A survey of mining companies suggests that resource evaluation techniques used in the mining industry are remarkably consistent and that exploration and acquisition target parameters fall in a narrow range directly relating to company size. Stephen Bartrop and Andrew White report that discounted cashflow modelling is the primary technique used to evaluate projects with at least an inferred resource.

Resource project evaluation (expansion to feasibility) or valuation (as an operating concern) are integral parts of the business of the mining industry. This paper examines evaluation/valuation practices involving some degree of financial analysis. While some companies carry out preliminary evaluations of hypothetical deposits to assist in target generation and ground selection, financial analysis is generally applied to more advanced projects based on identified resources.

Evaluation of identified resources becomes increasingly objective, first with increasing geological confidence in the resource through further delineation and infill drilling, and, second, through continual refinement of the costs associated with mining, milling and marketing as the project advances towards feasibility study. The latter can be illustrated with the "trumpet curve" notion (see Figure 1). The valuation of operating mines, or mines on care-and-maintenance, has scope for greatest reliability, given that it is based on an established mining method, metallurgical performance and market value.

Recently interest has been directed at the ethics and methodologies involved in evaluation/valuation and where these can exert direct influence in the stock-market. This has resulted in both guidelines for ore resource statements (JORC 1992) and a draft Mineral Valuation Code and Guidelines (Lawrence 1993).

The survey on which this paper draws involved interviewing 15 mining companies as well as several consultants through a series of questions relating to their company’s policies and methodologies. To ensure candour, confidentiality was assured to interviewees and only general findings are presented here. The questions directed to the companies related to the continuing evaluation of an in-house discovery of an ore-body prior to feasibility study, or an acquisition of a resource in varying stages of development, including as an operating mine.

The paper has three objectives:
- to document current practice;
- to explain why companies value the same resource differently; and
- to comment on corporate strategies and target parameters.

An important aim of the study is to provide data which will enable professionals working in the evaluation/valuation areas to compare their approach with those of other companies. Because companies vary in their activities, and since the people interviewed had varied backgrounds, some interpretation of the answers was necessary.
Table 1: Depreciation and working capital effects on taxation in real cashflow models

A: Real modelling without deflating depreciation allowance or return of working capital at end of project life

<table>
<thead>
<tr>
<th>Year</th>
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</table>

Company size is frequently cited and assumes a scale ranging from large blue-chip companies dominating the stock exchange to smaller “junior” explorers with or without operating mines.

**KEY PERSONNEL**

The survey began by assessing the key personnel likely to be involved in resource evaluation, first determining the nature of groups or teams responsible and then recording the professional backgrounds of individuals.

Smaller companies tend to create informal teams comprising members of senior management. These could include a (chief) geologist, mining engineer, metallurgist etc., often with some commercial input from those in the company with financial expertise. It was noted during the survey that there is concerted effort to keep evaluations “in-house”; consultants are used only to supplement deficiencies in technical expertise - for example, if senior management lacked metallurgical or marketing knowledge.

Most larger companies have permanent evaluation teams which comprise geologists, mining engineers and metallurgists. The larger companies have internal pools of expertise to draw on and generally do not use consultants except to scrutinise or audit internal evaluations, particularly in commercial areas.

Professional backgrounds varied according to people’s roles in the company. In both small and large companies, technical backgrounds predominate in the resource evaluation area, while acquisition teams are dominated by personnel with commercial (finance and accounting) backgrounds. It was common to find that those with technical backgrounds also had postgraduate, commercially-oriented training, the most common being a university MBA or a Graduate Diploma of the Securities Institute of Australia.

**EVALUATION TECHNIQUES**

The survey focused on techniques used in evaluation/valuation. Companies were asked to specify which of the following techniques were routinely or occasionally applied to projects:

- general industry standards (including market value of comparable groups);
- specific industry comparisons (including comparable transactions);
- discounted cashflow modelling;
- financial ratios (eg, price/earnings);
- gross resource values;
- position on cost curves.

Discounted cashflow analysis is the most common evaluation technique used in the industry. The survey showed that there is a direct relationship between the sophistication and accuracy of cashflow models and supplementary evaluation techniques, and the size of the organisation carrying out the evaluation.

The commodity involved also influences techniques used. For example, gross resource values and/or acquisition price per ounce were commonly calculated in the evaluation of gold deposits.

Smaller companies tend to concentrate solely on DCF analysis with simple models. These companies compensate for lack of accuracy in the model parameters - for example, grade and tonnages, metallurgical performance, variable costs - with
B: Deflating the depreciation allowance and return of working capital at end of project life (6% p.a. inflation rate)

<table>
<thead>
<tr>
<th>Year</th>
<th>1</th>
<th>2</th>
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<tr>
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<td>7782</td>
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<td>9492</td>
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</tbody>
</table>

Note: The model is simplified with depreciation calculated on a straight line basis over production life. Depreciation and working capital are deflated to the year of capital expenditure.
The modeller therefore has discretion in assigning periods as calendar or financial years.

Irrespective of size, companies vary between mid and end calendar year cashflow modelling, although there is a strong tendency towards the latter. Mid calendar year cashflows were often modelled to account for taxation outflows.

Gearing
Most projects are evaluated on an equity-only basis for initial acceptance or rejection. If a project has attached tax credits or tax shields, these may be incorporated into the evaluation. One company reported that gearing may be incorporated in the evaluation of projects in third world countries, which implies that this was a strategy to offset risk in these countries.

Table 2: Taylor’s Rule
Taylor (1977) developed the following relationship after studying many actual projects of a wide range of size and for all ore-body shapes except thin deposits of large lateral extent.

Life (years) \sim \left[ 6.5 \times \sqrt[3]{\text{Reserve size in million tonnes}} \right]^{1+0.2}

Taylor also published the following table.

<table>
<thead>
<tr>
<th>Expected tonnage (reserves) (mt)</th>
<th>Medium lifetime (years)</th>
<th>Range of lifetime (years)</th>
<th>Average daily production (t/day)</th>
<th>Range of daily production (t/day)</th>
</tr>
</thead>
<tbody>
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<td>0.01</td>
<td>6.5</td>
<td>3.5-4.5</td>
<td>80</td>
<td>65-100</td>
</tr>
<tr>
<td>10</td>
<td>9.5</td>
<td>8.5-11.5</td>
<td>150</td>
<td>1250-1800</td>
</tr>
<tr>
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<td>2500</td>
<td>2100-3000</td>
</tr>
<tr>
<td>50</td>
<td>17</td>
<td>14-21</td>
<td>5000</td>
<td>4200-6000</td>
</tr>
<tr>
<td>100</td>
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<td>8400</td>
<td>7000-10000</td>
</tr>
<tr>
<td>250</td>
<td>26</td>
<td>22-31</td>
<td>14000</td>
<td>11500-17000</td>
</tr>
</tbody>
</table>

Note: While the formula originally related to US tons, the error produced using metric tonnes is negligible.

Figure 2. Discount rates applied to low risk projects

Working capital
The calculation of working capital may vary. For example:

- three to four months of fixed and variable operating costs;
- 2.5 to 3 per cent of total capital as replacement capital;
- estimated from experience of operating mines.

At the end of the project, working capital is either withdrawn, included in the salvage value or run down. Rarely it is deemed insignificant at the end of the project and ignored.

A nominal increase to the working capital may be applied each year to maintain the level.

Taxation and depreciation
All companies tend to use the standard company tax rate applicable irrespective of individual company standing.

Most companies use tax-allowable depreciation rates. When determining accounting depreciation, the straightline method is used, generally over the life of project.

Other parameters determined from cashflow models
Most companies will use a cashflow model to calculate a break-even grade as a matter of course. Cut-off grades for operations are often derived from mining optimisation programs, or occasionally a natural cut-off grade is evident from the mineralisation. However, some companies apply the break-even grade, with or without a margin, as a cut-off grade.
Forecasting commodity prices, foreign exchange and inflation rates

The approach of companies to forecasting is directly related to company size and corresponding information resources available. Smaller companies are reliant on external forecasting, using, for example, the average of five brokers’ forecasts or the current rates with a sensitivity analysis applied to alleviate any potential errors.

Larger companies often have a five to seven-year business plan which will include forecasting of commodity prices, inflation rates and occasionally foreign exchange rates for each year. The forecasting basis generally does not include a detailed study of future commodity supply/demand balances.

The difference between small and large companies is that the former do less forecasting of fewer variables. All internal forecasting obviously has some input from external forecasting and all companies compare internal with external forecasts.

In shorter-term projects, commodity price forecasting is focused on the forward rates. This is evident with gold-price forecasting in the use of the markets’ forecasts through the contango/backwardation on the LME.

Application is kept relatively simple; short to medium-term individual year forecasts are used and a longer-term trend up or down may be incorporated. Cyclic applications are rarely applied except in specialist areas such as smelter charges.

Companies often vary their approach with individual projects. An important issue is the length of the project with respect to the commodity price cycle. If a project does not extend beyond a cycle, for example, less than five years, then there is increased focus on the forward rates and current position in the cycle rather than the broad application of longer-term price forecasts. All companies expect that sensitivity analysis will highlight the extent of any problems associated with the inaccuracy of commodity-price, foreign-exchange and inflation-rate predictions.

Derivation of capital and operating costs and factors determining degree of accuracy required

The manner of derivation of these costs is directly related to:
- the company size, which generally translates to a number of similar operations within the company which provide comparable data; and
- the project’s stage of development.

Smaller companies or companies which do not have operating mines for comparison with the project being evaluated rely more on industry comparisons. A higher discount rate is likely to be used to compensate for possible inaccuracy in the forecast costs. This is particularly evident if the company is unfamiliar with the commodity or mining method.

Medium to large companies use data from their own operations, occasionally supplemented by industry comparisons. Deposits discovered or acquired near a company’s existing operations will have directly comparable operating/capital costs, ensuring a minimum discount is applied.

Most of the larger companies have engineering and metallurgical divisions which determine these parameters. In these situations it is often routine for the engineering arm to estimate the operating/capital costs. These estimates often have a higher degree of accuracy than the other assumptions in the evaluation. Yates (1993) noted that engineering estimates of capital and operating costs are generally within 10 per cent of actual.

RETURN AND RISK

Discount rate

Expected real rates of return for "low-risk" projects generally range between 7 per cent and 12 per cent, although 15 per cent and higher was sought by two of the larger companies. With a current inflation rate around 2 per cent, an average expected real rate of return would be approximately 10.5 per cent (Figure 2).

The discount rate applied to project evaluation can be derived from:
- the company’s cost of capital;
- a specific project’s cost of capital related to the type of industry; or
- hurdle rates derived from cost of capital and market rates.

Both larger and smaller companies tend to have company-designated hurdle rates, whereas medium-sized companies tend to use an approximation of their cost of capital.

Within the model, the evaluator may indicate the appropriate discount rate for projects to reflect inherent risk and/or the relationship to core business. Alternatively, the discount rate may be the hurdle rate to ensure that the project meets the company’s minimum investment criteria, and any additional risk is measured against the actual IRR. Evaluators may avoid having to select a discount rate by presenting a range of discount rates and allowing management/directors to determine which rate is appropriate.

Several companies use high hurdle rates rather than using different discount rates for different types of projects.

Sensitivity analysis

All companies conduct sensitivity analysis on key variables:
- commodity prices, foreign exchange and interest rates;
- capital and operating costs;
- production and grade;
- metallurgical recovery;
- discount rate.

Variables are commonly increased or decreased by 5 per cent or 10 per cent. Sensitivity analysis is considered a useful guide to the "show stoppers" and highlights where further work may be required.

Probability/Monte Carlo analysis

Few companies carry out probability analysis, although many consider it may be useful. It is evident that probability analysis will be used more routinely in the future, and the method is promoted.
as providing some measure of the reliability of the return.

**Project ranking**

NPV and IRR are clearly the most important measures of a project and further analysis will be conducted only with a favourable NPV.

Payback is only critical for companies without cash and/or overseas projects. It is also frequently used with gold projects. It is generally considered useful but not essential.

Several companies carry out other analyses including, for example, impacts on the balance sheet, EPS and net profit to generally reinforce the NPV/IRR outcomes or to scrutinise the project more carefully.

**EXPLORATION TARGETS**

**Project evaluation**

Critical stages in exploration are generally reviewed from "geological evaluations" focusing on geological parameters. However, the financial standing of a company often plays a major role in determining the extent to which any financial analysis is carried out during exploration. Larger companies will "drill on" if a project has potential, without any detailed assessment of the economics, while a smaller company may look critically at all aspects, particularly on marginal projects. Other companies are cautious of DCF evaluations "killing off" projects without thorough exploration.

Larger companies have generally undertaken some work on determining minimum acceptable target size and grades. This generally translates into orebody type and subsequently area selection in their approach to exploration.

**Target specifications**

The following summarises the key elements in exploration/acquisition targets for the companies interviewed:

- **minimum mine life** - greater than five years, depending on size of company (most important);
- **minimum gross revenue** - generally applies to larger companies;
- **minimum size** - variation to some degree on above two;
- **cost position significant** - projects which fall in the lowest quartile is the common ambition;
- **commodity** - chosen on the basis of strategic fit or as counter to market cyclicality;
- **good access and close to markets** (also dependent on commodity);
- **mining methods** (also dependent to some extent on commodity).

The most important specification appears to be size, translating into mine life. Minimum revenues are applied by larger companies, as are size and grade to some extent. Size and cost curve position appear to be the most important in determining acquisition targets along with strategic fit.

**DISCUSSION**

Mining companies tend to concentrate on DCF analysis to produce evaluations and valuations of resources, but generally require at least an inferred resource before starting an evaluation. Larger companies may verify or supplement the DCF analysis with estimation of financial ratios, gross resource values, etc.

If two companies carry out an evaluation on a resource property that meets each company's target criteria, the two companies are in fact likely to produce different valuations and thus different bidding positions. The critical parameters which will affect the valuation, given a selected mining method and metallurgical performance, are:

- forecast capital and operating costs;
- forecast metal prices, foreign exchange rates and inflation rates; and
- discount rate.

With operating and capital cost items, the degree of accuracy employed tends to be related to two factors:

- the degree of accuracy, determined by the stage of development of the project; and
- the ease of obtaining more accurate cost estimates.

The degree of accuracy matches the stage of the project; for example, highly accurate cost estimates are not determined for an inferred geological resource. However, larger companies with engineering divisions or companies operating similar mines to the resource being evaluated may produce reasonably accurate cost estimates for relatively little effort. These translate into greater confidence in the cashflow model and a corresponding lower discount rate or higher project value.

In other situations there is a trade-off between accuracy and effort (cost) in obtaining more accuracy as in the "law of diminishing returns".

Apart from short-term forward selling, metal price and foreign-exchange-rate forecasting is particularly hazardous. Here, larger and smaller companies tend to be on a more level playing field although forecasting and treasury departments will produce more "informed" forecasts. Where prices are relatively secure because of forward selling, sophisticated cashflow models may
apply a different discount rate to revenues.

The discount rate is one of the key variables which will alter valuations determined by different companies. If the company is large and the commodity is a major part of its core business, then it is likely that a discount rate, related to the company’s cost of capital, will be lower than that used by a smaller company, and lower than the average expected return for that commodity as established by the stock exchange.

The greater potential inaccuracies in cost estimates and forecasts in models developed by smaller companies also tend to ensure that these companies apply a higher discount rate.

Sensitivity analyses are routinely carried out and will indicate the critical parameters of the project where further work may be directed. Probability analysis or Monte Carlo simulations are useful in providing some indication of the "reliability of the return" (Figure 3) although they are somewhat subjective. If there are a number of key variables highlighted in the sensitivity analysis, then there is a likely corresponding lower "reliability of the return".

While mining methods or metallurgical issues have not been addressed, it is interesting to note the different approaches smaller companies use in seeking development niches. Many smaller companies consider themselves more cost-efficient than larger companies by virtue of smaller underground development, better control on dilution, greater recoveries etc. and will tackle the economics of resources rejected by larger companies.

**Non-quantifiable assessments**

Non-quantifiable assessments generally have a moderate-to-major influence in overriding evaluations which indicate that a project has marginal economics. Board and CEO dislikes and preferences generally have a major influence. Companies attributing a moderate influence to non-quantifiable assessments tend to look at closing competition, integration creating a synergy, or the fact that an operation will provide an in-house technical pool which can be drawn on for other projects. This also includes the creation of other options; for example, plant expansion to improve economics of mining, or allowing more funds for exploration.

Smaller companies may embark on a marginal project from the moment generated within the company by continual reviewing of the project and previous investment in data collection.

**Sovereign risk**

The influence of sovereign risk generally translates into higher expected returns or higher discount rate. Some companies will not enter high-risk areas, irrespective of the returns, and this is directly related to the attitude of the directors.

**CONCLUSIONS**

Mining companies are generally well focused on exploration or acquisition target parameters. While these parameters may be specific to a particular company, it is evident that target parameters set across the industry fall into a narrow range with most companies considering life of project (or mine life) to be critical. The size of the company tends to determine minimum revenue requirements during this mine life.

DCF modelling is routinely carried out to determine viability or bargaining positions on projects with at least an identified (inferred) resource. Sophistication and accuracy of models and the application of additional evaluation techniques are often related to company size.

Two different companies valuing the same project in a similar commodity to their core business can be expected to produce different valuations, primarily due to the use of different discount rates related to each company's cost of capital.

Perceived risk or assessed inaccuracies in the model parameters tend to increase the discount rate applied in modelling. Larger companies tend to be better informed in these aspects. However, the survey indicated that larger companies often have average or above-average hurdle rates. Companies use market-derived discount rates for evaluation of projects unrelated to their core business.

Boards and CEOs commonly use evaluation/valuation outcomes as just one of the tools for decision-making. Corporate strategies such as closing competition, vertical integration or perceived synergies will fundamentally affect the value of a target to a particular company and may displace the influence of DCF analysis.

Acknowledgment: This paper represents part of a Master of Science (mineral economics) at the W.H. Bryan Mining Geology Research Unit at the University of Queensland. The authors thank Kit Clifford, Brian Hall and Bob Kelsey for reviewing the draft and the companies and personnel participating in the survey. An AusIMM Gold Endowment grant provided financial assistance for this research.

**REFERENCES**


