow random variables for times 1 to k;
$U(x_1 .. x_k)$	is the multidimensional utility function; and
$P(x_1 .. x_k)$	is the joint probability density of the cash flow variables representing the beliefs of the investor or his (trusted) advisers regarding the cash flow outcomes.

The scalar values obtained from applying the utility function to a number of risky cash flows rank the alternative investments and obtain the highest valued.

The utility values have ordinal rather than cardinal significance, that is to say, ranking is not changed by a linear transformation $U' = a + b\,U$. This is true for every monotonically increasing function $(\partial U / \partial x_i > 0)$. This condition is most reasonable and simply implies that all investors prefer more of x_i to less of x_i.

The multidimensional utility formulation is totally general in its accommodation of preferences and beliefs. However its information requirements are immense including elicitation of a k variate joint probability distribution function and a k variable utility function. In the interests of obtaining a practical valuation methodology, some sacrifice of generality is warranted. For a specific application, loss of generality is of no concern if additional assumptions are appropriate, and may still be tolerable if assumptions are defensible and reasonable.

THEORETICAL DERIVATION OF NPV CRITERION

Owing to its information requirements, it is not usually practical to directly apply the multidimensional utility formulation to a particular valuation. By making reasonable assumptions it is possible however to greatly reduce the information requirements and derive a practical valuation method.

Firstly it will be supposed that the utility function is additively separable and the probability densities of the cash flows are independent (the second assumption is not necessary but will aid exposition):

$$U(x_1 .. x_k) = U_1(x_1) + .. + U_k(x_k)$$

and the random variables $x_1 .. x_k$ are independent:

$$P(x_1 .. x_k) = P_1(x_1) .. P_k(x_k)$$

This enables equation **[1]** to be written as:

$$E[U(x_1 .. x_k)] = \sum_{j=1..k} \int U_j(x_j)\, P_j(x_j)\, dx_j \qquad \textbf{[2]}$$

These assumptions greatly reduce the information required for the valuation but further reasonable assumptions will be made to reduce the preference data requirements to a single scalar value for time preference and a single utility function for risk.

It will be observed later that a simple adjustment of the time preference scalar value (discount rate) is often suggested as a treatment for risk. This treatment has no theoretical basis and is ill founded.

It is most reasonable to assume that investors have a positive time preference for returns: the investor strictly prefers *more* than *less* and *more now* to *more later*. However it is convenient to be more specific about the nature of this preference, that is to say, specify the functional form that describes the relation between the preference for timing of returns. It will be assumed that the relation between U_j and U_{j+1} which gives rise to this condition is linear:

$$U_j(x_j) / U_{j+1}(x_{j+1}) = d_{j,j+1}$$

where $x_j = x_{j+1}$ and $d_{j,j+1} > 1$; and further $d_{j,j+1} = d_{j+1,j+2} = d$; i.e. the linear rate d is constant.

This assumption is defensible on the grounds of simplicity and the lack of a good reason to adopt a different form of relationship. Of course in practice a value must be chosen for d. In terms of this exposition, d must strictly reflect time preference as risk is treated explicitly and separately.

Making these changes to **[2]** gives an equation, which involves just one single variable utility function U_1 describing the investor's preference for returns in the first year.

$$E[U(x_1 .. x_k)] = \sum_{j=1..k} d^{-(j-1)} \int U_1(x_j)\, P_j(x_j)\, dx_j \qquad \textbf{[3]}$$

It is now noted rather than assumed that if the utility function is linear:

$$U1(x_j) = a + b\, x_j$$

then the resultant ranking of risky cash flows will be the same as the net present value criterion applied to expected cash flows. In effect, if $a = 0$ and $b = 1$ the ***NPV*** formula is obtained:

$$NPV = \sum_{j=1..k} E(x_j)\, d^{-(j-1)} \quad \textbf{[4]}$$

where E is the expectation operator since, by definition

$$E(x_j) = \int x_j\, P_j(x_j)\, dx_j$$

The conclusion is that the ***NPV*** criterion is theoretically grounded in utility theory and can be derived by making a number of assumptions about time preference and risk aversion.

Furthermore, if one has linear risk preferences, as would a government or a large company undertaking many projects each of which is small compared to total wealth, discounting of expected cash flows is theoretically correct.

In many cases however, risk preferences are non-linear as Daniel Bernoulli (1738) postulated with risk aversion decreasing with increasing wealth. It should be noted that if the time-step is annual then the utility function describes the investors' preference for annual return.

An alternative approach is to determine the distribution of the random variable:

$$NPV = \sum_{j=1..n} x_j\, d^{-(j-1)} \qquad \textbf{[5]}$$

where x_j has density $p_j(x_j)$, that is to say, the probability distribution of ***NPV***, and apply the utility function $U_{NPV}(NPV)$ where U_{NPV} describes the investors preference for net present value.

This approach implies that the investor is interested only in variation in present value and not the possible size of loss in any one year, which is allowed for in equation **[4]**.

UTILITY APPRAISAL OF NPV

Equations **[3]**, **[4]** and **[5]** provide the theoretical basis for robust and sound valuation methods for mineral properties and projects:

- the net present value of expected cash flow
- the utility of the probability distribution of annual cash flow
- the utility of the probability distribution of net present value

The simplest method is plainly the net present value of expected cash flow. However, its underlying assumption is valid only in the case of a very wealthy investor.

In most cases one must choose between the latter two methods. If these two are equivalent then the same ranking of risky cash flows will be achieved by either method.

What if this is not the case? Then either the method of eliciting the utility functions is inaccurate or investors are inconsistent in or unclear with respect to their preferences. Unfortunately the accuracy of preference elicitation methods and whether investors are consistent in their choices are valid criticisms of the theory in practical application.

In practice most analysis concerns itself with the utility of the probability distribution of net present value - explicitly or implicitly.

Explicit analysis requires either the specification or elicitation of a utility function, which is rarely attempted, or the application of stochastic efficiency analysis, based on less specific assumptions about investors' preferences.

More common implicit analysis focuses on the probability that NPV attains a satisfactorily high value or that loses do not exceed a certain probability.

While implicit analysis (the intuitive appraisal of the distribution of NPV) makes the problem of considering the investor's risk preferences manageable, it still leaves the problem of estimating the probability distributions of all the variables which when combined together give the probability distribution of annual cash flow.

There are suggestions that this difficulty can be escaped by sensitivity analysis of the net present value of expected cash flows (Butler P, 1994) or by the adjustment of discount rate, that is to say by using a risk premium model (Ballard, 1994). An older method was to attempt to compensate for risk by conservatism in estimation of reserves, grade, operating and development costs and output prices. These are unsatisfactory techniques as these methodologies are not based in any sound theoretical basis and are grounded in very subjective judgements.

PORTFOLIO THEORY

Portfolio theory is concerned with opportunities to reduce risk by diversification. The idea is that the risk associated with a particular asset may in fact be desirable if its returns are not highly correlated with the returns from the investor's existing assets.

The approach of Markowitz (1952) is to construct the means and variances of all combinations of investments. To do this one must estimate the mean and variance of all investments and the correlations between them. For a given level of risk (variance) one can eliminate all combinations other than the one with the highest mean.

Central to the portfolio approach to valuation is the consideration of the impact of the proposed investment on the investor's existing portfolio of assets. It is this consideration that is emphasised by proponents of the Capital Asset Pricing Model (CAPM) and causes them to adopt critical views of methods that do not consider portfolio impacts. Lewellen and Long (1972) for instance criticised the simulation approach with respect to the chief benefit claimed for it - its provision of an improved appreciation of risk. They argued that simulation provides descriptions of the project's 'own risk' while not revealing the projects addition to 'total risk'. The most important criterion of investment worth is according to Lewellen and Long - portfolio impact i.e. the correlation of the project's return with the returns of the existing assets of the firm. In many instances the portfolio effect is not important. Their criticism is irrelevant where investors are not diversified and are not driven by portfolio considerations in their investment decisions.

RISK PREMIUM MODELS AND THE CAPITAL ASSET PRICING MODEL

Risk and uncertainty are often treated by conservatism in estimation and/or adjustment of the discount rate. For instance Malone (1994) quotes *it is sound practice to be conservative...final decision should represent a true value qualified slightly on the conservative side*. This is the least satisfactory approach for treating risk and according to Ballard (1994) *each forecast project parameter is or should be the expected value of that parameter*.

The practice of adjusting the discount rate to account for risk is an old one and is motivated by the observation that investors demand higher returns as compensation for taking on risk. <u>This type of adjustment is completely arbitrary.</u>

The development of the Capital Asset Pricing Model by Sharpe (1964) provided a means of objectively computing the size of the adjustment. The Capital Asset Pricing Model deals with risk and portfolio impacts at the same time. Its attraction is in suggesting that risk can be handled through appropriately high discounting i.e. it is a risk premium model which assumes that investors require increasingly high returns to take on increasingly high risk.

The CAPM is popular because it provides an objective method of obtaining an *appropriate* risk-adjusted discount rate through a time-series regression of the form

$$r_i = r_f + \beta_i (r_M - r_f)$$

where:

- r_i return of ***i-th*** security;
- r_f riskless interest rate;
- r_M return of the market portfolio, and
- β_I systemic risk of the ***i-th*** security

The beta factor represents the intrinsic risk of a company as distinct from the more general and undiversifiable risk of the market as a whole.

The CAPM is a simple model and is easy to understand. However, its assumptions must not been ignored: it assumes that

- investors make choices on the basis of risk and return,
- all investors have the same expectations of risk and return,
- returns are measured by the mean, and
- risks are measured by the variance.

There is some evidence that these assumptions are not always descriptive of investor behaviour. For example, a serious practical limitation are the stability of beta factor: the risk associated with any one security change over time as company circumstance change. A change in market conditions – such as commodity prices – could affect in a significant way the risk profile of a venture producing that commodity.

Most practitioners make the simplistic assumption that the beta factor is normally distributed and stable over time, both unwarranted and leading to serious distortions in the estimation of an appropriate discount factor. This is despite the fact that there is a vast body of economic literature describing the not too difficult calculation of *robust* beta factors. Unfortunately, most practitioners seldom calculate robust beta factors.

RISK AND UNCERTAINTY
IMPORTANCE OF AN ADEQUATE TREATMENT

The pressing need for an adequate treatment of risk in mineral property valuation is undisputed and emphasised by a number of authors. Major sources of risk are associated with the quantification of the size and grade of reserves, and with the evolution of future metal prices.

According to Malone (1994), *errors in reserve estimation are probably responsible for more errors in valuations than any other cause*. This is supported by R Butler (1994) who says *in general more projects fail because reserves do not measure up to prediction than any other reason* and *industry research and experience indicate that in general the most significant risk area to address - particularly in gold, is the resource estimate*.

Ballard (1994) emphasises that *price is always the most sensitive parameter in any valuation ... and a reasonable price range with high and low price forecasts should always be considered in any valuation*. Of course price variability can be managed up front through forward sales contracts and to some extent dynamically through flexible operating plans. This is not to say that price forecasts are not important as Butler R (1994) considers optimism in price forecasts a significant reason for non-gold projects failing to meet cash flow projections.

Lenders put a lot of emphasis on researching mineral project performance and the results indicate that project proposers tend to be optimistic in their estimates. Lenders clearly operate within a Bayesian learning paradigm forming prior beliefs on the basis of the performance of past similar projects. In seeking finance the proposer must convince the lender to revise its prior beliefs in favour of his project.

Sorentino (2000) is concerned by the problem of optimistic forecasts and points out that between 1983 and 1987 34% of gold mines in Australia produced gold below forecast. Butler gives examples of non-gold projects where two thirds failed to meet cash flow projections owing to optimism in commodity price forecasts. This evidence suggests that uncertainties should be better reflected in valuation perhaps though a Bayesian analysis or statistical ore body models with uncertain parameters.

<u>PROBABILITY - OBJECTIVE AND SUBJECTIVE</u>

Historically there has been a tendency to distinguish between risk and uncertainty. The usual distinction is that *risk can be measured whereas uncertainty cannot be*. This distinction is attributed to Knight (1921) and basically means that if there is sufficient information to justify the assignment of probabilities to outcomes the situation is risky, if there is not enough information it is uncertain.

Juttner (1987) explains that risk describes a situation where each action is associated with an objectively known or objectively assigned probability, whereas uncertainty refers to an action where the probabilities of the outcomes of the actions are completely unknown or cannot be meaningfully defined.

In explaining the term uncertainty, Keynes (1936) mentioned a number of events about which he considered *there is no scientific basis on which to form any capable probability whatever.* As examples he cited the prospect of war in Europe and the obsolescence of a new invention.

According to Herbst (1990) the generally accepted distinction in the literature between risk and uncertainty is that in the case of uncertainty we know the possible outcomes are random variables but we do not know the probability distribution that governs the outcomes, or its parameters, and cannot estimate them a priori.

Levy and Sarnat (1984) take a different view. *The term risk will be used to describe an option whose return is not known with absolute certainty, but for which an array of alternative returns and their probabilities are known; in other words for which the probability distribution of returns is known. The distribution may have been estimated on the basis of objective probabilities, or on the basis of purely subjective probabilities.* On the grounds that *in financial investment probability beliefs are almost invariably subjective,* Levy and Sarnat go on to use uncertainty and risk interchangeably.

In statistics there are two approaches to probability:

- the *objectivist* or *frequentist* approach defines probability as a relative frequency and presupposes a past history of occurrences.

- the *subjectivist* or *Bayesian* approach defines probability as a judgement.

Those who recommend the use of subjective probabilities believe that with practice, experts should be able to estimate probabilities in the same way as engineers estimate costs and quantities based on their past experience with similar projects. According to the subjectivist approach, beliefs, quantified by subjective probabilities are functions of knowledge and as the investor learns he factors in new knowledge and updates prior beliefs. Bayes theorem is a model of this learning process and states that

$$P(H_j/E_k) = P(H_j)\,P(E_k/H_j) \,/\, \Sigma_l\, P(H_l)\,P(E_k/H_l)$$

where:

$P(H_j)$ is the prior probability of hypothesis j being true;

$P(E_k/H_j)$ is the probability of evidence E_k being observed given that hypothesis H_j is true; and

$P(H_j/E_k)$ is the posterior probability of H_j being true given that evidence E_k has been observed.

The theorem is a learning model in that is specifies how to sample evidence, additional information, experience and advice modify prior beliefs. If little is known initially one uses a so-called *diffuse prior*.

An example is a uniform distribution over the variable's range. This is in accordance with Laplace's *principle of insufficient reason* (Dasgupta and Pearce, 1972) which states that if one cannot tell whether one event is more likely than another then both events should be treated as equally likely.

Critics of the subjectivist approach claim that numerous biases are inherent. Exponents (Anderson *et al*, 1977) believe that methods of elicitation can be developed which overcome these biases.

Experiments undertaken by psychometricians involving simple applications of Bayes theorem suggest that most people are poor estimators of probability. Tversky and Kahneman (1974) present a discussion of cognitive biases, which stem from reliance on judgemental heuristics. They conclude that the heuristics people use in assessing probabilities are in general quite useful but sometimes lead to severe and systematic errors.

HOW TO TREAT RISK AND UNCERTAINTY

Risk and uncertainty have been treated in valuation exercises through risk premium models based on upward adjustments to the discount rate and by accompanying net present value of expected cash flow calculations with sensitivities.

It is maintained that neither method provides an adequate treatment of risk and uncertainty.

The question of whether an explicit treatment of risk through probability analysis should be attempted has been linked to whether sufficient information is believed to exist for an objective estimation of probabilities.

It hardly needs to be said that for many mineral properties objective data is not available. The choice then is either to admit the use of subjective probabilities into the analysis or to move away from the theoretically based utility appraisal of distribution of NPV approach and attempt to infer the value of the property by some other means.

Given that these other methods not only lack a theoretical basis but *also depend on subjective judgements*, it is difficult to see why subjective probabilities should not be more readily accepted.

To the extent to which Comparable Sales, Joint Venture Terms, the past history of Exploration Expenditure and Geoscience Factors provide any useful information upon which to base a valuation, it is difficult to accept that the methods could not be integrated with improvement into a Bayesian subjective probability framework.

REVIEW OF THE VALMIN METHODOLOGIES

Most authors generally agree that discounted cash flow analysis should be the principal valuation method. However, most of them authors dismiss it as not applicable to certain categories of mineral property:

- According to Bruce *et al* (1994), *rigorous, methodical, and prescriptive valuations of exploration properties are in general spurious unless the assumptions and subjective judgements that have been used are fully disclosed*.

- According to Lawrence (1994), *the expected value method has little application in the valuation of exploration mineral assets*.

- Butler P (1994) considers DCF techniques only applicable when sufficient information is available to quantify, with some confidence most of the parameters affecting the value.

- Edward's (1994) view is rather confused: *the mining valuer is expected to have undertaken a probability analysis and applied significant discounts to reflect the uncertainty/probability of ultimately recouping the cash flows reflected in the DCF value. Difficulties arise if the DCF methods have been applied too simplistically to exploration properties without due regard to allowing for probability*.

Most valuers prefer the so-called *technical* valuation methods for properties without defined resources where their value is inferred through:

- the exchange value of similar properties, the *Comparable Sales* method,

- the willingness to pay to participate in a share of expected future returns, the *Joint-Venture* method,

- value inferred through prior exploration expenditure, the *Multiples of Exploration Expenditure* method, and

- subjective rating of attributes most frequently requisite to successful mining, the *Geoscience Rating* method.

According to Lawrence (1994), *the valuation methodology chosen to value a mineral asset depends upon the amount of data available on that asset and the reliance that can be placed on that data*.

In the same vein, commenting on the quality of data and reliability of forecasts used in discounted cash flow calculations, O'Connor and McMahon (1994) warn *that it is important not to allow the science of the methodology to dominate the assessment*. In other words, subjective judgements are more important than objective valuations.

Where DCF is applied there is disagreement concerning the treatment of risk and the selection of discount rate:

- Ballard (1994) is satisfied that risk can be accommodated through a discount rate estimated by means of the Capital Asset Pricing Model.

- O'Connor and McMahon (1994) recognise the deficiencies of CAPM but apply it in the absence of what they termed *a better methodology*.

- Runge (1994) considers that the uncertainties in mineral valuation are too project specific to be assessed using the CAPM.

- Butler P. (1994) regards Monte-Carlo simulation as impractical and is happier with the presentation of discrete sensitivities.

- O'Connor and McMahon (1994) point out that NPV is only one input into a mining company's investment decision and discuss other relevant inputs including the special strategic interests of the company.

- Runge (1994), Lonergan (1994) and Winsen (1994) are insistent that managerial flexibility be incorporated into valuation analysis. This is especially relevant to sensitivity analysis as it is commonly applied in which mine management is assumed to blindly follow a fixed operating plan irrespective of what commodity prices are doing.

In valuing exploration tenements, most authors consider it misleading to conduct NPV analysis on speculative data.

In its place a number of alternatives are considered which are basically inferential and scoring methods. Unfortunately, these methods *lack a firm theoretical basis*. Furthermore, their misuse can lead to logical absurdities.

It is surprising that no attempt has been made to estimate the accuracy of these methods on the basis of statistical analysis or simulation experiments. Valuation of exploration tenements appears well suited to a subjective probability treatment and it is surprising that this approach has not been either attempted more frequently or more strongly advocated by valuers.

With the exception of Runge (1994) and Sorentino *et al* (1994), who are favourably disposed to their use, subjective probabilities are hardly noticed. Suited to quantify the beliefs of experts, their apparent unacceptability in mineral valuation seems to imply either that geological input is irrelevant or at best highly questionable, or if relevant, that geologists are incapable of expressing their beliefs in a probabilistic form.

INFERENTIAL AND SCORING METHODS

Onley (1994) discusses in detail the *Multiples of Exploration Expenditure Method*. In favour of this approach he points out that *in many situations ... the method may represent the only semi-quantitative option available*. The method involves the use of a subjectively selected *prospectivity enhancement multiplier* to derive value from expenditure.

The method postulates the hypothesis that *money is spent on exploring a property in proportion to its perceived value*. This hypothesis is of a form that allows empirical testing in terms of the strength of the correlation between the accumulative expenditures spent on mineral properties and their value. However, no empirical testing has been performed to this date and the hypothesis remain unproven.

In defence of the method Onley (1994) notes that a party would be inclined to use its past exploration expenditure as the basis of farm-in terms. Lawrence (1994) suggests a relation between this method and the joint venture method. It is doubtful however whether the party buying in relies principally on past exploration expenditure as a guide to value.

The method is susceptible to a number of criticisms.

- Past exploration costs are irrelevant if all the information generated by past expenditure is in the public domain and freely available, as for example, in mining authorities' public files. The important thing *is what is known* about a prospect *not how much it cost to find that knowledge out*.

- The acquisition of this knowledge may have been slow, it may have included the pursuit of false leads, and it may have been inefficient and, hence, it is critical that only relevant data be used in the estimate. If this information is not available then the past expenditure costs may be relevant inasmuch as they are a surrogate for past perceptions of value, which made the exploration worthwhile.

- According to Butler R (1994) the method assumes that the exploration has been well directed and funds spent effectively and that the method implies *that exploration properties in difficult terrains are more valuable because they cost more to explore:* this logical absurdity points to the need to carefully apply this method.

The Prospectivity Enhancement Multiplier tends to be highly variable amongst its proponents and, sometimes, even the same valuer. Some insights into the value of this method could be tested using analysis based on Baye's theorem in which could be used to synthesise a large number of consecutive decisions to commit to exploration expenditures. Given that the simulation is sufficiently realistic, regression analysis could be applied to the simulation results in order to assess how good exploration expenditure is as a surrogate for value. Until such time as these empirical tests are performed and made available, this method must be used with caution and only by well experienced valuers.

The *Joint Venture Method* is discussed by Appleyard (1994) who admits that it has *failings in both mathematics and logic*. The method is an attempt to infer the value of a buyer's interest in a project by his preparedness to incur expenditure in acquiring that interest.

Bruce *et al* (1994) make the point that the price settled by the seller may be calculated to recover previous expenditure and has less to do with what the seller thinks the property is really worth.

Goulevitch and Eupene (1994) propose the *Geoscience Rating Method* for the valuation of exploration properties, which contain no identified resources or reserves. They note that Kilburn, the original proposer of this method, distinguished four main mineral property characteristics

- location with respect to off property mineral occurrences of value,
- grade and amount of mineralisation known to exist on the property under valuation,
- geochemical and geophysical targets present, and
- geological patterns present which may be considered favourable for occurrences of exploitable mineralisation (based on previous experience or comparison with known mineable deposits).

Subcategories are defined within these groups and rated according to relative importance. A base acquisition cost of a standard sized exploration area is obtained by quantification of relative importance and combination of value factors. The method is valuable as a checklist and a framework to assist the expert to achieve consistency. It also exposes the opinions of valuers to investor scrutiny.

Its main criticisms are that:

- The method is really a scoring method and it has the associated problem that different experts will score differently and the method may not include factors some valuers consider relevant.
- Similar to the Multiples of Exploration Expenditure, this method also requires subjectively chosen factors to convert the technical scores into a market value.
- Central to this valuation method is the estimation of a *unit* value for exploration properties. Without empirical research, this unit value is often estimated in a highly subjective manner.
- Butler R (1994) thinks the procedure can give a false impression of thoroughness and reliability.

It would be better to replace this method with a formal Bayesian framework. The beliefs of experts could be elicited in the form of subjective probabilities and variability in net present value estimated.

The Comparable Sales Method, also known as the Real Estate Method, is discussed by Grant (1994) who, recognising the practical limitations of the method in terms of the limited number of transactions and comparability, maintains that *any available evidence on sales that are even remotely comparable can provide some input to the valuation process*. This statement clearly claims too much, as the information provided by remotely comparable sales is almost irrelevant. Grant also leaves open the question of what weighting to place on the comparable sales method in the valuation.

According to Butler R (1994) relatively few properties change hands and the method can only be practical in rare instances.

This method is highly regarded by North American valuers, and often used as the basis of the so-called y*ardstick* methods that derive value from other market transactions.

ROBUST VALUATION METHODS

Discounted Cash flow Methods

The principal economic methodology to analyse the worth of a project is discounted cash flow analysis. As Sorentino *et al* (1994) point out, if the discount rate represents the cost of capital to investors, then any positive NPV represents an addition to their wealth and, therefore, DCF analysis is applicable to both ongoing mineral assets and mineral projects.

Ballard (1994) deplores the arbitrary adjustment of discount rate as a means of allowing for project risk and states that *valuation should incorporate a thorough and objective analysis to obtain appropriate discount rates reflecting acceptable returns commensurate with the project's risk profile and market condition*s. The analysis he recommends is the Capital Asset Pricing Model but he fails to anticipate the objections raised by Sorentino *et al*.

According to Butler P (1994) *Monte-Carlo simulation models can be costly, time consuming and complex*. He indicates a preference for the use of discrete sensitivities.

Sorentino *et al* (1994) show that sensitivity analysis does not address the principal cause of risk in resource projects and propose the use of stochastic discounted cash flow analysis (SDCF). These authors point out the deficiencies of sensitivity analysis including the ceteris paribus and linearity assumptions. They strongly argue that advances in computer hardware and software make possible the quantitative evaluation of financial risk.

Options Valuation Methods

In his paper *Evaluating Cyclical Projects*, Guzman (1991) argues that non-stochastic DCF methods do not take into account the flexibility of managerial response to external developments, especially price fluctuations. Managerial flexibility has a value. The limitations of conventional analysis can be overcome by *decision tree analysis* (*dynamic programming*) or options-based techniques.

According to Guzman *... a negative NPV implicitly assumes that management will maintain a ruinous operating programme to its preset conclusion without exercising better judgment and altering the original plan,* and *traditional DCF methods of investment valuation implicitly assume* *inflexible managements and this may systematically undervalue actively managed investment projects*.

Arguing for a dynamic approach to mine design and assessment, Runge (1994) asserts the importance of taking into account managerial flexibility as a means of risk management. He criticises the traditional static valuation approach as he regards real risk as the inability to adapt to change. In Runge analysis, it is important to allow for the risks that can be managed to be managed. What Runge is approaching is *robust decision-making* in which flexibility is valued. This has occurred in stochastic control theory where the old criterion of maximising the expected value of the objective function has been replaced with the notion of a robust controller*, which focuses more on limiting the probabilities of adverse consequences*. The expected value criterion presupposes the investor has an infinite bank (i.e is not preoccupied with the probability of ruin) and gets to play the game a large number of times. From the point of view of investors, individual mining projects may be unique and the game of operating them is played once only. Runge says *the ex post analysis of certain aggregates may well demonstrate strong correlations between variability and return on investment, but this is not a meaningful piece of information for anyone managing or evaluating any one project*.

Runge's emphasis on the importance of operating flexibility is particularly relevant to the conduct of sensitivity analyses - *worst case scenarios should not just involve remodelling an unchanged mine plan. Changes to the plan are always required*.

Lonergan (1994) gives a number of examples of real options in the mining industry and concludes that potential to apply option pricing techniques is vast and expects that increasing attention will be placed on the value of flexibility in the future.

It is to be noted that with respect to the assessment of managerial flexibility it is not necessary to apply methods such as dynamic programming to the solution of stochastic optimal control problems. Simulation analysis is well suited to the evaluation of possibly complicated operating policies prescribed in advance. The valuation of managerial flexibility can be accommodated as a straightforward extension to stochastic discounted cash flow analysis.

CONCLUSIONS

While most authors largely agree that the correct method of valuing mineral properties is discounted cash flow analysis, many object to applying the method to properties concerning which data is imprecise.

For such properties inferential methods including joint venture valuation, geoscience rating, multiples of exploration expenditure, and comparable sales are used.

The justification for this is that application of discounted cash flow analysis would necessitate considerable speculation concerning cash flows and that it is better to adopt simple methods which are readily understood.

The fact of the matter is that these methods are theoretically unsound, incorporate very subjective and personal judgements and provide valuations of doubtful quality.

There is scope to apply simulation and statistical analysis to assess the performance of these methods: the fact that no author refers to any such testing suggests that the proponents of these methods are more comfortable not knowing and hiding behind assurances that despite their defects these methods are legitimised when used by expert valuers.

It is granted that a discounted cash flow analysis can suggest that values are known with more confidence than they actually are and that in the words of Bruce *et al* (1994) *rigorous, methodical,* *and prescriptive valuations of exploration properties are in general spurious unless the assumptions and subjective judgements that have been used are fully disclosed.* Nevertheless it is difficult to accept that discounted cash flow analysis could not be applied to all types of mineral property.

It is accepted that in the case of exploration tenements, the uncertainty associated with estimates will be large. In this case the variables should be treated as probability distributions and entered into a stochastic discounted cash flow analysis.

There is no reason why presentation of the probability distribution of net present values for a number of discount rates and of internal rate of return could not be accompanied by tabulations of the probability distributions used in the analysis.

The widespread availability of powerful computer hardware and software packages for the evaluation of risk destroy the arguments that stochastic discounted cash flow analysis is impractical. Furthermore the Monte-Carlo simulation underlying this analysis is ideal for studying alternative operating plans and thus valuing managerial flexibility.

The discount rate used in stochastic discounted cash flow analysis should be the firm's cost of capital. There is no need to adjust the discount rate for project risk as the method allows risk to be treated explicitly. Risk premium models, other than robust estimates of the Capital Asset Pricing Model, are inadequate in treating project specific risk.

Linear sensitivity analysis of variations in the key inputs of a non-stochastic is misleading and of no value in assessing or managing risks.

An integrated framework for mineral property valuation is already available in the form of stochastic discounted cash flow analysis and Bayesian analysis. Valuers need to be more flexible in their definition of probability and it appears that more use should be made of subjective probabilities.

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