

ABSTRACT

Irrespective of the mining method, mining starts with prospecting and exploring for an orebody of economic interest from which geological data is gathered. Using the data, a three-dimensional (3D) model representing the orebody is created. The orebody model is then divided into regularly sized blocks to form a geological block model which is converted into an economic block model by calculating the net economic value of each block called the block economic value (BEV).

An economic block model is a key input for the mine design and planning process therefore, its realistic representation in 3D is important. However, its realistic representation is affected by uncertainty associated with input parameters used to calculate BEVs. It is known that uncertainty is inherent in mine design and planning and introduces risk into the process, something which mine planners must consider and plan for. Nonetheless, despite this known fact, most mine design and planning practices are deterministic including BEV calculation. Deterministic BEV calculation assumes that at the time of creating an economic block model, BEV input parameters are known with certainty, when they are not in reality. This invariably results in an incomplete representation of the orebody which subsequently leads to unrealistic mine designs and plans and subsequently to the destruction of shareholder value. Incomplete information due to uncertainty at the mine planning stage has been, and will continue to be, a challenge for the mine planning fraternity.

To address this challenge, this thesis developed a probabilistic BEV calculation approach that was applied on a synthetic geological block model for a gold deposit. The uncertainty associated with BEV input parameters (rock density, gold grade, gold price and processing recovery rate) was represented using different probability distributions. Density and recovery rate were assumed to follow the normal and uniform probability distributions, respectively. The Geometric Brownian Motion (GBM) was assumed for gold price. Uncertainty in gold grade was first analysed using conditional simulation and then the lognormal probability distribution was used to simulate gold grade. Average mining and processing costs were assumed in the BEV calculation. All these input parameters were then simulated simultaneously in Microsoft Excel using the Monte Carlo simulation method to determine the range of

all possible BEVs for each block under different future scenarios. Five thousand iterations were run and from the simulated BEVs, the probability of each block being positive, hence economic, was calculated.

One of the advantages of Monte Carlo simulation is that it can simultaneously consider the uncertainty of key input variables and generate a probability distribution of the output. Instead of a single deterministic economic orebody model and stope design, multiple possible economic orebody models which incorporated varying levels of risk were created. These models were then used to create multiple stopes and their associated conceptual development infrastructure designs at varying levels of risk. Finally, a simple Discounted Cashflow (DCF) analysis was done to calculate the Net Present Value (NPV) of a few selected designs. The aim of the thesis was to analyse the impact of uncertainty on the size of the deposit and subsequently on stope boundaries and NPV.

The thesis demonstrated that uncertainty in geological and economic factors significantly affect the economics of a mining project. Therefore, the integration of this uncertainty early in the mine design and planning process (that is, BEV calculation) is important to create optimal and robust underground mine designs and plans. The thesis found that as the confidence in BEVs increases, the size of the orebody and life of mine (LOM) decrease, while the average grade of the orebody increases. On the other hand, as probability increases the total economic value of the orebody increases to peak at approximately 50% probability and then starts to decrease. The same trend was observed with the total number of stopes, total stope tonnage, total stope economic value and ultimately NPV. The results also showed that the amount of primary development required remained the same regardless of the confidence associated with the orebody. However, the amount of secondary development required reduces as confidence in the orebody increases. The DCF analysis also confirmed that the design consisting of probability stopes with at least a 50% confidence level (that is, P50 stopes) in terms of economic value and chance of the stope's blocks being within the ultimate stope boundary (P50 design), provided the highest NPV of approximately US\$29 m for the analysed designs compared with US\$19 m for the deterministic design. Therefore, the results indicated that

deterministic BEV calculation underestimated the true potential of the orebody by about 35%.

These results suggest that for any given orebody and after incorporating uncertainty, there is a level of confidence at which the total economic value and NPV of the orebody is maximum. Therefore, the orebody at this level should be used for planning purposes during underground mine design and planning. In this thesis, based on the case study orebody and assumptions made, P50 stopes should be considered for planning purposes.

However, it should be noted that the level of risk hence the optimal range of probability may vary from orebody to orebody depending on probability distributions underlying the input parameters used to calculate BEVs. Also, the ultimate decision on which confidence level to use, may vary from one company to another depending on the perception or tolerance of risk of the respective company. Therefore, it is recommended that actual specific project data be used so that the actual stochastic behaviour of the input parameters used in calculating BEVs is modelled to generate a realistic behaviour of BEVs specific to each orebody being evaluated.