

ABSTRAK

Kegiatan *blasting* tambang bawah permukaan sangat kompleks akibat keterbatasan ruang dan sumber daya alat berat. Penjadwalan harian di PT Citra Palu Minerals masih menggunakan metode deterministik konvensional dengan pengurutan lokasi kerja (*heading*) *First-In-First-Out* (FIFO). Pendekatan statis ini rentan terjebak pada kondisi optimum lokal (local optima) karena hanya mengevaluasi satu urutan prioritas *heading*. Akibatnya, waktu menganggur (*idle time*) alat tinggi, target kemajuan tambang tidak maksimal, dan jadwal menjadi kaku terhadap kendala dinamis lapangan. Oleh karena itu, diperlukan pendekatan komputasi cerdas untuk memecahkan permasalahan optimasi penjadwalan tersebut.

Penelitian ini mengembangkan sistem optimasi penjadwalan *blasting* yang mengintegrasikan *Rule-Based System* dan Algoritma Genetika. Data operasional bersumber dari hasil wawancara dan studi dokumentasi di PT Citra Palu Minerals periode Juni - Oktober 2025. Pada sistem yang dikembangkan, *Rule-Based System* bertugas menyusun jadwal yang mematuhi seluruh batasan keselamatan operasional (*hard constraints*). Sementara itu, Algoritma Genetika bertindak sebagai mesin optimasi untuk mengeksplorasi dan mengevolusikan urutan prioritas *heading* terbaik menggunakan operator seleksi, persilangan (*crossover*), dan mutasi.

Hasil pengujian membuktikan bahwa implementasi Algoritma Genetika secara signifikan mengungguli metode konvensional. Pada pengujian standar, metode konvensional hanya mampu menghasilkan total kemajuan tambang sebesar 72,00 meter. Sebaliknya, Algoritma Genetika berhasil meningkatkan kemajuan hingga 87,00 meter pada pengujian standar, dan bahkan mencapai kemajuan maksimal 99,00 meter dengan rekor nilai *fitness* 91.666,15 pada skenario kebijakan *blasting* fleksibel. Sistem berhasil meminimalkan idle time secara optimal dengan alokasi waktu komputasi sekitar 33 menit untuk mengevaluasi ribuan kemungkinan jadwal. Kontribusi utama penelitian ini adalah terciptanya model sistem penjadwalan berbasis optimasi komputasi yang fungsional untuk membantu perencana tambang menyusun jadwal harian yang jauh lebih efisien dan produktif.

Kata Kunci: Algoritma Genetika, Penjadwalan *Blasting*, Tambang Bawah Permukaan, Optimasi, *Rule-Based System*

ABSTRACT

Underground mine blasting operations are highly complex due to limited working space and heavy equipment resources. Daily scheduling at PT Citra Palu Minerals is still performed using a conventional deterministic method that prioritizes work locations (headings) based on a First-In-First-Out (FIFO) sequence. This static approach is prone to becoming trapped in local optima because it evaluates only a single heading-priority sequence. As a result, equipment idle time remains high, mine development targets are not maximized, and schedules lack flexibility in responding to dynamic field constraints. Therefore, an intelligent computational approach is required to address this scheduling optimization problem

This study develops a blasting scheduling optimization system that integrates a Rule-Based System and a Genetic Algorithm. Operational data were obtained through interviews and documentation studies conducted at PT Citra Palu Minerals during the period from June to October 2025. In the proposed system, the Rule-Based System is responsible for generating schedules that comply with all operational safety constraints (hard constraints). Meanwhile, the Genetic Algorithm functions as the optimization engine, exploring and evolving the best heading-priority sequences through selection, crossover, and mutation operators.

The testing results demonstrate that the implementation of the Genetic Algorithm significantly outperforms the conventional method. Under standard testing conditions, the conventional approach achieved a total mine development advance of only 72.00 meters. In contrast, the Genetic Algorithm increased mine development advance to 87.00 meters under standard testing conditions and even achieved a maximum advance of 99.00 meters with a record fitness value of 91,666.15 under the flexible blasting policy scenario. The system successfully minimized equipment idle time while requiring approximately 33 minutes of computational time to evaluate thousands of possible scheduling alternatives. The main contribution of this research is the development of a functional computational optimization-based scheduling model that assists mine planners in creating daily schedules that are significantly more efficient and productive.

Keywords: Genetic Algorithm, Blasting Scheduling, Underground Mining, Optimization, Rule-Based System