Discounted Cash Flow Analysis
Input Parameters and Sensitivity

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Abstract

Discounted cash flow analysis provides a means of relating the magnitude of expected future cash profits to the magnitude of the initial cash investment required to purchase an asset or to develop it for commercial production. The objectives of discounted cash flow analysis are to determine:

< The net present value of a stream of expected future cash revenues and expenditures.
< The rate of return which the expected future cash flows will yield on a given level of initial cash investment.

In the case of mineral properties, discounted cash flow analysis is generally accepted as the preferred method of valuation, whenever sufficient data are available to permit its reasoned application. Sufficient data are required to support estimation of all of the individual elements of cash revenue and cash expenditure which will be associated with the development and operation of the property, up to the end of its estimated life. It is the accuracy of these input estimates which determines the validity of the resulting determinations of profitability and rate of return on invested capital.

In undertaking any discounted cash flow analysis, it is important to recognize certain fundamental attributes of the mining industry:

< The basis of any mineral development is the existence of an ore reserve.
< Costs are determined by the number of tonnes mined and processed, while revenues are determined by the number of pounds or ounces of metal produced. The two are related by the recovered grade of the ore.
< Profit is typically more sensitive to changes in revenue than it is to changes in cost.
< Commodity price is a principal determinant of revenue, but it is also the factor with which is associated the greatest level of financial risk.

In the end, of all of the factors which must be considered in the discounted cash flow valuation of a mineral property, the most significant are the reliability of the reserve estimate, particularly with respect to recovered grade, the price at which the product is to be sold, and the risk of not maintaining the projected level of price.

INTRODUCTION

As a method of valuation, discounted cash flow analysis relies upon the principle that cash is the universal medium of exchange, and that a cash investment can be justified rationally only by the expectation of a cash return. The method recognizes that anyone who invests cash will look, for a return on that cash, to the future cash profits expected to be generated by the investment. Discounted cash flow analysis is simply a method which relates the magnitude of the expected future cash profits to the magnitude of the initial cash investment.

In performing any discounted cash flow analysis, it is necessary to prepare, typically for each year between the present and the end of the project life, an estimate of the annual amount of cash which the investor will be required to spend so that the project can be built and maintained, and an estimate of the annual amount of cash which the investor will receive from the production and sale of mineral commodities. Since the investor will require not only the return of the original investment, but also an appropriate rate of interest thereon, all future cash flows are discounted to the present, at the required rate of interest.
The resultant net present value represents the amount, in cash, which the investor would rationally be prepared to pay to acquire the property at the date of valuation.

MECHANICS OF DISCOUNTED CASH FLOW ANALYSIS

Mechanically, a discounted cash flow valuation is prepared in the form of a spreadsheet, a simplified example of which is shown in Figure 1. The left-hand column of the spreadsheet will list the various factors (typically in much greater detail than shown in Figure 1) which influence the levels of cash revenue and cash expenditure associated with the property being valued, while the top line specifies the time periods, typically years, over which the property is to be valued. This time period should cover the full productive life of the known reserves and may be extended further to account reasonably for the discovery of new reserves, should the geological potential of the property so warrant.

![Figure 1](image)

**SIMPLIFIED DISCOUNTED CASH FLOW VALUATION**

(all units in thousands)

<table>
<thead>
<tr>
<th></th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gold produced</td>
<td>100</td>
<td>150</td>
<td>150</td>
<td>400</td>
<td></td>
</tr>
<tr>
<td>Gold price</td>
<td>300</td>
<td>300</td>
<td>300</td>
<td>300</td>
<td></td>
</tr>
<tr>
<td><strong>Sales Revenue</strong></td>
<td><strong>30,000</strong></td>
<td><strong>45,000</strong></td>
<td><strong>45,000</strong></td>
<td><strong>120,000</strong></td>
<td></td>
</tr>
<tr>
<td>Less: Site Operating Cost</td>
<td>17,500</td>
<td>22,500</td>
<td>22,500</td>
<td>62,500</td>
<td></td>
</tr>
<tr>
<td>Refining</td>
<td>500</td>
<td>750</td>
<td>750</td>
<td>2,000</td>
<td></td>
</tr>
<tr>
<td><strong>Operating Profit</strong></td>
<td><strong>12,000</strong></td>
<td><strong>21,750</strong></td>
<td><strong>21,750</strong></td>
<td><strong>55,500</strong></td>
<td></td>
</tr>
<tr>
<td>Less: Income Tax</td>
<td>-</td>
<td>3,500</td>
<td>8,700</td>
<td>12,200</td>
<td></td>
</tr>
<tr>
<td>Capital Expenditure</td>
<td>25,000</td>
<td>200</td>
<td>500</td>
<td>3,000</td>
<td>28,700</td>
</tr>
<tr>
<td><strong>Net Cash Flow</strong></td>
<td><strong>(25,000)</strong></td>
<td><strong>11,800</strong></td>
<td><strong>17,750</strong></td>
<td><strong>10,050</strong></td>
<td><strong>14,600</strong></td>
</tr>
<tr>
<td>Discount Factor (12%)</td>
<td>0.893</td>
<td>0.797</td>
<td>0.712</td>
<td>0.636</td>
<td></td>
</tr>
<tr>
<td><strong>Net Present Value</strong></td>
<td><strong>(22,325)</strong></td>
<td><strong>9,405</strong></td>
<td><strong>12,638</strong></td>
<td><strong>6,392</strong></td>
<td><strong>6,110</strong></td>
</tr>
<tr>
<td><strong>Total Net Present Value ($ million)</strong></td>
<td><strong>6.1</strong></td>
<td><strong>6.1</strong></td>
<td><strong>6.1</strong></td>
<td><strong>6.1</strong></td>
<td><strong>6.1</strong></td>
</tr>
</tbody>
</table>

The body of the discounted cash flow spreadsheet consists of a matrix of individual cells, each of which must contain a number, representing the forecast level of a particular factor at a specified future period of time. Obviously, the accuracy of the numbers placed in each cell of the spreadsheet will determine the validity of the resultant estimates of profitability and rate of return on invested capital. In order to perform a proper discounted cash flow analysis, therefore, it is necessary to make a separate and reasoned estimate of the future value of each of the factors which will influence cash revenue and cash expenditure.

Once all the necessary estimates have been compiled and inserted into the spreadsheet, it is a simple matter arithmetically to compute the overall net cash flow forecast to accrue to the property in each year of its future life. The final step in the discounted cash flow analysis is to convert the estimated future annual net cash flows to present value through application of the selected discount rate, or the rate of interest which the investor desires to receive on the initial capital investment.

The discounting procedure is fully analogous to the calculation of the periodic payments required under a residential mortgage. In each year, the available cash flow is used first to pay interest on the outstanding amount of the original capital investment. Any surplus cash flow which remains available after paying interest is then allocated to repayment of the invested capital.

In the simplified valuation shown in Figure 1, the computed net present value of the stream of future annual cash flows, at a discount rate of 12% per year, is $6.1 million. This means that, if an investor paid $6.1 million for this property, the future cash flow stream would be sufficient to return to him the entire $6.1 million, plus interest at the rate of 12% per year on the annual outstanding balance of the original investment.
APPLICATIONS OF DISCOUNTED CASH FLOW ANALYSIS

Valuation Applications

Discounted cash flow analysis is a forward-looking methodology which requires that forecasts be made with respect to technical and economic conditions which will prevail in the future. All predictions of the future are inherently uncertain, but the level of uncertainty will be materially reduced if adequate data are available from which to project future rates of production and future costs. The more comprehensive the available data, the more reliable will be the discounted cash flow valuation.

These observations suggest that the most definitive application of discounted cash flow analysis will be in the valuation of an existing mining operation with a well-defined mineable reserve, no potential for additional discoveries, and an established history of consistent production rates and cash costs, sufficient to permit the confident projection of future operating conditions.

One step removed from this is the property for which a favourable bankable feasibility study has been prepared. Almost invariably, such a feasibility study will use discounted cash flow techniques to assess the economic viability of the proposed development, based on the current reserve estimate, comprehensive engineering studies, detailed estimates of capital expenditure and operating cost, and rational projections of product revenues. In this instance, however, the resultant net present value at any selected discount rate may not, by itself, provide an accurate measure of the value of the property.

It is not uncommon for a mining company to commission a bankable feasibility study and commit to production from a new property as soon as a sufficient tonnage and grade of mineralization has been identified to warrant development, but before the entire property has been fully explored. In such cases, the feasibility study will typically make provision, within the original design, for the possible future expansion of the productive facilities to accommodate the definition of additional mineable reserves. Under these circumstances, the net present value derived in the feasibility study will represent a base, demonstrated value for the property, but it is clear that some additional value must be attributed to any inferred resources and unexplored geological potential.

Since discounted cash flow analysis is fully capable of assessing the profitability of various levels of expansion, or increases in operating life, associated with various levels of additional ore discovery, it remains the preferred method for valuing properties which are at the stage of a bankable feasibility study. The value derived, however, will not be as definitive as that for a producing mine, and will be heavily influenced by informed geological judgment as to the most likely level of future discovery.

At a lower level of definition come those properties which have been subjected to preliminary or conceptual feasibility studies, on the basis of a resource which has been identified to a greater or lesser degree of assurance. In these cases, the economic viability of the property will typically be assessed by discounted cash flow analysis, based on preliminary estimates of production, revenue and cost. Despite the preliminary nature of the underlying estimates, it is still generally accepted that discounted cash flow analysis is the best method of valuing mineral properties at this stage of development.

Ultimately, as long as a resource has been identified, it is possible to make a reasoned estimation of production rates, revenues and costs. Discounted cash flow analysis, therefore, can be validly applied to the valuation of any property with an identified resource. In the absence of an identified resource, however, there simply are no data to support the application of discounted cash flow analysis, and such properties must be valued using other methodologies.
Other Applications

Although discounted cash flow techniques are not appropriate for valuing properties without identified resources, they still provide a powerful tool for analyzing investment decisions at various stages of exploration and subsequent project evaluation.

Grassroots exploration is typically undertaken to test a geological hypothesis with respect to the existence of mineralization in a particular location. It is a valid and useful procedure, before committing any funds to exploration, to prepare a conceptual discounted cash flow analysis which will identify, in approximate terms, the minimum tonnage and grade of material required to justify commercial development at that particular location. If the minimum economic target is so large or so rich that there is minimal chance of discovery, there is little purpose in funding the exploration program in the first place.

Similarly, if initial drilling has yielded geologically encouraging intersections and budgets are being proposed for further exploration, it is well worthwhile to use conceptual discounted cash flow analysis to determine whether or not the thicknesses and grades encountered initially have any chance of being economically producible. If they do, then exploration clearly should proceed. If they do not, the same analysis can be used to identify the degree of enhancement required in thickness and/or grade to render the material of economic interest. Rational judgments can then be made as to the probability of economic success and, hence, as to the justification of continued investment in exploration.

At subsequent stages of project definition, discounted cash flow analysis is the method normally used in evaluating alternative scales of production, and different mining and processing methods, as well as analyzing trade-offs between, say, Owner and contract mining.

**INPUT TO DISCOUNTED CASH FLOW ANALYSIS**

The principal factors which need to be estimated in providing input to a discounted cash flow analysis are:

- The tonnage and grade of the mineable reserve.
- The annual production of both ore and saleable mineral commodities.
- The annual revenue to be received from the sale of mineral commodities.
- The annual cash cost of production, both on-site and off-site.
- The annual cash liability for royalties and taxes.
- The annual level of cash capital expenditure required, initially to construct the project if it is not yet developed and, subsequently, to sustain it in operation.

**Mineable Reserves**

The fundamental asset which underpins the value of any mining project is its ore reserve, and a thorough understanding of the reserve is the first requirement of any discounted cash flow valuation.

The size and grade of any reserve is estimated from a limited number of samples which constitute a very small proportion of the total deposit. Sampling, by its nature, is a statistical procedure and so is the estimation of reserves. All reserve estimates, therefore, are subject to a greater or lesser degree of uncertainty.

Estimates of in-situ mineral resources or reserves have two essential components: an estimate of contained tonnage and an estimate of average grade. Given a sufficient number of appropriately located samples, the total tonnage of material contained within a mineral deposit can typically be estimated with a reasonable level of assurance. Estimates of average grade, on the other hand, can be subject to significant error. Yet, in terms of the valuation of mineral deposits, the average grade is almost always far more significant than the total tonnage. It is of fundamental importance, therefore, that the distribution of ore-grade material, within the total volume of mineralized rock, be thoroughly understood.

During actual mining operations, it is inevitable that some waste material will be mined along with the ore. As a result of this dilution, the grade of ore, as mined, will invariably be lower than the grade of ore in-situ.
It is fundamental to the economics of mining that costs are determined by the number of tonnes mined and processed, while revenues are determined by the number of pounds or ounces of metal produced. These two factors, cost and revenue, are related by the grade of the ore. Dilution by waste rock increases the tonnage of material mined and reduces the grade. It increases cost and reduces revenue. It reduces value.

Mining methods vary in their ability to minimize dilution through the selective mining of ore-grade material. Generally speaking, the cheapest mining method is also the least selective, but it may be false economy to choose a mining method simply because it is the cheapest. The added cost of a more expensive mining method is often outweighed by the added revenue arising from the increased grade which results from improved selectivity. Some level of dilution, however, will always occur and it is of paramount importance that it be reflected appropriately in the discounted cash flow valuation.

The importance of a thorough understanding of the mineable reserve, as the fundamental underpinning of any discounted cash flow analysis, cannot be over-emphasized. Most frequently, when mining projects fail, they do so because the mineable reserve has not been properly identified. The most common sources of error in this regard are an inaccurate analysis of the distribution of ore-grade material, leading to an over-estimation of in-situ grade, and an inadequate allowance for dilution, leading to a further over-estimation in mined grade. This in turn, leads to over-estimation of revenue.

Typically, mechanical failures of mining or processing equipment can be rectified with time. An inherent over-estimation of mined grade, however, will have adverse economic effects throughout the life of the project.

The Determinants of Revenue

In discounted cash flow analysis, value is determined by the magnitude of future profits, and future profits are determined by the relationship between revenues and costs. In the general case, however, the magnitude of profit is more sensitive to changes in revenue than it is to changes in cost. Accordingly, in estimating the value of a mining project, the most significant factors are those which influence revenue.

Revenue, in a mining context, is the product of the following factors:

< The annual tonnage of ore mined and processed.
< The grade of that ore.
< The metallurgical recovery of saleable commodity.
< The price of the saleable commodity.

The annual tonnage of ore mined and processed is a principal design criterion, chosen on the basis of the scale of the ore reserve and the ability of the market to absorb the final product. With the major precious and base metals, once they have been smelted and refined, there are markets of last resort, such as the London Metal Exchange, which are capable of absorbing the entire output from a new mining project. For these metals, marketability of product is generally not a concern. With most industrial minerals and specialty metals, however, the annual rate of production will frequently be constrained by the level of demand for the product. In such cases, comprehensive market analyses are required before a realistic rate of ore production can be selected.

In the valuation of an existing mine, future rates of production can generally be forecast reliably on the basis of historical operating experience. For an undeveloped property, however, there is no such body of experience and valuation must be based on a design production rate. In this context, it must be recognized that few, if any, mining projects achieve their design rate of production immediately upon start-up. Discounted cash flow analyses which fail to provide for a progressive ramp-up of production during the first year of operation will typically overstate the cash flow to be achieved in the first year and, hence, will overstate value. In the author’s view, valuation should be based on an estimated rate of ore production during the initial year of 60% to 75% of the design rate, depending on the complexity of the mining cycle and the process circuitry.
Once the annual rate of ore production has been established, the next step in the valuation procedure is to determine the rate of production of the saleable commodity. This is a function of the mined grade of the ore and the level of metallurgical recovery. Losses to process tailings have the effect of reducing recovered grade in the same way that waste dilution reduces mined grade, and the application of the proper recovery factor is just as important as the application of the proper dilution factor. Both of these factors act to reduce the quantity of saleable commodity which will be produced from the in-situ ore.

Typically, metallurgical recovery will be estimated on the basis of testwork. The most common sources of error in this regard are that the samples submitted for metallurgical testing are not fully representative of the design mill feed, and that realistic scale-up factors have not been applied to the process design in translating the results obtained under controlled laboratory conditions to those expected to be obtained in a full-scale commercial plant.

Ultimately, particularly if a mine has been in operation for some time, the throughput of ore, the mined grade of ore and the metallurgical recovery are reasonably well identified and are, to some extent at least, controllable. The remaining determinant of revenue, the price of the commodity, is normally totally beyond the control of the individual mine operator. It is, nonetheless, not only the most important determinant of revenue, but also the most important determinant of overall value.

Some commentators argue that it is futile to attempt to forecast future commodity prices and, hence, that mine valuation should be based on the assumption that today’s commodity prices will persist indefinitely into the future. But this is tantamount to arguing that the most significant determinant of future profit is today’s commodity price.

It is true that future metal prices are notoriously difficult to forecast accurately, but this does not mean that no attempt should be made to do so. In the author’s opinion, a thorough, well-reasoned forecast of supply, demand and price is an integral part of any valuation. It is clear, however, that there is a great deal of uncertainty and risk inherent in any such forecast.

In the case of industrial minerals, for which there are few sources of transaction prices comparable to LME prices, the problem of projecting future prices for a new project is compounded both by site specific issues such as accessibility to market, and by the lack of suitable historical and current price data. The need for a reasoned forecast of mine-gate price, based on analysis of supply and demand, is a critical component of valuation of an undeveloped industrial mineral property.

In the end, the commodity price emerges as the most important factor in determining value, as the most difficult factor to forecast with assurance, and as the factor with which is associated the highest level of risk.

Some years ago, copper was trading at about US$1.50 per pound, but a detailed market analysis would have shown that this price was unlikely to persist for very long. A discounted cash flow valuation based on the simple assumption that the copper price would hold at this level indefinitely, in constant dollar terms, would have yielded grossly erroneous results, which could have been avoided through careful analysis.

**Operating Costs**

In the general case, cash operating costs will be incurred both on-site, in producing the commodity which is shipped from the property, and off-site, in the transportation and downstream processing of that commodity into saleable end products.

Most commonly, on-site operating costs are estimated under the functional headings of mining, processing, and general and administration. Each of these functional costs will then include estimates of the cost of labour, materials and supplies, and purchased services such as electric power and insurance. The estimation of site operating costs follows a fairly standard set of procedures based on a selected rate of production, a complement of mining and processing equipment capable of meeting that rate of production, and the ancillary and infrastructural facilities which are necessary to support the project. Most estimators will typically derive similar estimates of on-site operating costs for a given project.
The base estimate of on-site operating cost, therefore, is rarely an issue in discounted cash flow valuation. Rather, it is the limit of accuracy of the estimate which requires the greater degree of attention. Even at the stage of a bankable feasibility study, operating cost estimates are generally considered accurate to within about plus or minus 15%. Estimates prepared at earlier stages in the development of a property will have even wider limits of accuracy and it is imperative that sensitivity analyses be undertaken to determine the influence on value of quite wide variations in site operating cost.

The risk of materially under-estimating site operating costs can be offset, at least to some degree, by including a contingency allowance within the estimate. In the author’s experience, however, while contingency allowances are routinely applied to capital cost estimates, they are applied only infrequently to estimates of operating cost.

Most mining projects produce partially-processed products, such as doré bars or mineral concentrates. While these are saleable products in their own right, they require further processing at off-site facilities in order to render them suitable for industrial end use. The mining company bears the cost of downstream processing and one of the most common errors in discounted cash flow valuation is that these off-site costs are not adequately reflected in the analysis.

For a gold mining operation producing doré bars, the costs of transportation and of refining the bars into gold and silver metal are typically not material in relation to the ultimate value of the metal produced. In these cases, inaccuracies in the estimate of transportation and refining cost have little impact on the results of the discounted cash flow analysis. Where gold is recovered in a sulphide concentrate, such as a copper concentrate, however, the costs of transportation, smelting and refining take on added significance. In these instances, the on-site processing plant is typically operated to maximize gold recovery, with the result that the copper grade of the concentrate is frequently relatively low. Considerable care must be taken in determining the terms under which such concentrates can be sold, since copper smelters are likely to increase their charges for treating low-grade concentrates.

For base metal operations producing, say, copper, zinc or lead concentrates, the costs of transportation, smelting and refining typically account for a significant proportion of the gross value of metal contained in the concentrate. In the general case, after allowing for concentrate transportation costs and smelter terms, the mine operator will receive a net revenue, at the mine gate, of only about 50% of the gross value of lead and zinc contained in concentrate, and about 70% of the gross value of contained copper. Clearly, then, the cost of downstream processing of base metal concentrates is a significant factor in discounted cash flow valuation, and it is imperative that these costs be accurately identified and accounted for.

**Royalties and Taxes**

All mining operations are subject to taxation and many are subject to royalties of one form or another, payable to either private parties or government agencies.

Royalties based on either production or net smelter revenue represent an added cost to the operation which obviously must be fully reflected in the valuation. In addition, however, the added costs associated with such royalties must be taken into account in determining the cut-off grade used in the estimation of mineable reserves. Royalties based on revenue or production will tend to increase the break-even cut-off grade and, thus, will tend to turn ore into waste.

Regulations governing the levels of taxation applicable to mining companies vary from jurisdiction to jurisdiction. In Canada, for example, mining companies are subject to three levels of taxation: federal income tax, provincial income tax and provincial mining tax. Different deductions may be applied in determining the income subject to each of these taxes, with the result that the calculation of cash tax liabilities is often a time-consuming task. Nonetheless, since the cash taxes payable are invariably a significant component of the valuation, it is a task which must be undertaken with a degree of care.

It is important, also, to understand the nature of the tax regime in the jurisdiction in question. Most of the major mining jurisdictions in the western world allow some form of accelerated depreciation of the cost of mining and processing assets, when computing the income subject to tax. Accelerated depreciation does not reduce the total amount of tax payable over the life of the mine. It does, however, defer the payment of tax from the early years of mine life to the later years, thereby enhancing cash flow in the early years and increasing the value of the project as determined by discounted
cash flow techniques. Some jurisdictions also allow additional tax deductions for depletion of the mineable reserve, further reducing the level of tax payable. The regulations governing the deductions for depreciation and depletion in a given jurisdiction can have a significant impact on the discounted cash flow valuation, and these regulations should always be fully reflected in the tax calculations which form an integral part of the valuation procedure. Inaccurate gross simplifications of tax regulations may lead to significant under-estimation or over-estimation of value.

**Capital Expenditure**

In the general case, capital expenditure estimates will need to be prepared first of the initial preproduction cost of constructing the project and, secondly, of the on-going cost of replacing worn out equipment throughout the productive life of the operation. Preproduction capital expenditures for a new mining project will typically be in the tens or hundreds of million dollars, and these expenditures will be incurred over a period of two or three years. Annual on-going capital expenditures will be at a lower order of magnitude but, since they are incurred in each operating year, they can be quite significant in total.

The most definitive estimate of preproduction capital expenditure is that typically prepared by a recognized engineering firm, in conjunction with the compilation of a bankable feasibility study. This estimate will be based on a comprehensive project scope, a detailed construction schedule, and a series of general arrangement drawings, single line electrical diagrams, and piping and instrumentation diagrams. These drawings will then be used to compile lists of the required mechanical and electrical equipment, and to estimate the required quantities of earthworks, concrete, structural steel, siding for buildings and similar items. Unit costs of major equipment and bulk materials will be based on budgetary quotations received from suppliers. Contingency allowances of the order of 8% to 12% are typically applied to the estimates of surface capital expenditure, with somewhat higher allowances applied to the estimated cost of capital mine development.

The estimates of preproduction capital expenditure prepared in conjunction with a bankable feasibility study are based on a considerable amount of engineering study and detailed cost estimation. Even so, the degree of accuracy claimed for the estimate is normally in the region of plus or minus 15%. Obviously, capital expenditure estimates prepared at earlier stages of study will be subject to even wider limits of accuracy, perhaps of the order of plus or minus 30%. As is the case with operating costs, it is again imperative that sensitivity analyses be performed to investigate the influence on value of quite wide variations in preproduction capital expenditure.

In the author’s experience, the most common errors which occur in the estimation of preproduction capital expenditures relate to over-optimism in the construction schedule and under-estimation of Owner’s cost. The capital cost estimate contains a number of components which are time-related. Construction camps must be maintained throughout the preproduction period, while heavy cranes and other construction equipment, as well as temporary power and other facilities which are required throughout the period, are commonly rented. Slippage in the construction schedule, then, will always result in an overrun of capital expenditure, and care must be taken to ensure that the accepted construction schedule is realistic, particularly with respect to identified critical path items.

The Owner’s cost component of preproduction capital comprises those expenditures which will be incurred by the mine operator in supervising the work performed by the prime engineering, procurement and construction management contractor. Most commonly, the Owner’s capital account is also burdened by the costs of insurance, permits and licenses, environmental baseline studies and impact assessments, associated public meetings, and like items. Owners typically begin with the view that they can manage the activities of their prime contractor with a very small team. As time goes on, however, particularly in remote or foreign locations, it is frequently found that the Owner must allocate far more personnel and other resources to this function than had been anticipated originally. In foreign locations, the Owner’s representatives will be overwhelmingly expatriate, and the cost of maintaining senior expatriate staff in the field is very high.

On-going capital expenditures required to sustain a project in operation can be estimated in detail on the basis of the assessed operating lives of the various components of stationary and mobile equipment. Alternatively, annual sustaining capital expenditures can be estimated more grossly as a percentage of preproduction capital. Generally speaking, discounted cash flow valuation is not sensitive to the annual allowances for sustaining capital, and relatively gross
methods of estimation may be acceptable. The major exception to this principle is the underground mine which is only partially developed during the preproduction period and which requires sustained on-going capital development in order to provide sufficient working faces to support future operation. In this case, on-going annual expenditures for mine development may be substantial in magnitude, requiring considerably more care in adequate estimation.

Finally, with respect to capital expenditures, there is one area which commonly receives scant attention, and that is the issue of reclamation cost upon closure. Perhaps ten years ago, it was adequate to assume that the salvage value of the on-site equipment at the end of the mine life would be sufficient to cover the final cost of reclamation and, hence, that there would be no net cash cost associated with closure. Under environmental regulations in most jurisdictions, and internationally accepted best practices, this assumption is no longer valid. Almost invariably, the cost of final reclamation of the site outweighs, by a large measure, the value of salvageable equipment. Many jurisdictions now require that a formal closure plan be prepared and costed prior to the commencement of production, and that financial assurances be put in place throughout the life of the operation in order to ensure that funds are available to pay for final reclamation. The funding of final closure costs, however, is frequently overlooked in the valuation process. This is of little significance in the discounted cash flow valuation of a mine with a projected operating life in excess of, say, fifteen years, but can be important in the valuation of projects with lives of ten years or less.

FINANCIAL CONSIDERATIONS

In addition to the technical estimates of rate of production, revenue and cash cost discussed above, there are several considerations of a financial nature which must be considered in discounted cash flow analysis. The most important of these are:

< The treatment of inflation.
< The availability of debt finance, typically in the form of a bank loan, to fund a portion of the preproduction capital expenditure.
< The treatment of exchange rates between various currencies.

Dealing with Inflation

Discounted cash flow valuations are most commonly conducted in terms of constant dollars. This form of valuation makes no specific provision for future inflation. Rather, it implicitly assumes that revenues and expenditures are most likely both to escalate at the same rate. In addition, and perhaps more importantly, it also assumes that the investor who provides the initial capital will want that capital, and its associated interest, returned to him in dollars having the same purchasing power as the dollars he originally invested.

In times of high inflation, the use of constant dollars will introduce inaccuracies in the calculation of tax liabilities and, potentially, also in the calculation of interest payments. A more accurate estimate of these components of cost can be made if all other elements of revenue and cost are escalated at a reasonable rate of annual inflation, so that the resulting estimates of overall annual net cash flow will be expressed in inflated dollars, rather than in constant dollars. In such instances, the preferred practice is to deflate all estimated future annual net cash flows back to constant dollars, prior to applying the discount rate. The net present value of the future cash flows will then be expressed in constant dollars, having a purchasing power directly comparable to the purchasing power of the dollars in which the original investment is made.

Occasionally, discounted cash flow valuations will be found in which revenues and expenditures are inflated at different annual rates. Almost invariably, when this is done, it is revenues which are inflated at a higher rate than costs. It is extremely rare to see a valuation in which costs are inflated at a higher rate than revenues.

The differential inflation of revenues at a rate in excess of costs will typically result in a much higher valuation than that obtained by working in constant dollars. In the author’s opinion, this is generally an invalid procedure which is not supported by the long-term history of most commodity prices. Any valuation based on a more rapid inflation of revenues than costs should be regarded with great caution.
The Effect of Debt Financing

The capital cost of constructing a new mining project typically exceeds the internal cash resources of most mining companies and bank financing of a portion of the capital cost is commonplace. From the standpoint of discounted cash flow analysis, the availability of bank financing will enhance the value of the project to the Owner, provided that the effective after-tax interest rate payable on the loan is less than the discount rate used to reduce future cash flows to present value.

A marginal project, however, is not rendered less marginal simply by the availability of relatively inexpensive debt financing. Some of the risk is merely transferred from the Owner of the project to the financing agency. The inclusion of debt financing in a discounted cash flow valuation, then, may serve to mask the inherent marginality of a particular project. For this reason, it is strongly recommended that, even if bank financing is readily available, the base case discounted cash flow valuation should be performed under the assumption of 100% equity funding. Only by following this procedure can the inherent economic merit of the proposed project be judged adequately. Once this base case has been evaluated, however, it is perfectly valid to incorporate a reasonable level of debt financing in all subsequent discounted cash flow runs.

Exchange Rate Considerations

The prices of most mineral commodities are quoted in terms of major currencies, such as US dollars or pounds sterling and, most commonly, revenues are actually received in these currencies. Some components of cost, such as fuel oil, spare parts for heavy machinery and equipment, and many process reagents, are also commonly quoted and paid for in major currencies. A significant portion of cost, however, most notably labour cost, is incurred in the local currency of the country in which the project is located.

Discounted cash flow analysis may be performed in terms of any desired currency but, in most cases, it is necessary to select an exchange rate by which to convert at least one foreign currency into whatever currency is being used for the valuation. Exchange rate considerations also enter into the estimates of preproduction capital expenditures, where construction crews will comprise mainly local labour and where budgetary quotations for different items of equipment are sought from manufacturers in different countries.

Experience suggests that international monetary exchange rates can be subject to significant variations over the medium to long term, but such variations are extremely difficult to forecast with any reasonable degree of reliability. The need to forecast future exchange rates, therefore, introduces another area of uncertainty into the valuation process.

DEALING WITH UNCERTAINTY

It is evident from the foregoing discussion that there is a greater or lesser degree of uncertainty inherent in each of the estimates which form part of a comprehensive discounted cash flow valuation. This uncertainty starts with the estimates of in-situ resources and mineable reserves, and carries through the estimates of each of the factors which influence future cash revenue and future cash cost.

Uncertainty, however, is not unique to discounted cash flow analysis. It is a component of all valuation methodologies. The advantage of discounted cash flow analysis in this regard is that it forces the evaluator rigorously to consider the most appropriate estimate for each of a large number of individual factors. The expectation is that, taken overall, the uncertainties inherent in each individual estimate will cancel out and, hence, that the resultant net present value will represent the most reasonable and reasoned assessment of the value of the property, when viewed from the present time.

Uncertainty can never be entirely removed from the valuation process. Even the most thorough estimates of capital expenditure and operating cost are still subject to potential variations of, say, plus or minus 15%, while metal prices have been subject historically to quite wide fluctuations, even over the short term. If all of these factors were simultaneously to move in an unfavourable direction, the economics of most mining projects would be seriously compromised. Conversely, if a number of factors move simultaneously in a favourable direction, projects which appeared marginal at the feasibility study stage can suddenly become highly profitable.
The accepted procedure for analyzing the effect of uncertainty in discounted cash flow valuations is sensitivity analysis. Traditional sensitivity analysis involves varying one input parameter at a time, while keeping all other parameters constant at their base case levels. In this way, the effect upon value of each individual parameter can be determined separately.

The results of a typical sensitivity analysis are illustrated in Figure 2. For simplicity of presentation, only three high-level input factors are shown (revenue, operating cost and capital expenditure), and each has been varied over a range of plus or minus 30% from the base estimate. In practice, more extensive analyses would be undertaken to evaluate, for example, the influence of changes in the individual components of revenue, such as tonnage of ore produced, mined grade, metallurgical recovery, commodity price and monetary exchange rate. Nor is it necessary always to vary each of the factors over the same percentage range. Metallurgical recovery, for example, may be sufficiently well identified that a range of, say, 5% above and 10% below the base estimate may be entirely adequate to cover the reasonable range of possible outcomes.

![Figure 2: Typical High-Level Sensitivity Analysis](image)

It can be seen from Figure 2 that an equal percentage change in estimated revenue, operating cost and capital expenditure can have a markedly different influence on net present value, and the results shown in Figure 2 are typical of most discounted cash flow valuations. In almost all cases, value is significantly more sensitive to changes in revenue than it is to changes in either operating cost or capital expenditure. Value is also typically somewhat more sensitive to changes in operating cost than it is to changes in the level of capital expenditure.

These observations suggest that considerable care should be taken in estimating the levels of future revenue expected to accrue to the project being valued. Often, however, more attention is paid to the detailed estimation of capital and operating costs.

More specifically, consideration of the individual components of revenue will most commonly show that the factors to which overall value is most sensitive are the recovered grade of the ore and, even more importantly, the price of the commodity. Typically, then, the most significant requirements of a discounted cash flow valuation are a thorough
understanding of the mineable reserve, particularly with respect to recovered grade, and a fully-supported, reasoned assessment of the long-term price to be received for the commodity produced.

**TREATMENT OF RISK**

It is the author’s opinion that, in the context of discounted cash flow analysis, it is important to distinguish between uncertainty and risk. Uncertainty is an attribute of any prediction of the future, but it carries with it the connotation that actual results may vary from the predicted results either positively or negatively, with a more or less equal probability of occurrence. Risk, on the other hand, refers principally to the probability that actual results will fall short of predicted results, and the use of the word tends to imply that actual results will vary negatively from the estimates more often than they will vary in the positive direction.

In the mining industry, because of intermittent contingent occurrences such as strikes or major equipment failures, actual rates of ore production fall short of design capacity more frequently than they exceed it. Similarly, experience indicates that, more often than not, the recovered grade of the ore is lower than predicted, and that both capital expenditures and operating costs are higher than estimated. Risk, then, is a word which is properly applied to the mining industry, and it is a factor which must be considered in the valuation of mineral properties.

In discounted cash flow analysis, the question of risk is handled in the discount rate, or the rate of interest by which estimated future cash flows are reduced to present value. In essence, the discount rate represents the risk-adjusted rate of interest expected to be yielded by an investment in mineral property, whether that investment be the capital cost of constructing a new mine, or the acquisition cost of buying an operating or undeveloped property.

A detailed discussion of contemporary practice in the selection of the discount rate to be applied to the valuation of mineral properties is beyond the scope of this paper. There is universal agreement, however, that mining is a risky business, and that a risky investment should command a higher rate of interest than a secure investment. Thus, in the valuation of mining investments, it is common to include within the discount rate a relatively high increment for risk.

In the author’s experience, the discount rate applied to the constant-dollar valuation of mineral properties will most commonly be within the range of 8% per year to 20% per year. Discount rates at the lower end of this range are applicable to the valuation of well-established operating mines, while rates at the high end of the range are applied to properties with identified resources, but at a relatively early stage of investigation. For properties which have reached the stage of a bankable feasibility study, the author normally recommends discount rates of between 12 and 15% per year.

Some commentators argue that gold properties represent a special case which should be valued at lower discount rates than properties containing other commodities. The author of this paper, however, disagrees with that view.

**CONCLUSION**

In the case of mineral properties, discounted cash flow analysis is generally accepted as the preferred method of valuation, whenever sufficient data are available to permit its reasoned application. Sufficient data are required to support estimation of all of the individual elements of cash revenue and cash expenditure which will be associated with the development and operation of the property, up to the end of its estimated life. It is the accuracy of these input estimates which determines the validity of the resulting determinations of profitability and rate of return on invested capital.

In undertaking any discounted cash flow analysis, it is important to recognize certain fundamental attributes of the mining industry:

< The basis of any mineral development is the existence of an ore reserve.
< Costs are determined by the number of tonnes mined and processed, while revenues are determined by the number of pounds or ounces of metal produced. The two are related by the recovered grade of the ore.
< Profit is typically more sensitive to changes in revenue than it is to changes in cost.
< Commodity price is a principal determinant of revenue, but it is also the factor with which is associated the greatest level of financial risk.
In the end, of all of the factors which must be considered in the discounted cash flow valuation of a mineral property, the most significant are the reliability of the reserve estimate, particularly with respect to recovered grade, the price at which the product is to be sold, and the risk of not maintaining the projected level of price.