Construction Inspection Information Management with Consortium Blockchain

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Abstract: Blockchain can be regarded as a distributed database that records transaction data in a shared manner. This new technology is considered destructive and can transfer many data-driven industries, including construction. On the other hand, as one of the necessary measures to ensure quality, progress, and safety, construction inspection records still rely on paper. This leads to many problems, such as time-consuming, input errors, file loss, and even data manipulation. This research aims to develop a blockchain-based construction information management platform to expand blockchain applications in construction inspection management. First, conduct a literature review to explore blockchain technologies, types of blockchains, blockchain platforms, and existing construction inspection processes and issues. Based on the review, a method called design thinking is used to develop a blockchain prototype. As a result, a consortium blockchain prototype is developed to help inspection information management. The proposed solution can be tested and fine-tuned in future research. The study also discusses issues related to the current blockchain implementation, which provides numerous opportunities for further investigation. Not only limited to general discussions, one contribution of this research is the development of a configurable prototype so that construction stakeholders can follow and develop their blockchain-based solutions.

Keywords: Blockchain; Construction industry; Information management; Inspection; Smart contract.

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1 Introduction

Blockchain was first known as the basic technology of cryptocurrency in 2008[1]. Subsequently, blockchain was introduced for applications beyond cryptocurrency. Perera et al. (2020) pointed out that blockchain is considered to have disruptive capabilities and can change many global industries, including the construction industry[2]. Blockchain can be seen as an immutable ledger, recording information in a decentralized manner. It combines three key underlying technologies: distributed database, cryptography, and consensus protocols[1]. Together, these underlying technologies enable information to be submitted, endorsed, and shared with a high degree of security. Blockchain can be divided into three types, namely public, private, and consortium. They are categorized by the right to access ledger on the blockchain[2]. Many existing blockchain platforms, such as R3 Corda and Hyperledger Fabric, can develop decentralized applications. If the existing platform does not meet user requirements, one can also develop a self-built platform.

Construction inspection plays a vital role in every phase of projects. In general, construction inspections are usually carried out as a contractual responsibility performed by the consultants to offer the client an independent view of construction quality, work progress, and site safety. Most of the existing inspection information is recorded on paper[3]. Issues such as incorrect placement of steel bars, schedule delays, and unsafe operation behaviors are identified and integrated through manual processes; therefore, the process is expensive, inefficient, and error-prone. Also, the construction stakeholders are known for their lack of mutual trust. The development of mutual trust between stakeholders (e.g., clients, main contractors, consultants, and subcontractors) in construction depends on tamper-proof construction inspection records[4]. Nevertheless, existing information management technologies cannot meet the stakeholders' requirements.

The aim of this paper is threefold: (a) to explain blockchain technology so that stakeholders in the construction industry understand its potential; (b) to develop a consortium blockchain prototype (Hyperledger Fabric-based) by following which stakeholders in construction can develop their case-specific blockchain solutions for managing construction inspection information; (c) To discuss issues related to the current blockchain implementation so that future research can provide potential solutions. The rest of the paper is structured into five sections. In the second section, we briefly introduce blockchain and describe inspection works in the construction industry. In the third section, we provide the methodology. In the fourth section, we propose our blockchain prototype. Discussions are conducted to deepen the understanding of blockchain technology in the fifth section, and conclusions are given at last.

2 Literature Review

2.1 Blockchain Technology

Cryptography, distributed databases, and consensus mechanism are the three basic technologies of blockchain[2]. Blockchain protects transaction data and interactions on the chain through a hash algorithm and public key infrastructure (PKI). PKI guarantees that the transaction data is encrypted and decrypted through the unique relationship between the public key and the corresponding private key, while the hash algorithm ensures that the transaction data is tamper-proof[2]. The blockchain retains a growing set of transaction data, bundled together into blocks of data (Figure 1). Each block includes the block number, the previous block's hash, the current block's hash, the timestamp, the target difficulty, and the nonce[5]. A nonce is a random number that considers the network rules to identify the hash. The hash value is unique for each block, so if people intentionally or unintentionally alter the block's transaction data, the corresponding hash value will be changed instantly. Each block retains the previous block's hash value to ensure that the current block cannot be changed without changing the previous block.

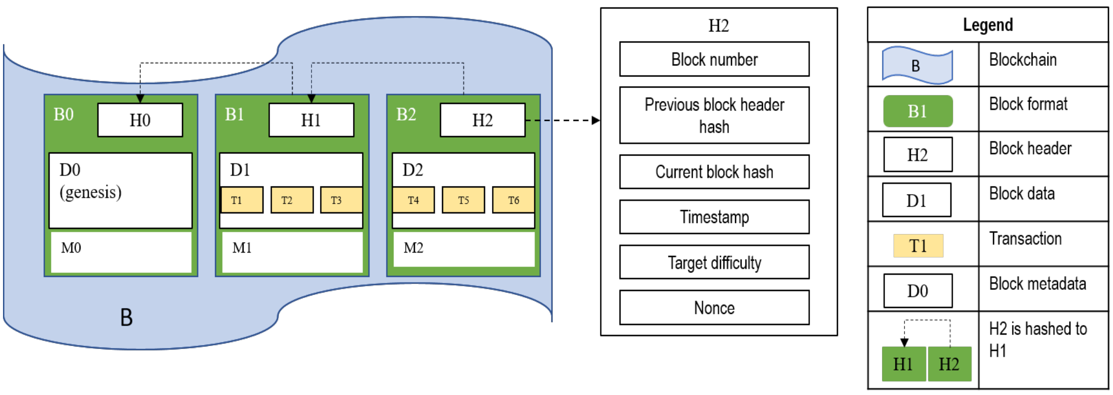

Figure 1. Blockchain structure

A blockchain database is not a single information storage source but is composed of ledgers scattered in many locations in a shared manner[2]. A distributed database is also a network where participants (also called peer nodes) can have transactions without intermediaries. The blockchain consensus mechanism makes direct transactions between interacting parties possible. The blockchain's consensus mechanism is to accept the transaction data into the distributed ledger by verifying the transaction data's order and correctness[5]. There are many consensus algorithms to choose from, such as Proof of Work (PoW), Proof of Stake (PoS), and Practical Byzantine Fault Tolerance (PBFT), and each consensus has its own advantages and disadvantages.

2.2 Blockchain Options

Blockchain can be categorized as public, consortium, and private[2]. The public blockchain allows anyone interested to join, and everyone can read the data on the public blockchain[1]. Public blockchains are commonly used for cryptocurrencies such as Bitcoin. The consortium blockchain only allows a limited number of pre-authorized groups/organizations to read data and submit transactions[1]. The private blockchain is only open to one organization, so the network is centralized[1]. Many existing blockchain frameworks and platforms can be used to implement public, private and consortium blockchains. Table 1 gives an overview of three popular blockchain platforms. People can also develop customized platforms, but it may be challenging to ensure their code security.

Table 1. Popular blockchain platforms overview

Features	Ethereum[2]	Hyperledger Fabric[2]	Ripple[6]
Industry usage	Cross-industry	Cross-industry	Financial Services
Blockchain type	Public	Consortium	Private
Consensus	Proof of Work/ Proof of Stake	Pluggable consensus	Ripple protocol consensus
Mining rewards	No	Yes	No

2.3 Construction Inspection

In construction projects, the client entrusts inspectors to manage the project quality, schedule, safety, contract, and other aspects of a business. The inspector is an impartial third party between the client and the contractor who can correctly handle disputes. Besides, inspectors are required to understand engineering and technical knowledge, accounting, and construction regulations. Quality control inspections usually include on-site inspections of materials and construction processes[7]. The purpose of quality control inspections is to ensure high-end quality at delivery. Inspectors can also check quality-related documents, work instructions, and action plans to control the construction process better and prevent opportunism. Besides, regular progress inspections are conducted on construction sites to ensure that the project can be completed within the agreed contract time[8]. Construction inspections are also important to ensure that relevant people work in a safe environment[9]. For example, check whether there are fences to prevent people from falling from heights, ensure that employees wear personal protective equipment, and check whether equipment and work platforms are maintained. On-site inspectors usually keep daily construction logs or on-site diaries, photos, and construction progress meeting minutes, and then submit reports regularly.

There are many problems with construction inspection information management. At present, a large number of inspection works are paper-based[10]; construction inspection records can be tampered or altered without being found[11]. Also, there may be information gaps between participants because many inspection forms are filled out and sent manually, which leads to informal filling, incomplete attachments, poor real-time sharing, and low efficiency[11]. Moreover, compared with other engineering industries, construction projects are temporary and one-off. Therefore, organizations involved in construction projects find it difficult to maintain long-term partnerships. The development of mutual trust between organizations with different interests is challenging. Without trust, many organizations are reluctant to share detailed inspection information[11]. Participants can cut corners and blame others in collaboration because the existing information management system has very low traceability[11]. Participants may also be dishonest and violate the contract to pursue private interests[11].

Blockchain, with its salient features, has the potential to solve the above-mentioned inspection information management issues. Blockchain can introduce reliability and immutability. Based on the hash algorithm, no one can modify or tamper with approved records[2]. The agreed inspection information is stored in distributed ledgers, and all participants have the same ledger that updates simultaneously. This can enhance information transparency and sharing[2]. In addition, all participants have encrypted signatures based on PKI. Combining the signature with timestamps, the blockchain can ensure the traceability of inspection information[11]. Each inspection document needs to be endorsed by relevant stakeholders based on a consensus mechanism. Therefore, blockchain can establish mutual trust between stakeholders and prevent later disputes[11]. By combining blockchain and smart contracts, inspection information can be automatically checked according to contracts, regulations, and standards to ensure construction quality, progress, and safety. Smart contracts are digital contracts that can perform operations when predetermined conditions are met[1].

3 Methodology

This research used a hybrid approach, which includes literature reviews and design thinking (Figure 2). Generally speaking, a literature review is a systematic method of collecting and integrating previous research results[12]. As a research method, an organized literature review lays a concrete footing for advancing the existing knowledge system and promoting theory development[13]. Through comprehensive findings, a literature review can solve research problems with capabilities that no single study has. In view of the difficulty of exhausting all related research work, it is usually necessary to delimit the research scope. Keywords used to search for related papers in this study include “Construction Inspection”, “Block chain”, “Blockchain”, “Consortium Blockchain”, and “Hyperledger Fabric”. A preliminary analysis was conducted to determine each paper’s basic information; that is, the research objectives include blockchain applications and technologies, construction inspection process, information management, and information management systems.

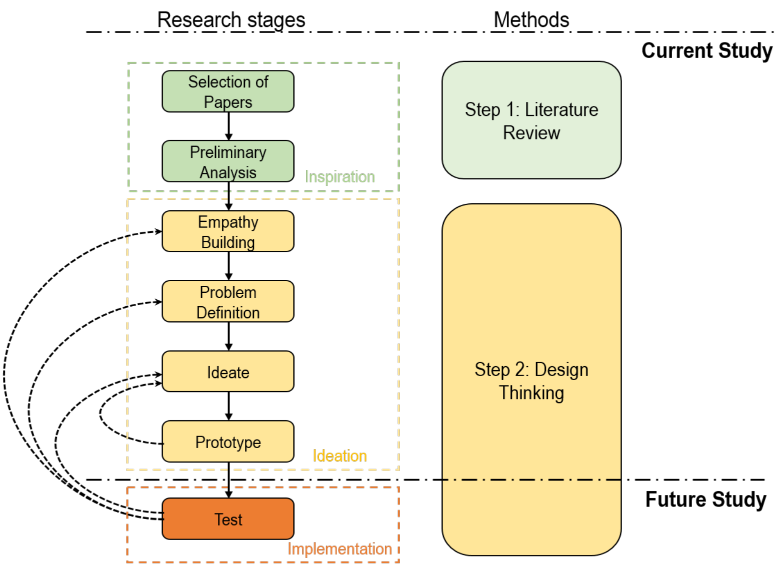

Figure 2. Proposed Hyperledger Fabric-based solution

Next, this research adopted design thinking to learn from existing practices and design a prototype suitable for construction inspection information management. It emphasizes "thinking like a designer", who usually focuses on improving a product's functionality according to customer needs[14]. The design thinking process includes five stages, namely, empathize, define, ideate, prototype, and test. In this research, empathy was about understanding the interrelationships among construction stakeholders (e.g., customers, contractors, and consultants). In the next step, we defined the key issue. The issue here was to propose a Hyperledger-fabric prototype so that a consortium blockchain-based system can manage construction inspection information. Then, we carried out several group meetings to discuss and propose various design options. Finally, a designed prototype was proposed. The testing stage was not covered in this study. In future research, this stage will aim to interact with users to fine-tune the proposed solutions.

4 Proposed Solution

The upper part of Figure 3 shows a typical quality, progress, and safety inspection process. The contractor's engineer can submit an inspection request from the construction site. Usually, a client entrusts consultants (e.g., inspectors) to conduct inspections on construction sites. The client's project manager will supervise the entire inspection process in the project-based organization, endorse the consultant's inspection reports, and issue payment instructions if all content meets the contracts and requirements.

To achieve reliability, immutability, information sharing, traceability, and self-execution in business transactions, organizations participating in inspection must have identical and immutable inspection records as the foundation for building trust. Based on the review in Section 2.2, we chose the consortium blockchain because it allows multiple authorized parties to join the blockchain network and ensures privacy. Besides, consortium blockchain can provide membership services (e.g., identity authorization and verification) for multiple parties. In the process of cooperation, different information may have different degrees of confidentiality. The ideal platform should provide isolated communication channels to protect privacy. For example, the client can establish an isolated communication channel with the inspector without the contractor's involvement. As a result, the Hyperledger Fabric platform is selected for construction inspection information management.

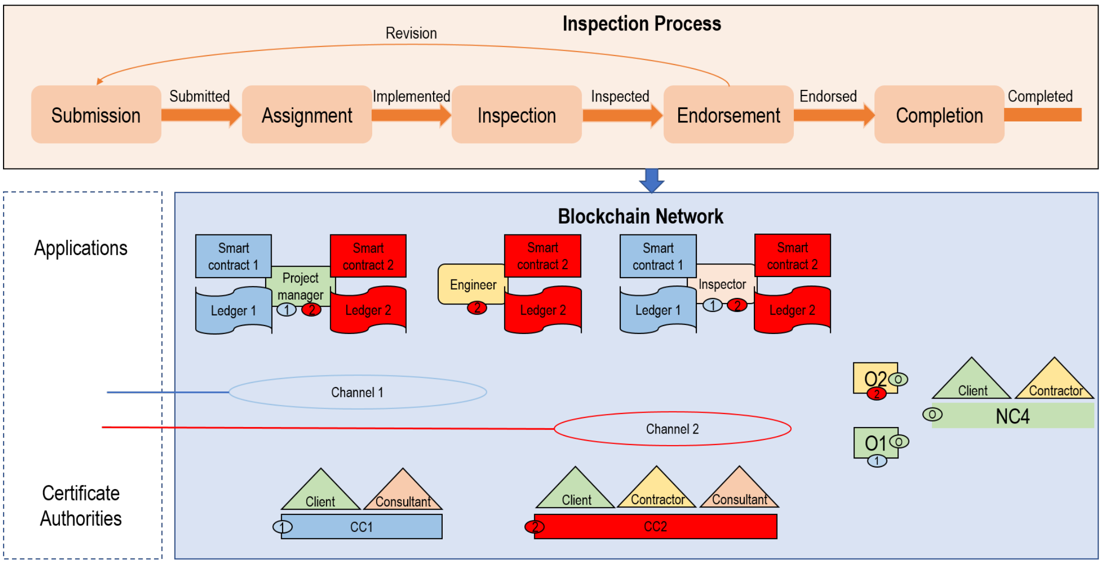

Figure 3. Proposed Hyperledger Fabric-based solution

The designed blockchain system based on Hyperledger Fabric in the lower part of Figure 2 can enhance inspection information management. This digital inspection platform can benefit all construction stakeholders. The submission of inspection requests can be digitalized and sent to inspectors to perform inspections effectively. Inspectors use their smart devices (e.g., smartphones, iPads) to complete assignments, conduct inspections, approve inspection forms or record any unqualified events, and report to the client's project manager through the platform. Photos and conversation records can also prove the inspection process. The advantages of this platform include quickness, digitization, and transparency. Another advantage is that all submitted documents should reach a consensus in the blockchain to prevent future disputes. Most importantly, there is a timestamp on each inspection-related document submitted to the platform. The platform can also enhance trust because the blockchain structure provides security, auditability, and the submitted documents are immutable.

In the designed Hyperledger Fabric blockchain network, the Client, Consultant, and Contractor plan to use this platform to manage inspection information. The Client is the initiator of the network. Client, Consultant, and Contractor can have applications that perform inspection information in two channels. Client and Consultant can privately exchange information about inspections in channel 1, while Client, Consultant, and Contractor can also communicate in channel 2 together. The peer nodes Project manager and Inspector have two ledgers, which record inspection information related to Channel 1 and 2. They also have two smart contracts associated with channels 1 and 2, respectively. In contrast, the contractor's peer node Engineer has only one ledger and one smart contract associated with channel 2. CC1 and CC2 are "Endorsement Policies", so relevant parties can manage their channel access rights through them. Similarly, NC4 allows the Client and Contractor to manage the entire blockchain network. O1 and O2 are two ordering nodes used to manage the channel (e.g., packing inspection documents into blocks). Each organization also has a certification authority that can issue digital identities to their peers.

5 Discussion

There are many existing problems in real life related to blockchain implementation. Security is one of the biggest issues related to blockchain. In the construction industry, practitioners mistakenly believe that blockchain can be a panacea to ensure the information's authenticity. However, there is an off-chain issue that needs to be resolved in the future. For example, there is no 100% secure solution to ensure that information is not tampered with before being submitted to the blockchain. Therefore, it is necessary to convene engineers, blockchain developers, and even lawyers to sit down and discuss the security framework for off-chain issues. Also, because the number of participants in a construction project is limited and clients have strong decision-making power, determining the number of peer nodes in a construction project to reduce the risk of 50% attacks will become a big challenge. A 50% attack means that once someone has 50% of the blockchain network's computing power, they have the opportunity to tamper with the information on the blockchain[2].

Secondly, how to choose a blockchain is also a problem. Although some studies have provided some guidelines for construction practitioners to decide whether they need to use the blockchain, to the best of our knowledge, no studies have proposed a systematic method to guide users to choose blockchain types and platforms. Simultaneously, there is also a lack of relevant literature and industry guidance to help people design a blockchain system that meets their needs. The lack of guidelines for choosing blockchain options greatly limits the implementation of blockchains in real life.

Finally, one of the most issues concerned by the construction industry- the economic cost of using blockchain-based systems has not received much attention. Only a small amount of literature calculates the cost of blockchain transactions. However, there is no detailed explanation and case to prove the overall cost of blockchain use. The blockchain cost may include initial platform setup, deployment, cloud storage, ongoing maintenance, and monitoring. Thus, when better empirical data is available, a detailed cost-benefit analysis is required.

6 Conclusions

The purpose of construction inspections is to ensure construction projects' quality, progress, and safety. However, there are many problems with current construction inspection information management. For example, inspection information is easily tampered with and cannot be shared in real-time. The inspection information received by clients is not reliable, and the traceability is low. Besides, it is not possible to automatically check whether the information meets the requirements. In terms of inspection information management, blockchain allows various construction stakeholders to realize immutable, transparent, shared, traceable, and automatic construction inspection information management and this is the footing for mutual trust.

This paper proposed a blockchain-based prototype for managing construction inspection information in a decentralized manner. The Hyperledger Fabric platform under the consortium blockchain can collect, encrypt, share, and record construction inspection information. Also, with the support of smart contracts, an automated compliance check process can be realized. Further research should be conducted to test and fine-tune the proposed prototype. In addition, this research discusses issues related to blockchain applications. These issues provide many opportunities for future investigations. One of the important contributions of this research is developing of the configurable prototype so that construction project stakeholders can follow and develop their blockchain-based solutions.

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