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Real option in action: An example of flexible decision making at a mine operational level

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ABSTRACT

Flexibility and operational adaptability are essential for long term corporate success and real option (RO) appears suitable for analysing risky projects. Nevertheless, its application in engineering design has been slow-moving compared to financial uses. Therefore, there is a compelling argument for using visual, intuitive and transparent models, such as the binomial decision tree, which has the potential to eliminate decision maker apprehension and improve RO use in engineering design and decision making. This paper reviews RO applications in mining projects and proposes a new methodology to explore technical applications of RO in mine design and decision making at the mine operational level. The research will investigate the suitability of using the RO method at the mine operational level where production decisions are made frequently, rather than organisational strategies that are reviewed after several years. The proposed approach is applied to a case study. This will demonstrate how RO can be used in designing multiple pits in multi-zone ore deposits to create a switching option between pits regarding changing ore grades and fluctuating commodity prices. The main rationale of this option involves deferring waste materials by switching mining activities from a high to low strip ratio pit. This creates a choice between using new RO thinking and the traditional methodology. The option is analysed using the binomial decision tree. The results summarised in this paper's conclusion reveal that the project's value increased considerably when flexibility was included in the mine design. These increases in project value were between eight to 15 per cent, depending on the number of flexible options incorporated into the design.

Introduction

The mining industry is one of the riskiest sectors when compared to other industries. A skilled team, courage and an optimistic view are required to attract financial investor support for mining projects. Most natural resource investments are irreversible, implying that if a firm has made a commitment to finance a mine, then it will be difficult to wind back that investment (Martinez and McKibben, 2010). Investors and managers normally face a dilemma regarding whether to continue with the mining investment when the commodity market is worse than expected, or simply forgo the capital already invested and discard the project. Considering the amount of capital investment required to develop a mine, the above choices are not easy for managers to make.

Engineers and project managers involved in the mining industry resort to, and make use of, the unique advantages the mining sector has over other industries. It takes a number of years from the commencement of an investment to the actual production of saleable ore product (SOP). This can range from between three to seven years, providing an opportunity to gather more information and make informed decisions. Most people involved believe that the best way of doing this is to use the real option (RO) approach (Topal et al., 2009.). This describes the possibilities a firm has, allowing the world to be opened up as a map of opportunities (Edelmann & Koivuniemi, 2004). The methodology is used to justify an increase in system flexibility under uncertainty (Groeneveld et al., 2010).

Despite an ever-increasing level of uncertainty, most corporations make their financial decisions based on discount cash flow (DCF) methods, such as net present value (NPV) and internal rate of return (IRR), which are static. Economists have long recognised that possible future events can cast shadows on the present. Any future value must be discounted down to the present to be comparable to any current price (Adelman & Watkins, 1995; Topal, 2008). Production planning and design would be easy if variables like price or ore grade followed a known value. Methodologies such as linear programming (LP), mix integer programming (MIP) and the heuristic method commonly used in

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engineering design (and especially in the mining industry) can also be used to model flexibility and maximise a project's NPV, based on the assumptions of the DCF analysis (Akbari et al., 2009).

Guj and Garzon (2007) have argued that techniques such as the modern asset pricing (MAP) model provide minimum risk-adjusted value (floor value). This is better than the DCF model, but falls short of the RO method. de Neufville (2003) developed the value at risk base RO valuation to propagate systems thinking and flexibility in engineering design; this is known as an RO ‘in’ system (de Neufville, 2003). Flexibility in design has significant value creation and the potential for radically changed economic risks in design-embedded ROs, reducing the overall investment required (Hassan et al., 2006; Kalligeros, 2010). This was noted earlier by Zhao and Tseng (2003), as an expected pay off of the option. Neely and de Neufville (2001) summarised valuation of ROs in five phases: setup, analysis, financial perspectives, technological perspectives and sensitivity (sensitivity analysis of the key assumptions). A follow-up study, conducted by Kalligeros et al. (2006), introduced an algorithm for qualitative identification of platform components at multiple levels of system aggregation among variants within a family system. The shortcomings of this method include the assumption that the architectural concept and functional requirements for variants are predetermined. This supposition is not always true in many scenarios of the initial design stage. de Neufville et al. (2009) demonstrated that the RO ‘in’ system design states the following: 1) the major requirements of the system are partially unknown; 2) the future is uncertain; 3) there is value in having the right (but not the obligation) to react to future development; 4) forces that lead to engineering design-fix assumptions are identifiable and 5) the derivers of values like demand are outside engineering previews.

Kim (2010) proposed a model to determine the optimum timing of projects by using ROs that focus on ownership ratios, synergy effects and payment options. This approach is an RO ‘on’ system, without any technical design involved, and is similar to the dynamic DCF analysis studied by Herbelot (1994) regarding coal-fired power plant projects. The greatest issue at present is not to prove that ROs increase project, but to apply RO at the ‘operational level’, particularly in the mining sector, where projects constantly face uncertain futures.

The special characteristics of any mining project are the high levels of uncertainty in ore grade estimation and the volatile fluctuations in commodity prices (Groeneveld and Topal, 2011). Moreover, there are myriad risks and uncertainties associated with individual operations. Some of these uncertainties stem from the industry itself, and the operating environment, as well as the geopolitical factors of the host country. As outlined by Kazakidis and Scoble (2002), the main uncertainties of any mining project can be categorised as either exogenous, endogenous or a combination of both. Those uncertainties that fit into both major categories are shown in Table 1.

Regardless of these known uncertainties, the mining sector has continued with a DCF analysis that is rigid and ignores future values of the information. DCF works on fixed assumptions and disregards the notion that situations do change. Groeneveld et al. (2010) and Dimitrakopoulos and Abdel Sabour (2007) acknowledge that RO ‘in’ projects can be used to quantify system flexibility under uncertainty. The mining sector currently uses a ‘just in time’ production system, which requires that ore is exposed only when prices are high (Archambeault, 2007). The RO paradigm requires that a flexible design can be used to determine parameters such as cut-off grade, production rates and when to mine certain sections of the mine in relation to challenges posed by commodity price fluctuations and uncertainties in ore reserves.

Unlike past studies that have focused on the strategic application of the RO approach, this research centres on using RO in design and decision making at the mine operational level. A literature review has indicated very limited studies in this area. Therefore, it is envisioned that this article will highlight and contribute to opening up new research frontiers into RO applications at the operational level. Results from the case study show the clear advantages of using the proposed method in handling project risks at the operation level.

Table 1
Uncertainty categories in the mining industry (Originally presented as a diagram by Kazakidis and Scoble, 2002).

Uncertainty sources in mining projects	
External (exogenous)	**Internal (endogenous)**
• *Market prices* • *Industrial relations* • *Legislation/Regulations* • *Political risks* • *Government policies*	**Operating** • *Grade distribution* • *Ground-related* • *Equipment* • *Infrastructure* • *Recovery method*
	Other • *workforce* • *Management/operating team*
• *Environmental and societal issues*	

How do mines become flexible at the operational level?

All mining companies, whether at the strategic or operational level, aim to identify development and production activities that maximise the net present value. The main value creation centre for a mine's commercial viability is its operational level. This objective can be achieved or neglected, depending on the proposed engineering design and how the mine has been planned. Introducing flexibility into mine's operations is something that cannot be created simply when the mine is in production; rather, it starts at the feasibility study stage. Depending on the ore reserve, geological characteristics and the size of capital investment required for building the proposed mine infrastructure, mine planners analyse various options for mining the ore. This follows recognition that capital expenditure can be used for developing either inflexible (conventional mine design) or flexible stage-based mine design to access ore development. Identifying sound operating strategies that take advantage of the ore body's geological structures—such as scaling down a high-cost stage in response to a fall in mineral prices—can determine the mine's survival during tough times. Three common options are used by mine planners to identify these strategies, but they are normally ignored in favour of traditionally created open pit shells using algorithms such as Lerchs–Grossman (L–G):

- Design multiple pits in multi-zone ore deposits to create a switching option between the pits in regard to changing global situations. The main rationale of this option involves deferring waste material by switching mining activities from high to low strip ratio pits. This creates choice between the RO approach and the traditional method, which is to mine the ultimate pit shell without flexibility in accordance with industry-established practices that maintain the status quo.
- Pre-strip pits that are not planned for mining at the present to expose the ore, creating an expansion option in response to high prices or high demand.
- Design multiples pit entries and develop pit auxiliary infrastructure, even though there are no plans to mine the pit