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Transforming Maintenance in Underground Mining: A Maturity Model Approach to Digitalization and Automation

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Abstract

The digital transformation of maintenance is critical for high-risk, asset-intensive industries such as underground mining, where operational efficiency, safety, and sustainability must coexist under extreme conditions. This research presents a multidimensional maturity model developed to assess, manage, and advance digitalized maintenance strategies in such environments. Based on a mixed-methods approach—including expert interviews and a global survey—the model integrates technical, organizational, data-related, and cultural dimensions, supported by a tailored KPI system, an aggregated digitalization index, and an AI-assisted evaluation framework. The findings highlight the transformative potential of sensor-based monitoring, predictive analytics, and artificial intelligence in reducing downtime, enhancing safety, and supporting decarbonization efforts. However, successful implementation requires more than technology; it demands adaptive governance structures, skilled personnel, and cultural readiness. This study contributes a validated framework that enables mining companies to benchmark digital maturity, prioritize investments, and accelerate strategic maintenance innovation in alignment with Industry 4.0 objectives.

Keywords: Digital Maintenance, Underground Mining, Maturity Model, KPI System, Predictive Analytics, Artificial Intelligence, Industry 4.0