Optimisation of proportional influence of mining and processing costs on the production of an open pit mine

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Introduction

- Open pit mining depends on finding the right balance between mining and processing costs.
- These two costs play a big role in how efficient and profitable a mine can be.
- Many production decisions are made without fully understanding how one cost impacts the other.
- The proposed study presents a sensitivity analysis of mining and processing costs on mine production planning

"Continuous improvement is the key to survival; optimisation is the science that makes it possible."
— W. Edwards Deming

Background

Comminution

- Refers to the reduction in size of rock by crushing and grinding into smaller or finer particles
- According to the literature, comminution accounts for 50 – 70% of the processing costs
- Investigate the effects of comminution costs
- The need for improved comminution practices

Comminution economics

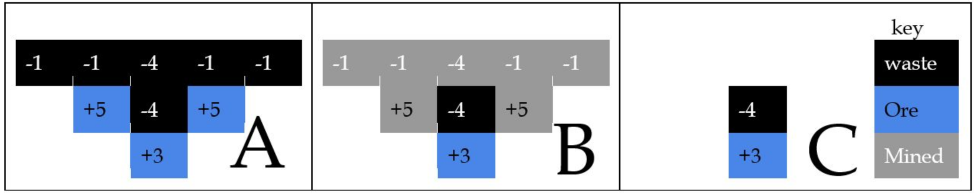
- Researchers argue that processing costs are an important economic factor of a mining operation.
- Some other facts are self-evident e.g. commodity prices, grade of ore, energy consumption.

Pit optimisation

- Pit optimisation is used to define the most profitable pit shells (or nested pit shells) for a given set of economic parameters

- Each block is evaluated to see if its value outweighs the cost of removing the overburden.

- The estimation uses a breakeven test to check if income from an ore block covers the cost of mining the waste, after which the mine's design and production schedule are developed.

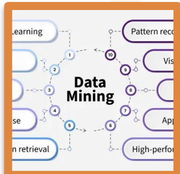


- Optimisation and simulation techniques, including **graph theory, linear and integer programming, dynamic and mixed-integer programming, moving cones, genetic algorithms, and network analysis**, are applied to improve mining planning and decision-making.

- Successful open pit design and output scheduling (OPOPS) is crucial in surface mining projects, and it is based on the **Lerch-Grossman algorithm.**
- **The cone is floated from left to right along the top row of blocks in the segment. Where there is a positive square, it is eliminated or mined. Seeing that the top row has no positive block, the negative blocks are then removed to get access to the second row.**

Simulation setup

This section covers the techniques employed to collect the data for analysis in line with the objectives set out for this work. The methodology revolves around computer simulation. This was used to investigate the effects of variable comminution costs on mine planning. This work is **exploratory**, which ignores the orebody geometry.



SimSched, the Direct Block Scheduler

•**Newman1**

%
ppm

Optimisation and planning of open pit mines in SimSched DBS

slope, process recoveries, time

Modelling and simulation work

(30×30 m, 45° slope) density (2.75 t/m³), 10% discount rate, Cu and Au recovery (0.88 and 0.60), processing and dump capacities (30 M and 50 M tons per period),

scenarios varied mining and processing costs from 70% to 140%

Simulation scenarios considered

- The Newman1 block model is selected for the purpose of this study and has **1060 blocks, 3922 rules of precedence, and 6 time periods.**
- Login parameters that SimSched DBS requires as input data are a valued block model that considers at least two economic destinations for process and disassembly, using Equations (In the paper)
- Calculations are performed for each block considering assumptions on input data as well as on mining and processing costs.
- In addition to this, the **economic and geometric parameters that remain fixed** are listed below. Simulation model inputs included: **mining fixed cost (1.5 USD/t), rehandling cost (0.8 USD/t), annual discount rate (10%), minimum mined width (50 m), bottom width (100 m), and maximum vertical advance rate (150 m).** Block data encoded slope angles, metallurgical recovery, and Au grades (ppm).
- For this work, a matrix was made with different periods to get the optimal production rate. Mining and processing costs were systematically varied from **70% to 140% while the NPV associated with each case was estimated**.

Determination of the break-even cut-off grade

- A break-even cut-off grade (COG) is the grade at which income covers all cash-related and capital expenses.
- The COG of a multi-mineral ore deposit can be determined using parametric COGs.
- For a deposit like Newman1, with **copper being the fundamental mineral** and **gold (Au) the by-product,** a single parametric COG can now be applied to copper and gold simultaneously.
- Estimate of the break-even COG applicable to the Newman1 block model is obtained using the following assumptions.

Description	Symbol	Units	Value
Dilution	D	%	
Processing cost	H	USD/t milled	43.87
Unit time costs	F	USD/t milled	37.53
Copper recovery	Y	%	95
Cu metal exchange	PCu	USD/t metal	9 000
Selling cost per tonne	KCu	USD/t metal sold	495.88
Element processing cost - copper	HCu	USD/t copper contained in feed	671.35

$$COG = \frac{D\times(H+F)}{Y\times(PCu - KCu) - HCu}$$

Therefore, $COG = \frac{43.87+37.53}{95\times(9000 - 495.88) - 671.35} = 1\ \%$

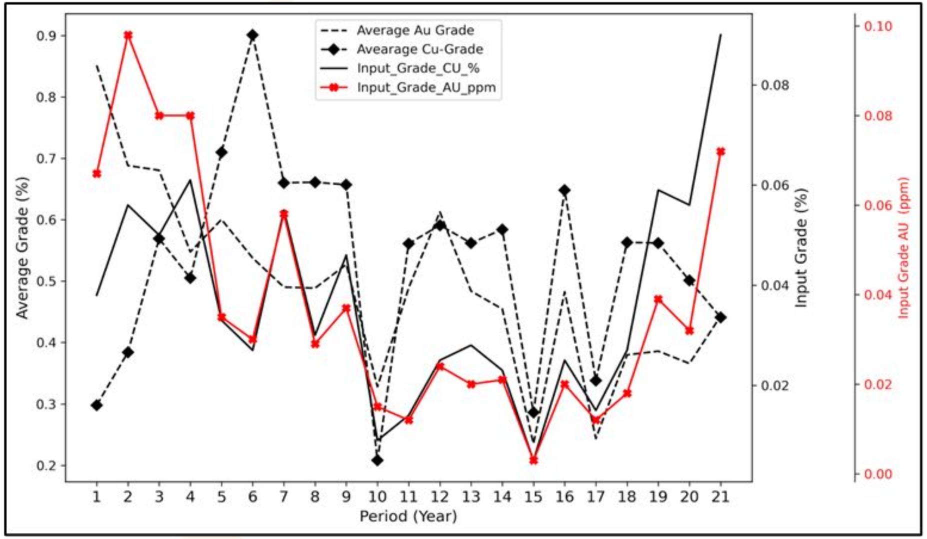
Anything beneath the COG is regarded as **waste**.

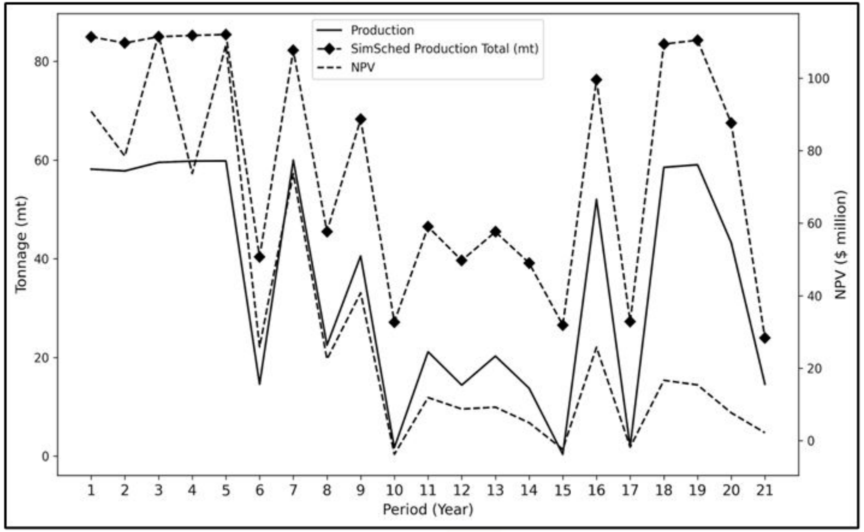
Results

The **key objective** was to evaluate the influence of mining and processing costs on the production plan of a typical open-pit mine. The motivation for the scenario analysis is to evaluate whether there is a benefit in implementing cost savings on comminution operations from the point of view of strategic mine planning. Subsequent to this, the implications of cost savings on the COG are also explored. All the above is tested on the Newman1 block model, a copper-gold deposit hosted on the MineLib electronic database.

- Comparison of cut-off grade policy
- Comparison of mined tonnages
- Effect of processing costs on the cut-off grade
- Effect of mining and processing costs on the NPV
- Effect of the discount rate on the NPV

Comparison of cut-off grade policy and Comparison of mined tonnages

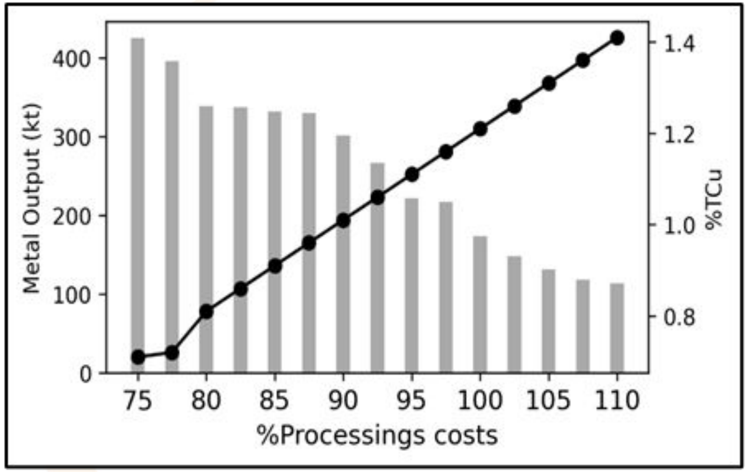




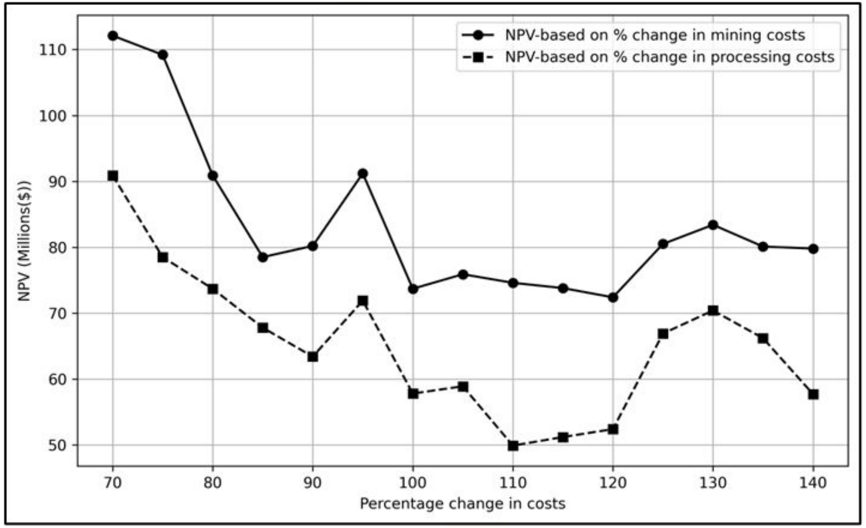
- Gold (Au) and copper (Cu) grades generally decline over the 21-year period, with fluctuations at different points.
- Input grades below the COG sent to the dump, but average grades above it, suggesting the current COG may be too low and reduces overall recovery efficiency.

- NPV peaks in the early years.
- Production follows SimSched trends with higher outputs initially, and metal yields decline after year ten, indicating full utilisation of both high- and low-grade ores over the mine life.
- The first five years show a stripping backlog with high production and NPV, while NPV fluctuates mid-mine; the current plan and COG policy sustain early productive operations.

Effect of processing costs on the cut-off grade and Effect of mining and processing costs on the NPV

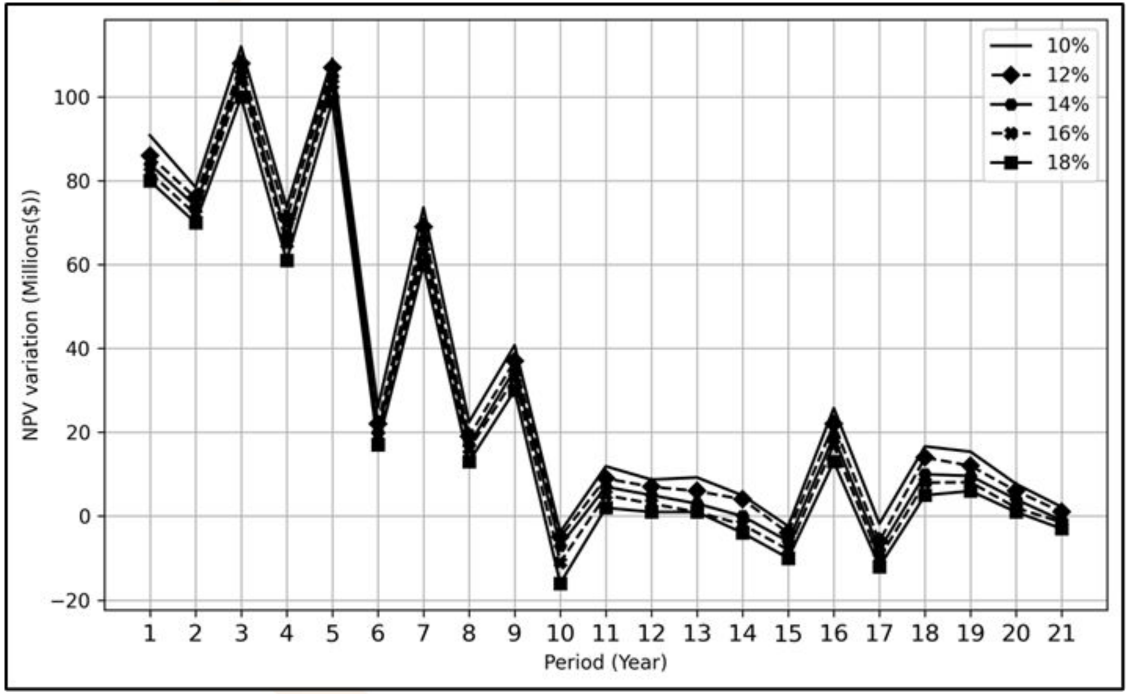


- The figure shows how processing costs, total copper grade, and metal output are related.
- Processing costs varied from 70% to 140% of the baseline.
- Slight COG increase occurs between 70–75% cost, but overall higher costs raise COG.
- Metal output declines as processing costs increase, reducing economic viability.
- Minimal output decline occurs between 80–95% costs, but a sharp drop occurs from 100–140%.
- Higher processing costs and COGs limit the volume of economically treatable ore.



- NPV ranges from about USD 50 million to 112 million, mostly around 79–80% due to cut-off grade optimisation.
- Changes in mining costs have little effect on NPV.
- NPV drops slightly when mining costs are 70–85% of the baseline but stabilises at higher costs.
- Processing costs have a bigger impact on NPV, with higher costs reducing NPV, especially between 70–90% of baseline.

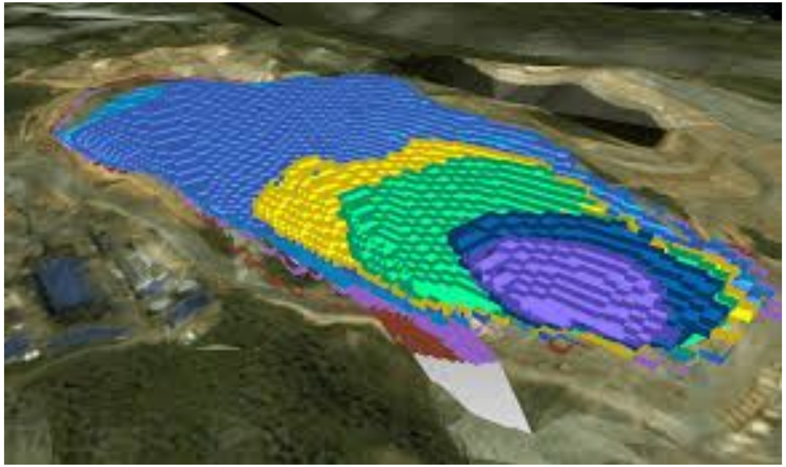
Effect of the discount rate on the NPV



- The discount rate determines the rate at which a project’s NPV equals zero.
- This study tested how sensitive NPV is to changes in the discount rate.
- The Figure shows that discount rates above the 10% baseline reduce NPV.
- Increasing the discount rate does not help recover capital for the Newman1 block model.
- Higher discount rates lower total NPV and negatively affect block model estimates.
- NPV variations show non-neutral distributions, but all curves follow the baseline pattern: higher discount rate → lower NPV.

Conclusion

- This work explored the effects of processing and mining costs on open pit mine planning.
- Simulations were carried out to generate production schedules from the block model of a copper-gold deposit.
- Mine planning was done using SimSched DBS, a freely downloadable software for pit optimisation.
- Various scenarios were considered as part of the simulation work.
- The findings revealed that there is a great opportunity to boost the NPV of the block model by properly aligning processing and mining costs.
- This exploratory work opens possibilities for further improvements on the NPV in mining projects.
- The pressing issue is to determine the interrelation between processing and mining costs, which in this work was assumed non-existent.



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Thank you