Assessing the “Value-at-Risk” of a Quarry Operation Using Monte Carlo Simulation for Valuation Purposes

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In some cases, a quarry operation can be the highest and best use of a real property. In the valuation of a quarry, the traditional real estate comparative market valuation method in most instances does not suffice. Unlike residential and commercial properties, quarry sales do not transact frequently and so there are limited sales evidence. In addition, no two quarries are ever the same as there are many operational parameters that can differ. These can include, but are not limited to:

- Size of the resource that is finite and a wasting asset
- Quality of the resource that determines the range of possible products that can be produced
- Volume of sales dictated by the local and national markets
- Range of products and associated pricing
- Cost of production relating to the range of products produced
- The age, efficiency and specification of the processing plant
- Distance from the market that affects the ex-bin selling price

It is for these reasons that the best way to value real property used for quarrying is to consider the cash in and out flows generated from the property and analyse these using various valuation methods. One such method is the discounted cash flow (DCF) method.

Decisions on purchasing, selling and/or financing a quarry operation are often made on a single DCF net present value (NPV). This can be fraught with danger for the reasons mentioned above. Choosing a single set of assumptions to derive a single NPV is only one of many possible outcomes for the value of a particular quarrying operation. It is important to understand the range of possible values by considering the impact of changes in key parameters to the valuation using a risk analysis tool such as Monte Carlo simulation.

Assessing the sensitivity of a derived NPV to account for the key risks associated with a quarry operation is an important aspect of the valuation process. The way risks are assessed and managed is critical to the business over the life of the operation. An established means of capturing key risks during the valuation process would be to adopt a probabilistic (stochastic) approach to the DCF in an effort to quantify the risk in achieving a particular NPV. This is also known as a “Value-at-Risk” (VaR) assessment.

In a stochastic (none deterministic) approach where there are many possible outcomes for price, costs and production volume assumptions these are identified and estimated separately. The sensitivity of the NPV to the variation in these possible assumptions (uncertainties) are then simulated within the cash flow using Monte Carlo simulation producing a probability distribution of NPV’s, which is essentially hundreds of “what-if” scenarios: What if product prices, operating costs and even sales volumes are separately and independently higher or lower, what would the new NPV be?

Monte Carlo Simulation can generate many “what-if” scenarios producing a distribution of NPVs as illustrated in the bar chart below. This distribution can then quantify the probability of an unsatisfactory NPV that may be negative with a specific set of prices, costs and sales volume assumptions, known as the VaR.

In a deterministic discounted cash flow approach, an appropriate discount rate is selected to reflect the uncertainty and risks associated in achieving the cash flows from the quarry. However, it is difficult to determine the appropriate discount rate due to the large number of risk factors that need to be considered and this is left, very often, to a valuer’s better judgement. Lai et al (2009) suggests that a lower discount rate should be used when performing a stochastic valuation using Monte Carlo simulation. Davis (1995), however, demonstrated that we should not lower risk-adjusted discount rates when performing a stochastic NPV simulation. Ultimately, it is left to the valuer to determine whether to alter the risk-adjusted discount rate when conducting a VaR assessment and consider the sensitivity analysis of the NPV providing reasoning behind the choice of discount rate adopted.
In a hypothetical example illustrated below, three main risk input parameters were selected for simulation of an operating quarry cash flow analysis, these being the forecast average ex-bin price, operating cost and sales product profile. Then 500 randomly selected sample data sets for each input parameter were generated within a Normal Distribution using Monte Carlo simulation. The resultant quarry NPV probability distribution was determined.

Overlying the frequency distribution of 500 different “what if” scenario NPV’s (blue bars) is a green line that shows the increasing probability of achieving a corresponding NPV. In this case, there is 90% confidence (between the 5% confidence and 95% confidence levels) that the NPV of the quarry operation lies between negative $2.8 million and $20.4 million with an expected market value of $10 million. Table below summaries the statistical values of the example graphically illustrated in the chart above.

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (expected value)</td>
<td>$10,030,577</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>$7,320,785</td>
</tr>
<tr>
<td>Minimum</td>
<td>-$15,155,496</td>
</tr>
<tr>
<td>Maximum</td>
<td>$28,471,825</td>
</tr>
<tr>
<td>5% confidence limited</td>
<td>-$2,766,817</td>
</tr>
<tr>
<td>95% confidence limited</td>
<td>$20,447,392</td>
</tr>
</tbody>
</table>

The risk, as illustrated by the red line in the chart, is the inverse of the probability (green line). Risk reduces in achieving a specific NPV on the line moving to the right at the end of the frequency distribution. More importantly, from this analysis we can determine that there is a 10% probability (right hand axis) of achieving a negative NPV which in this case is the VaR as illustrated by the red arrow and vertical red line.
This type of analysis gives both the owner of the quarry operation and the party relying on the valuation, that may be providing finance, a chance to make more informed decisions knowing the VaR and put in place risk mitigating strategies. In this example, the risk of loss is 10% and could be reduced, for example by:

- Fixing contractor operating costs reducing the variability
- Producing higher value products resulting in increased margins
- Securing long term sales contracts to reduce the variability in sales prices

By making adjustments to the Monte Carlo simulation of the key assumptions associated with the above risk mitigation strategies, a new NPV probability distribution can then be generated and compared to see the impact on the VaR. The objective would be to reduce the VaR to an acceptable level for both the owner of the operation and financial institution providing finance.
References:

Davis, G. A. (1995) (Mis)use of Monte Carlo simulations in NPV analysis, Mining Engineering, Technical Papers


