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MINING EQUIPMENT SELECTION: THE PROBLEM OF CHOICE BETWEEN FLEXIBILITY VERSUS SCALE

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ABSTRACT

The replacement of equipments is very important in the mineral industry due to several reasons: 1) the value of equipments and machinery is high if compared to other industries; 2) many of these equipments have a specific use; 3) high risk exposure to few suppliers; 4) others.

The common practice in the mining industry has been the choice of larger models in the search for reducing the operating cost, although this is at a substantial increase in capital cost. This strategy can be justified in terms of the simple net present value (NPV) of costs, but it ignores an important point: as equipments become larger and larger, operating cost can go down, but managerial flexibility to adapt to new market and operational realities such as high fixed costs, need of special roads, high break-even point of production, etc is reduced.

The, we have to balance our decision between saving operating cost versus potential gains from keeping alive flexibility. In order to analyze the choice between flexibility versus scale we use real option theory. The model is applied in a simplified fashion to the problem of selection of off-road trucks for large-scale mine operations.

According to the traditional NPV under certainty, the optimal choice is the selection of that alternative that presents the lowest NPV of costs. On the other hand, under presence of uncertainty, in many cases managers should choose lower equipments because of their flexibility to adapt to the new market conditions despite of their higher operating cost.

These results confirm what is intuitive of many managers in mineral industry: "*it can be more important keep alive the managerial flexibility to face the future uncertainty than short-term savings due to economics of scale*".

Key-words. Equipments, mining, investment, real options, scale versus flexibility.

1. THE PROBLEM OF SELECTION OF MINING EQUIPMENTS

The iron mining industry has presented a strong growth over the last years. However, we know from macroeconomic theory business evolves over time in cycles and many researchers believe we are now in a cycle of expansion of the mining industry, especially because of increasing demand from China and India, apart from those traditional consumers such as Japan, USA, etc.

There is no doubt this expansion cycle will end. The problem is: when? When will the increase in demand of mineral commodity? Will it continue for the next decade? What is the impact of these uncertainties in the selection of mining equipments today?

Apart from these concerns, there are many other important variables to be considered in the selection of equipments:

- Type of material to be mined (hard, soft, abrasive, etc);
- Scale of production over the time (high, low, random, etc);
- Irreversibility of investment in specific equipments and machinery;
- Dependency of the technology of each suppliers;
- Others;

In general, if capacity of equipment is too low, there is a potential to loose profits if demand is high. But, if management invests in equipment with larger capacity there is a risk of losses in case of downturn in demand. Then, there is a tradeoff between expectation of losses versus expectation of gains.

This is the case of the selection of off-road truck used in ore transportation in most mining operations. A larger truck will require wider roads, higher volumes and, higher capital investment[1]. But, under these conditions, its operating cost is much lower. A small truck has a higher operating cost, but allows more flexibility – for example, small trucks can be used to transport ore from different benches.

If there is no uncertainty, the choice is classic: choose the equipment with the lowest Net Present Value (NPV) of cost over its entire life. But, if there is uncertainty, the choice depends on the strategic value of flexibility to overcome downside of uncertainty and take advantage of its upside. Then, the choice depends of balancing short-term savings due to economics of scale versus potential value of flexibility to prevent huge losses.

In this paper, we will present a simple model to analyze the problem of choice between economics of scales and value of flexibility. This model is applied to a simple numerical problem, but can be extended in order to solver much more complex real life problem of mine managers.

2. THE MODELING OF REAL OPTIONS IN MANAGEMENT OF SELECTION OF EQUIPMENTS

The classical problem of equipment selection and/or replacement depends basically on deterioration over time and failure at work, as discussed in most textbooks on engineering economy such as Brealey and Myers (1992) and Gentry and O'Neil (1985).

The problem of equipment selection[2] has been based solely on static cash flow analysis, but there are many problems with this model such as:

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[1] A problem that is currently faced by ore mining companies is with the supply of tires for large equipments because there are few suppliers. In case of small equipments, there is a competitive industry to deliver peaces and services.

[2] Traditionally, the choice depends on two components: the present value of operating cost during one year and the present value of the investment in new equipment plus operating cost during its life.

- It does not consider the uncertainty in many components of cash flow such as demand, commodity price, operational cost (opex), among others;
- It ignores the value of managerial flexibilities in order adapt the project to new market realities – for example, in case of price reduction, possibly management will have to contract production, close operations, etc and this real option has value;
- It ignores the value of new information that is gained from operations, that is, as new values of grade are revealed management by using larger or even smaller equipments.

A model to consider all these uncertainties is complex. Instead, just to show up some aspects of problem of flexibility versus scale we consider that ore demand (D) is uncertain and oscillates over time as binomial process of Figure 1.

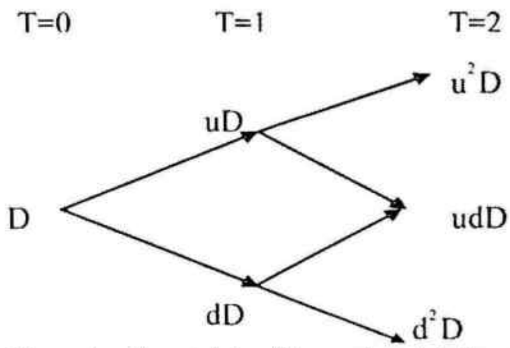
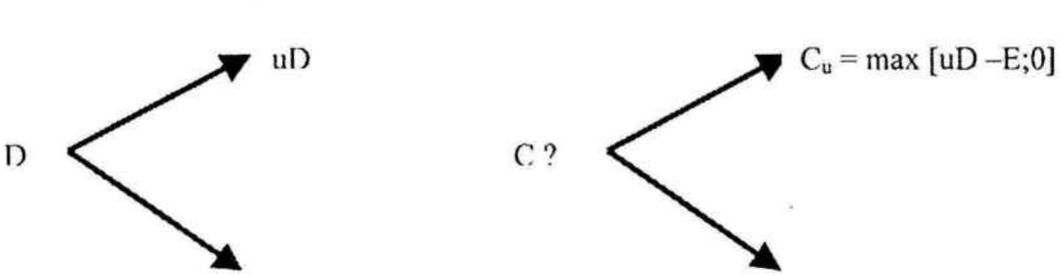


Figure 1 – Uncertainty of demand modeled as a binomial process

In time zero, the demand D is know, but at time 1 it will be unknown, since it can jump to uD or drop to dD, where, $u > 1$ and $d < 1$. At time 2, again demand can increase or decrease, and so on. The model of Figure 1 has a number of interesting properties: i) as the time period increases, in one extreme demand grows to infinite and in the other one it approaches zero; ii) at any time, the demand will be a random variable with a lognormal distribution; iii) the volatility of demand is constant over time.

The modeling of demand is the first step in our problem of valuation of the managerial flexibility to use larger equipments in case of strong demand and small ones in case of week demand[3]. This problem can be analyzed using the theory of valuation of financial American call options. An American call option is contract that gives to its owner the right (not obligation) to buy an asset by paying a pre-specified exercise price. This is similar to investment decision where the exercise price is the investment (or cost) and underlying asset is the present value of cash flow (profits or costs).

In order to receive cash inflows from demand, corporation has to invest in capacity of production. Consider C_0 the value of option at time zero, demand is D and that investment is E – in the language of option pricing, D is the underlying asset and E is exercise price. At a particular time, the value of investment options (C) is: C = max [D – E; 0]. If the demand goes to uD, the payoff is: C_u = max [uD-E;0) and if demand goes to dD the payoff is C_d = max [dD-E;0], where E is the exercise price. This situation is shown in Figure 2.



[3] This flexibility to exchange size of equipments has a cost because in order to make use of it mine companies have to engage strategically and à priori in long-term contracts with suppliers. This can explain at least in part because today some companies have problem in buying tires whereas others don't.

Figure 2 – Modeling of the oscillation of the underlying asset in a single period

The value of the investment option (Cu and Cd) in time 1 is known because we have an estimation of underlying asset. But, the value of call option in time zero (C) is unknown. By using the theory of absence of arbitrage, Costa Lima, Suslick and Schiozer (2007) shows that the value of the option in time zero is:

$$E[C_0] = \frac{C_u\left[\dfrac{(1+r)-d}{(u-d)}\right] + C_d\left[\dfrac{u-(1+r)}{(u-d)}\right]}{(1+r)} \qquad (1)$$

Where:

- u and d are parameters that can be estimated, for example, from historical data of demand;
- r is the risk-free interest rate,
- Cu = max [uD – E;0] and Cd = max [dD – E;0];

From equation (1), we can define the risk-neutral probability (p):

$$p = \frac{(1+r)-d}{(u-d)}. \qquad (2)$$

This model of option pricing is standard in the financial literature. For more details about the derivation of these equations, the reader is encouraged to consult Cox and Rubinstein (1985), Copeland and Antikarov (2002) and Costa Lima, Suslick and Schiozer (2007).

In order to value these flexibilities, at each time managers must choose the best between two mutually exclusive alternatives: i) implement the decision immediately and receive the value (D-E); ii) wait for one more period and receive the expected value of the option in the future. We will apply this model to analyze the problem of choice between flexibility versus scale.

3. A SIMPLE EXAMPLE OF ANALYZING THE PROBLEM OF CHOICE BETWEEN FLEXIBILITY AND SCALE

In this section we analyze the problem of choice between large and small off-road trucks for mine operations. Our first assumption is about capex (capital expenditure) and opex (operating cost) of trucks of both sizes. The general cost function:

$$C = capex + opex^{*}Q, \qquad (3)$$

where capex is the capital expenditure, opex is the operating cost and Q is the production. For this case, we consider assumptions of Table 1.

Table 1 – Assumptions about costs of two size trucks

Type of trucks	Capex fo the fleet	Opex
Small	50	4.0
Big	100	3.3

Note that capex of small trucks is lower, but its opex is much higher. This implies that for some interval of production management will choose small trucks whereas for other interval management will choose large trucks. This model is shown in Figure 1.

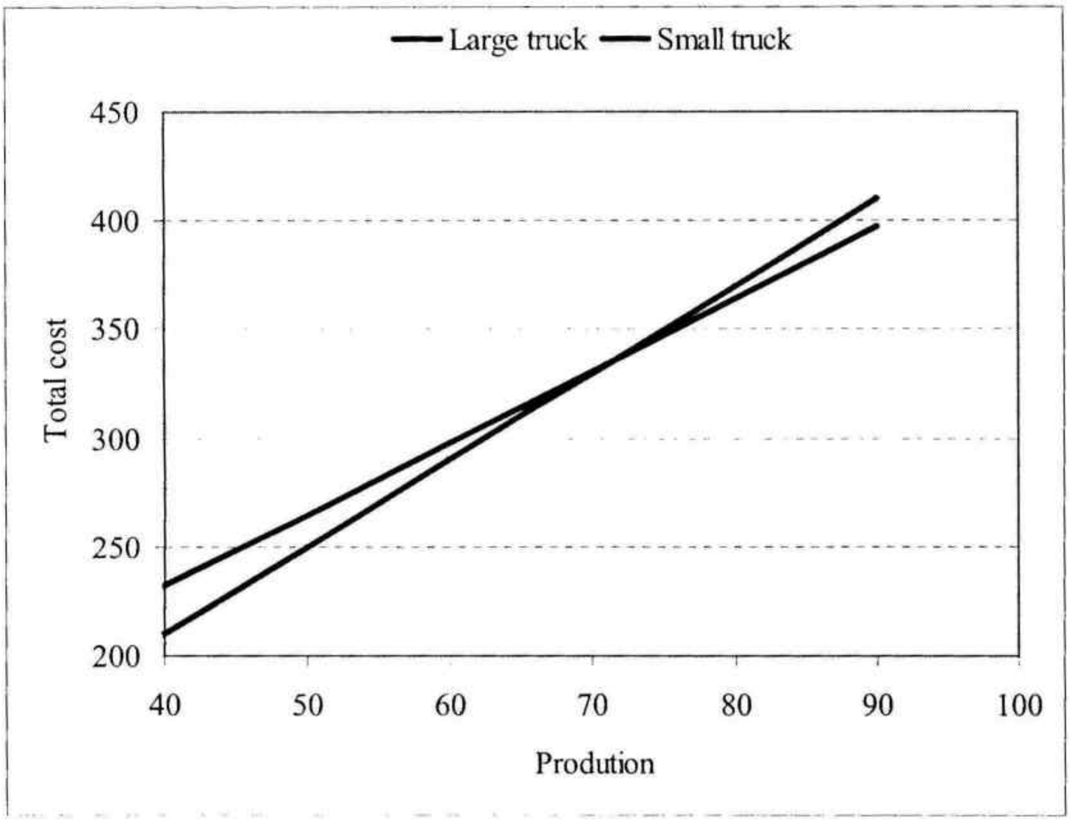


Figure 1 – Behavior of total cost of large and small trucks

In Figure 1, we see that if production is 71.4 units management should select large trucks, whereas if demand is lower than 71.4 units the optimal choice is for small trucks. In case of certainty, the choice is simple. The problem is that future is uncertain and we don't know when we will have the real option to choose small or large trucks.

In order to give more realism to this example, we assume that expected demand is 50 million tones per year, but it can oscillate over time according to a GBM with yearly volatility equal to 25% ($u = e^{0,25} = 1{,}289$ and d= 0,779). Then, the dynamics for three years of demand is as shown in Table 2.

Table 2 - Modeling of the ore demand over time

2006	2007	2008
50.00	64.20	82.44
	38.94	50.00
		30.33

In year 2006, the demand is known and is equal to 50 million tones, but from year 2007 on it is unknown and can go up by 28.4% or down by 22.1% and this process goes in this way until year 2008.

Next we estimate the total production cost for large and small trucks, considering that whatever the type of truck we choose it will work forever. If we choose the fleet of large trucks, the cost will be as shown in Table 3.

Table 3 – Estimation of operating cost of the fleet of large trucks

2006	2007	2008
265.00	311.86	372.04
	228.50	265.00
		200.08

The result of Table 3 is derived from considering opex of large truck and ore demand shown in Table 2. Note that the operating cost in 2006 is known, but in 2008 it can range from $ 200.08 million up to $ 372.04 million.

On the other hand, if we choose fleet of small trucks, the operating cost will be as shown in Table 4.

Table 4 - Estimation of operating cost of the fleet of small trucks

2006	2007	2008
250.00	306.81	379.74
	205.76	250.00
		171.31

If we compare results from Table 4 with those of Table 3 we see that if demand is low, say, 50 million tones per year, then operating cost of small fleet of trucks is $ 250 million whereas the operating cost of the fleet of larger trucks is $ 265 million. But, if in year 2008 demand goes above 71.4 million, than the choice of the fleet of larger trucks is much better.

The problem is that we don't know if demand goes up or down and in this case management must take opportunity of real options of adapting the haulage fleet according to the oscillation in demand and this flexibility has value.

In order to value this flexibility, we have to use the real option pricing approach. We consider that the risk-free interest rate is 5% and that volatility is 25%. In table 5 we present results of the valuation of operating cost considering that management can exchange the type of trucks as long as necessary.

Table 5 – Estimation of the operating cost of the considering the real option to exchange fleet

2006	2007	2008
243.34	300.48	372.04
	203.38	250.00
		171.31

From Table 5 we see that if demand is year 2008 is high, the optimal choice is the large fleet of trucks ($ 372.04 million), whereas if demand goes down the optimal choice will be fleet of small trucks.

After working backwards, using the risk-neutral approach, we find that the value of operating cost in year 2006 is $ 243.34 million. Note that this value is much less that if we use only the fleet of large trucks. In this case, the value of managerial flexibility to change the entire fleet of trucks is $ 21.66 million. On the other hand, the value of flexibility related to rigid use of small trucks is $ 6.66 million.

In practice, the value of the real option to exchange fleet of trucks can be used, for example, to value a contract of preference of buying equipments in the future from manufacturers. Note that value of flexibility is around 8.17% of the total operating cost of large trucks and this total cost can be reduced simply if management makes use of real options correctly as opportunities appear over the life of mine.

The value of flexibility is dependent on the level of uncertainty in the future, which is quantified in the model by volatility. In Figure 3 we show a picture of the value of flexibility to exchange transportation fleet compared to a single type of transportation.

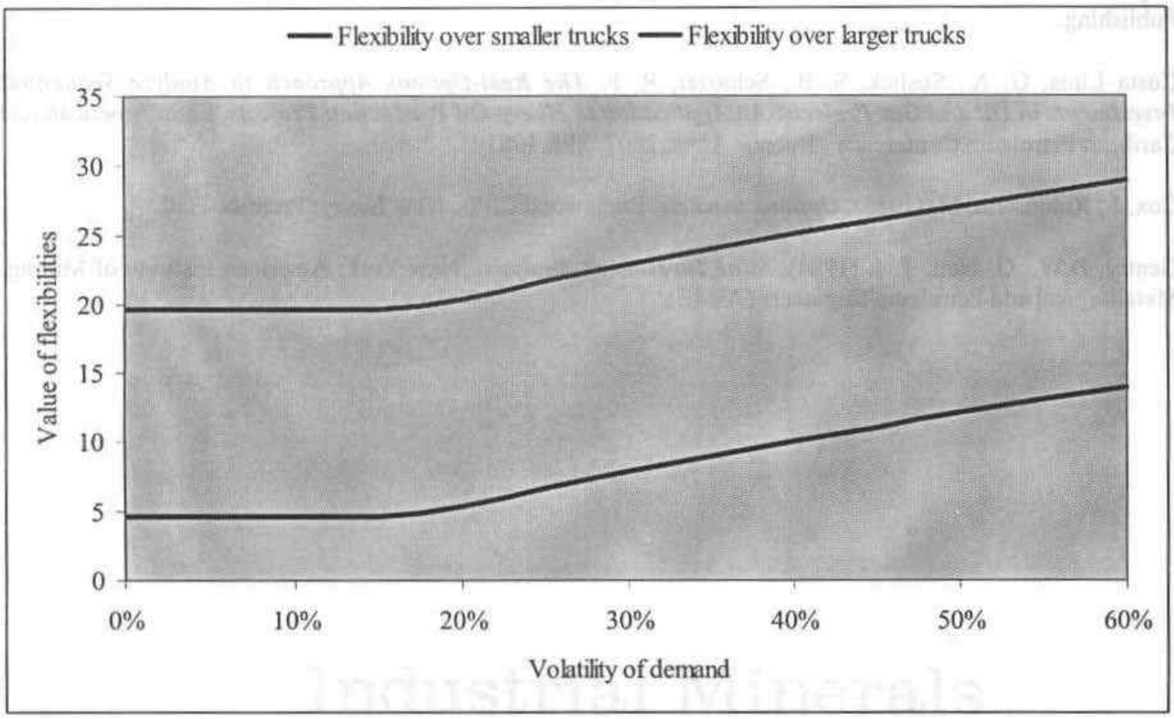


Figure 3: Sensitivity of value of flexibility to uncertainty in demand of ore

Note that an increase in uncertainty over the future demand increases the value of flexibility. This is easy to understand: if future demand is uncertainty, then the flexibility to exchange from fleet of large to small trucks (and vice-versa) is what can redirect the projects towards maximization of its return.

This assumes that managers can freely exchange from small-to-large-to-small trucks what is not realistic in most cases. This model can be extended to accommodate such situations and become an important tool for managers in the mine industry.

5. REMARKS

In this paper we have discussed the problem of the choice between flexibility and scale for a simple example involving the selection of small and large trucks for mine operations.

We found that the value of flexibility to exchange from large to small fleet is $ 21.66 million and the value of flexibility related to rigid use of small trucks is $ 6.66 million. These values could be used in order to value, for example, a contract of preference in the supply of trucks.

Finally, we found that if the uncertainty in demand increases, than the value of flexibility also increases. This has a very interesting managerial interpretation: as long as uncertainty is high, buy flexibilities to survive in the future.

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