

Implementation of Blockchain Technology to Improve Transparency and Accountability in the Mineral Supply Chain

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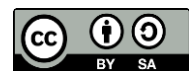
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Abstract

This study analyzes the potential and challenges of implementing blockchain technology to enhance transparency, accountability, and traceability in mineral supply chains. Using a qualitative approach with case-study methods and thematic analysis of interviews, company reports, regulatory documents, and scientific literature, the study compares initiatives by several industry actors. The findings show that blockchain strengthens end-to-end provenance tracking, authenticity verification, compliance with environmental and ethical standards, and minimizes data manipulation and illicit trade practices. In addition, blockchain integration drives operational efficiency and inter-stakeholder trust through immutable, auditable transaction logs. However, adoption faces structural barriers in the form of regulatory uncertainty, limited digital infrastructure in developing countries, and organizational resistance to system change. This study recommends establishing clear regulatory frameworks, public-private collaboration, cross-platform data standardization, and capacity building including integration with IoT and digital identity to maximize blockchain's impact on more sustainable and responsible governance of mineral supply chains.

Keywords: Blockchain, Transparency, Traceability



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INTRODUCTION

The mining industry, particularly the mineral sector, plays a crucial role in supporting the global economy. Mineral resources serve as fundamental raw materials for numerous industries, including electronics, construction, renewable energy, and automotive

manufacturing. Although the sector generates substantial economic value and investment opportunities, it also faces serious challenges related to transparency and accountability throughout supply chains. Various reports have revealed the existence of illegal mining activities, money laundering, corruption, and human-rights violations associated with mineral extraction and distribution. These issues not only harm local communities and ecosystems but also damage the credibility and reputation of companies and governments involved in the industry. As global awareness of sustainability and ethical business practices continues to increase, the demand for systems capable of monitoring and verifying supply-chain activities has become increasingly urgent (Ye & Zhang, 2026; Ziaya et al., 2025).

One technological innovation proposed to address these challenges is blockchain technology. Blockchain is widely recognized for its ability to provide transparent, secure, and decentralized systems for recording transactions and managing data. Through blockchain implementation, all transactions within a supply chain can be recorded permanently and monitored transparently by authorized participants. This capability offers a promising solution for improving accountability and reducing fraudulent activities within mineral supply chains. Consequently, blockchain technology has attracted growing attention from researchers, governments, and mining companies seeking to establish more reliable and sustainable supply-chain management systems.

Blockchain operates as a distributed digital ledger in which information is stored in interconnected blocks and replicated across multiple nodes within a network. Each transaction added to the blockchain is verified collectively by network participants, making data manipulation extremely difficult. In the context of mineral supply chains, blockchain technology can be utilized to monitor processes ranging from mineral exploration and extraction to processing, transportation, and distribution to end consumers. The integration of blockchain into these operational stages enables real-time monitoring and traceability, ensuring that supply-chain information remains accurate, transparent, and accessible to stakeholders involved in the mining sector.

The implementation of blockchain technology in mineral supply chains can significantly improve transparency and accountability across the industry. This is particularly important because mining operations are often associated with risks such as resource theft, labor exploitation, environmental degradation, and illegal trading practices (Sukumar et al., 2026; Vakil et al., 2025). By using blockchain systems, companies can verify the origin and movement of minerals more effectively while ensuring compliance with environmental and ethical standards. Furthermore, blockchain adoption can help create a more responsible and sustainable mining ecosystem by enabling stakeholders to monitor whether mineral resources are sourced legally and processed according to established regulations.

A growing number of studies have examined blockchain applications in various industries, including mining, and have demonstrated its significant potential for improving supply-chain transparency and operational efficiency (Kandasamy et al., 2025; Zhou et al., 2026). Blockchain technology enables all participants within a supply chain to access consistent and tamper-resistant information, thereby reducing opportunities for corruption, fraud, and information asymmetry. Previous research also indicates that blockchain can improve traceability by minimizing human error and reducing the risk of data manipulation. In addition, blockchain implementation has been found to lower transaction costs, strengthen

coordination among stakeholders, and increase trust between companies, regulators, and consumers participating in mineral trade activities.

Despite its considerable potential, the practical application of blockchain technology within the mineral sector remains relatively limited. Several studies have identified important barriers to implementation, including regulatory uncertainty, inadequate technological infrastructure in developing countries, and organizational resistance to replacing conventional legacy systems (Salehi et al., 2026; Zhou et al., 2026). Nevertheless, blockchain continues to offer important opportunities for addressing persistent issues in the mining sector, particularly in ensuring accurate and transparent mineral provenance tracking from extraction sites to final consumers. Through improved traceability and accountability, blockchain technology can reduce the risk of illegal mineral trading while promoting compliance with social, environmental, and sustainability standards in global mineral supply chains.

RESEARCH METHOD

This study employs a qualitative approach using a case-study method to examine the implementation of blockchain technology in mineral supply chains from both theoretical and practical perspectives. A qualitative approach is considered appropriate because it enables an in-depth exploration of stakeholder experiences, industrial practices, and regulatory perspectives regarding blockchain adoption in the mining sector. The case-study method is applied to analyze several companies and organizations that have implemented blockchain systems within their mineral supply chains, allowing the research to investigate transparency, sustainability, traceability, and operational efficiency associated with the technology (Abdullah & Hs Alani, 2025; Marcelletti et al., 2026). Through this approach, the study seeks to generate a comprehensive understanding of the opportunities and challenges of blockchain implementation in global mineral trade networks.

Research Design

The research design of this study is based on a multiple-case qualitative case-study framework. The study focuses on selected cases involving organizations and companies that have implemented blockchain technology in mineral supply chains, including De Beers, Everledger, IBM & Maersk (TradeLens), BHP Billiton, and Zinc8 Energy Solutions. These cases were selected because they represent diverse applications of blockchain technology in mineral traceability, logistics monitoring, sustainability assurance, and supply-chain transparency. The design allows comparative analysis across cases to identify similarities, differences, implementation strategies, and operational outcomes associated with blockchain adoption in the mining industry. The research integrates primary and secondary data sources to strengthen analytical validity and provide broader contextual understanding of blockchain applications in mineral supply chains.

Research Target/Subject

The research subjects consist of stakeholders directly involved in mineral supply chains and blockchain implementation. These include managers and officials from mining companies, government regulators responsible for mining governance, representatives from international organizations engaged in global mineral trade, and non-governmental organizations (NGOs) concerned with sustainability and human rights issues in mining activities. In addition, secondary sources such as company reports, government regulations, blockchain platform documentation, scientific journals, and technical reports are utilized to support the

investigation. The selection of these participants and documents aims to provide diverse perspectives regarding the operational, regulatory, technological, environmental, and ethical dimensions of blockchain implementation within mineral supply chains.

Research Procedure

The research procedure begins with case identification by selecting companies and organizations that have adopted blockchain technology in their mineral supply chains. Data collection is conducted through in-depth interviews, literature studies, and document analysis. Interviews are carried out with stakeholders who possess substantial knowledge and experience regarding blockchain implementation in the mining sector. The interviews use a semi-structured format with open-ended questions to encourage detailed responses and allow participants to explain their experiences comprehensively. Literature studies involve reviewing academic articles, industry reports, white papers, and sustainability reports related to blockchain implementation in mineral supply chains. Document analysis is also conducted on government regulations and policy documents associated with mining governance and emerging technologies. After data collection, the information is categorized and interpreted to identify recurring themes and significant findings related to blockchain adoption, transparency, sustainability, and supply-chain efficiency.

Instruments and Data Collection Techniques

The primary research instrument used in this study is a semi-structured interview guide designed to explore stakeholder perspectives regarding blockchain implementation in mineral supply chains. The interview guide includes open-ended questions focusing on transparency, operational efficiency, sustainability, regulatory challenges, and technological adoption. Data collection techniques consist of in-depth interviews, literature studies, and document analysis. In-depth interviews are conducted with mining companies, government regulators, international organizations, and NGOs to obtain qualitative primary data concerning blockchain implementation and its impacts. Literature studies are used to collect secondary data from scientific journals, company reports, blockchain platform publications, and technical documents to provide theoretical and industrial insights into blockchain adoption (Patel et al., 2025; Soe et al., 2025). Document analysis is conducted to examine government regulations, legal frameworks, and policy documents related to mining operations and blockchain utilization. The combination of these techniques enables triangulation of data sources and improves the credibility and reliability of the research findings.

Data Analysis Technique

The data analysis technique employed in this study is thematic analysis. This method is used to identify, categorize, and interpret patterns or themes emerging from interview transcripts, literature reviews, and document analysis. The analysis process involves data organization, coding, theme identification, theme interpretation, and conclusion development. Thematic analysis allows the researcher to systematically examine how blockchain implementation influences mineral supply chains in terms of transparency, accountability, sustainability, and operational efficiency. Furthermore, the method helps identify key challenges such as regulatory barriers, technological integration, and stakeholder adaptation, as well as the benefits generated through blockchain adoption in the mining sector (Bhuvaneshwari et al., 2025; Yousef et al., 2025). The findings are then interpreted comprehensively to develop deeper insights into the role of blockchain technology in improving governance and sustainability within global mineral supply chains.

RESULTS AND DISCUSSION

The results show that implementing blockchain technology in mineral supply chains has the potential to enhance transparency and accountability. Companies that have implemented blockchain report that the technology helps track mineral provenance, verify product authenticity, and ensure compliance with ethical and environmental standards throughout the supply chain (Bruzzese et al., 2025; Pongnumkul et al., 2025). For example, mining companies collaborating with blockchain platforms can verify that the minerals they procure do not originate from areas controlled by illegal armed groups or from mining practices that damage the environment.



Figure 1. Gal Armed Groups or from Mining Practices that Damage the Environment

In the mining industry, raw materials are the minerals extracted from the mine. The process involves exploration and extraction of various minerals such as gold, copper, nickel, or coal (Bang et al., 2026; Ebrahimi et al., 2026).

After extraction, suppliers act as intermediaries between miners and processing plants, delivering raw minerals to facilities for further processing.

At the plant, raw minerals are processed and transformed into semi-finished or finished products depending on the mineral type for example, gold refining or nickel ore processing.

After processing, semi-finished or finished products are stored in distribution centers, prepared for shipment to various outlets or for export. These facilities manage inventory to ensure supply availability.

Imports may occur when raw materials or components for mining processes are sourced from other countries. Exports occur when processed mineral products are shipped to international markets.

Outlets are the points at which end products from mining are distributed to end users for example, metal or mineral products used by the automotive, electronics, or construction industries (Abid et al., 2026; Liu et al., 2026).

Major challenges include limited technological infrastructure in some countries and the absence of clear regulations governing blockchain use in the mining sector. Many jurisdictions

lack adequate regulatory frameworks for this new technology, creating legal uncertainty for companies seeking to adopt it (Irwan et al., 2025; Kumar et al., 2025).

Blockchain implementation in mineral supply chains can have significant impacts, particularly in reducing corruption and illicit trade. However, effective implementation requires strong collaboration among governments, companies, and international organizations to develop supportive regulatory frameworks (Pavithra et al., 2025; Petrillo et al., 2025).

CONCLUSION

This study concludes that implementing blockchain technology holds considerable potential to improve transparency and accountability in mineral supply chains. The technology allows every transaction within the supply chain to be recorded and monitored in real time, reducing the likelihood of data manipulation or resource theft. Blockchain can therefore play an important role in improving a sector long considered vulnerable to corruption and injustice. The main challenges are limited infrastructure in many developing countries and the lack of clear regulations concerning the technology's use in the mining sector.

The study recommends that governments and relevant stakeholders design regulations that support blockchain use in mineral supply chains. Mining companies should also be more proactive in adopting the technology to meet rising demands for transparency and sustainability. With appropriate implementation, blockchain can not only increase accountability and transparency but also contribute to building a more sustainable and responsible mining industry.

AUTHOR CONTRIBUTIONS

Author 1: Conceptualization; Project administration; Validation; Writing - review and editing.

CONFLICTS OF INTEREST

The authors declare no conflict of interest

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