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POTENTIAL APPLICATIONS OF BLOCKCHAIN TECHNOLOGY IN ENHANCING OCCUPATIONAL HEALTH AND SAFETY SYSTEMS

Abstract: *Occupational health and safety are of fundamental importance, with a particular emphasis on high-risk industries. The growing responsibility toward employees, along with increasingly stringent legislative frameworks, necessitates effective solutions for monitoring safety procedures. Traditional occupational health and safety systems face challenges such as a lack of transparency and data integrity, as well as inefficient auditing and compliance processes, which could potentially be addressed through blockchain technology. This paper explores possible applications of blockchain technology to enhance occupational health and safety systems, including secure and transparent incident reporting, improved management of training records and certifications, real-time monitoring of workplace conditions, and the establishment of secure mechanisms for data access. The application of blockchain technology in occupational health and safety systems is still in its early stages, and there are certainly challenges to be overcome. To enhance the understanding of practical opportunities and challenges associated with the implementation of blockchain technology within occupational health and safety (OHS), a comparative analysis was carried out on two contemporary studies conducted in distinct industrial contexts — the construction and healthcare sectors.*

Keywords: *occupational health and safety, blockchain technology, safety procedures*

1. Introduction

Occupational Safety and Health (OSH) is a multidisciplinary field focused on protecting workers' well-being, with particular emphasis on identifying, preventing, and controlling hazards present in the work environment (Salvador et al., 2016). The principles and practices underlying OSH systems are conceptually tied to minimizing risks and promoting a healthy work environment, and should not be merely associated with regulatory compliance. Effective management of OSH systems involves strategic management of various hazards in high-risk industries. In the

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chemical industry, employees are frequently exposed to toxic substances, while in the healthcare industry, there are risks from infectious agents. In the construction and mining industries, employees face numerous challenges, such as working in inaccessible and demanding environments, handling heavy machinery, and exposure to high noise levels, all of which can lead to a wide range of injuries, often with fatal outcomes. Furthermore, almost all high-risk industries feature psychosocial hazards, such as stress and harassment, with particular attention to working under extreme conditions or in high-responsibility jobs (Lerman et al., 2012). Prioritizing safety in these industries is not only a moral obligation but also an operational necessity to protect workers and prevent hazardous incidents (Rahimdel, 2021). A strong commitment to safety can help reduce the risk of accidents and injuries, minimize work disruptions, and improve employee morale. The implementation of an effective OSH management system in high-risk industries requires establishing rigorous safety standards, specific preventive measures, and ongoing employee training to reduce the number of injuries and accidents (Habuc et al., 2024). OSH represents a structured framework for managing risks that includes the development of policies, procedures, and processes focused on hazard identification, risk assessment, and implementing control measures. Furthermore, an effective OSH system must provide mechanisms for monitoring and evaluating performance and for the continuous improvement of the system to optimize the health and safety protection of the workforce.

The challenges faced by traditional OSH management systems, such as limited transparency, difficulties in tracking and verifying safety practices, and data integrity issues, hinder the timely identification of systemic problems and the implementation of corrective measures (Hamid et al., 2019). Increasing transparency is key to building trust among employees, managers, and regulatory bodies, as it allows for clear definition of responsibilities and the assessment of the effectiveness of safety measures (Zhang et al., 2023).

In addition, centralized architectures in traditional OSH systems are prone to manipulation and may compromise data integrity through unauthorized access and alterations (Iftekhar & Cui, 2021). In contrast, decentralized systems distribute data across multiple locations, preserving the integrity and accuracy of the data, which is critical for accurate risk assessment and the implementation of appropriate preventive measures, as well as for conducting thorough investigations in the event of incidents. One of the greatest challenges faced by organizations in traditional systems is the complexity of regulatory compliance and the inability to track in real-time, due to the complexity and dynamic nature of OSH standards (Hamid et al., 2019). This gap can lead to unintentional violations despite organizations' efforts to adhere to relevant laws and regulations.

These issues highlight the need for more advanced approaches to OSH management. The application of blockchain technology, with principles such as decentralization, transparency, and data immutability, has the potential to address these challenges and improve the efficiency and security of OSH systems (Iftekhar & Cui, 2021).

2. Analysis of the Potential Application of Blockchain Technology in Occupational Safety and Health (OSH) Systems

2.1. Secure and Transparent Incident Reporting

One of the key challenges in modern OSH systems is ensuring accuracy, comprehensiveness, and transparency in incident reporting. In practice, employees often hesitate to report incidents due to fear

and lack of trust in the integrity of the process itself (Monrat et al., 2019). By recording incidents on a blockchain network, an immutable audit trail is created, resistant to tampering, which allows for more accurate data collection and facilitates risk identification, thereby helping to prevent future occurrences. This fosters a culture of openness, accountability, and trust. The transparency of the system further encourages employees to report safety incidents.

Moreover, blockchain can significantly improve the efficiency of the investigation process. In practice, incident investigations often involve multiple parties, safety officers, supervisors, and management, where the exchange of information is complex and time-consuming. By implementing a distributed system, all relevant data can be stored in one digitally secure location, accessible only to authorized users (Salah et al., 2019). This facilitates coordination, speeds up the implementation of measures, and contributes to the thoroughness of the investigation.

Smart contracts, as automated protocols within the blockchain system, further optimize incident management by triggering notifications, assigning tasks, and tracking their completion. This enables timely responses, accurate identification of causes, and efficient implementation of corrective measures.

Additionally, blockchain technology can facilitate the secure sharing of relevant data with external parties, such as regulatory bodies and insurance companies, reducing administrative burden while simultaneously enhancing transparency regarding compliance and safety standards. The use of blockchain in this context has the potential to significantly increase accountability and efficiency in OSH systems, contributing to the creation of a safer work environment and reducing the incidence rate.

2.2. Improved Management of Training and Certification Records

One of the key aspects of OSH is ensuring that employees possess the appropriate skills and knowledge to perform their tasks safely. In many sectors, particularly in high-risk industries, having valid and up-to-date training and certifications is essential for protecting individual and collective safety, as well as for safeguarding property and ensuring continuity of operations. Traditional systems for managing training records are often inefficient, error-prone, susceptible to data loss, or even document forgery.

The application of blockchain technology in this context can significantly improve the accuracy, security, and credibility of training and certification data. Records stored on the blockchain create a decentralized, immutable, and transparent ledger accessible to both employers and regulatory bodies (Chen, 2018). This approach eliminates the need for paper documentation and reduces the risk of data manipulation. Smart contracts can further enhance the certification management process by automating expiration notifications, thus enabling timely renewal of qualifications (Turjo et al., 2021). This ensures a consistently high level of employee competence, thereby reducing the risk of incidents resulting from insufficient training.

Moreover, blockchain facilitates the mobility of qualifications across different organizations and sectors. Workers can maintain a personal digital training record that is easily transferable when changing jobs, significantly reducing administrative burdens and expediting the hiring process. This model contributes to the standardization of training and enables consistent tracking and recognition of qualifications within a broader business ecosystem.

By implementing blockchain in the management of training and certification, it is possible to achieve greater efficiency,

accuracy, and transparency, which directly contributes to the development of a more competent and safer workforce.

2.3. Real-time Monitoring of Workplace Conditions

The integration of blockchain technology with the Internet of Things (IoT) represents an effective solution for enhancing OSH systems, as it enables real-time monitoring of working conditions and the identification of potential hazards before they result in incidents. IoT devices, including sensors, wearables, and environmental monitors, can continuously collect data on various parameters such as temperature, noise levels, the presence of toxic gases, air quality, equipment performance, and workers' physiological conditions (Chamola, 2020). These data are then securely transmitted and stored on a blockchain platform, creating a transparent and immutable record of the workplace environment.

The analysis of such data allows organizations to identify patterns that indicate potential risks and take proactive measures to mitigate them. For instance, in the mining sector, sensors can detect the presence of hazardous gases and automatically alert workers and supervisors to danger (Pincheira et al., 2022). In construction, wearable devices can monitor workers' vital signs and detect fatigue, dehydration, or stress, enabling timely responses to prevent injuries (Rahman et al., 2019).

In addition to protecting workers, IoT sensors can monitor machinery, detecting malfunctions or irregularities in operation (Joshi et al., 2021). This facilitates preventive maintenance, thereby reducing the likelihood of mechanical incidents. Furthermore, smart contracts implemented within the blockchain framework can automate responses to specific risks, such as triggering alarms, shutting down machines, or notifying the appropriate personnel. This enables rapid and coordinated intervention to protect workers' health and lives.

By employing these technologies, organizations not only enhance workplace safety but also improve the efficiency of supervision and data-driven decision-making.

2.4. Ensuring Secure Data Access and Privacy

Data security and privacy represent key aspects of any OSH system. The decentralized nature of blockchain technology enables a more secure approach to data management, distributing information across multiple nodes, which makes unauthorized access and data manipulation more difficult (Zhang et al., 2019). Access to data from OSH systems can be controlled through cryptographic keys, ensuring that only authorized individuals can view or modify sensitive information.

In addition, blockchain enables secure data exchange between various actors, such as employers, employees, regulatory bodies, and insurance companies. Each participant can be assigned specific permissions to access certain types of data, thereby protecting privacy and enabling effective collaboration (Guo et al., 2019). For example, employees may have access to their own training records and incident reports, while employers can analyze aggregated workplace risk data to identify areas requiring improvement. Regulatory bodies can use the data necessary to conduct inspections and ensure compliance with regulations, while insurance companies can access information for risk assessment and premium determination.

The use of blockchain ensures that all access and modifications to data are transparently recorded on the blockchain, increasing trust and accountability regarding the data.

3. Comparative Analysis of Potential Blockchain Solutions in the Context of Occupational Health and Safety

For the purpose of gaining a deeper understanding of the practical possibilities and challenges of implementing blockchain technology in the context of OSH, a comparative analysis was conducted of two contemporary research studies (Pinna et al., 2020; Barrit & Niset, 2023), which explore this topic in different industrial contexts: the construction and healthcare sectors. These sectors were selected due to their high level of risk exposure, the complexity of regulatory frameworks, and the critical role of safety protocols.

The analysis of examples of potential blockchain implementation in the management of temporary construction site workers, as well as in a decentralized system for tracking working hours and the well-being of healthcare professionals, allows for the identification of specific ways in which blockchain can be used as a tool to improve safety, transparency, and accountability in professional environments.

Both approaches demonstrate a high degree of technical maturity but differ in focus: the construction model is more structured and more tightly aligned with regulatory requirements, while the healthcare model strives for greater flexibility, user participation, and the preservation of employees' mental health. Key aspects, such as methodological approaches, technologies used, relevant actors, and primary goals, are presented in Table 1.

Table 1. Key aspects of blockchain implementation in high-risk sectors

Criterion	Construction sector	Healthcare sector
Methodology of development	Blockchain-Oriented Software Engineering (BOSE) + Agile Blockchain DApp Engineering (ABCDE)	Modular system + Decentralized Autonomous Organization (DAO)
Blockchain technology	Ethereum + Ethereum Request for Comments 721 (ERC-721)	Open ledger with DAO-based organizational control
Key actors	Workers, companies, inspectors	Healthcare workers, employers, third parties
Focus	Employment and safety management	Time tracking and mental health monitoring
Sustainability dimensions	Technical, economic, environmental, individual, social	Decentralization, privacy, flexibility

The comparative analysis demonstrates that blockchain technology can be applied in a way that responds to the unique challenges of various sectors, as long as its implementation aligns with the actual needs of users and relevant regulatory frameworks. In the construction industry, the focus is on legal compliance and the verifiability of procedures; in healthcare, attention is given to the preservation of mental health, employee autonomy, and the security of personal data.

The results suggest a strong potential for transferring solutions across sectors. For instance, formalized procedures and smart contracts used in construction could help enhance regulatory structures in healthcare. Conversely, participatory management approaches and behavioral analysis tools from healthcare may improve flexibility and adaptability in construction settings. This mutual exchange of principles opens new opportunities for creating hybrid models applicable to other high-risk domains.

The analysis further underscores important implications in the context of sustainability.

While blockchain technology offers increased transparency and operational efficiency, careful consideration must be given to its energy demands, particularly in systems that rely on consensus mechanisms such as Proof of Work (Sriman et al., 2020). Moreover, the issue of privacy protection (Jiang & Shi, 2021) remains a pressing concern, especially in platforms handling sensitive information. To ensure broad usability, technical solutions should be designed with simplicity and accessibility in mind, allowing non-expert users to interact with them effectively.

Given these factors, blockchain technology should be regarded as more than a mere technical instrument. It holds the capacity to reshape dynamics of trust, control, and accountability within contemporary work environments, especially in industries characterized by heightened safety concerns.
A visual representation of the comparative evaluation of the construction and healthcare sectors is shown in Figure 1, illustrating the potential impact of blockchain on improving four key criteria: workplace safety, transparency, process automation, and user access. Based on the descriptive indicators from the analyzed studies, a qualitative evaluation of each sector was carried out within the specified dimensions.

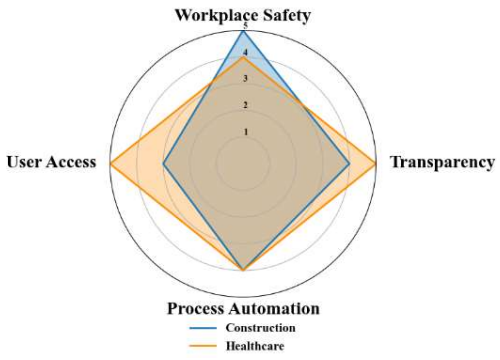

Figure 1. Comparative evaluation of sectoral blockchain solutions by OSH criteria

Both industries recognize the specific challenges within their OSH systems and the comparative advantages of blockchain-based solutions. In the area of occupational safety, the construction sector stands out due to its use of automated compliance checks with legal regulations and its focus on preventing physical injuries, particularly in high-risk environments. Transparency is rated higher in the healthcare sector, where decentralized systems provide employees with direct, verifiable access to their own data, thus enhancing trust and safeguarding workers' rights.

While both sectors apply a similar level of process automation, they do so through different approaches: the construction sector uses smart contracts for access control and employment management, while the healthcare sector relies on behavioral analysis tools and work-time monitoring. Regarding user access, the healthcare industry demonstrates greater flexibility, with personalized solutions such as tags and labels for data management, fostering inclusivity and improving system efficiency.
The findings suggest that blockchain technology offers sector-specific benefits that can be further refined, considering the unique risk profiles and organizational structures of each industry. A clear understanding of these distinctions is crucial for developing effective and sustainable OSH solutions.

4. Conclusion

The potential of blockchain technology is that it can provide improved data management, and its implementation in OSH systems, especially in high-risk sectors such as construction and healthcare, is a key step towards enhancing the safeguarding of workers. The blockchain application enables greater transparency, reliability, and efficiency in key areas, ranging from incident reporting and training management to real-time working condition monitoring and control of data access. The comparative

analysis of models across different industries shows that blockchain solutions need to be tailored to the specific context of needs and regulatory frameworks, but also points to opportunities for intersectoral transfer of best practices.

Although the analyzed models represent theoretically based and experimentally proposed concepts rather than solutions applied in real industrial environments, their evaluation enables the identification of key potentials for enhancing OSH systems.

In addition to the numerous advantages identified, including decentralization, immutability of data, and process automation through smart contracts, it is important to emphasize that the implementation of blockchain technology requires addressing certain challenges, ranging from technical (energy consumption, interoperability) to regulatory and institutional. Full integration of blockchain systems into the OSH domain would require a strategic approach that involves not only technological development but also standardization, legal compliance, and continuous user education.

Blockchain technology represents not only a tool for the technical modernization of OSH systems but also a means to redefine the relationships of trust, responsibility, and participation in modern work environments. It's a carefully planned and sector-sensitive application that could contribute to the creation of more sustainable, safer, and more inclusive occupational health and safety systems.

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