Operational and Environmental Optimization in Surface Mining through IoT and Artificial Intelligence

Jhonnatan Gonzales1

1. Student, [Curtin University's Western Australian School of Mines](https://www.bing.com/alink/link?url=https%3a%2f%2fwww.curtin.edu.au%2f&source=serp-local&h=QgGMckW%2baxzCcU1hv%2bHwShtTkIK4u2iJSvAp%2fONaXFc%3d&p=lw_tpt&ig=3F4B1C70BA194099A1AFA9B37705318B&ypid=YN3724x12084783339853381757), Kalgoorlie 6430, email: j.gonzalesangulo@student.curtin.edu.au

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# ABSTRACT

Operational improvement without affecting productivity and complying with strict environmental regulations represents one of the most important challenges in today’s mining industry. This study proposes a conceptual model based on the integration of Artificial Intelligence (AI) algorithms and the Internet of Things (IoT) to optimize operational performance and reduce pollutant emissions in open-pit mines.

The use of mathematical models programmed in Python to create virtual sensors allows for the monitoring of key parameters such as CO₂, NOₓ, SO₂, and particulate matter emissions, fuel consumption, equipment downtime, and haulage cycles. These sensors do not require physical installation and are capable of estimating values from simulated or existing operational data. The collected information is processed on a centralized platform, where machine learning algorithms identify patterns, predict KPI trends and parameter deviations, and provide real-time recommendations to reroute trucks and schedule preventive maintenance.

The simulation environment was developed in Python using libraries such as SimPy, Pandas, and Scikit-learn. While other mining software could be adapted for this purpose, this study demonstrates that an open-source and customizable approach can be effective and replicable.

Initial results from the simulation show a 10.7% reduction in CO₂ emissions, a 10.5% decrease in fuel consumption, and a 14.9% increase in total haulage output compared to the baseline scenario. Unlike previous approaches, this proposal offers an integrated and data-driven framework, where predictability and adaptability become key competitive advantages.

The proposed model is scalable according to the size and complexity of the mining operation and is suitable for future field validation. This study supports the transition toward more efficient and environmentally sustainable mining practices by leveraging digital technologies.