INTEGRATING ESG FACTORS INTO CONSTRUCTION PROJECTS: A BLOCKCHAIN-BASED DATA MANAGEMENT APPROACH

Xingbo Gong, Xingyu Tao, Moumita Das, Helen H.L. Kwok & Jack C.P. Cheng*
Department of Civil and Environmental Engineering, The Hong Kong University of Science and Technology, Hong Kong SAR.

ABSTRACT: *Environmental, Social, and Governance (ESG) investing has become increasingly significant in the Architecture, Engineering, and Construction (AEC) industry. However, the AEC industry faces challenges such as non-uniform standards, complex information sources, and data security concerns when collecting and verifying ESG data. At the same time, as one of the key points of carbon emission in AEC projects, the ESG management of construction projects is still lacking. This paper proposed a blockchain-based ESG data management framework, which designed to address these challenges in the AEC industry. The framework and the smart contract and transaction data model applied in it realize data collection and information verification in construction projects. By leveraging blockchain technology's key features of transparency, immutability, and traceability, the framework ensures secure and efficient ESG data management. Additionally, the InterPlanetary File System (IPFS) technology enables access to original files for data verification and comparison, further enhancing authenticity. By integrating blockchain and IPFS technologies, our proposed solution enhances the reliability and traceability of ESG data in the construction projects, paving the way for more sustainable and transparent practices.*

KEYWORDS: *AEC, Blockchain, Construction Project, ESG, IPFS, Smart contract*

1. INTRODUCTION

Environmental, social, and governance (ESG) investing refers to a set of standards for a company's behavior, which socially conscious investors use to screen potential investments. In the Architecture, Engineering, and Construction (AEC) industry, ESG reporting serves as a method for evaluating a company's contributions to environmental protection, corporate governance, and financial capability. Investors and government management agencies often jointly assess a company's green development prospects based on ESG reports and other indicators. Concurrently, some investment institutions and market participants may establish ESG funds and investment expectations according to the company's ESG score. These behaviors directly influence the company's capital and stock market conditions. However, collecting and verifying ESG-related information is challenging due to various parallel standards, unclear evaluation criteria, and data security concerns. Ensuring that collected data can be safely verified by a third-party organization is also an essential issue since data tampering may render the company's ESG report and score unreliable if all data is controlled by a single department.

Blockchain technology, characterized by high transparency, immutability, traceability, and non-repudiation, is a potential solution for recording transactions and tracking business operations. From cryptocurrencies to smart contracts, blockchain technology demonstrates its potential applications in the construction industry (Turk and Klinc 2017). In the current research, the intelligent construction platform or technology based on blockchain has shown a high degree of usability and advantages. During the construction phase of a building, a large amount of data is exchanged between various departments and personnel. Effective management of these data can improve work efficiency and reduce unnecessary data and economic losses. Features of Blockchain make it conducive to storing and tracing ESG-related data for AEC projects. The construction industry, in particular, plays an important part in global carbon emissions management.

Regarding ESG-related research, the relationship between ESG and corporate performance highlights importance of ESG for business (Zhao, Guo et al. 2018). However, there is currently no available solution for AEC companies with complex information sources and data formats in construction projects. This paper aims to (1) propose a Blockchain-Based ESG Data Management framework, (2) design and apply technical components within the framework, and (3) verify the framework's feasibility through illustrative example. In order to provide a usable ESG data management method in the construction stage.

2. LITERATURE REVIEW

2.1 ESG in AEC Industry

The ESG (Environmental, Social, and Governance) evaluation framework is a multi-level system. The ESG

Referee List (DOI: 10.36253/fup_referee_list)
FUP Best Practice in Scholarly Publishing (DOI 10.36253/fup_best_practice)
Xingbo Gong, Xingyu Tao, Moumita Das, Helen H.L. Kwok, Jack C.P. Cheng, *Integrating ESG Factors into Construction Projects: A Blockchain-Based Data Management Approach,* pp. 327-334, © 2023 Author(s), CC BY NC 4.0, DOI 10.36253/979-12-215-0289-3.31

framework is to measure the ability of enterprises to achieve sustainable development. Since the signing of a series of environmental protection and sustainability-focused documents and conventions, such as the Kyoto Protocol (Protocol 1997) and the Paris Agreement (Agreement 2015), sustainable development has become an increasingly important topic from national to corporate levels. The ESG framework focuses on a company's environmental, social, and governance performance rather than financial performance, helping global investors identify genuinely sustainable businesses.

As climate and environmental issues become more severe, ESG assessment for companies has become a growing trend. The development of ESG-related management has become a focal point for research and disclosure. In 2021, the construction industry emitted approximately 10 billion tons of carbon dioxide, accounting for about 37% of global emissions (Programme 2022). Analysis of carbon emissions management or ESG in the construction industry is important. Related research on ESG and carbon emissions of engineering projects is also in progress, such as carbon emission estimation methods for highway project construction (Liu, Wang et al. 2017), and carbon emission analysis based on BIM in construction stage (Li, Fu et al. 2012).

Popular ESG evaluation frameworks include GRI, ISO and SASB, each with its own set of analytical indicators and disclosure requirements. Certified assessment indicators are accepted by various stock exchanges and can impact the position of a listed company's stock. Research on the impact of ESG on the economic environment and corporate finance (Broadstock, Chan et al. 2021) has proved that ESG has a positive impact on corporate investment and market value. In the practices of ESG integration in AEC projects, some large listed companies have already attempted and explored this approach. For example, companies such as Gensler, China State Corporation, and JLL have carried out ESG analysis and planning. At the same time, industry research also conducted an analysis of the impact of ESG on the construction industry (Daszyńska-Żygadło, Fijałkowska et al. 2022).

However, there are still some challenges for implementing ESG in the AEC industry. The current ESG standards are not uniform, and the information during the construction phase is abundant and complex, making it difficult to apply directly. During the ESG-related management of enterprises, a large amount of business data needs to be submitted to the review unit. Management methods for sensitive data including materials, supplier data, etc. are also not securely secured (Oltsik, J. 2014). Moreover, available statistical standards still need to be constructed. As ESG reporting and rating directly affect the stocks and economic situation of companies, ensuring the reliability of related data has become a difficult issue that needs to be addressed. The ability to ensure the traceability of ESG data still needs further exploration.

2.2 Blockchain in AEC Industry

Blockchain technology is a distributed information system proposed by Satoshi Nakamoto. From its initial development of cryptocurrencies to the current adoption of smart contracts, blockchain technology has been rapidly researched and applied in various fields. Unlike centralized databases, blockchain technology has high transparency, cannot be modified, and is traceable. Its structure is shown in Figure 1. Therefore, while ensuring the characteristics of information security, the application of blockchain technology can provide benefits such as the application of blockchain and Industry 4.0 (Bodkhe, Tanwar et al. 2020), the attempt in the financial system (Treleaven, Brown et al. 2017), etc

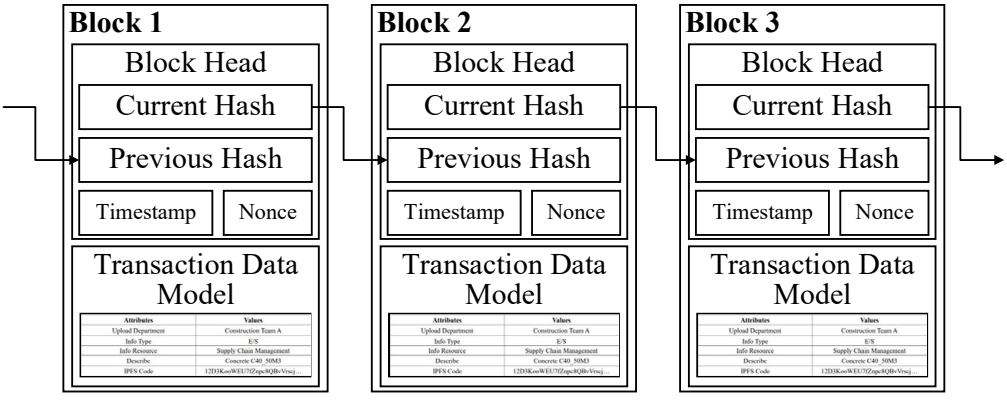

Fig. 1: Structure of Blockchain

In the AEC industry, researchers are exploring the applications of blockchain technology. Examples include a

blockchain-based architectural design collaboration framework (Tao, Liu et al. 2022), a blockchain-enhanced BIM (Building Information Modeling) design process integrated with IPFS (Tao, Das et al. 2021), construction project supply chain systems that combine blockchain with IoT (Li, Lu et al. 2022), and a blockchain-based construction quality management platform (Zhong, Wu et al. 2020). These blockchain-based frameworks demonstrate the potential of blockchain technology to enhance the security and interactivity of construction project information, and they contribute to the industry's development of information management capabilities across various domains.

Blockchain systems offer efficient and trustworthy features for smart construction in the AEC industry. In the area of ESG, the requirements for data verification and credibility are high. Due to its high transparency, traceability, and undeniable nature, blockchain technology is a good means of recording ESG data. The potential of blockchain technology in promoting ESG integration, monitoring, and reporting in the AEC industry is worth exploring. In this context, some attempts are already underway, such as research on ESG performance in sustainable supply chains (Liu, Wu et al. 2021), the use of blockchain token designs for ESG reputation to create a more comprehensive carbon trading market (Golding, Yu et al. 2022), and blockchain-based assessment systems using Life Cycle Assessment (Jiang, Gu et al. 2022). However, because the blockchain system cannot store large data. And as a new technology, the technical components and workflow applied in the blockchain system are still lacking. The current research on blockchain technology in ESG management is limited.

3. METHOHOLOGY

3.1 Blockchain-based ESG Data Management Framework

Based on the analysis of the construction process and the sources of ESG data, this paper proposes a blockchain-based ESG data management framework for the construction process, as shown in Figure 2. The framework divides the construction process into three parts: project beginning, construction stage, and project delivery. The information required for ESG collection is placed in the data layer, with specific information sources and types (environmental data or social data) also labeled.

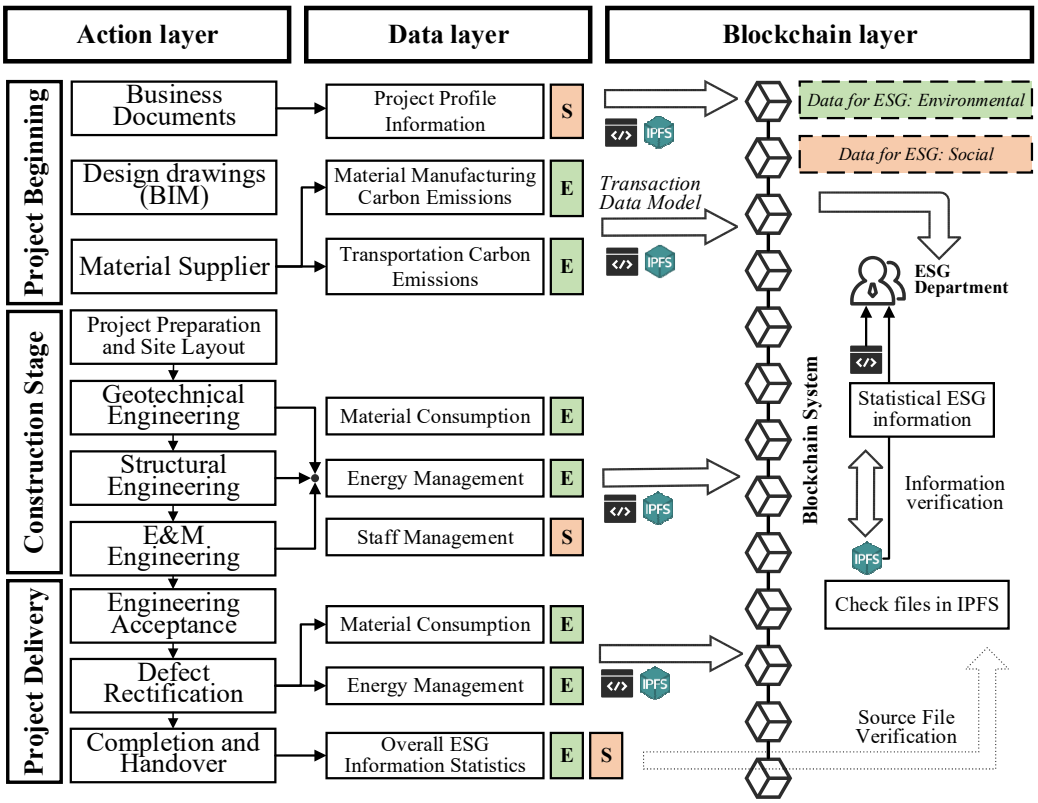

Fig. 2: Blockchain-Based ESG Data Management Framework

The collected information will be uploaded to the blockchain system through the transaction data model. This information includes the identity of the uploader and ESG-related information, and the source files' hash values

obtained through the IPFS system are also recorded within the blockchain. When the construction project is completed or the ESG department needs to compile these data, they can access the information within the blockchain system. At the same time, ESG department reviewers can obtain source files through the IPFS system and compare the data in the files with the information in the blockchain to verify the information. Due to the transparency and immutability of the blockchain, all information uploaded to the blockchain system can be properly preserved and traceability is ensured.

3.2 Transaction Data Model for ESG Management

The assessment standards for ESG performance are not uniform, and some exchanges accept ESG assessment scores from multiple institutions for companies. Therefore, this paper has researched several widely recognized ESG assessment standards, compiling their assessment scope and target companies and user groups. Four representative standards include GRI, SASB, ISO, and CDP, as shown in Table 1. Among them, ISO's ESG performance assessment is dispersed across multiple standards, and some NGOs have adopted these standards.

Table 1: ESG Standards and Objects.

Standard	Abbreviation	Scope	Industry	Target	Detailed Name
Global Reporting Initiative	GRI	ESG	Universal	All parties involved	GRI200 GRI300, GRI400
Sustainability Accounting Standards Board	SASB	ESG, Business model	Industry assessment	Investor	SASB Standards
Organization for Standardization	ISO	ESG	Universal	All parties involved	ISO 9001, ISO 26000, ISO 14001, ISO 50001
Carbon Disclosure Project	CDP	Environment	Universal	All parties involved	CDP Standards

Based on the definitions of environmental and social-related information within the collected standards mentioned above, this paper gathers indicators and data sources related to these types of information in construction projects within the AEC industry, as shown in Figure 3. The primary information sources include business documents, BIM (which includes design drawings), supply chain information, and construction site management information. After filtering and processing, this information will affect the ESG reporting and scoring of the construction project.

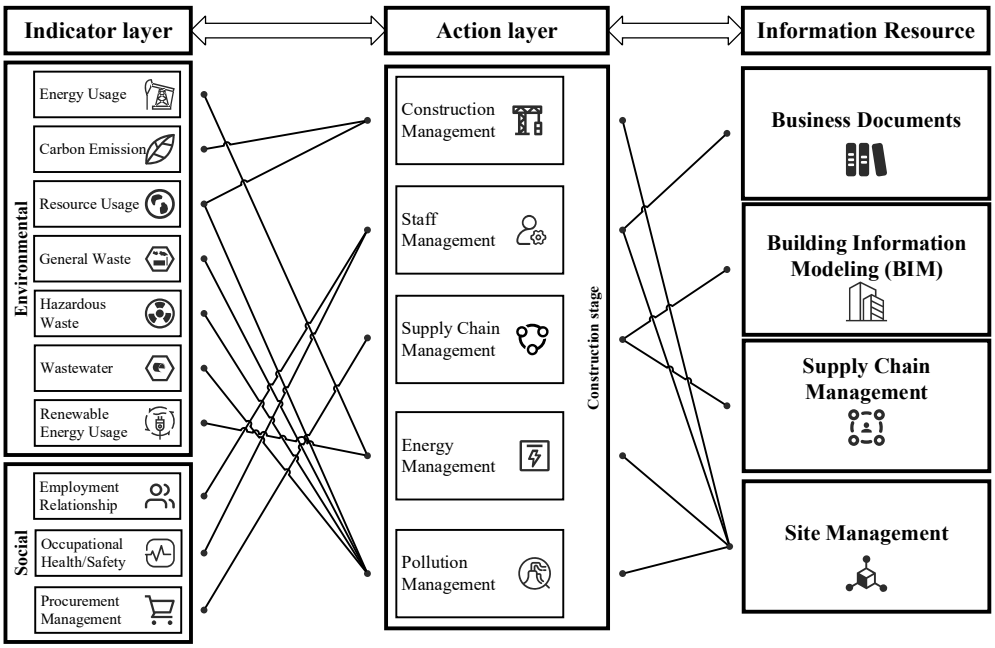

Fig. 3: Sources of ESG Information in Construction Projects

In the blockchain system, both data upload and query need to go through the transaction data model, with the information stored within blocks. A well-designed transaction data model is shown in Table 2. It includes the

information uploading department, information type, information source, data description, and IPFS hash code. For instance, when different construction teams upload ESG information, they are required to provide their team identity and specify whether the information is environmental data or social data. For energy usage, the type of energy and consumption can be described; for materials usage, the type and number of materials can be noted; and for personnel management information, descriptions can be provided according to the requirements of the governing department. Once stored in the blockchain system, this information can be provided to the ESG department for analysis and further processing. When needed, the source files can be found in the IPFS system for verification and comparison.

Table 2: Transaction Data Model

Attributes	Values
Upload Department	Construction Team A
Info Type	E/S
Info Resource	Supply Chain Management
Describe	Concrete C40_50M3
Date	20230401
IPFS Code	12D3KooWEU7fZnpc8QBvVrscj…

3.3 ESG-Construction Stage Smart Contract

The blockchain system developed in this paper is based on Hyperledger Fabric. In accordance with the designed transaction data model, this paper presents a smart contract written in the Go programming language, as shown in Figure 4. The smart contract's functions include uploading current information, querying the latest information, and querying all information stored on the blockchain.

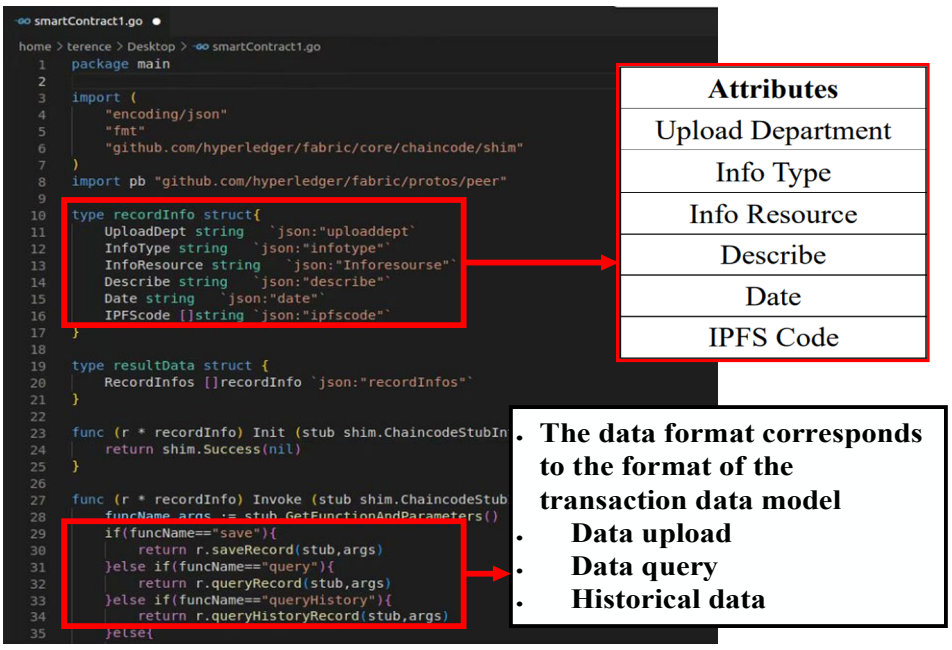

Fig. 4: ESG-Construction Stage Smart Contract

In practical scenarios, the data upload function will be frequently used to ensure real-time updates of ESG data. The other functions of smart contract mainly serve the ESG assessment department. The blockchain-based ESG data management framework consists of two developed technical components: the transaction data model and the smart contract. These two parts support the usage of the framework.

4. ILLUSTRATIVE EXAMPLE

This paper designs two scenarios to test the usability of the blockchain-based ESG data management framework. The first scenario involves data uploading and querying, as this process often needs to be repeated. For example, in actual construction projects, large amounts of materials and energy are used by multiple teams at the same time, and these records are essential in ESG analysis and score. The second scenario involves the ESG analysis department verifying the authenticity of past data. The team can verify the information based on the time information in transaction data model, the timestamps of the blockchain system, and the original files in the IPFS system. These two scenarios serve to validate the usability and traceability, which are characteristics needed by ESG analysis.

4.1 ESG Data Upload and Query

In this paper, the framework is built based on Hyperledger Fabric 2.2. For the first scenario, ESG data is fully stored within the blockchain. The data structure is consistent with the transaction data model settings, and the data query function is also implemented, as shown in Figure 5.

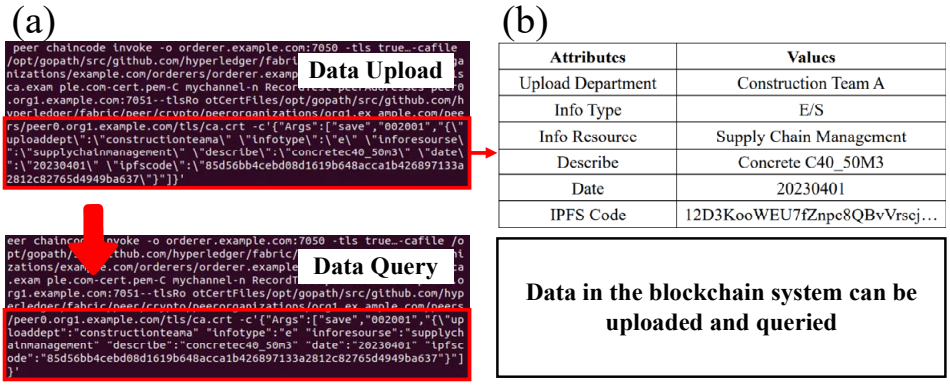

Fig. 5: (a) ESG Data Shows in Blockchain System; (b) Correspondence Between Blockchain System Data and Transaction Data Model;

In this scenario, Construction Team A received 50 cubic meters of C40 concrete from the supply chain management system. Relevant participants were recorded, including the time of the reception event and the IPFS code for the source file (receipt document). The verification results for the upload and query functions of this framework were successful.

4.2 ESG Data Verify

For the second scenario, the verification in this paper utilizes the historical information query function in the smart contract. The results show all submitted ESG-related information. Additionally, by restoring the IPFS code stored in the blockchain and accessing the IPFS system, the experiment retrieves the material receipt document for Construction Site 001 that was stored in the IPFS system during the upload process. The information in the document is consistent with the information stored in the blockchain, as shown in Figure 6.

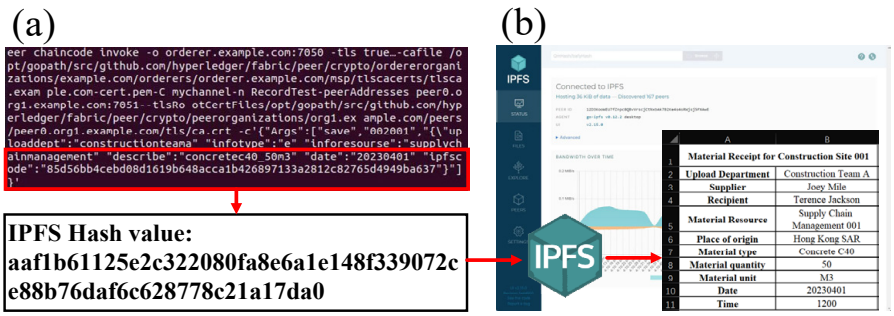

Fig. 6: (a) IPFS Hash Value in Blockchain System; (b) Verification of source files obtained through IPFS;

This experiment demonstrates the successful implementation of the historical information query function in the Blockchain-Based ESG Data Management Framework and its integration with the IPFS system. By providing

access to the original files through IPFS, the framework meets the traceability requirements in ESG data management.

5. CONCLUSIONS

In conclusion, the blockchain-based ESG data management framework proposed in this paper effectively addresses the challenges of ESG data collection and verification in the construction project. By leveraging blockchain technology's advantages, such as transparency, immutability, and traceability, the framework ensures the credibility of ESG data while maintaining data security. The integration with IPFS further enhances the data traceability and availability. The verification result of the experiment was also successful.

However, there are still limitations in the research: (1) The framework has only been verified in limited scenarios, and its stability and information throughput capacity have not been tested in actual engineering projects. (2) This design only considers the construction process, and other stages requiring ESG assessment have not been taken into account. In future research, the ESG management process in construction projects should be further considered, while further reducing the cost and efficiency of ESG assessment through secure information technology. As carbon neutrality goals are established and the demand for low carbon solutions becomes increasingly urgent within the AEC industry, further exploration of ESG analysis and technological applications is still needed.

REFERENCES

Agreement, P. (2015). Paris agreement. Report of the Conference of the Parties to the United Nations Framework Convention on Climate Change (21st Session, 2015: Paris). Retrived December, HeinOnline.

Bodkhe, U., et al. (2020). "Blockchain for industry 4.0: A comprehensive review." 8: 79764-79800.

Broadstock, D. C., et al. (2021). "The role of ESG performance during times of financial crisis: Evidence from COVID-19 in China." 38: 101716.

Daszyńska-Żygadło, K., et al. (2022). Communicating on ESG impacts: The case of the largest European construction industry companies. Corporate Social Responsibility and Sustainability, Routledge: 199-213.

Golding, O., et al. (2022). Carboncoin: Blockchain Tokenization of Carbon Emissions with ESG-based Reputation. 2022 IEEE International Conference on Blockchain and Cryptocurrency (ICBC), IEEE.

Jiang, L., et al. (2022). "Blockchain-based Life Cycle Assessment System for ESG Reporting."

Li, B., et al. (2012). "Research on the computational model for carbon emissions in building construction stage based on BIM." 30(5): 411-425.

Li, X., et al. (2022). "Blockchain-enabled IoT-BIM platform for supply chain management in modular construction." 148(2): 04021195.

Liu, X., et al. (2021). Blockchain-enabled ESG reporting framework for sustainable supply chain. Sustainable Design and Manufacturing 2020: Proceedings of the 7th International Conference on Sustainable Design and Manufacturing (KES-SDM 2020), Springer.

Liu, Y., et al. (2017). "Estimation and uncertainty analysis on carbon dioxide emissions from construction phase of real highway projects in China." 144: 337-346.

Oltsik, J. (2013). The big data security analytics era is here. Retrieved August, 28, 2014.

Programme, U. N. E. (2022). 2022 Global Status Report for Buildings and Construction: Towards a Zero-emission, Efficient and Resilient Buildings and Construction Sector. Knowledge Repository - UNEP.

Protocol, K. J. U. W. A. o. h. u. i. k. p. i. p. (1997). "Kyoto protocol."

Tao, X., et al. (2021). "Distributed common data environment using blockchain and Interplanetary File System for secure BIM-based collaborative design." 130: 103851.

Tao, X., et al. (2022). "Confidentiality-minded framework for blockchain-based BIM design collaboration." 136:

104172.

Treleaven, P., et al. (2017). "Blockchain technology in finance." 50(9): 14-17.

Turk, Ž. and R. J. P. e. Klinc (2017). "Potentials of blockchain technology for construction management." 196: 638-645.

Zhao, C., et al. (2018). "ESG and corporate financial performance: Empirical evidence from China's listed power generation companies." 10(8): 2607.

Zhong, B., et al. (2020). "Hyperledger fabric-based consortium blockchain for construction quality information management." 7(4): 512-527.