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Transforming Zimbabwe's Mining Sector: The Role of Digitalization in Enhancing Efficiency and Safety: Systematic Literature Review

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Abstract

Zimbabwe's mining industry plays a crucial role in the national economy, significantly contributing to the gross domestic product (GDP) and employment. Amidst the challenges faced by the industry, including environmental concerns, outdated operational practices and safety concerns, resulting in injuries and loss of lives, digital technologies offer a transformative opportunity to address these issues. This systematic literature review investigates the transformative impact of digitalization on improving operational efficiency and safety within Zimbabwe's mining sector in alignment with the Vision 2030 smart mining agenda. Search engines and databases such as JSTOR, Google Scholar, and Science Direct were used to gather data for this study. This review synthesizes existing research, identifying key trends, benefits, and barriers to digital adoption within Zimbabwe's mining sector. Results show that integrating cutting-edge technology such as automation, data analytics, real-time monitoring systems, and communication technologies into Zimbabwe's mining sector enhances operational efficiency and safety resulting in substantial growth and output.

Keywords: Digitalization, Mining Digitalization, Efficiency and Safety, productivity

1. Introduction

According to the Zimbabwe Investment Development Agency (ZIDA), Zimbabwe is among the top 10 mineral producing countries in Africa, contributing 70% to FDI, 19% government revenues, 80% to exports, 3% to direct formal employment and 13,5 % to national income. Furthermore, the Chamber of Mines state of mining survey report states that mining sector is the key driver of economic development and growth accounting for 12% of Zimbabwe's gross domestic product. Hence, the mining sector is an important part of Zimbabwe's economy significantly contributing employment and gross domestic product (GDP). However, difficulties such as environmental problems, safety hazards, and antiquated operational procedures hinder its growth. The incorporation of cutting-edge technologies, often known as digitalization, offers a viable way to overcome these obstacles as global trends move toward digital transformation. This study looks into how digitization might improve safety and efficiency in Zimbabwe's mining industry.

The primary objectives of this study are:

a) To assess the existing state of digitalization in Zimbabwe's mining sector.

b) To identify digital technologies used in mining sector and their effect on mining operational efficiency.

c) To explore the challenges encountered while implementing digital technologies

d) To evaluate the usefulness of digitalization in improving mining safety

e) To propose recommendations for enhancing the adoption of digitalization in the mining sector.

The term "digitalization" describes how digital technology is incorporated into several facets of corporate operations, changing conventional methods into more effective and data-driven procedures. This involves the application of automation, data analytics, real-time monitoring systems, and cutting-edge communication technologies in the mining sector. By increasing production, reducing environmental effects, and boosting safety, these advances have the potential to completely transform the mining sector.

Adopting digitization becomes essential as Zimbabwe looks to revive its mining industry and draw in foreign investment. The wealth of the nation's mineral resources, including diamonds, platinum, and gold, present excellent growth prospects. But the industry's potential is limited by its reliance on antiquated methods and technologies. Therefore, maintaining the industry's competitiveness in a global market that is changing quickly requires an understanding of and commitment to digital solutions.

The mining industry in Zimbabwe has yet to embrace sophisticated technologies, despite the potential advantages of digitization. Numerous businesses still struggle with operational inefficiencies, safety issues, and budgetary limitations. This resistance to adopting new technologies not only hinders output but also puts worker safety and environmental sustainability at serious danger. For Zimbabwe's mining sector to succeed and remain sustainable in the future, these issues must be resolved through digital transformation. In order to provide industry stakeholders with a roadmap for navigating this revolutionary process, this study intends to explore the ways in which digitalization might effectively improve efficiency and safety.

2. Literature Review

This literature review synthesized existing research on the role of digitalization in enhancing mining efficiency and safety, with a particular focus on its application in Zimbabwe. It examined various technological innovations, including artificial intelligence and machine learning, assessing their impact on operational efficiency, safety, and resource management. By identifying gaps in the current literature and highlighting best practices, this review aims to provide a comprehensive understanding of how technology can transform efficiency in mining operations and contribute to the sustainable development of the mining industry in Zimbabwe.

2.1. Importance of Digitalization in Mining

Digital transformation is changing how various industries including mining operate. The incorporation of digital technologies like automation, data analytics, and real-time monitoring systems has the potential to completely transform mining operations, claim Nyoni et al. (2023). These technologies lower operational risks, boost productivity, and enable better decision-making. The importance of real-time monitoring systems in enhancing safety results is emphasized by Chikodzi et al. (2021). By enabling the ongoing evaluation of environmental factors like ground stability and air quality, these technologies lower the risk of accidents and increase worker safety.

2.2. Enhancing Operational Efficiency

Digitalization enhances operational efficiency in mining. According to Dube et al. (2023), the use of automation and robots lowers the need for human intervention in risky operations, reducing the possibility of mishaps while boosting output. For example, it has been demonstrated that autonomous cars enhance material handling and expedite logistics in mining operations. Additionally, Baker et al. (2022) noted that data analytics-enabled predictive maintenance can result in significant cost savings and decreased equipment downtime. Mining businesses can increase overall operating efficiency by optimizing their maintenance plans and predicting faults before they happen.

2.3. Safety Improvements through Digital Technologies

Safety is still the top priority in the mining industry. According to research by Gumbo et al. (2022), wearable technology and sophisticated communication systems are examples of digital technologies that enhance safety protocols. Real-time health monitoring of employees is made possible by wearable technology, which also ensures timely emergency responses and potential hazard notifications.

The significance of efficient communication technologies in underground mining is further covered by Davis (2022). Wireless communication system deployment improves worker collaboration, speeds up emergency response times, and increases worker safety.

2.4. Challenges to Digitalization Adoption

The widespread adoption of digital technologies in Zimbabwe's mining industry is hampered by a number of obstacles, despite the obvious advantages. Infrastructure constraints are a major problem, according to Moyo et al. (2022), especially in isolated mining regions where dependable electricity and connectivity are frequently scarce. The deployment of cutting-edge technology that need reliable energy and communications networks is hampered by this lack of infrastructure.

For many mining enterprises, especially smaller ones, financial limitations are another obstacle. According to Chirinda et al. (2021), investments in digital solutions may be discouraged by the high upfront expenses of adopting new technologies. Because of this, many businesses still use antiquated methods, which reduce their ability to compete in the global market.

2.5. Research Gaps

Current literature often focuses on individual technologies (like IoT, AI, or data analytics) without addressing how these systems can be integrated into cohesive operational processes. Understanding how to create interoperable systems is crucial for maximizing efficiency.

There is limited research on the combined effects of using multiple digital technologies. For example, how does integrating predictive maintenance software with real-time monitoring systems impact overall operational efficiency and safety?

3. Research Methodology

A systematic literature review summarizes prevailing evidence and detects gaps and directions for upcoming research. The researcher conducted a systematic literature review of existing studies to investigate the transformative impact of digitalization on improving operational efficiency and safety in Zimbabwe's mining sector. This study employed systematic literature review to collect the relevant literature on digitalization in Zimbabwe's mining sector. Search engines and databases such as Google scholar, Science Direct and JSTOR were searched using the following key words and phrases: Digitalization, Mining Digitalization, Efficiency and Safety. The researchers selected these multidisciplinary databases as they index a wide range of journal articles, review papers and conference proceedings in both management and information systems domain published in English from 2020 to 2025. A total of 35 articles were extracted at this stage.

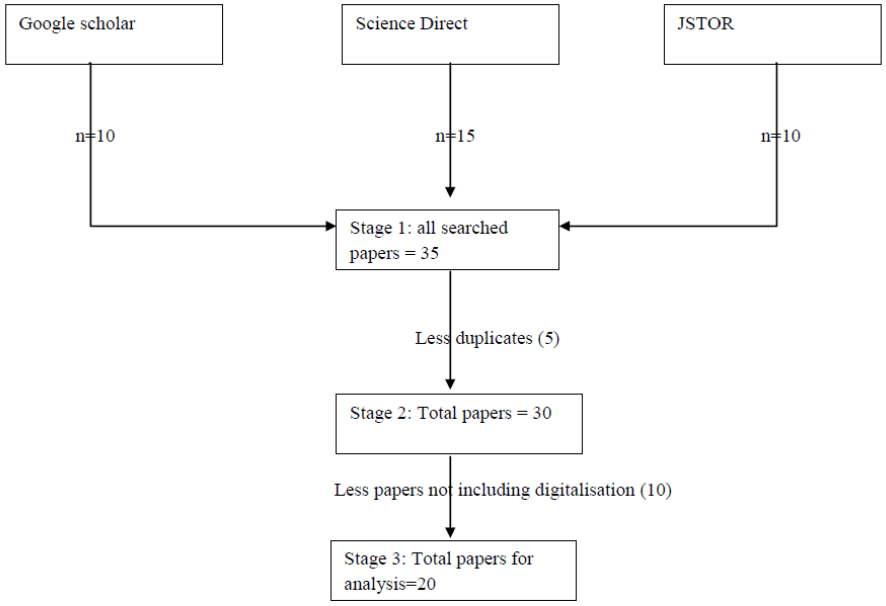

Figure 1: Research protocol

For maintaining the quality of the review, all duplications were checked thoroughly. Abstracts of the articles were checked deeply for the analysis and purification of the articles to ensure the quality and relevance of academic literature included in review process. 35 records were screened and 5 records were excluded because they were duplicates. The next exclusion criteria were to exclude papers that did not include digitalization, 10 articles were excluded. A total of 20 papers were selected for the synthesis. Data was analyzed using thematic analysis

4. Results and Discussions

4.1. Results

Objective 1: Assessment of the Existing State of Digitalization in Zimbabwe's Mining Sector

The current level of digitization in Zimbabwe's mining industry reveals a landscape characterized by both enormous opportunities and formidable obstacles. Digital technology adoption is still low overall, despite some mining companies having begun to adopt it. Recent studies show that many mining companies continue to operate using traditional methods, which affects their productivity and responsiveness to market demands (Chikodzi et al., 2023).

Objective 2: Digital Technologies Used in the Mining Sector and Their Effects on Operational Efficiency

Data analytics, artificial intelligence (AI), and the Internet of Things (IoT) are among the technical advancements that are radically changing mining operations. These technologies allow for predictive maintenance, which can drastically cut downtime, by enabling real-time monitoring of environmental variables and equipment (Gonzalez et al., 2022).

For example, IoT sensors can monitor the performance of machinery and notify operators of possible malfunctions before

they happen, reducing expensive disruptions. Large-scale datasets may be analyzed by AI algorithms to optimize resource allocation and production schedules, which will increase operational efficiencies (Moyo, 2023).

Furthermore, data analytics is essential to decision-making because it enables businesses to extract useful insights from both historical and current data. In addition to increasing productivity, this capacity aids in predicting market changes and modifying operations appropriately (Kakonda et al., 2024).

Objective 3: Evaluation of the Usefulness of Digitalization in Improving Mining Safety

Additionally, digitization makes a substantial contribution to improving safety in the mining industry. Employing automated equipment and remote monitoring systems can help businesses reduce the amount of time that people are exposed to dangerous situations. To lower the risk to human workers, automated drilling devices, for instance, can function under hazardous conditions (Dube et al., 2023). According to Rugare et al. (2023), improved training programs that incorporate virtual reality (VR) and augmented reality (AR) technologies can offer immersive learning experiences that prepare employees for emergency circumstances without exposing them to real-world threats.

These improvements in safety enhance operational effectiveness in addition to worker protection. Businesses may see fewer mishaps and interruptions with better-trained staff and safer working environments, which eventually results in improved resource management, higher output, and lower operating expenses (Mateko, 2024).

Objective 4: Challenges Encountered While Implementing Digital Technologies

Digital technologies hold promises for the mining industry in Zimbabwe; however, a number of obstacles prevent their widespread use. The absence of qualified professionals capable of efficiently implementing and overseeing these technologies is a major challenge. This skills gap is made worse by inadequate institutional frameworks that do not provide the required training and development initiatives, claims (Mateko (2024).

Furthermore, as they do not have the funds to invest in cutting-edge technologies, smaller mining firms may be discouraged from using digital solutions due to the high implementation costs. The digitalization effort is further complicated by infrastructure problems, such as erratic power supplies and insufficient ICT facilities (Chikodzi et al., 2023). Asymmetric information and regulatory obstacles also make it difficult for businesses to handle the complexities of digital adoption, which makes stakeholders resistant to change (Gonzalez et al., 2022).

Objective 5: Recommendations for Enhancing the Adoption of Digitalization

A number of tactical suggestions can be made to improve the mining industry in Zimbabwe's usage of digital technologies. First and foremost, it is essential to fund education and training initiatives in order to create a workforce with the necessary skills. The skills gap can be closed by collaborations between government organizations, educational institutions, and mining firms (Kakonda et al., 2024).

Secondly, to foster an environment that is conducive to technological innovation, it is imperative to enhance institutional frameworks. Simplifying rules and offering incentives to businesses that invest in digital technology are two ways to achieve this (Moyo, 2023).

Furthermore, resolving infrastructure issues like improving power dependability and increasing access to ICT will be essential to creating an atmosphere that is favourable for digital adoption. Finally, efforts to lower internet connection and digital tool prices can assist in removing financial obstacles that mining businesses confront. These suggestions can help Zimbabwe's mining industry better use digitization to increase operational safety and efficiency.

4.2. Discussion of Results

The study's findings show how digitization has the potential to revolutionize Zimbabwe's mining industry, but they also point to important obstacles that need to be overcome in order to fully reap these rewards. The evaluation of the current level of digitization shows that although certain mining firms are starting to use cutting-edge technologies, there is still little overall integration. The findings of Chikodzi et al. (2023) are in line with this, since they pointed out that many businesses continue to use antiquated operating techniques, which limits their capacity to successfully compete in a market that is changing quickly.

The importance of digital technologies in improving operational efficiency is highlighted by the identification of important technologies including data analytics, AI, and IoT. In order to reduce downtime and maximize resource allocation, these technologies provide real-time monitoring and predictive maintenance (Gonzalez et al., 2022). IoT sensors, for example, can give constant data on how well equipment is performing, enabling prompt repairs that avoid expensive malfunctions. Similarly, by analyzing big datasets to spot patterns and predict future operational requirements, AI-driven analytics can improve decision-making (Moyo, 2023). This is consistent with the larger pattern seen in mining operations around the world, where digital tools are being used more and more to boost operational resilience and productivity.

Furthermore, the analysis of the safety effects of digitalization shows that these technologies have the potential to greatly improve working conditions in the mining industry. The use of automated equipment and remote monitoring systems lowers the possibility of people being exposed to dangerous situations, increasing public safety (Dube et al., 2023). In order to make workplaces safer, improved training programs that make use of virtual reality (VR) and augmented reality (AR) technology help employees get ready for emergencies (Rugare et al., 2023). This finding is especially pertinent to

Zimbabwe, where the mining sector has long been beset by safety issues.

The study does, however, also point out a number of obstacles that prevent the widespread use of digital technologies. Mateko (2024) pointed out that a major obstacle is the lack of qualified staff, emphasizing that the skills gap restricts the efficient use and administration of digital instruments. Poor institutional structures that do not support the required training and development programs exacerbate this problem. Furthermore, because they might not have the funds to do so, smaller mining businesses may be discouraged from investing in digital solutions due to the high implementation costs (Chikodzi et al., 2023).

Digitalization is made more difficult by infrastructure issues including erratic power supplies and insufficient ICT facilities. According to Mateko (2024), these infrastructure shortcomings produce an atmosphere in which mining firms find it difficult to successfully adopt and use digital technology. It is challenging for businesses to manage the intricacies of digital adoption because of regulatory obstacles and information asymmetries, which further fuel stakeholder resistance to change (Gonzalez et al., 2022).

The study suggests a number of measures to improve the mining industry's adoption of digitization in order to overcome these obstacles. The first step in creating a workforce with the skills to manage and operate digital technologies is funding education and training initiatives. Governmental organizations, educational institutions, and mining corporations can work together to overcome the skills gap (Kakonda et al., 2024).

Secondly, to foster an environment that is conducive to technological innovation, it is imperative to enhance institutional frameworks. It is possible to promote an innovative culture by streamlining laws and offering incentives to businesses that invest in digital technology (Moyo, 2023). Furthermore, resolving infrastructure issues like improving power stability and increasing access to ICT will be essential to fostering an atmosphere that encourages digital adoption.

Finally, efforts to lower the price of digital tools and internet connectivity can mitigate the financial obstacles that mining businesses confront. Through the implementation of these suggestions, Zimbabwe's mining industry can more effectively utilize digitalization to enhance operational effectiveness and safety, thus bolstering the industry's long-term viability and viability.

5. Conclusions and Recommendations

The findings indicate that digitalization in Zimbabwe's mining sector offers substantial opportunities for enhancing operational efficiency and safety. However, significant challenges remain, including skill gaps, cybersecurity vulnerabilities, and regulatory barriers.

To maximize the benefits of digital technologies, it is crucial for stakeholders to focus on integrated systems, ongoing workforce training, and developing robust cybersecurity measures. Future research should prioritize longitudinal studies to better understand the long-term impacts of digitalization, as well as explore the socio- economic effects on local communities and the workforce.

By addressing these gaps and leveraging the findings, the mining sector in Zimbabwe can not only improve its operational performance but also contribute positively to the local economy and workforce development.

The current level of digitalization in Zimbabwe's mining industry is thoroughly examined in this report, which also highlights the major obstacles to its adoption as well as its transformative potential. The results show that cutting-edge technologies like data analytics, artificial intelligence (AI), and the Internet of Things (IoT) have the potential to improve mining operations' operational effectiveness and safety. These digital solutions can greatly optimize resource management and lower operating costs by facilitating real-time monitoring, predictive maintenance, and better decision-making.

The study also highlights how important digitization is to establishing safer workplaces. Using automated equipment and remote monitoring systems reduces the dangers of dangerous situations while also improving worker training with cutting-edge technologies like virtual reality (VR).

Significant obstacles to digital adoption are also noted in the report, such as a shortage of qualified staff, expensive implementation, weak institutional frameworks, and infrastructure issues like unstable power supplies and subpar ICT facilities. To enable a more thorough integration of digital technology into the industry, these challenges must be overcome.

The enhancement of institutional support frameworks, investments in workforce training, and projects to improve infrastructure and lower the prices of digital technologies are some of the strategic ideas put forth to encourage the successful adoption of digitalization. The mining sector in Zimbabwe may better utilize the promise of digitalization by putting these concepts into practice, which would improve safety, operational efficiency, and eventually the industry's ability to grow sustainably.

In conclusion, Zimbabwe's mining industry faces many obstacles on its path to complete digital transformation, but there are also a lot of chances for modernization and advancement. To get beyond these obstacles and guarantee that the industry can prosper in a world that is becoming more and more competitive, stakeholders must work together.

Declaration of Competing Interests

The authors declare that they are not aware of any competing financial interests or personal relationships that may have influenced the work described in this document.

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Ethical considerations

The article followed all ethical standards appropriate for this kind of research.

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