ICCEPM 2024 https://dx.doi.org/10.6106/ICCEPM.2024.0887
The 10th International Conference on Construction Engineering and Project Management
Jul. 29-Aug.1, 2024, Sapporo

A Conceptual Blockchain and Token-Incentive Approach for Near Miss Reporting in Construction

Eric J. NYATO[1]*, Emmanuel C. KIMITO[2], Dongmin LEE[3], Chansik PARK[4]

[1] *School of Civil & Environmental Engineering, Chung-Ang University, Seoul, South Korea*, E-mail address: ericnyato@cau.ac.kr
[2] *School of Architecture & Building Sciences, Chung-Ang University, South Korea, E-mail address: emmachalz@cau.ac.kr*
[3] *School of Architecture & Building Sciences, Chung-Ang University, South Korea, E-mail address: dmlee@cau.ac.kr*
[4] *School of Architecture & Building Sciences, Chung-Ang University, South Korea, E-mail address: cpark@cau.ac.kr*

Abstract: Near miss reporting is essential for improving safety performance in construction organizations. Traditional methods, however, often fail to sufficiently motivate worker participation due to a lack of incentives and the absence of secure, reliable, and transparent reporting mechanisms. This paper introduces a conceptual framework that leverages blockchain technology and token incentives to increase employee involvement in near miss reporting. The integration of blockchain ensures transparency and decentralization, while token incentives effectively monetize employees' efforts in reporting near misses. The study begins by identifying key modules essential for developing this framework and proceeds to detail their integration, illustrating a comprehensive process flow of activities within the system. This research significantly contributes to the enhancement of near miss reporting practices in construction, ultimately fostering safer and more proactive workplace environments.

Key words: Blockchain, Near miss reporting, Tokenization, Proactive safety management

1. INTRODUCTION

In the dynamic landscape of the construction industry, safety concerns are predominant, with statistics revealing alarming rates of fatalities and injuries among workers [1]. The construction industry consistently ranks as one of the most hazardous sectors [2], characterized by a multitude of risks ranging from falls and electrical hazards to struck-by incidents and trench collapses [3]. Despite efforts to improve safety regulations and technologies, accidents remain prevalent, taking a toll on workers' lives and livelihoods. In this context, near miss reporting emerges as a proactive measure to mitigate construction hazards [4]. Near miss incidents, though they don't result in immediate harm or damage, serve as precursors to potential accidents. Timely identification and resolution of these near misses are crucial for preventing future disasters and ensuring the safety of workers and projects [5].

Despite their significance, traditional near miss reporting systems in construction have encountered substantial challenges arising from various factors. Firstly, the absence of rewards for effective reporting diminishes employees' motivation to engage proactively in near miss reporting. Without tangible incentives, employees may perceive reporting as burdensome or unimportant, leading to underreporting

[6]. Furthermore, concerns surrounding secure data storage represent a critical issue. Given the sensitive nature of near miss reports, ensuring the security and integrity of stored data is imperative. Traditional systems often lack robust security measures, leaving data vulnerable to breaches or unauthorized access. This vulnerability not only undermines employee trust in the reporting process but also poses significant risks of data manipulation or tampering, compromising the accuracy and reliability of reported incidents [7]. Collectively, these challenges among many others, compromise the effectiveness of traditional near miss reporting systems in construction. The inability to incentivize effective reporting, potentially contributes to underreporting together with concerns over data security, integrity, and transparency. Consequently, the construction stakeholders end up missing critical opportunities for proactive safety management and preventive actions, leading to a decline in safety outcomes and an increased risk of accidents within construction sites [8].

Recognizing the limitations of conventional approaches, there is a pressing need to thoroughly reassess and modernize near miss reporting practices within the construction industry. In response to these challenges, this paper proposes a blockchain-based and token incentives near miss reporting framework for enhancing employee involvement and promoting proactive safety management. The paper presents a conceptual framework outlining how incentivizing employees can be achieved through the utilization of blockchain technology. Additionally, critical tools necessary for seamless collaboration and near miss management within the framework are identified.

2. BACKGROUND

This section discusses the vision towards a blockchain-based token incentives near miss reporting in construction. Firstly, a theoretical background of blockchain-based near miss and safety information management is presented and highlighting its importance. Secondly, the concept of tokenization and its potential in near miss reporting practices is presented.

2.1 Blockchain for near miss and safety information management

Blockchain technology, initially popularized by cryptocurrencies like Bitcoin [9], emerges as a transformative solution, with wide-ranging applications beyond the realm of finance [10]. Blockchain, essentially a decentralized digital ledger, revolutionizes how information is stored and shared. Unlike traditional centralized systems, blockchain operates across a network of computers, ensuring that data is not controlled by any single entity and remains tamper-proof and transparent [11]. Each recorded transaction, or in this case, near miss report, is cryptographically linked to the preceding one, creating an unchangeable and traceable chain of information [12]. In the context of construction safety and near miss management, blockchain holds immense potential for transforming traditional practices. By leveraging blockchain technology, construction companies can streamline the management of safety information and enhance transparency, integrity and trustability throughout the project lifecycle. For instance, Mortez et al. [13]proposed framework utilizes distributed ledger technology (DLT) to offer a new architecture of trust for reliably sharing information among all entities involved in a construction project who may not trust one another. Yang et al. [14] presented a blockchain-based system for scaffolding work to grant reliability and efficiency of information management. The authors in [15] presented a framework of system for construction site information management using blockchain and smart contracts in which multiple independent smart contracts are developed for different data types to ensures that the system can dynamically deploy new smart contracts without interrupting service, facilitating the expansion of scenario services. Moreover, Pan et al. [16] proposed a blockchain deep learning framework that focuses on how to efficiently extract and securely store key information (i.e., video summarization that involves worker's unsafe behavior) on-blockchain for data traceability. On a more relatable study by Ahmadisheykhsarmast et al.[17] a system that leverages the benefits and advantages of blockchain, smart contracts, and decentralized IPFS storage to address the security transparency, tampering, and trustworthiness issues of the conventional approaches in accident reporting and management was proposed. However, these studies failed to explore potential methods for

incentivizing stakeholders within construction projects who exhibit effective safety practices. This gap in the research limits our understanding of how incentives could further promote and sustain a culture of safety in the construction industry.

2.2 Integrating Tokenization for Incentivizing Near-miss practices

One of the most promising aspects of blockchain technology in construction safety management is its potential to incentivize safety practices through tokenization. Tokenization, a concept originating from the field of cryptocurrency, is a process that can be described as the encapsulation of value of any kind including reputation, work, copyright, utility, and voting rights, into tradeable units of account, called tokens or coins[18, 19]. These values are represented as digital tokens on a blockchain, and these tokens can be exchanged, traded, or redeemed for specific benefits or rewards. The governing of the creation, distribution, and management of these tokens gives rise to an economic model called tokenomics.

In construction management, tokenization offers a novel approach to monetizing and rewarding various practices and behaviors. For example, Hunhevicz et al.[20] presented a prototype and evaluated a novel process to use blockchain and smart contracts in construction projects to trace and save project data while incentivizing participants to create high-quality data sets through reward tokens. Zhao et al. [21] proposed a blockchain-based token economic model to incentive construction companies for their Environmental, Social, and Governance (ESG) performance and addresses the issues of transparency. The authors in [22] developed a blockchain-based supervision (BBS) model with incentives for application in cross-border logistics in modular construction (CLMC). Furthermore, some studies have specifically pointed out the potential integration of tokenization in construction safety management practices. Bao et al.[23] proposed a token incentive mechanism based on blockchain technology for VR-based safety training, consisting of unique safety training scenarios and a flexible virtual environment that enables users to acquire knowledge of construction safety regulations. Park et al.[24] proposed an entire platform ‘iSAFE’ for an automated construction safety management with iSAFEIncentive aiming to transform the safety culture of the construction industry by incentivizing and rewarding safety performance, shifting the focus from blame and punishment to a collaborative worker-driven approach. The authors in [25] introduced an automatic incentive mechanism that rewards contractors with Fungible Tokens (FTs) and Non-Fungible Tokens (NFTs) by capturing and processing visual data of construction sites through a computer-vision module, which reports safety performance of the company. The current research proposes a conceptual framework for incentivizing near-miss reporting practices in construction projects by leveraging blockchain technology and tokenization to enhance workers’ participation.

3. CONCEPTUAL FRAMEWORK FOR NEAR MISS REPORTING

3.1. Framework Development: Key Modules and Integration

To develop the proposed framework, it is essential to first identify and define the required key modules for integration. These modules will serve as the building blocks upon which the framework will be constructed, ensuring its functionality and operation. Identifying and defining these modules is a critical step that sets the stage for framework’s development.

1. *User Decentralized Application Module (UserDApp)*: The User DApp serves as the primary interface for users to interact with the system, facilitating seamless report submissions and communication with the blockchain network. Users utilize the DApp to submit near miss reports, while the application interacts with the blockchain via smart contracts to record submissions and process token transactions. The User DApp prioritizes a user-friendly experience while maintaining the integrity and security of data transactions.
2. *Smart Contract Module:* The Smart Contract Module acts as the core of the system's operations by governing the execution of the operational processes and comprises two essential components. Firstly, the Near Miss Reporting Contract which automates the

submission, validation, and storage processes of near miss reports onto the blockchain. This contract ensures the integrity and transparency of reported data by securely recording submissions and verifying their authenticity through consensus mechanisms. Secondly, the Token-Incentives Contract manages the creation, distribution, and trading of tokens issued as incentives within the system. These two smart contracts are deployed on the blockchain allowing every action to be transparent and immutable, providing a trustworthy and tamper-proof system.

3. *Blockchain Module;* The Blockchain Module serves as the foundation of the system's data storage, providing a decentralized and immutable ledger for storing reports. It ensures transparency and traceability of near miss reports' records, enabling users to access a secure and tamper-proof history of all submissions. By operating without a central authority, the blockchain module reduces the risk of data tampering and unauthorized alterations, thus enhancing the integrity and reliability of the system. Through its decentralized nature, the blockchain module promotes trust among participants and fosters a transparent environment for near miss reporting.
4. *User Wallet Module;* The User Wallet Module serves as a secure personal ledger for users to receive and store their incentive tokens. It provides users with a dedicated space to manage their tokens, view transaction history, and engage with the system's incentive mechanisms. Seamlessly integrated and compatible with the User DApp, the wallet ensures a smooth user experience, enabling users to effortlessly access their tokens and actively participate in the system's activities.

Together, the integration of these modules ensures the seamless operation of the framework, facilitating user engagement and promoting the objectives of incentivizing near-miss reporting practices in construction projects. By leveraging blockchain technology and tokenization to enhance workers' participation as well as trust among stakeholders. Below is the architecture of the proposed framework.

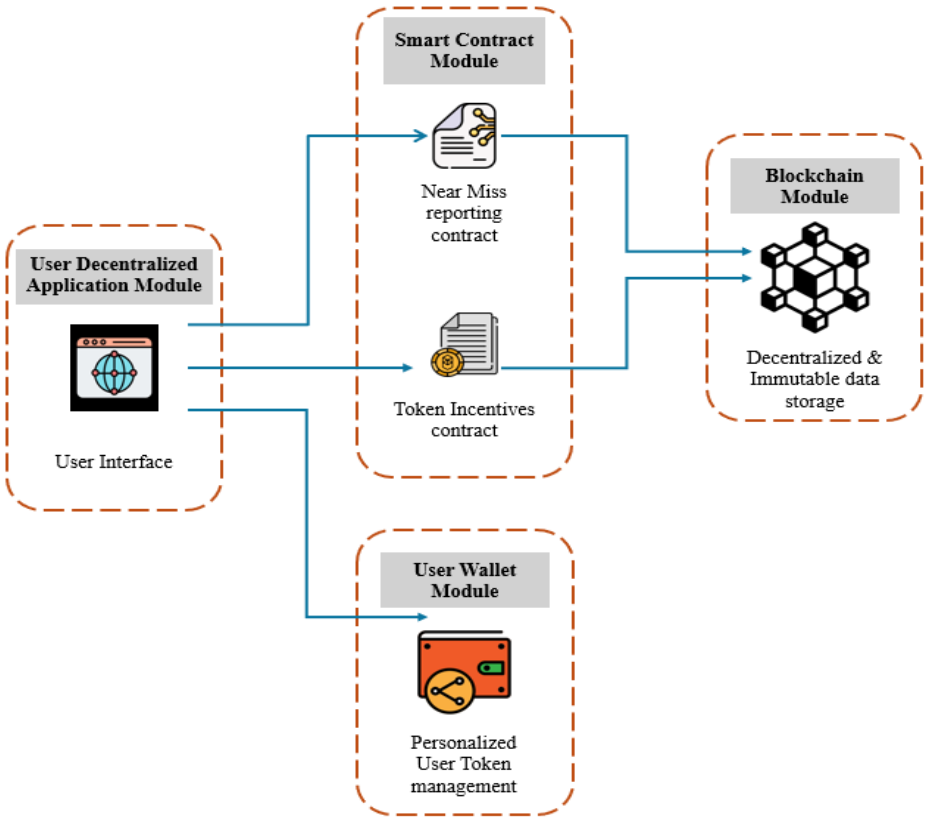

Figure 1. Conceptual Framework Architecture

3.2. Near Miss Reporting Workflow and Token Incentivization Process

In this section, a systematic workflow of each step and process from report submission to token distribution of the proposed token-incentives blockchain-based near miss reporting framework is vividly described and further elaborated in *figure 2*. The diagram serves as a visual aid to understand the seamless interaction between the user DApp, smart contracts, blockchain network, and user wallets.

- *Submission phase*: In this initial stage participants engage with the UserDApp to document the near miss. The user is guided on how and what to report through a series of prompts that help to ensure that comprehensive details of the event are captured.
- *Storage phase*: The Smart Contract receives the report via the UserDApp and autonomously records it onto the blockchain. The blockchain serves as an immutable ledger, ensuring that the report, once recorded, cannot be altered.
- *Validation phase*: A function within the Smart Contract (validate report) checks the integrity of the report to ensure it is valid. This involves verifying that the report is complete, meets certain criteria, and passes specific checks agreements that are encoded and programmed in the smart contract.
- *Decision phase* : this phase indicates two potential outcomes based on the validity of the report:
  - *If the report is valid*: The Smart Contract *confirms the submission* back to the UserDApp and then proceeds to issue tokens as a form of reward for reporting the near miss through the Token-incentive smart contract. After the tokens are issued, the User Wallet is updated with the new token balance, reflecting the reward received.
  - *If the report is invalid*: A message indicating that the report is invalid is sent back to the UserDApp. This triggers a response for the user to correct the report or provide additional information.

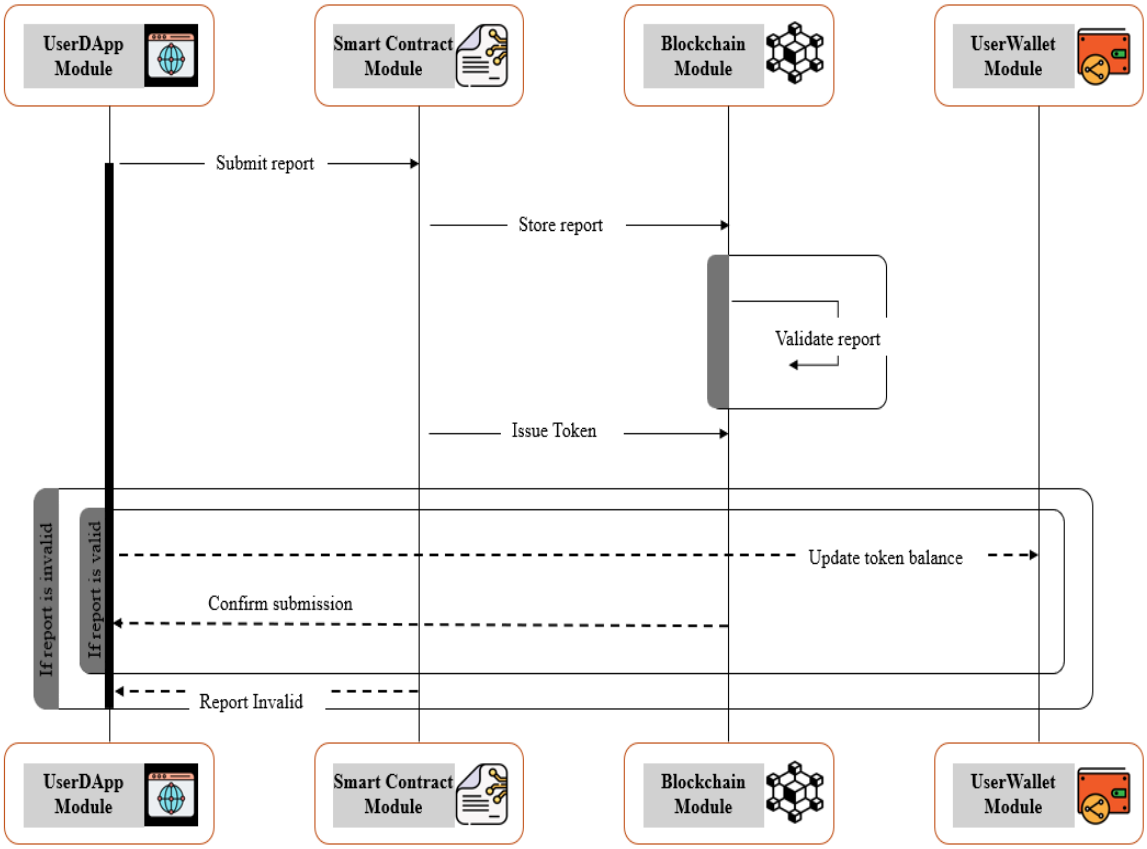

Figure 2. NMR and Tokenization process flow sequence diagram

Overall, the described process flow of the framework has the potential to significantly enhances safety practices within organizations by encouraging proactive reporting of potential issues through a structured, transparent system. By leveraging token-based incentives to motivate individuals to report near misses and Integrating technologies like Smart Contracts and blockchain ensures secure, reliable report processing thus fostering a culture of safety within the organization.

4. CONCLUSION

A key objective of construction safety management is to cultivate a culture of safety practices among construction employees so as to reduce accidents at jobsites. Reporting near misses that occur during projects is an essential practice of safety management that contributes to achieving this goal. However traditional near miss reporting approaches have long been hindered by pressing challenges such as underreporting mostly caused due to lack of workers' motivation to participate in these programs together with a lack of secure, reliable, and transparent reporting methods. To tackle these issues, this study proposes a blockchain-based framework with token incentives for near miss reporting. This approach not only has the potential to enhance the security and transparency of data through blockchain technology but also stimulate employee involvement by offering token rewards for reporting near misses. The integration of these elements fosters a proactive safety culture, shifting the focus from reactive to preventive safety management. One of the main challenges in adopting the proposed framework in real-world settings is its inability to ensure the anonymity of reporters. This aspect is critical as it usually leads to reporter's fear of repercussions, a key factor discouraging workers from reporting incidents. Future work will focus on the practical implementation and validation of the proposed framework, while exploring potential solutions to address concerns regarding anonymity.

ACKNOWLEGEMENTS

This study was financially supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government Ministry of Science and ICT (MSIP) [No.NRF-2019R1A2B5B02070721].

REFERENCES

[1] Kaur, H., et al., Occupational Injuries Among Construction Workers by Age and Related Economic Loss: Findings From Ohio Workers' Compensation, USA: 2007–2017. Safety and health at work, 2023. **14**(4): p. 406-414.

[2] Karakhan, A.A., et al., Leading Indicators of the Health and Well-Being of the Construction Workforce: Perception of Industry Professionals. Practice Periodical on Structural Design and Construction, 2023. **28**(1): p. 04022054.

[3] Alsharef, A., et al., Severe injuries among construction workers: Insights from OSHA's new severe injury reporting program. Safety science, 2023. **163**: p. 106126.

[4] Hallowell, M.R., et al., Proactive construction safety control: Measuring, monitoring, and responding to safety leading indicators. Journal of construction engineering and management, 2013. **139**(10): p. 04013010.

[5] Golovina, O., Right-time safety system to prevent close calls between construction workers and equipment. 2022, Dissertation, Bochum, Ruhr-Universität Bochum, 2022.

[6] Saqib, G., M.U. Hassan, and M.U. Zubair, Barriers to Incident Reporting in the Pakistani Construction Industry: An Exploratory Factor Analysis Approach. Journal of Construction in Developing Countries, 2023. **28**(2): p. 243-264.

[7] Ammar, A. and G. Dadi. Evaluation of Near-Miss Reporting Program Perceived by Employees' Challenges and Opportunities. in International Conference on Transportation and Development 2023. 2023.

[8] Haas, E.J., B. Demich, and J. McGuire, Learning from workers' near-miss reports to improve organizational management. Mining, metallurgy & exploration, 2020. **37**(3): p. 873-885.

[9] Nakamoto, S., Bitcoin whitepaper. URL: https://bitcoin. org/bitcoin. pdf-(: 17.07. 2019), 2008.

[10] Abou Jaoude, J. and R.G. Saade, Blockchain applications–usage in different domains. Ieee Access, 2019. **7**: p. 45360-45381.
[11] Kim, H.J., Technical aspects of blockchain, in The emerald handbook of blockchain for business. 2021, Emerald Publishing Limited. p. 49-64.
[12] Mitani, T. and A. Otsuka, Traceability in permissioned blockchain. IEEE Access, 2020. **8**: p. 21573-21588.
[13] Morteza, A., M. Ilbeigi, and J. Schwed, A blockchain information management framework for construction safety, in Computing in Civil Engineering 2021. 2021. p. 342-349.
[14] Yang, J., et al., Leveraging blockchain for scaffolding work management in construction. IEEE Access, 2022. **10**: p. 39220-39238.
[15] Zhang, Y., T. Wang, and K.V. Yuen, Construction site information decentralized management using blockchain and smart contracts. Computer-Aided Civil and Infrastructure Engineering, 2022. **37**(11): p. 1450-1467.
[16.] Pan, X., et al., Novel blockchain deep learning framework to ensure video security and lightweight storage for construction safety management. Advanced Engineering Informatics, 2024. **59**: p. 102334.
[17] Ahmadisheykhsarmast, S., et al., A transformative solution for construction safety: Blockchain-based system for accident information management. Journal of Industrial Information Integration, 2023. **35**: p. 100491.
[18] Freni, P., E. Ferro, and R. Moncada. Tokenization and Blockchain Tokens Classification: a morphological framework. in 2020 IEEE symposium on computers and communications (ISCC). 2020. IEEE.
[19] Freni, P., E. Ferro, and R. Moncada, Tokenomics and blockchain tokens: A design-oriented morphological framework. Blockchain: Research and Applications, 2022. **3**(1): p. 100069.
[20] Hunhevicz, J.J., T. Schraner, and D.M. Hall. Incentivizing high-quality data sets in construction using blockchain: a feasibility study in the swiss industry. in ISARC. Proceedings of the International Symposium on Automation and Robotics in Construction. 2020. IAARC Publications.
[21] Zhao, R., J. Wang, and F. Xue. A blockchain-based token economic model for incentivizing ESG in the construction industry. in EC3 Conference 2023. 2023. European Council on Computing in Construction.
[22] Wu, L., et al., A blockchain-based model with an incentive mechanism for cross-border logistics supervision and data sharing in modular construction. Journal of Cleaner Production, 2022. **375**: p. 133460.
[23] Bao, Q.L., et al., Token incentive framework for virtual-reality-based construction safety training. Automation in Construction, 2024. **158**: p. 105167.
[24] Park, C., et al. ISAFE: Automated Construction Safety Management Platform. in Proceedings of CIB W099 & W123 Annual International Conference: Digital Transformation of Health and Safety in Construction, University of Porto. 2023.
[25] Naderi, H., A. Shojaei, and R. Ly, Autonomous construction safety incentive mechanism using blockchain-enabled tokens and vision-based techniques. Automation in Construction, 2023. **153**: p. 104959.