Application of Fault Tree Analysis in Mining: A Review of Strategies and Advances for Risk Assessment.

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# ABSTRACT

Mining is a fundamental component of global economies, facilitating industrial growth and resource availability. However, it remains an inherently high-risk industry, facing significant challenges related to safety and environmental impact. As mining operations reach greater depths and exploit increasingly complex mineral deposits, it becomes essential to implement robust risk assessment methodologies.

Fault Tree Analysis (FTA) is a systematic, graphical method of risk assessment that is used to analyse quantitatively and qualitatively the potential causes of multiple failure scenarios and to understand failure pathways. This review examines the application of FTA in mining contexts, analysing its principles, advantages and challenges to improve safety and sustainability. Its applications cover critical areas such as the management of subsidence in underground mines, the prevention of gas explosions, the assessment of failures in conveyor systems and heavy machinery and, risk analysis of over excavation in blasting operations. These studies illustrate the value of FTA in risk prioritization and the guidance of preventive measure design. Nonetheless, applying FTA to large-scale mining systems poses challenges, such as data limitations and the inherent complexity of modelling interconnected risks. Technological advancements, including real-time monitoring systems and artificial intelligence, offer promising opportunities to enhance FTA’s accuracy and scope. These innovations allow for more precise modelling of failure probabilities and the integration of dynamic risk factors, ultimately improving decision-making processes.

This article also discusses the potential of combining FTA with other analytical methods, such as Bayesian networks and fuzzy logic, to overcome its limitations and adapt to the complexity of modern mining operations. Recommendations for its practical implementation are provided, alongside an outline of future research directions to further optimize its application and effectiveness in the mining sector.