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Simultaneous stochastic optimization of mining complexes: Integrating waste management and progressive reclamation with encapsulation

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Abstract : Effective waste rock management is a crucial aspect of long-term planning of industrial mining complexes. When waste management is not considered during the optimization of the production schedule, it leads to an inaccurate assessment of the financial outcomes of the mining complex. This oversight can be especially costly when dealing with potentially acid-generating (PAG) waste rock, as it introduces the risk of significant treatment costs with rehabilitation, primarily due to acid rock drainage (ARD). Traditional practices don't optimize production schedules while addressing this risk and fail to integrate geological uncertainty so as to create a production schedule resilient to waste misclassification and uncertain supply of material extracted from the related mines. To prevent or mitigate ARD, proactive measures such as encapsulating PAG material with non-acid-generating (NAG) material are essential. Furthermore, stricter legislation reinforces the necessity to restore mining sites to an acceptable post-mining condition using ongoing reclamation to ensure environmental stability and reduce long-term liabilities. This work integrates waste management and progressive rehabilitation into the simultaneous stochastic optimization framework, employing gradual encapsulation of PAG material to promote progressive reclamation, thereby reducing long-term environmental and financial liabilities. Uncertainties in acid generation are addressed using geostatistical simulations of the rock's geochemical properties. A case study at a copper-gold mining complex demonstrates that incorporating waste management using progressive encapsulation has a minimal financial impact.

Simultaneous Stochastic Optimization of Mining Complexes: Integrating Waste Management and Progressive Reclamation with Encapsulation

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Background

A block model represents a mineral deposit as a three-dimensional array. The sequence in which blocks are extracted from the ground significantly impacts the financial outcome of a mining complex. Additionally, destination policy decisions and downstream processing choices play a crucial role in determining the value of the final products sold to the market. This set of decisions controls which facility an extracted block is sent to and how material flows between them.

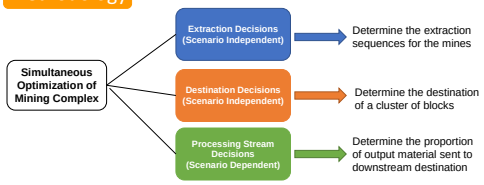
Uncertainties in the block model can lead to decisions with unpredictable results. In light of this, the problem is to make decisions resilient to uncertainty regarding which blocks to extract, in which period, where to send them, and how to control the flow of material between destinations to maximize the net present value (NPV) of the mine while respecting various constraints.

Introduction

Effective waste rock management is a crucial aspect of long-term mining planning. When waste management is not considered during the optimization of the production schedule, it leads to an inaccurate assessment of the financial outcomes of the mining complex. This oversight can be especially costly when dealing with potentially acid-generating (PAG) waste rock, as it introduces the risk of significant treatment costs with rehabilitation, primarily due to acid rock drainage (ARD).

This work integrates waste management into a simultaneous stochastic optimization framework, employing gradual encapsulation of PAG material to promote progressive reclamation, thereby reducing long-term environmental and financial liabilities.

Methodology



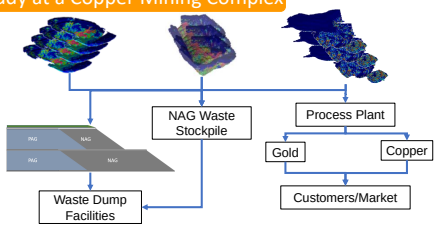
A generalized two-stage stochastic optimization model is proposed by Goodfellow and Dimitrakopoulos (2016) to maximize the profit from product sales while minimizing deviations from production targets.

$$Max \frac{1}{\|\mathbb{S}\|} \sum_{t\in\mathbb{T}} \sum_{s\in\mathbb{S}} \sum_{a\in\mathbb{A}} p_{a,t} v_{a,t,s} - \frac{1}{\|\mathbb{S}\|} \sum_{t\in\mathbb{T}} \sum_{s\in\mathbb{S}} \sum_{a\in\mathbb{A}} \boxed{c^{+}_{a,t} u_{a,t,s} + c^{-}_{a,t} l_{a,t,s}}$$

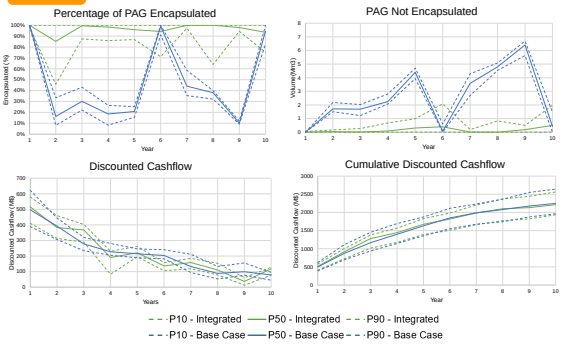
$$\boxed{c^{-}_{NAG\ waste,t,s}} \boxed{l_{NAG\ waste,t,s}}$$

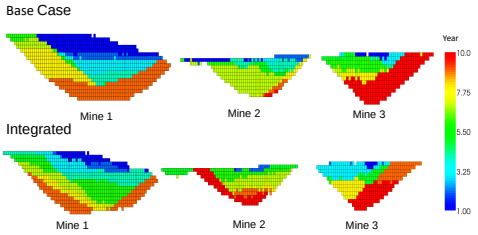
$$NAG\ Production_{t,s} - NAG\ Required_{t,s} + \boxed{l_{NAG\ waste,t,s}} \geq 0$$

Case Study at a Copper Mining Complex



Results





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Goodfellow, R., & Dimitrakopoulos, R. (2016). Global optimization of open pit mining complexes with uncertainty. Applied Soft Computing, 40, 292–304. https://doi.org/10.1016/j.asoc.2015.11.038