

Application of Smart Technology, IoT, GIS And AI in Sustainable Critical Minerals Development

C. Mudyazhezha, M. M. Manyuchi and C. Mbohwa

Sustainable Technology Environmental Management Company, Harare, Zimbabwe

Sustainability and Future Technologies Center

University of South Africa, Pretoria, South Africa

mercy.manyuchi@gmail.com

W. Stinner

Germany Biomass Research Center, Leipzig, Germany

N. Sukdeo

Department of Quality and Operations Management

Faculty of Engineering and the Built Environment

University of Johannesburg, South Africa

Abstract

The global shift toward clean energy has increased demand for critical minerals such as lithium, cobalt and rare earth elements, creating the challenge of expanding mining while protecting the environment and local communities. This paper examines how smart technologies including the Internet of Things, Geographic Information Systems (GIS) and Artificial Intelligence (AI) can support more sustainable mineral development. Evidence from research and real world applications shows that IoT enables real time monitoring of water and energy use, GIS improves exploration and land use planning whilst AI enhances ore prediction, equipment maintenance and supply chain transparency. These tools can reduce environmental impacts, improve efficiency and strengthen accountability. However, technology alone cannot resolve ethical and social concerns linked to mineral extraction. Key risks include algorithmic bias, data exploitation, limited digital infrastructure in resource rich regions and the danger of relying on technological fixes instead of addressing deeper inequalities. While smart technologies can lower emissions, improve worker safety and increase resource efficiency, their benefits depend on strong regulatory oversight and responsible governance. The paper argues that ethical and inclusive deployment of AI, GIS and IoT is essential to ensure a just energy transition that does not repeat historical patterns of extraction and inequality.

Keywords

Artificial Intelligence, circular economy, clean energy transition, critical minerals, ethical governance, Geographical Information Systems