



Research article

Valuation of the Sechahoon XI Mine Using a Real Options Portfolio and Linear Programming

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Keywords

Valuation
Open pit mine
Real option portfolio
Mine finite Limit
Linear programming

English Extended Abstract

Summary

Mining projects are considered one of the riskiest yet most profitable areas of investment in the world. The main source of these risks is related to the uncertainty present in geological models, geomechanical models, exploitation operations, mine geometry, crushing and processing, environmental factors, and the economic model, including fluctuations in the final product price and production costs. Improper management of mine production planning will lead to the wastage of natural resources. This research, using a portfolio of real options, seeks to find the best decision that maximizes mining profit. The titles of mining real options are shown in Figure 1. The study of this research focuses on the Sechahoon XI iron ore mine, with the aim of physical optimization of the final pit limit and optimization of management decisions in real options. Modeling in this research was carried out in two separate parts: first, the final pit limit of the studied open-pit mine was optimized and designed using the Lerchs-Grossmann method. Then, the real options model was used for mine valuation using the influence diagram, regression, and simulation method.

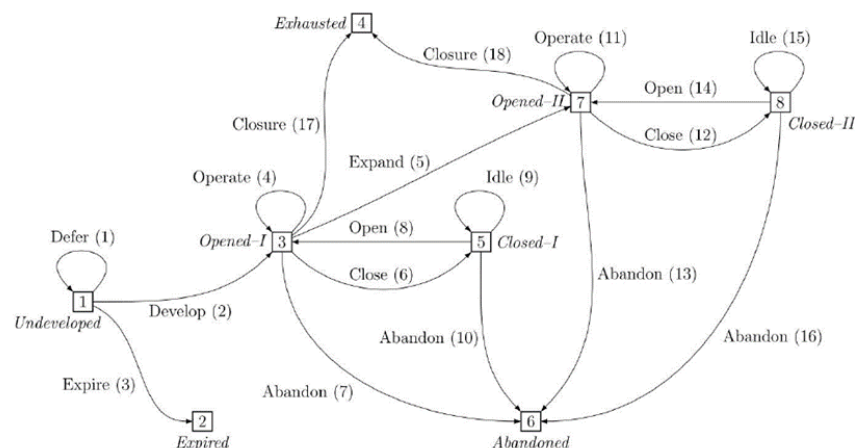


Fig. 1. Influence diagram, regression and simulation of real options.



In Figure 1, the valuation of the mine is shown with a set of interdependent real options. The flexibilities existing in this set of interdependent real options are modeled through an identifier consisting of a graphical part and a numerical part. The graphical part consists of two components: a set of decision nodes, which represent operational states or development stages, and a set of directed edges, which represent the flexibilities available to the decision-maker.

Introduction

In this research, the problem of determining the optimal value of the interdependent real options portfolio is formulated as a multi-stage stochastic zero-one programming. The interdependent real options portfolio uses a set of constraints and a vector of binary variables to model the interdependencies of decisions. The value of the interdependent real options portfolio $G_0(S_0)$, is obtained by solving the following stochastic optimization problem by maximizing the profit function:

$$G_0(S_0) = \max_{(a_t)_{t \in T}} E \left[\sum_{t \in T} e^{-kt} \prod_t (S_t, a_t) | S_0 \right] \quad (1)$$

And using Bellman's principle of optimality, the optimization problem of Eq. (1) can be solved recursively at time t :

$$G_t(S_t) = \max_{a_t} \prod_t (S_t, a_t) + E[e^{-k\Delta h} G_{t+\Delta h}(S_{t+\Delta h}) | S_t, a_t] \quad (2)$$

The initial modeling resulted in three final pit limits for the Sechahoon XI mine. Table 1 summarizes the results, and Figure 2 shows the final pit limit in the base case scenario.

Results and Conclusions

As discussed, this research, using a portfolio of real options, seeks to find the best decision that maximizes mining profit. The results are as follows:

Table 1. Summary of the final pit limit optimization results for the Sechahoon XI mine in three different scenarios

Stripping Ratio	Mineable Reservoirs (Million tons)		Pits	Row
	%	Million ton		
3.7:1	95.5	92	Base Case	1
4.07:1	100	94.8	Optimistic	2
3.25:1	85	80.6	Pessimistic	3

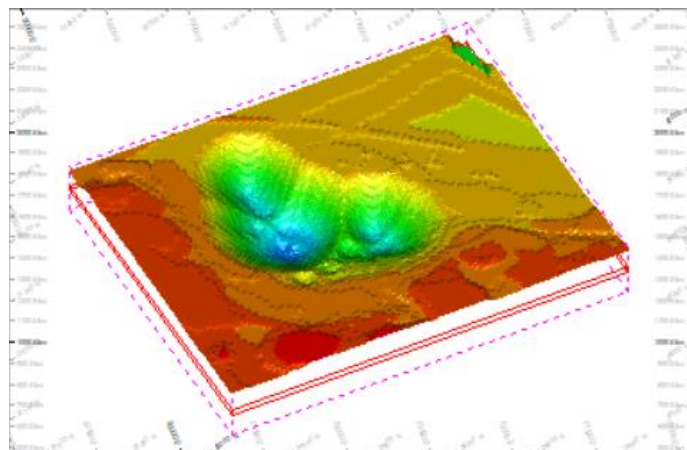


Fig. 2. The final pit limit in the base case scenario.



For each of the three pits, four random factors (mineral price, mineral production cost, risk-free return rate, and welfare return rate) were simulated 100 times and used as inputs to the code prepared in GAMS software. The optimization was based on the integer programming method, using the CPLEX solver, and the path with the highest profit was selected from among 9 to the power of 94 decision paths. Table 2 shows the final profit obtained from optimizing the real options portfolio using the influence diagram, regression, and simulation method for the three designed final pit limits, in two situations: with and without the real options portfolio.

Table 2. Final profit obtained from optimizing the real options portfolio for the three designed final pit limits

Base Case	Optimistic	Pessimistic	Situation
8.804	12.540	5.506	With Real Options Portfolio
6.995	9.652	4.236	Without Real Options Portfolio

As can be seen, the use of the real options method has been able to increase the final profit of each of the designed pits by about 30% without imposing any cost.

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