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Real options decision framework: Strategic operating policies for open pit mine planning

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ABSTRACT

This paper presents a first approach towards the development of a dynamics decision-making tool (DDMT) for open pit mine planning projects. In this paper, a decision framework, the so-called real option decision framework (RODF), is developed based on a real-options approach with practical applicability to a mining investment project. Four strategic operating options namely, deferral options, maintain options, expand options, and shutdown options, are assumed for mining operations. We illustrated the proposed framework and developed methods for a hypothetical gold mine. The standard discounted cash flow (DCF) method was carried out to analyze the project values without options. The real option valuation (ROV) approach was calculated for the deferral and expand options. We used a system dynamics (SD) modeling method to solve real options problems and the discrete-event simulations were used to simulate the potential values of the projects. The findings are that investors are prone to lose an opportunity to invest if relying on traditional DCF-NPV rules as they suggest accepting the project if and only if NPV is greater than zero. However, results obtained from real options suggest that the project has a value to an investor across different time horizons. The insight is that it is of paramount importance to find an optimal time to exercise a strategic option. It is indicated that strategic options such as the deferral option may yield a higher value than the base case (DCF-NPV) mine option because project risks can be hedged, whereas the expand option may also offer additional value to mine operators. However, such extra-additional values can only be captured through managerial flexibility.

1. Introduction

Mine planning is a difficult task. Even for small operations, it involves reasoning with complex variables and the practical difficulties of mining. It is also about predicting and planning the future in an unpredictable physical of economic environments. Planning affects everyone in the organization. Company executives demand more reliability and stability in cost and revenue forecasts from their operations. Management wants to explore ways of being more cost-effective. Miners and contractors need useful plans and realistic targets. Planners have to describe the method that will translate business into implementable plans (Varenfdorff, 2003). A decision making process involves formulating options, predicting their outcomes and evaluating these against some objectives of company. This process is regularly repeated until either the objective is met or there is no more time to consider more options or refine existing ones.

The real options method builds upon the core concepts of option pricing theory (OPT), and Contingent Claim Analysis (CCA), which were developed for the assessment of future price of securities in stock markets. A key concept of ROV is that it is an asymmetric derivative; this means that to acquire an option, one must pay a premium upfront, including a future expense if the option is exercised. Brennan and Schwartz (1985) published the first pioneering paper applying real options to value copper mines. Since then, numerous authors have extended the concept to many areas of study (Azimi et al., 2013; Kulatilaka, 1995; Longstaff and Schwartz, 2001; McDonald and Siegel, 1985; Samis et al., 2006; Samis et al., 2007). Recently, interesting research yielded findings that the traditional DCF method is inadequate for assessing the economic value of capital-intensive investments (Dimitrakopoulos and Sabour, 2007; Dixit and Pindyck, 1995;

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Frimpong and Whitting, 1997; Hamphrey, 1996; Mun, 2002; Moyen et al., 1996; Mardones, 1993; Rigby, 2001; Sinan and Erzurumlu, 2014; Slade, 2001). In essence, in a standard DCF method, two concepts of investment indicators are used, namely the net present value (NPV) and the internal rate of return (IRR) Kazakidis (2001). In this context, cash flows are assumed to be known and the investment costs are spread over the entire operation time period. Hence, the cash flows are like payments for a loan and the IRR is like a borrowing rate; therefore, the lower the IRR, the better. However, the IRR can change over time since costs and prices may be beyond an ability to predict. Hence, wrong investment decisions may occur or unexpected business failures may happen. Many researchers include Barghav and Ford (2006); Behrang et al. (2014); Grobler et al. (2011); Gudinho (2006); Huh et al. (2006); Koushavand et al. (2014); Putten and McMillan (2004); Dixit and Pindyck (1994); Paddock et al. (1988); Singh et al. (2012); and Trigeorgis (1996), have performed ROV to evaluate values of the energy and the mineral resources investment projects. Sontamino and Drebenstedt (2013) developed decision supported systems for evaluating the feasibility to open a coal mine project in Thailand. Inthavongsa et al. (2015) proposed concepts and a prototype of real options valuation framework. Martinez (2009) suggested that it is of paramount importance to do more research to develop new tools that can account for uncertainty and risk in mine project evaluations. Cox et al. (1979) developed binomial methods to valuate values of the financial options. This method uses the multiplicative process to replicate the stochastic process of the partial differential equations (PDE) of Black-Scholes's. Brandao et al. (2005) enhanced the binomial methods by adding decision nodes into lattices, which he called the binomial decision tree. Johnson et al. (2006) discussed the contribution of the SD application to extend ROV for the energy sector. They claimed that using SD could address some key challenges in ROV and increase the use of ROV in industries, while exposing SD to new audiences. Richardson and Meyers (2008) discussed on understanding the dynamics of complex systems for the purpose of policy analysis and design. Ford and Sobek (2005) applied SD to investigate the use of options among multiple product designs during the development of projects to assess their values. Cooke (2004) used SD to model stochastic prices, and two-factors mean reverting behavior, and the famous Black–Scholes's differential equations. Cooke (2004) stated that “to show how many of the complex price processes that have been researched by scholars in Finance can easily be translated into system dynamics models.” Carol and Feniosky (2009) integrated ROV and SD to study the effect of different resolution strategies on the value of the investment of the construction projects. Tan et al. (2010) incorporated SD into decision tree analysis, which they called SD-based decision tree approach, for valuing economic value involved managerial flexibility of the alternative energy sectors. Kasiri and Sharda (2013) used SD and ROV to value the IT investment decisions. Yet, it is clear that, so far, little research on the incorporation of ROV into SD methods has been done. In fact, this lack of research must be overcome to improve the evaluation of mining projects. So far, no study has developed dynamics decision-making tools that can account for uncertainty and risk in open pit mining projects.

Typically, mining consists of five phases: (1) prospecting, (2) exploration, (3) development, (4) exploitation, and (5) reclamation as depicted in Fig. 1. Any decision to proceed from one to the next stage requires a detailed study to ensure that the mineral deposit is worth the investment. A traditional feasibility study is generally carried out after a detailed exploration confirms an economically mineable potential of the ore reserves. The result of this techno-economic evaluation allows mine operators to decide on whether to ‘accept’ or ‘reject’ the project. However, this traditional framework assumes that any decision from stage-to-stage is a one-time-decision with no interruption from exogenous influential factors. This is seemingly not realistic, especially when management owns the rights to make a recourse decision based upon the development of investment opportunity during the mine lifecycle. The paper provides the fundamental linkage of option pricing theories to value the mineral resource investments. It uses a stochastic process analysis for a real options based approach and system dynamics. In addition, a new proposed paradigm ensures a solid valuation of a project by sequencing each mining phase into strategic options. For these, their values can be calculated with a technique which is simple to understand. The remainder of this paper organizes as follows: in Section 2, we present the concepts, framework, and the proposed strategic operating policy models. In Section 3, we describe the core concept of SD method in cooperation with ROV approach. In Section 4, we hypothesize a case study to demonstrate the developed methods. In Sections 5 and 6 we explain results obtained from simulations, and discuss the key findings, respectively. Section 7 contained conclusions and highlights future works of this research.

2. Methodology

In this section, we provide the methods that are developed in this study. Firstly, we constructed the decision framework based upon the basis of the ROV approach; the so-called real options decision framework (RODF) along with the valuation algorithms. Then we developed the strategic operating policy, mine inventory models and the stochastic price models. In this paper, the strategic operating options are interchangeable, which offers flexibility for a mine to start-up, manage, and operate its operations under predefined conditions. The DDMT being developed in this study will incorporate the RODF, evaluation algorithms and decision-making criteria into computer applications. The system dynamics software, Vensim® DSS6b, was used to develop models and to simulate the value of alternative operating policies. This software will be used to develop the DDMT for the end-

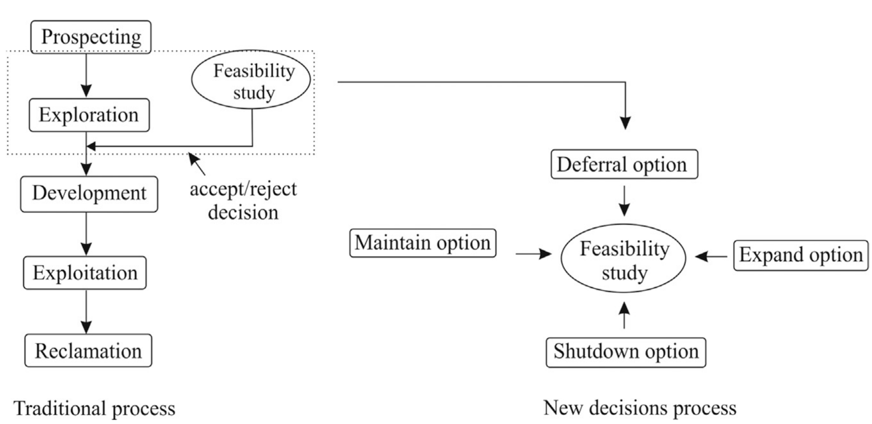

Fig. 1. Proposed new decision process.