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**AN ANALYSIS THE EFFECTS OF CHANGES IN PRICE OF
METAL AND OPERATING COSTS TO THE PROFIT IN
EXPLOITATION THE COPPER ORE DEPOSITS, A CASE STUDY:
COPPER MINE MAJDANPEK, SERBIA*****

Abstract

Mining is the process of extracting a naturally occurring material from the earth to derive a profit. Whether the company make a profit or not depends on many economic parameters, among which the most important are the metal prices on the world market and realized operating costs in the process of exploitation. This work presents the influence of copper price change and value of operating costs on the generated cash flows, i.e. profit, in the case of the open pit South Mining District, which operates within the Copper Mine Majdanpek, Serbia.

Keywords: metal price, operating costs, profit, Copper Mine Majdanpek

1 INTRODUCTION

The design and scheduling of the open pit mines is a significant and complex problem in mine planning. The principal aim of a mining operation is to ensure that an ore body is mined in a way such that the value realized from the mine is maximized.

Profitable exploitation of the mineral deposits requires a certain economic assessment and planning of exploitation. First, it must be determined which part of the deposit is economical for the mine (mineable reserve) and what methods of excavation can be applied under the given

conditions. The next step is defining the final limit of the open pit and mining dynamics of the mineable ore reserves. Finally, a DCF analysis is performed. The aim of these efforts is to determine the most profitable excavation plan and the highest rate of return of invested funds. These activities are carried out in the field of long-term planning or strategic planning. Planning an open pit can be explained in a series of steps, each preceding the next, as shown in Figure 1.

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Figure 1 Steps in planning an open pit

Market scenarios are often explored, usually in terms of an upside and downside case for metal prices. Metal prices arguably have the largest impact on project valuation, and an impact on what the optimal operational plan will be.

Also, the operating costs have a significant role in achieving the maximum cash flows during the life of ore exploitation at the open pit.

2 PRICE-COST RELATIONSHIPS

The revenue to the mine every year depends upon the tons of concentrate produced and the price. The costs to the mine on the other hand depend upon the amount of material mined and processed [1].

If one assumes that K tons of concentrate are produced every year, then the yearly revenue depends directly on the price received for the product.

A large capital investment is required at the start of the mining. As will be discussed later this must be recovered from the yearly profits. If the yearly profits are not as expected, then the payments cannot be made.

Therefore it is important that the price projections or price forecasts be made covering at least the depreciation period (that period in which the investment is being recovered). The operating cost can be reported by the different unit operations: drilling, blasting, loading, hauling and other. The “other category” could be broken down to include dozing, grading, road maintenance, dump maintenance, pumping, etc. Some mines include maintenance costs together with the operating costs. For analysis it is also necessary to define the direct and indirect costs incurred in concentrating, smelting, and refining metal.

There are certain costs which are regarded as the ‘fixed’, or independent of the production level. The other costs are ‘variable’, depending directly on production level. Still other costs are somewhere in between.

3 MARKET METAL PRICES

In order to reduce uncertainty about the correct assessment of the metal price on the market, three deterministic approaches are often applied:

- technical approach,
- fundamental approach, and
- combination of technical and fundamental approach.

From the listed deterministic approaches, in the previous practice, it has been

shown that the best results are a combination of technical and fundamental approach.

Figure 2 gives a historical overview of the copper price trends for the period 1960 ÷ 2015 [2].

Figure 2 Trends of copper price for the period 1960 ÷ 2015 [2]

A long term forecast of copper price trends for the period 2013 ÷ 2025 is presented in Figure 3 [2].

Figure 3 A long term forecast of copper price trends for the period 2013 ÷ 2025 [2]

4 OPERATING COST MEASURES

Reduction of the unit operating costs is one of the most important goals of the company. It leads to an increase in the net cash flow and profitability, and helps to ensure a sustainability of operations even at the low metal prices. However, there are two ways of looking at it [3].

- 1) The first way is to try to reduce the unit costs for input and reduce the consumption. This is the basic goal of productivity that should be implemented in the exploitation process. In the process of planning the long-term

development of the mine, there are limited ways to reduce costs such as:

- *Reduction of the unit input costs*, which is applicable while the reduction of costs is not followed by a decrease in quality and hence an increase in total costs.
- *Reduction of the consumption rate*, as long as consumption is not already reduced to an effective rate of consumption that can not be improved. Any further attempt to reduce, for example, by limited supply, can only result in reduction the related activities, which will be a counter productive.

So, there are good and bad ways to reduce costs.

- 2) Another way of looking at minimizing the unit costs is based on the results of the optimization strategy, what is the goal of the feasibility study. In the same way, the NPV can be found for several strategies and choose the one that brings the maximum NPV; the unit costs can be also found for different strategies and choose the ones that generate the minimum unit cost. As a result, the basic productivity and cost-change factor are the same in each case, and certain differences are taken into

account in the analysis. Variations in the unit costs are then the result of interaction between the physical activities and costs incurred in different plans, and are not the result of measures to reduce the costs.

5 ULTIMATE PIT AND PUSHBACK SELECTION

Optimization of the open pit implies the obtaining of possible contour of the open pit, based on a block model of deposit that has an economic value, and which can be calculated. The concept of a possible contour of the open pit means the open pit contour with the maximum slope of the general slope, formed after drawing the transport routes and safety berm, and which meets the stability criteria.

A well-known early contribution to this field was made by Lerchs and Grossmann [4], who presented a graph-theoretic algorithm for determining the final contour of the open pit, known as the *ultimate pit*, such that the total profit from the mine is maximized.

Figure 4 shows the NPV - tonnage graph on the basis of which the Whittle process finds an optimal excavation limit and *pushbacks*. The graph shows the achieved NPV, as well as the quantities of ore and tailings for each nesting pit.

Figure 4 A typical NPV tonnage graph by the Whittle method

A cash flow curve relative to the tonnage tends to be at the top. Behind the point of maximum, it is not economical to excavate, but excavation of this part of the deposit can be considered in case of improving the economic conditions (increase of metal prices, or reduction of costs) or improvement of technological conditions.

The choice of one of the open pit shells as the open pit ultimate limit is made by the planning engineers and management, and the choice is made in accordance with the company goals. An inexperienced choice may be considered to be the best contour of the best case curve. The experienced engineers usually choose the best open pit on the basis of the average net value obtained on the basis of a curve of the best and worst case. Some users modify this technique and choose the open pits that by the value fall to 60 to 70 percent of difference between the curves of the best and worst case [5], [6].

6 SCHEDULE OPTIMIZATION

Scheduling is the process of determining the timing of activities. With the widespread use of a discounted cash flow as a value measure, the ability to optimize value through strategically focused scheduling is very important. Cash received earlier in the project is worth more, in present value terms, than the same amount of cash received later in the project. This encourages the mine planner to bring forward the positive cash flows and defer negative cash flows. The common methodology is to access ore as early as possible whilst mining as little waste is necessary.

The removal of material is contingent upon the removal of a cone of material situated above it, the size and shape of which is dictated by the requirement of safe wall slopes for the pit. This is modeled in the precedence constraints for the mine. An additional class of constraints are the production constraints, imposed by the availability of extraction and processing capacity

in each year. Techniques applied to solve the mine production scheduling problem include heuristics [7], parametric methods [8], dynamic programming [9], [10], [11] and integer linear programming [12], [13], [14]. The major limitation with these approaches is that they encounter significant computational difficulties when trying to solve problems of realistic size.

7 CASE STUDY

The Copper Mine Majdanpek, in the production, technical and technological sense, represents a complex mining system that has activities from geological explorations of mineral resources, ore exploitation and processing to a number of supporting activities as the necessary support to the core activities.

Production and processing of ore in the Copper Mine Majdanpek is currently developed at the open pit South Mining District and is of great importance for copper production in the system of company Mining Smelter Basin Bor Group (RTB Bor Group) [15].

The economic results of the mine operations, and therefore the company itself, depend primarily on the metal price on the stock exchange and costs arising in the production process.

Based on the defined economic variables, the analysis was conducted for five scenarios:

- 1) Scenario 1 – an analysis of cash flow change for the forecasted copper price on the market and projected operating costs.
- 2) Scenario 2 - an analysis of cash flow change for the copper price increase by 5%, whereby the operating costs do not change.
- 3) Scenario 3 - an analysis of cash flow change for the copper price increase by 5%, whereby the copper price does not change.

- 4) Scenario 4 – an analysis of cash flow change for the copper price and operating costs increase by 5%.
- 5) Scenario 5 - an analysis of cash flow change for the copper price and operating costs reduction by 5%.

The Mineable reserve of the copper deposit South Mining District Majdanpek are calculated on the basis of a block model of deposit, formed in the software Gems [15]. View of a block model of the Cu deposit South Mining District is shown in Figure 5.

Figure 5 View of 3D block model of the deposit South Mining District Majdanpek [15]

The optimization process was carried out in the software Whittle using a modified Lerchs-Grossmann (LG) algorithm, based on which the ultimate pits and pushbacks were selected. The optimization of excavation dynamics and DCF analysis were carried out in the same software, based on which the cash flows for defined scenarios were generated.

The analysis does not include the capital costs and capital replacement costs.

8 RESULTS AND DISCUSSION

The obtained results of conducted analysis are shown on graphs in Figures 6 and 7.

Based on the obtained results, shown in the graphs, the following can be concluded:

- 1) The best economic results are achieved in the case of Scenarios 2, that is, increase of the copper market price.

Compared to Scenario 1, where the analysis was carried out for the projected economic parameters, significantly better Cash Flow is achieved, which generates an increase of NPV by 12.8%.

- 2) In the case of Scenario 3, the lowest profit is realized, that is, increase of the operating costs leads to a reduction of NPV by 10.7%.
- 3) In the case of an increase in both copper and operating costs, Scenario 4, the company operation is slightly improved, expressed through an increase of NPV by 2.1%.
- 4) Reduction the price of copper and operating costs, Scenario 5, leads to a fall in the company economic benefits, i.e. a decrease of NPV by 2.1%.

Figure 6 Cash Flow Graph for different Scenarios

Figure 7 NPV Graph for different Scenarios

CONCLUSION

The conclusion is that the profit depends upon the relative changes of the price and costs.

Therefore, the mining companies apply different strategies for sustainable business in the market in terms of changing the metal

prices on the stock market, thereby paying a special attention to the management of operating costs arising in the process of mining and processing of mineral raw materials.

The conducted analysis is important looking from the real aspect the impact of metal prices and operating costs, as economic variables, not only to the economics of mine, but also the entire company RTB Bor Group. On the example of the open pit South Mining District Majdanpek, the conducted analysis showed how sensitive the NPV is to a change in copper prices on the market, or projected mining operating costs.

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