A Robust Scheduling Framework for Short-term Planning of Underground Mining Operations Using Constraints Programming: A Canadian Case Study

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# ABSTRACT

Underground mining presents significant challenges due to escalating costs and reduced profit margins, particularly as extraction reaches greater depths. These operations follow a cyclical workflow, comprising sequential tasks—such as drilling, charging, blasting, and loading—that rely on specialized equipment to progress each stage efficiently. Given the complexity and dependency of each step, effective scheduling of tasks and equipment is crucial for optimizing resource management, ensuring operational efficiency, and maintaining profitability. This study introduces a robust scheduling framework tailored specifically for these operations, with a practical application to a Canadian underground mine. By leveraging Constraints Programming, the framework addresses both production and development scheduling across a one-month planning horizon, accounting for the multifaceted nature of the problem. The study models and solves the scheduling problem through three distinct approaches, each capturing varying degrees of certainty and complexity: (1) a deterministic model where task processing times are fully known and fixed, (2) a deterministic model incorporating uncertain processing times, and (3) a two-stage multi-scenario stochastic model where task processing times are generated by a probability distribution, enabling multiple scenarios being solved simultaneously. The stochastic approach is particularly beneficial in handling the inherent uncertainties of the problem, allowing for adaptability to variable real-world conditions. Through a comparative analysis of the three models, this research underscores the value of accounting for uncertainty, revealing that the stochastic model not only achieves an optimal scheduling outcome but also produces schedules that are significantly more resilient and adaptable to unexpected disruptions. By demonstrating the effectiveness of stochastic scheduling in enhancing operational robustness, this framework provides a pathway for improving decision-making in underground mining, offering a scalable solution for resource-intensive and high-risk environments.