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Reserve Estimation during (Pre)Feasibility Study of Mineral Projects using Micromine Pit and Stope Optimizers

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SUMMARY

This paper discusses the use of Mining Optimisation Tools during of (Pre)Feasibility Study. The constraining mining, processing and economic parameters can be considered as modifying factors. Resources constrained by these parameters are economically and technically recoverable reserves. Usually, a more advanced stage of techno-economic assessment (Preliminary Economic Assessment – Prefeasibility Study – Feasibility Study) requires higher categories of source resources, as well as higher reliability and confidence of the constraining parameters (modifying factors) assessment.

Introduction

One of the most common overarching objectives for most companies is to increase shareholder value in the long-term by maximizing Net Present Value (NPV). NPV is a financial metric used to evaluate the profitability of an investment project by comparing the present value of its expected cash inflows to the present value of its expected cash outflows.

A mining company may have various objectives apart from just maximizing profits, such as extending the life of the mine, reducing production costs, improving the efficiency of operations, increasing the recovery of metals, etc.

The standard sequence of technical and economic studies involves several main phases, including Preliminary Economic Assessment (PEA), Prefeasibility Study (PFS) and Feasibility Study (FS). The assessment accuracy of financial indicators during a project's development increases due to more detailed assessment of its technical and economic features (Figure 1).

Business idea ↓ Decision on PFS ↓ Decision on FS ↓ Investment Proposal ↓

Stage	Preliminary Economic Assessment (PEA)	Prefeasibility Study (PFS)	Feasibility Study (FS)
Concept	What it could be	What it should be	What it will be
Targets	Economic analysis of the potential viability of a project's mineral resources	Compare and select investment options. Demonstrate economic viability and establish mineral reserves	Prepare technical decisions. CapEx & OpEx estimate and determine financial feasibility
Cost Accuracy	±50%	±25%	±15%
Engineering	<1%	1-5%	5-15%
Mineral Estimate Inputs	Inferred / Indicated Resources	Indicated / Measured Resources	Indicated / Measured Resources
Mineral Estimate Outputs	Inferred / Indicated Resources	Probably / Proven Reserves	Probably / Proven Reserves

Figure 1 *Phases of technical and economic evaluation of mineral resources*

The tasks of different phases of the technical and economic study also differ. Thus, Preliminary Economic Assessment allows us to assess potential viability of a project. The Prefeasibility Study stage compares and selects the most effective technical parameters, mainly concerning mining and processing. In this stage, we can transfer resources into reserves. Feasibility Study prepares more accurate technical decisions and allows us to make more informed investment decisions.

Methodology

Optimisation algorithms helps us to determine the optimal mining contour to maximize profit while meeting operational requirements. The main basis is the Block Resource Model *(Bariatska and Safronova, 2019)*, which in addition to grade may contain other parameters such as ore type, process and geotechnical properties, etc. In addition to the block model, a number of mining, process and economic parameters are required for optimisation.
In the case of open mining, the Lerchs-Grossman Algorithm *(Lerchs and Grossman, 1965)* is considered to be the most suitable for pit optimization and is widely used in open pit design software, including Micromine *(Mining setting…, 2017)*, as an industry standard. In the case of underground mining, Stope Optimisation Module uses an integrated mathematical programming solver to identify the most profitable stope layouts for an orebody *(Thomas and Esmaili, 2019)*.

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-1	-1	-1	-1	-1	-1	-1	3	5	3	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	3	5	3	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	3	5	3	-1	-1	-1	-1	-1	-1	-1
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-1	-1	-1	-1	-1	-1	-1	3	5	3	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	3	5	3	-1	-1	-1	-1	-1	-1	-1

Figure 2 *Simplified Illustration of the Lerchs-Grossmann Algorithm*

Each unit in the model receives an optimisation value, which is the income from the sale of all elements minus all costs. If the optimisation value is positive, including this block in a solution increases the value of that solution; conversely, if the optimisation value is negative, including this block decreases the value of the solution. It is often necessary for negatively valued blocks to be included to ensure that the requirements of the design are met. The role of the optimiser is to maximise the number of positively valued blocks in the solution whilst minimising the number of negatively valued blocks that must be included to satisfy the requirements of the design.

The optimisation process involves the following key steps:

- Determine input (optimisation) parameters,
- Optimize the block model,
- Generate a set of pit shells / stopes,
- Determine analysis parameters and analyse pit shells / stopes,
- Generate a report.

The optimization process can be iterative. After results analysis, the input parameters can be revised and refined, and the optimization can be repeated *(Mining setting…, 2017)*. The block diagram in the Figure 3 shows the optimization algorithm on the example of pit optimization.

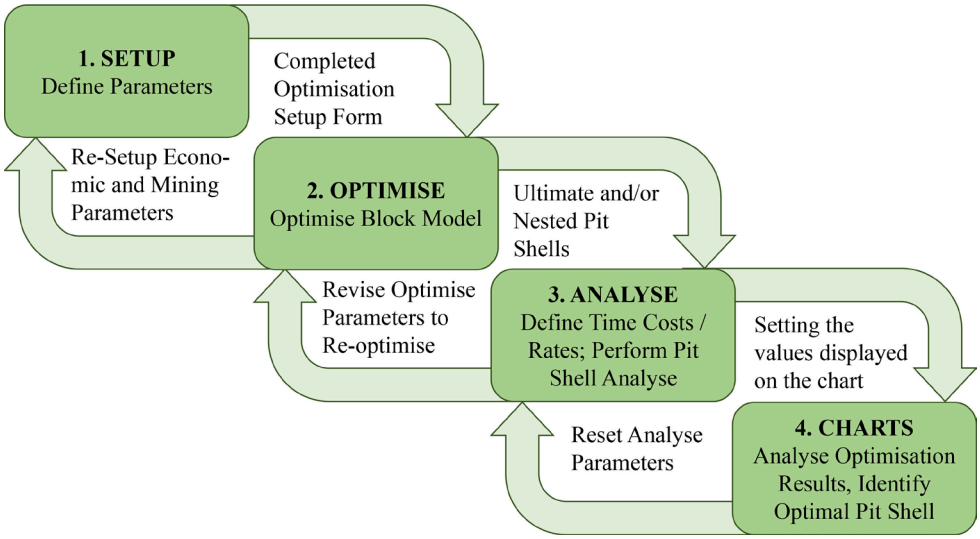

Figure 3 *Algorithm of Micromine Optimization Process*

Optimization parameters include the following groups:

- Model: Block Model; Ore types; Valuable components; Rock Types; Dilution and Recovery / Losses; Density; Mining and Processing Cost Adjustment Factors; rehabilitation cost values (in absence of block-specific information);
- Design: Optimisation method and design regions (for underground mining); Slope Restrictions (for open mining); Mining costs; Exclusion Zones (optional); Revenue Adjustment factor;
- Processing: Processing Cost; General and administration cost; Processing Recovery; Threshold; Additional processing cost;
- Selling: Price and Selling costs for each component (element).

Both pit and block optimizers use almost identical input parameters with the exception of the mining parameters. This makes the transition from open pit to mine, in combined mining easier, much easier. Such a transition is usually a specifically complicated task *(Whittlea et al., 2018)*. The determination of this transition site can be based on the pit and stope optimization results.

Results

The main optimization results are:

- Reports including details of data pre-processing,
- Staging Points – File of coordinates of block centres for each mining stage,
- Staging Wireframes – Wireframes for generated pits / stopes (Figure 4),
- Block Model Attributes – Fields in the block model updated with results from optimisation.

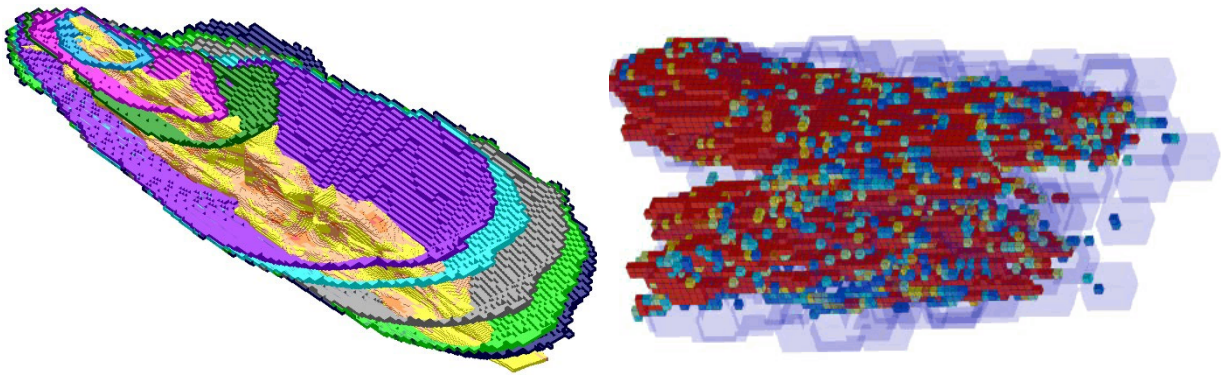

Figure 4 *Nested Shells Resulting from Pit Optimization (left) and Stope Optimization Outcomes (right)*

A set of the pit shells / stopes with a mining life, waste and ore tonnage and grades, recovery, revenue, cost, profit value, and NPV will be generated as a result of the optimisation process. The optimisation results chart helps to select the optimum ultimate pit (stope) with the maximum economic effect (Figure 5). Such a chart may include the following data series: Cashflow / Undiscounted Cashflow; Present Value; Volume / Tonnage of Waste / Ore / Total; Strip Ratio of Volume / Tonnage; Average Grade; Metal; Revenue; Mining Cost for Waste / Ore / Total. In most cases, a company chooses the option with the highest NPV, but the volume of mined ore, waste rock and other indicators should also be taken into account.

A sensitivity analysis of economic and technological parameters can also be completed. You can see how the project is sensitive to changes in prices and costs, processing recovery, etc.

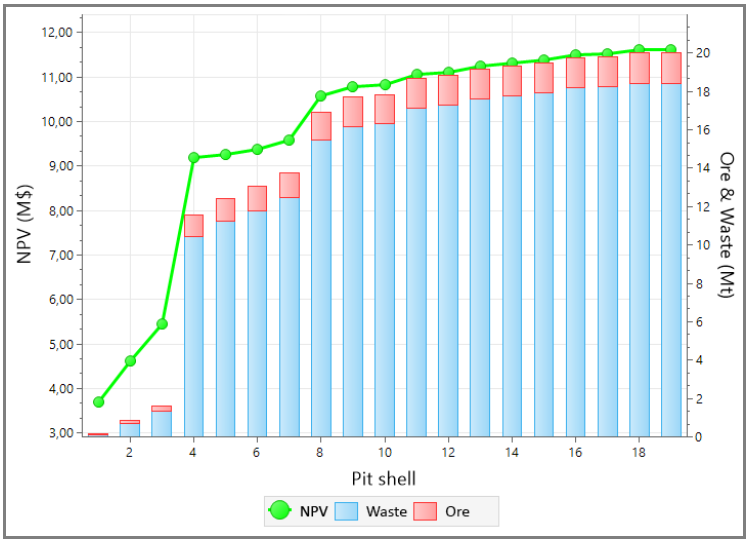

Figure 5 *Optimization Results Chart*

Conclusions

Pit / stope optimization can be performed during (Pre)Feasibility Study of a project and considered in terms of transition from resources to reserves. At the same time, optimization and analysis parameters can be considered as modifying factors, and the obtained optimal production volume can be viewed as economically and technically feasible recoverable reserves. The category of reserves (probably or proven) depends on the category of the source resources and the reliability and confidence of the constraining parameters (modifying factors)
assessment.

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