Utilising Monte Carlo Simulation for the Valuation of Mining Concessions

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Abstract

Valuation involves the analyses of various input data to produce an estimated value. Since each input is itself often an estimate, there is an element of uncertainty in the input. This leads to uncertainty in the resultant output value. It is argued that a valuation must also convey information on the uncertainty, so as to be more meaningful and informative to the user. The Monte Carlo simulation technique can generate the information on uncertainty and is therefore potentially useful to valuation. This paper reports on the investigation that has been conducted to apply Monte Carlo simulation technique in mineral valuation, more specifically, in the valuation of a quarry concession.

Keywords: *Monte Carlo Simulation, Quarry Valuation, Mineral Valuation, Risk, Uncertainty, Probability*

Introduction

Valuation is often associated with being an art rather than a science. This is because valuation cannot claim to be an altogether objective exercise. In a typical valuation exercise, there is potential for subjectivity in analysis. Valuation relies on input data to produce the value estimate; choosing an appropriate value for the input is subjective although experience and knowledge may operate to guide its determination. The element of subjectivity adds up as the number of input variables increases, and as valuation assignment increases in complexity, such as happens when specialist properties are involved, where evidence from the marketplace could be very limited, or even non-existent, to guide opinion of value.

Valuation invariably involves the analysis and synthesis of various input data to produce a value estimate. Each input itself is not definitive but rather an estimate that a valuer puts to represent what he deems to be the best in the given situation. There is therefore the element of uncertainty in the input. Because of the input uncertainty, the resultant output value is equally uncertain. Due to this uncertainty, it is argued that a valuation advice must increasingly incorporate a measure of the uncertainty so as to be more meaningful and informative to the user (Mallinson *et al*, 2000). The deterministic nature of the analysis in conventional valuation unfortunately does not provide for that type of information.

Valuers have often come under attack for the lack of 'accuracy' in their recommended value. While there is no doubt that improving valuation accuracy should be a matter of priority for the professional and academics working in this discipline (Boyd, 2003), the notion of an 'accurate' or 'correct' valuation is itself deceptive because it is inconceivable that a number of competent valuers appraising the same property would, working independently, arrive at the single 'correct figure'; more likely, they will arrive at a range of values (Mallinson *et al*, 2000). This is yet another argument why information on risk must be conveyed together with valuation; such information will assist the user in understanding what a valuation involves and what risks are associated with accepting the single value estimate and treating it as the 'correct' figure.

Monte Carlo simulation is one technique that a valuer can potentially use to identify and quantify risks in valuation. Although the valuation risks are pre-determined, the statistical outputs produced with this simulation technique may provide useful indicators to a valuation estimate as the range of the likely values are given. As such, the valuers can use their own judgment and experience in the market place to support and interpret the given outcomes.

In the United States, Monte Carlo simulation gained popularity among analysts in 1990s. In countries such as Malaysia, this technique has not received sufficient attention as to motivate active investigations into its potential utility, particularly in the context of real estate valuation. The case example will show how the use of the simulation technique can benefit the valuation of a mining concession. A case will be presented where the valuer could improve the quality of the valuation advice by making explicit the treatment of the likely risks involved, particularly for the uncontrolled input variables. The Monte Carlo simulation technique offers this. This paper aims to demonstrate the benefits of Monte Carlo simulation when it comes to improving the transparency in reporting the valuation output.

For mining concession, the valuation is not straightforward and involves a multitude of input variables whose estimations are often a matter of expert judgment rather than an objective exercise. There is nothing so deterministic about their determinations; yet the conventional approach of the valuation techniques operates on such pretense. By using mining concession as an example valuation situation, the way in which the stochastic treatment of the problem can lead to enhanced information for user decision-making will be demonstrated.

To provide context to the discussion, it would now be appropriate to give some background to mining concession.

Background To The Mining Industry

Minerals and their products contribute significantly to the national economy. Despite a reduced contribution from metallic minerals such as tin, gold, iron, copper and bauxite to foreign exchange earnings and employment in recent times, the total contribution from this sector has not weakened; this has been due to the increased output of industrial minerals such as clay, kaolin, silica, limestone, construction stone, sand and gravel to support the expanding infrastructure, construction and manufacturing sectors. In all, the mining industry remains as a major contributor to the economic, social and industrial developments of the nation (Heng, 2002).

Malaysia's mining industry consists of a small mining sector of coal and ferrous and non-ferrous metals, and a large mining and processing sector of industrial minerals and oil and gas. With the exception of oil and gas, mining and mineral-processing businesses were owned and operated by private companies incorporated in Malaysia. Oil and gas exploration, production, and processing businesses are owned and operated by Petroleum Nasional Berhad (PETRONAS), which was the state-owned oil and gas company, and by joint ventures of PETRONAS and foreign companies (IMF, 2004). Table 1 shows the gross export of major mining commodities.

Table 1 - Gross Export of major Mining Commodities

Year	Tin '000 Tonnes/RM Mil	Crude Oil '000 tonnes/ RM Mil	Natural Gas '000 tonnes/Mil
2000	20,614 / 435	16,672 / 14,241	15,430 / 11,422
2001	27,269 / 461	15,077 / 11,118	15,423 / 11,119
2002	27,076 / 425	16,192 / 11,600	15,007 / 9,888
2003	15,244 / 286	17,913 / 15,659	17,311 / 13,358
2004	29,966 / 946	18,090 / 2,1318	20,729 / 17,079

Source : Central Bank of Malaysia, Monthly Statistical Bulletin 2000-2005

The loans for mining and quarrying industries went through consolidation in 2000 but continued to drop annually at 10.5% by 2004, as shown in Table 2. These major mining and quarrying businesses consist of gold, iron, tin and cement

Table 2 : Loans by Sector (Mining and Quarrying)

Year	Total (RM Million)
2000	25,992.3
2001	21,064.2
2002	15,760.3
2003	13,018.0
2004	12,315.2

Source : Central Bank of Malaysia, Monthly Statistical Bulletin 2000-2005

Matters related to minerals and mining policies are governed by the National Mineral Policy. The same policy places geochemical surveys under the purview of the Department of Minerals and Geoscience Malaysia. Currently, the extraction of non-metallic (industrial) minerals is legislated by the National Land Code and the Land Ordinance. While land is a state matter, mineral is a federal matter. The need to coordinate the two different tiers of governance and address issues related to mineral policies, mineral agreements, administration and management led to the formation of the National Mineral Council. Such a move is aimed at facilitating the healthy growth of the mining sector in this country, in line with development on the international front. Other countries that actively place high importance on their mining industries are the United States, Canada and Australia.

Cement production increased by 20.3% in 2003 because of increased exports and continued growth in domestic demand; cement production was equivalent to about 60% of the industry's installed capacity. According to an estimate by Cement and Concrete Association of Malaysia, domestic demand for cement grew by 9% to 13 Mt and exports of clinker and cement grew by 39% to 3.9 Mt in 2003. As of 2003, Malaysia's installed capacity of clinker and cement was 17.8 Mt/yr and 28.3 Mt/yr, respectively (International Cement Review, 2003).

Mining properties fall into two categories: *static reserve* and *dynamic reserve*. The former is closer to the common view with regard to the nature a mineral deposit, as one with a fairly well defined estimate of reserve quantity at the beginning, and therefore an estimable time period within which to work on the mineral extraction to the finish. Examples include coal mining and gravel quarry reserves. The latter, on the other hand, is rather indeterminate and shows a propensity for the mine operator to keep finding and developing more reserves as needed to replace the reserves extracted; copper and gold deposits often fit this category (Ellis, 2000). For the formal definition though, only the portions of a mineral deposit that can be extracted for sale of their mineral content at a profit can be called *reserves* (SME, 1999).

It takes extensive geological studies, based on considerable amount of drilling, to appraise the deposit with reasonable degree of confidence. Preliminary studies and mine design will have at least been conducted to determine the feasibility and cost of extracting the reserves (Ellis, 2000). In the case of a gravel quarry, this requires determining the percentage of the stone contained in the mined rock that can be economically extracted, as well as determining the cost of extraction. Due to the prohibitive costs involved, only those with substantive historical and geological experience would have the capacity to embark on the appraisal (*ibid.*). Even so, such studies are often perfunctory, frequently produced merely to meet the requirements of potential lending institutions. Reliance on such inexpert geological studies has the risk of underestimating or overestimating the reserve of the quarry.

Valuing Mining Concession

Mining concession valuation or quarry business valuation is not so much about getting the "correct answer" as about selecting the relevant data, analysing this data and applying logical reasoning to arrive at a value conclusion that has the necessary level of reliability, supportability and defensibility for the purpose and intended use of the valuation. In valuation theory, there are no truly "correct values", but only estimates or opinions of value that are implicitly assumed to be based on the interpolation of some amount and quality of facts. The valuer's assumptions and limiting conditions add to this imperfect information. As a product of the exercise, the valuer must usually arrive at a single value that is believed to be the most probable estimate of value for the purpose and intended use of the appraisal.

The principles of mineral valuation are unlike the principles of natural sciences and mathematics, because they cannot be derived from or proved by the laws of nature, and they are not viewed as fundamental truths or axioms. Mineral valuation principles cannot be discovered; they are created, developed or decreed. Minerals valuation principles are supported by intuition, authority and acceptability (Ellis, 2000). As a result, the credibility of mineral valuation principles rests upon their general recognition and acceptance, which depend upon such criteria as usefulness, relevance, reliability, as well as upon cost benefit and materiality considerations.

Shortcomings normally result from lack of expertise on the part of the valuer, the inability to view certain portions of the property, the inherent drawbacks of relying on information supplied by others and limitations imposed by the time constraints of this engagement. There is also the economic constraint in that the budget is not unlimited for examination, inspection and acquisition of additional data. The valuer uses available resources in the collection, verification and analysis stages of this engagement in those areas that he considers most relevant to the purpose and intended use; there is a significant possibility that the valuer does not possess all the information related to the industry concerned.

Mineral valuation requires numerous inputs. While some of the inputs are known, many are uncertain and require expert judgment to ensure a realistic output. To improve the output accuracy, it is necessary to identify uncertain inputs that have a substantial effect on the resultant output. The numerous studies that have been carried out in the subject area suggest that important key variables include the volume of stones, the cost of extraction, the capitalisation rate and the sale price of rocks.

Under the Malaysian Valuation Standard (MVS) 1997, market value is defined as the estimated amount for which an asset should exchange on the date of valuation between a willing buyer and a willing seller in arm's length transaction after proper marketing wherein the parties have each acted knowledgeably, prudently and without compulsion (MVS, 1997). In the case of a quarry, an asset refers to quarry asset. By the above definition, the market value should not be affected by special or creative financing or sales concessions granted by any of the parties involved.

MVS further states that in order to estimate Market Value (Standard 1), a valuer must first estimate highest and best use or most probable use. That use may be for the continuation of a property's existing use or some other alternatives where these determinations are based on market evidence. However, Ellis *et al* (1999) argues that comparable market evidence may work well for surface real estate, or even for precious metal deposits, but not at all for most industrial mineral properties.

At the international level, a comprehensive framework of Generally Accepted Valuation Principles has existed for some time to cater for the valuation of all property or asset types, including real property, personal property, businesses and financial interests. The International Valuation Standards (IVS) have laid down standards for the valuation profession internationally. It is encouraging to note that the existing IVS standards are being modified to incorporate instructions pertaining to the extractive industries. This will help put the valuation of mineral and petroleum concessions on an equal footing with other industries.

Traditionally, the valuer has several valuation techniques available for determining fair market value. Three of the more popular techniques are asset-based, market-based, and income-based (Ellis *et al*, 2000).

Asset-based technique (Cost Method) - The basic principle of this technique is that the value of a business is the cumulative value of assets, including intangible assets such as goodwill. Quarry assets to be valued using this approach typically include the estimated values of the inventory and any equipment and real estate used in the business. However, this approach may provide value underestimate due to certain valid reasons. For example, quarry businesses are normally family-owned businesses that have been in operation for decades. Although they are profitable, their owners have elected to retain small equipment fleets of older equipment since they provide adequate service. Consequently, equipment values are relatively low. An obvious exception could be a quarry that has just made a large investment in new mobile equipment or processing plant. In this case, the reverse could be true.

Market-based technique (Comparable Sales Method) - Many valuers are familiar with the use of the sales comparison approach. This approach is commonly used when selling houses, offices, agricultural property, or other fairly liquid real estate. The market-based approach for determining the value of a quarry is basically the same. The theory behind this method is that the market for privately owned businesses determines what price provides an acceptable return for a quarry's earnings stream. Multiples commonly used include sales revenues, earnings, or profits. However, the approach does have limitations. For example, a big future project could be underestimated since its impact not yet realised. Similar for quarry business, its ownership position with respect to its mineral reserve and its life expectancy can materially impact value.

Income-based technique (NPV or DCF Approach) - The income-based technique typically provides the most reliable estimate of fair market value as investors are actually purchasing future profits (more specifically cash flow). This approach uses discounted cash flow analysis to determine value. It is straightforward and widely used. It is based on a quarry's long-term plan that takes into account numerous variables such as sales and market forecast, mineral characteristics, production capacities etc. However, the estimation of future profit may not be accurate enough due to the fluctuation of market variables. The valuer will never know whether his future projection is in line with the future economy situation. As such, the uncertainty factors should be considered in his valuation and Monte Carlo Simulation will become an important tool in helping the valuer's judgment in deriving a value conclusion.

Although the accuracy of data in traditional approach is seldom questionable, they are too deterministic in nature. What needs to be attempted in dealing with this problem is to incorporate probabilistic aspects into the techniques so as to make them closer to the reality of the problem. In the context of mineral valuation, the incorporation of probabilistic approach has been tried before, in works such as by Rose *et al* (1993) in the valuation of petroleum concession, and has been found to be useful by Gustavson *et al* (1997). This study also aims to add to the above works by demonstrating the utility of a probabilistic approach, namely the Monte Carlo simulation, for the valuation of quarry concession. The application of this simulation technique specifically to quarry concession has not been attempted before.

Monte Carlo Simulation In Quarry Valuation

Monte Carlo simulation has been an important probabilistic approach in risk assessment since mid-1960s (Hertz, 1964). Each input in the probabilistic model is represented by a probability density function, or a range of values that are possible, not just the single most likely value. The location and shape of distribution determine the chance that a single value will occur during each iteration of the model (Kelliher *et al*, 2000). The model is basically a series of what-if analyses where alternative estimates of parameters of the model are derived from probability distributions attached to them. If probabilistic information is used in Monte Carlo technique, the results will be expressed as a probability distribution rather than as a single point estimate (Allen,1989) as used in deterministic model.

Through random selection with random number generator, the computer draws a series of parameter values from each probability distribution and records results that are calculated. This process is repeated numerous times, each time recording the result (Sirmans *et al*, 1995). Like any statistically based methods, the success of probabilistic methods depends on the "law of large numbers", the requirement for a large number of valid data points to provide statistical reliability.

The application of simulation technique is fairly well explored in the realms of property investment and property development (MacFarlane, 1990, 1995; Martin, 1978; Vernor, 1989). In the context of valuation, however, work is very limited so far. As alluded to earlier, the valuation of mineral deposits involve more than one input variable. Each variable needs to be included in the valuation. However, the inputs are not independent from one another; it is thus necessary to consider the inter-relationships or correlations between the variables. The drawback of the conventional method is that, at any one time, only one variable can be changed while the others are held constant. This is not a realistic situation. One advantage of Monte Carlo simulation over the conventional deterministic techniques is that the former allows the decision maker to incorporate correlations and other inter-dependencies in the model.

Selecting the profile of the probable values of key input variables is assisted by the range of distribution profiles provided in simulation packages. To implement the simulation, a number of software packages are available in the market, of which Crystal Ball and @Risk are two. These two software products provide a choice of distribution profiles within the simulation programme (Boyd, 2003) although their applications are somehow different. An evaluation of the various software packages' performance lies beyond the scope of this study. Crystal Ball is chosen in the present study because this software does not have serious deficiencies, handles analysis as good as other packages, and was readily available for the study.

In the subject example, a quarry operator obtained a freehold interest on a piece of land from the State Government and was at the same time granted a quarry concession on the same land. Under the concession, the operator pays quit rent and royalty to the state government. The operator has applied for a bank loan to finance the business. The bank requires a valuation advice on this interest in order to determine the amount to approve in loan.

The first step in the value estimation would be to assemble the input data. For stone reserve, the valuer would consult a geological report to arrive at an estimate of the total capacity. For other input data such as the maximum capacity, expected gain, sales revenue, operation cost and yield, estimations are done by reference to data from comparable quarry operations. For the example, Table 3 below sets the basic calculation for the projected quarry lifespan based on assumed rock extraction rate, as given. Based on this data and other input estimates, a valuer's use of the conventional income-based technique would typically lead to a valuation layout as in Table 4.

Table 3: Basic Data for Quarry Valuation

Maximum Capacity	40,000 tonnes per month
Expected Gain @ 80%	32,000 tonnes per month
Therefore, Annual Production	384,000 tonnes per year
Stone Reserve	9,600,000 tonnes
Therefore, Projected Quarry Life	25 years

Many input variables are involved in producing the single output conclusion to the concession value. However, the nature of each input estimate itself is such that its accuracy is uncertain. This is because the 'true' value of the input is never known; the valuer can only aspire to get as close as he can to the unknown 'true' value through choice of data or comparisons that are perceived to be the perfect match for the subject case. Consequently, the accuracy of the single point outcome estimate is uncertain too. To mitigate the risks associated with the uncertainty of the single value estimate, an option would be

Table 4: Conventional Income-based Approach

Total Sale Revenue (RM)		5,952,000.00	
Total Operation Cost (RM)		2,939,200.00	
Estimated Gross Revenue		3,012,800.00	
Operator's Profit @ 30%	903,840.00		
Quit Rent	21,000.00	924,840.00	
Estimated Net Revenue		2,087,960.00	
Years Purchase for 25 years @ 11%		8.42174	17,584,265.99
Revert to Land Value 30 acres @ RM30,000 per acre		900,000.00PV	
25 years @ 11%		0.07361	66,247.28
CAPITAL VALUE			17,650,513.27

to release a lower, safer loan amount than the value proposed by the valuer. From the bank's point of view, it would be helpful to know what level of certainty is attached to releasing the lower amount. Unfortunately, the conventional approach does not provide such an indication. From the potential buyer's point of view, it would be useful to determine the degree of uncertainty in offering the right value.

In applying the simulation technique, a valuer needs to identify a probability distribution that best describes the uncertainty profile of a variable and applies it to that variable in generating the simulated samples. In the context of this study, six input variables are involved, in three types of distribution as follows:

Normal Distribution

Most natural phenomena conform to normal distribution. Under this distribution, the mean value is most likely, the distribution is symmetrical about the mean and the value is more likely to be close to the mean rather than far away. The shape, mean and standard deviation of the generated value will generally conform to this definition. Increasing the number of trials will enhance conformity to this distribution.

The normal distribution has been adopted for Expected Extraction Rate and Years Purchase. Assumption 1 shows a normal distribution for Expected Extraction Rate with a mean of 80% and a standard deviation of 2% while Assumption 2 shows the distribution for Years Purchase with mean of 11% and standard deviation of 2%. These represent the real-life assumptions on the two variables.

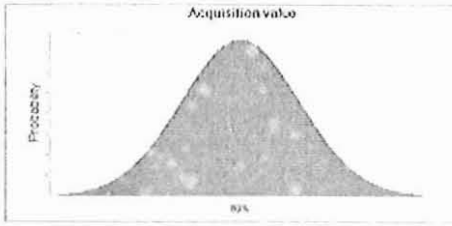
Triangular Distribution

Due to the limitation of the available data for reserved stone and maximum capacity of the machine, a valuer chooses the triangular distribution because the triangular distribution describes a situation where estimates can be made of the minimum, maximum and most likely values to occur. The valuer estimates the reserved stone provided in the geological report at between 9 million and 10.2 million tonnes, with a most likely amount of 9.6 million tonnes (Assumption 3). As in Assumption 4, the maximum capacity is expected at 35,000 to 45,000 tonnes per month, with a most likely amount of 40,000 tonnes per month (as used in deterministic approach).

Assumption 1: Expected Extraction Volume

Normal distribution with parameters:

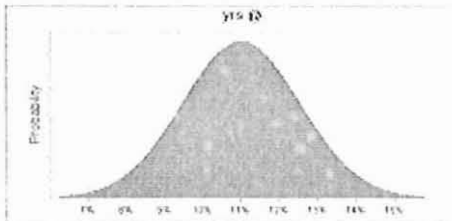
Mean	80%
Std. Dev.	2%



Assumption 2: Years Purchase

Normal distribution with parameters:

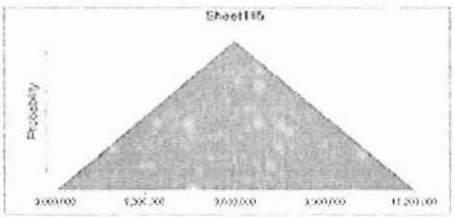
Mean	11%
Std. Dev.	2%



Assumption 3: Reserved Stones

Triangular distribution with parameters:

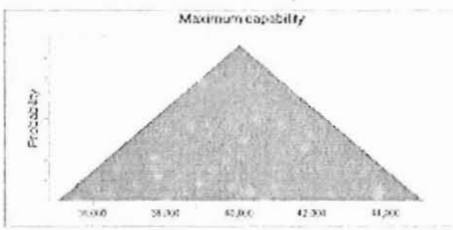
Minimum	9,000,000
Likeliest	9,600,000
Maximum	10,200,000



Assumption 4: Maximum Capacity

Triangular distribution with parameters:

Minimum	35,000
Likeliest	40,000
Maximum	45,000



Uniform Distribution

The uniform distribution is used to describe the Total Operation Cost and Total Sale Revenue. This is because experience shows that, within an identified range of values, these two variables have constant probabilities of occurrence. As such, its distribution of occurrence is best modeled with a uniform distribution. For Total Operation Cost, the valuer thinks that any value between RM2.5 million and RM3.5 million has an equal chance of being the actual value (Assumption 5). Further, the uniform distribution has two parameters: Minimum and Maximum. The valuer expects that the minimum Total Operation Cost for the quarry operation is RM2.5 million with a maximum value of RM3.5 million. The valuer also expects the Total Sales Revenue that the operator will get from this concession to be RM5.5 million with a maximum of approximately RM6.5 million (Assumption 6).

Assumption 5: Total Operation Cost

Uniform distribution with parameters:

Minimum	2,500,000.00
Maximum	3,500,000.00

Assumption 6: Total Sale Revenue

Uniform distribution with parameters:

Minimum	5,500,000.00
Maximum	6,547,200.00

Outcome Of The Simulation Analysis

Table 5 provides the outcome of the simulation analysis of the given quarry concession after 1,000 trials. This statistic will be used to elaborate the results using histograms and cumulative frequency charts.

Table 5 : Statistics after 1,000 trials of Monte Carlo Simulation

STATISTICS	CAPITAL VALUE
Trials	1,000
Mean	17,977,845.53
Median	17,703,067.61
ModeStandard	17,248,556.78
Deviation	3,355,833.00
Variance	11,261,615,133,288.70
Skewness	0.43
Minimum	10,053,050.41
Maximum	32,491,485.70
Mean Std. Error	106,120.76

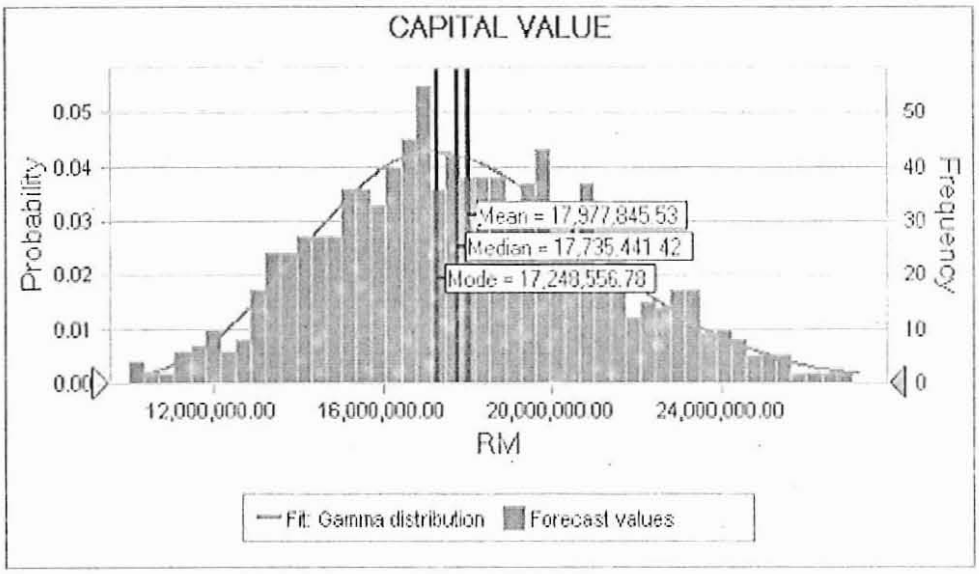
Chart 1 shows the total range of market values predicted for the quarry concession. Each bar on the chart represents the likelihood, or probability, that the true value of the quarry concession falls within the given value range. The cluster of columns near the centre indicates that the most likely value of the quarry concession is RM17.2 million. To the valuer, the Mean, Median and Mode should be important.

Mean represents the average market values for the 1,000 outputs obtained from the simulation analysis. In this case the mean is RM17,977,845.53.

Median represents the balance of point for the 1,000 outputs obtained from the analysis. The median for the analysis is RM17,735,441.42.

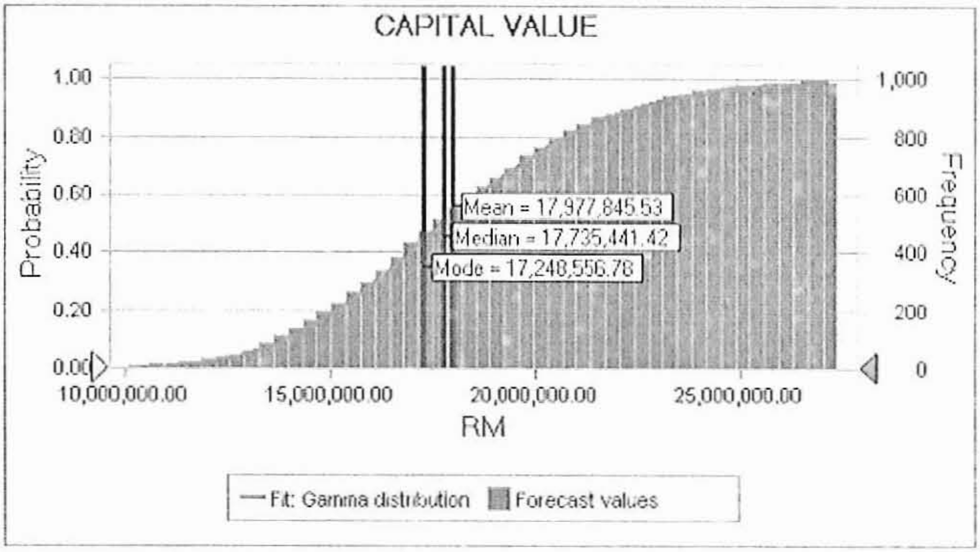
Mode represents the value with the highest frequency of occurrence for the total of 1,000 outputs. The mode given for this simulation is RM17,248,556.78.

Chart 1: Capital Value Forecast (Histogram)



The outcome can also be interpreted using the Cumulative Frequency chart as shown in Chart 2.

Chart 2: Capital Value Forecast (Cumulative Frequency Chart)



Given the above simulation outcomes, two alternative situations are possible, as follows:

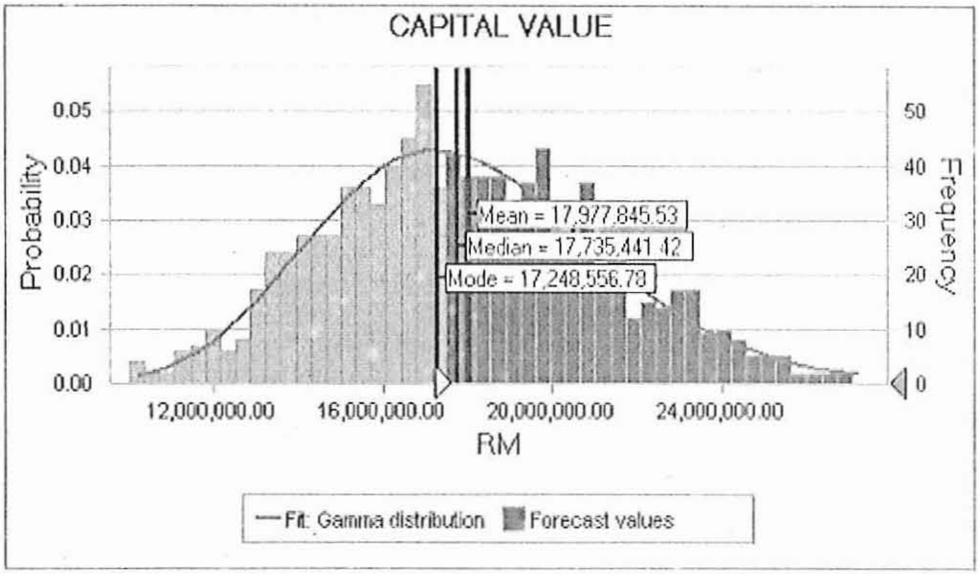
Situation 1 - Suppose a bank needs to determine how much loan to release for this quarry consession. Should the valuer scrap the value that has been estimated using a conventional approach or proceed to accept a lower or higher market value than the actual estimated value in helping the bank decision for loan purposes? Should the bank approve additional amount of loan as requested by the quarry operator?

Situation 2 - Assuming that a potential purchaser considers buying the quarry concession. Should he accept an amount lower or higher than the single value indicated by the conventional approach?

The authors argue that in both the above situations, the Monte Carlo simulation is useful.

In Chart 3, the display range includes values from approximately RM10.1 million to RM32.5 million. The chart also shows the Certainty profile to reflect the probability of a value level ranging from RM17.6 million to positive infinity – the probability of getting a value. With this information, the valuer is in a very much better position to make decision on whether to accept the proposed value of a deterministic model of the quarry valuation. In this example, there is an 80.8% chance that the RM17.6 million is the correct value. The valuer can therefore calculate a 19.2% chance of error in predicting the market value.

Chart 3: Certainty Profile (Result for RM17.6 million)



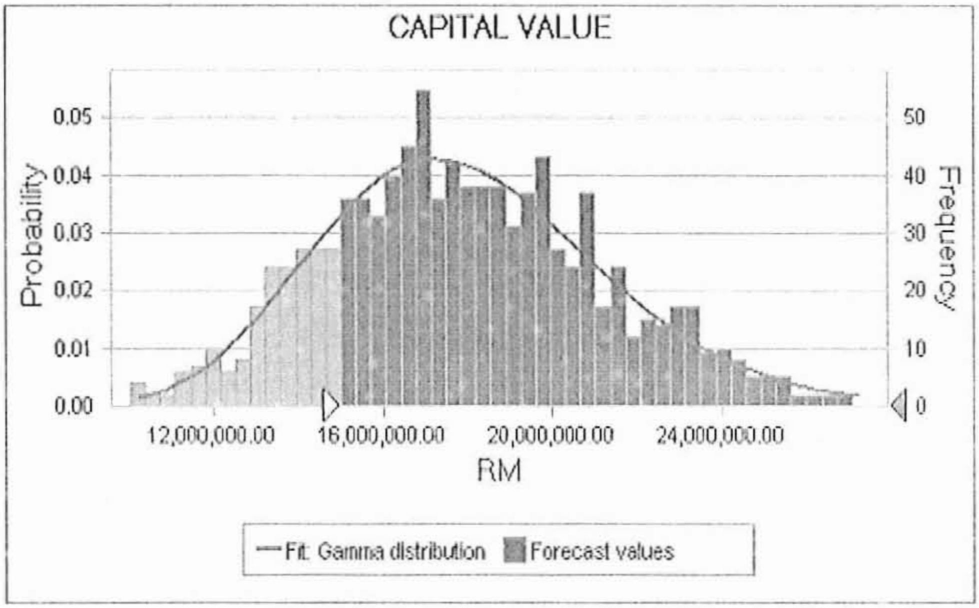
Summary:
Certainty level is 80.8%
Certainty range is from 17,650,513.27 to Infinity
Entire range is from 10,053,050.41 to 32,491,485.70
Base case is 17,650,513.27
After 1,000 trials, the std. error of the mean is 106,120.76

Consider the two situations again with certainty profile at RM15 million of market value.

For **Situation 1** above, assuming that the bank considers to approve the maximum amount of RM15 million to quarry operator. A valuer can be 81.9% certain of achieving a minimum market value of RM15 million as shown in Chart 4. If a valuer can show that a market value can be at least two-third certain of a RM15 million, the bank is ready to release this amount for this concession. In normal application, the valuer usually estimates the Forced Sale Value of the concession as requested by the client as a base for loan determination.

In **Situation 2**, assume the result of negotiation between a potential purchaser and an owner resulted in a minimum market value of RM15 million. If the valuer acts for the purchaser, he should advise that the quarry is worthwhile purchasing since he can be 81.9% certain of achieving a market value of RM15 million as shown in Chart 4.

Chart 4: Certainty Profile (Result For RM15 million)



Summary:
Certainty level is 81.9%
Certainty range is from 15,000,000.00 to Infinity
Entire range is from 10,053,050.41 to 32,491,485.70
Base case is 17,650,513.27
After 1,000 trials, the std. error of the mean is 106,120.76

Analysing the market value forecast again for RM21 million, the valuer can see a certainty level of 50.4% for achieving a market value of RM21 million (as given by the output).

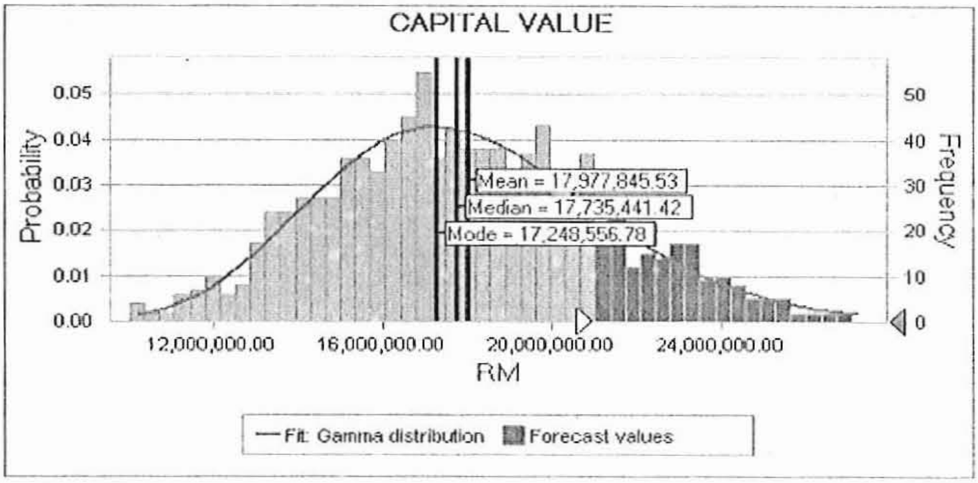
As for **Situation 1**, a valuer could advise the bank not to approve additional amount since the certainty level of this amount is only 50.4%; there is a 49.6% chance of suffering a loss (100% minus 50.4%) if the bank approves at RM21 million.

That means, in **Situation 2**, the valuer can be only 50.4% certain that RM21 million would be the 'correct' market value to pay. On this basis, the valuer can advise the purchaser that the offered amount is too high to be realised in the market.

Conclusions

The authors argue that as clients become more discerning and increasingly sophisticated in their demand, it has become increasingly important to offer greater transparency in valuation advice. Transparency means, among other things, affording to clients an array of analysis outputs in a way that allows him to choose decision in full awareness of the risks involved. Towards this, techniques such as the Monte Carlo simulation are useful and

Chart 5: Certainty Profile (Result For RM21 million)



Summary:
Certainty level is 50.4%
Certainty range is from 21,000,000.00 to Infinity
Entire range is from 10,053,050.41 to 32,491,485.70
Base case is 17,650,513.27
After 1,000 trials, the std. error of the mean is 106,120.76

should increasingly form part of the valuation toolkit. The level of computing power currently available should encourage this development. The technique itself does not replace the conventional valuation methods; it merely serves as an add-on to the capability of the conventional methodologies in the way that enhances their transparency and acceptability in the eyes of the valuation clients.

The superiority of Monte Carlo simulation lies in the fact that it allows the user to simulate a much larger range of possible outcomes compared to other simulation techniques such as scenario or sensitivity analyses, which produce limited number of valuation outputs. With large number of outcomes, the statistical reliability of conclusions is improved. In this way, the Monte Carlo simulation technique assists the valuer in expressing his value opinions with greater confidence.

Monte Carlo simulation is useful as a flexible, explicit and transparent "learning machine", which allows valuers to look carefully at the relationships between the factors affecting the valuation and helps clients look into the market value estimates and understand the risks associated with them. However, it measures only uncertainties that are relevant from the point of view of the valuer but does not provide any mechanism on how to incorporate the observed uncertainty into the estimation of market values.

In the context of mineral valuation, the valuer needs to understand the deposits and mining operations well in order to come to the 'correct' value as a mining industry buyer would see it. If the potential for reserve additions through exploration is present, this can add significantly to the value of the deposit, and should be taken into account. The estimation of the potential reserve is itself a very important exercise from the point of view of the basic input data; admittedly, Monte Carlo simulation has to work within the limitations of the data.

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