Long-Term Open-Pit Mine Planning with Quantum Computing: Concepts, Reformulations, and Implementation

A. Quelopana[1], *B. Keith*[2] *and J. Canales*[3]

1.Professor, Departamento de Ingeniería de Sistemas y Computación, Universidad Católica del Norte, Antofagasta, Chile, 1270709. Email: aldo.quelopana@ucn.cl
2.Professor, Departamento de Ingeniería de Sistemas y Computación, Universidad Católica del Norte, Antofagasta, Chile, 1270709. Email: brian.keith@ucn.cl
3. Scientist & Quantum Researcher, CoreDevX, Santiago, Chile, 7510838. Email: javiera.canales@coredevx.com

Keywords: long-term mine planning, strategic mine planning, open-pit mine, quantum computing, qubo.

ABSTRACT

Over the years, advances in long-term open-pit mine planning have made significant contributions to mine operations, resulting in improved ore extraction and its subsequent transportation to downstream processes. This planning involves scheduling mine production to maximise the Net Present Value (NPV) of the project while adhering to various operational constraints. However, as additional factors—such as uncertainty in grade and market price, additional stages in the mineral value chain, and further detail to increase realism—are integrated, model formulations have become increasingly complex when attempting improvements within the same optimisation framework. This complexity has heightened the demand for computational resources, often leading scholars and practitioners to prioritise efficiency over precision in their implementations, using metaheuristics or artificial intelligence. Furthermore, these limited computational capabilities have led to isolated improvements in individual stages of the mineral value chain, with attempts to orchestrate interactions between them to maximize synergistic benefits. However, this strategy also falls short of guaranteeing the optimum, as indicated by the general systems theory. The advent of quantum computing presents a promising approach to addressing these limitations. Unlike classical computers that process information as binary bits (0 and 1), quantum computers leverage qubits, which can exist in a superposition of states between 0 and 1. This capability enables quantum systems to process vast combinations simultaneously, providing computational power that has shown remarkable success across diverse fields. This potential has spurred significant investments from industry and governments worldwide in recent years, aimed at advancing the technology and expanding its applications. With the growing availability of quantum computers and simulators, this study presents preliminary findings from an ongoing Chilean project exploring quantum technology applications in long-term open-pit mine planning. Key concepts in quantum computing, necessary mathematical reformulations, and a case study implementation to exemplify these aspects are introduced, providing initial guidance for future developments.