FLEXIBLE OPEN-PIT MINE DESIGN UNDER UNCERTAINTY

B. Groeneveld and E. Topal*

The risk associated with a mining project comes from the uncertainties involved in the industry. Mining companies endeavouring to maximize their return for shareholders make important strategic decisions which take years or even decades to “play out”. However, many mining companies feel comfortable with point estimates of all project parameters but realize that no parameter value is known with certainty. A model that incorporates uncertainties and is able to adapt will help deliver a design with a better risk-return profile. In this paper, a new methodology is developed in order to have a design that is flexible and able to adapt with change. Following recent research on decision making methods in mine planning, this paper develops a mixed integer programming model that determines the optimal design for simulated stochastic parameters. The paper shows how to incorporate optionality (flexibility) in relation to mine, stockpile, plant and capacity constraint options. Obtained results are promising and are helping decision makers to think in terms of value, risk and frequency of execution.

Real options, robust design, uncertainty, flexibility, stochastic simulation, mine design

INTRODUCTION

Mining projects are characterised as being highly uncertain and risky due mainly to the volatile nature of commodity prices, as well as the inherent uncertainty around geological conditions. As risk in the mining project cannot be eliminated, the best that can be done is to minimize it. The uncertainties in mining projects arise from both nature of the variables and cost of obtaining information about them. They can come from many different sources including market prices, grade distribution, ground conditions, equipment reliability, recovery of ore, human capital and legislative change [1 – 4]. The mining industry will be more sustainable if projects were developed in a manner that increases flexibility to respond to uncertainties. For example, the minerals industry in the last decade saw unprecedented demand for its products which lead to a flurry of expansion activity, however no one predicted the global financial crisis which lead to a rapid decline in expansion activity. Had this information been known prior to these events occurring it is likely the path taken would have been vastly different. Being able to design an operation that has flexibility to respond to change quickly should deliver better returns to stakeholders.

Geological uncertainty, e.g. [5, 6], and risk have been incorporated in optimum mine planning and design by a few studies to date. Godoy and Dimitrakopoulos [7] developed a multistage optimization approach, based on a simulated annealing algorithm, for long term mine scheduling under geological uncertainty. In the case study a 28% higher NPV was generated compared to conventional methods, whilst also reducing the risk in meeting production targets. Similarly, a 26% NPV increase was obtained in recent studies by Leite and Dimitrakopoulos [8] by utilizing a variant of the same method. Ramazan and Dimitrakopoulos [9] developed a stochastic integer programming (SIP) model to generate the optimal production schedule using equally probable stochastically simulated orebody models as inputs. The proposed approach minimizes the risk of not meeting production targets as a
function of ore, metal and grade blending. Two applications of this methodology have showing an expected total NPV increase of ten and twenty five percent using a SIP model over a traditional schedule based on single estimated orebody. Leite and Dimitrakopoulos [8] use the same SIP formulation to generate risk-robust solution. The same copper deposit has been utilized in [10] and the stochastic formulation is shown to produce 29% higher NPV than the schedule obtained from a conventional scheduler. Meagher et al. [11] introduced an approach to integrate “block destination flexibility” in the process of assigning value to mining blocks in the planning process via real options valuation (ROV) considering geological and market uncertainties. The proposed approach; firstly assigns a dollar value to each mining block, considering the different aspects of uncertainty and management flexibility. Secondly, it utilizes a minimum cut algorithm to design a lower risk long-term mine plan. Applications of this method to a case study demonstrated significant differences in block value estimates then conventional approaches.

A decision making tool, called “real options “in” projects” (ROIP), has been developed to increase the flexibility of an engineering system under uncertainties. This method is located midway between financial real options analysis (which does not deal with engineering system flexibility) and traditional engineering approaches (which do not deal with financial flexibility). ROIP benefits by being able to adjust the underlying system in response to the resolution of uncertainties over time. Significant research into this method has been undertaken by de Neufville and his colleagues [12] with applications in various industries. A frequently used example to explore the concept of ROIP is that of a multi-story car park. Flexibility in this situation is in the design of the footing and columns of the building so that additional levels can be added at a later date. This flexibility comes at a cost, and the designer must determine if this is warranted [13]. Another example provided by Wang and de Neufville [14, 15] is that of the bridge over the Tagus River in Lisbon, Portugal. The original design of the bridge was ‘enhanced’ by including an allowance to build a second deck above the first. This was achieved by increasing the size of the initial footings. These additions to the design resulted in considerable additional cost. Subsequently the Portuguese government exercised their option to expand the bridge and added a second deck to carry a suburban railroad.

In [13] R. de Neufville implemented this technique into mining projects with a Chilean mine in the “Cluster Toki region. In the paper, a methodology using ROIP is implemented where different operating plans vary by truck fleet capacity and crusher size in response to changing prices. The application of this method resulted in approximately 30 to 50 % more project value than current estimates. Even though this approach provides a strong basis on which to grow ROIP theory for mining, there are several deficiencies in the current model. The approach limits the flexibility up front by initial static scenario construction, fails to deal with variation in ore grade and recovery, and fails to consider options in all stages of a typical mine value chain. Further information about ROIP applications can be obtained from following references [14 – 17].

Groeneveld et al [18] outlined a methodology for a new flexible mine design methodology. Under this methodology options could dynamically be included in the design to represent mining, plant and port constraints. This model was then processed multiple times with each run representing a different ‘state of the world’. The limitations of this model however was; the inability to model multiple capacity constraints in a flow path, lack of flexibility to include multiple circuits in the processing plants, only one product could be produced and only simple network designs could be created (i.e. mine to stockpile or/plant to port). The paper seeks to fix these shortcomings by providing a mathematical model that can incorporate more flexibility, hence incorporate more design options.