Open pit optimization and resource calculation of polymetallic deposits in the context of metal price fluctuations

Abstract

The objective of the following dissertation was to create a new methodology for resources evaluation and open pit mine planning. Majority of metal production is obtained from open pits. As it is well known, the minable deposit is the value of mining project (Nieć, 2002). Due to this fact, it is extremely important to determine the part of mineral project, within the optimized pit with the highest undiscounted value, including economically viable resources under given economic conditions.

Use of proper values critical to the shape of ultimate pit is a difficult task due to planned long life of mineral project and fluctuations of market metal prices. Proper shape of the ultimate pit design has a substantial impact on volume of estimated resources, strip ratio, and ultimately economical viability of the project. The shape of the ultimate pit should be flexible enough in order to make any possible changes in the production schedule dependent on diversified macroeconomic conditions (Niedbał, 2014).

As a result of mineral project analyses carried out with application of fuzzy sets, the shapes of ultimate pits might be considered with regard to different metal price scenarios. Furthermore, their degree of membership might be determined. This is how the possibility for occurrence of different price scenarios during long life of the project might be assessed. These price scenarios have a direct impact on tonnage, quality and value of estimated resources. This information is of fundamental importance to the investor, who wants to acquire the mineral project. With regard to the Canadian Ajax Project analyzed within the dissertation, the 1 billion Mg resources tonnage is obtained in fourth base case scenario (4550 USD/Mg Cu and 910 USD/oz Au) and fourth gold case scenario (2800 USD/Mg Cu and 1400 USD/oz Au) whereas it is obtained already in the third case of copper case scenario (6000 USD/Mg Cu and 480 USD/oz Au). The degrees of membership (possibility of occurrence in the life of the mineral project) are different for each of scenarios: base – 0,86, copper – 0,50 and gold – 0,57.

Furthermore, the information about metal influence (e.g copper and gold) on the project revenue in case of different scenarios is also crucial. Very often there is no correlation between base metal and precious metal price on the stock exchange. For polymetallic projects consisting of more than two usable elements such information is even more important. In the case study of the Ajax project the value of gold resources in gold (positive for gold prices and negative for copper prices) scenarios exceeds 50% of total value of the resources, in base scenarios it is between 29 and 34% and in copper scenarios (positive for copper prices and negative for gold prices) it is between 14 and 17%. In case of gold scenarios we should rather talk about gold and copper project because gold value exceeds 50% of total resource value.

For the purpose of mine planning, obtained ultimate pits for different metal price scenarios might be used. For example, the NPV analysis with the use of ultimate pits gold and base scenarios for the first 10 years of the production shows 23,6 % advantage of NPV value (with 8% discount rate) for gold scenario. Simultaneously the average grade of gold is 5% higher and copper is 11% higher with only 5% greater processing output and the same level of waste production for that scenario. The analysis shows that using ultimate pits for different scenarios, in specific economic conditions, might be beneficial to the financial result.

In the first part of the dissertation, the most important definitions are interpreted, fuzzy sets theory and its applications in the number of geological areas are presented and methods for investment uncertainty and value assessment with particular attention paid to the mineral projects are described. Further, the context of the study along with explanation of research motivation and the thesis are presented.

Additionally the methods of the metal price forecasting are described and the analysis of copper and gold forecasts that has been conducted by investment banks and funds are presented. The crucial part of the dissertation is the algorithm of assessment and mine planning method for polymetallic open pit mineral projects.

In the next chapters, with regard to the Ajax porphyry deposit example, a complete assessment process starting from making assumptions through optimization on the membership function to the analysis of results is presented. In this part, the analysis of the deposit parameters in ultimate pit as well as mining schedules is carried out. Furthermore, the analysis considering different slope angles and their impact on the resource value has been done as well as the Lerchs-Grossmann algorithm has been described in detail.

Finally, there are conclusions, summary and recommendations for further research.

The dissertation is interdisciplinary because it combines aspects of mathematics, economy, mining engineering and broadly-defined geology. In order to keep the dissertation as readable as it was possible, the following appendices might be found in the attachments:

1. *Due diligence procedure of polymetallic mineral projects,*
2. *Geology of porphyry deposits and alcalic porphyry Ajax deposit,*
3. *Specification of resource model.*

The real Ajax data were partially modified for analysis.