A BLOCKCHAIN-BASED APPROACH FOR MANAGING CONSTRUCTION CLAIMS

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Abstract

Construction claims can result in significant cost overruns and delays. Various management systems have been studied to overcome issues that may arise from claims. However, many challenges in the claim management process remain, including lack of collaboration and trust among parties, ambiguity in roles and procedures, and the unavailability of accurate, trustworthy, and traceable information records. To overcome these issues, a blockchain-based claim management using Hyperledger Fabric is proposed to improve the quality and reliability of records and enhance the availability of relevant information for effective claim management.

Introduction

Although construction claims can be legitimate, they can be one of the most detrimental events in a project (Ho and Liu 2004; Zaneldin 2020). A claim is a request for compensation for damages incurred by any party to a contract (Mishmish and El-Sayegh 2018; Semple et al. 1994). The impacts of claims in construction projects can be particularly destructive, often resulting in increased project costs and time, and in some cases, even the contract termination (Enshassi et al. 2009; Riveros et al. 2022). Construction project claims may arise due to a variety of factors, such as changes in site conditions that were not accounted for in the original contract, delays in obtaining necessary licenses or permits by the project owner, or change orders resulting from variations between actual and original project scope (Al-Qershi and Kishore 2017; Cinko et al. 2023; Do et al. 2022; Shaikh et al. 2020).

Effective claim management is crucial in mitigating the negative impacts of claims on construction projects (Bakhary et al. 2015). Claim management in construction can aid in preventing, mitigating, evaluating, and controlling claims and resolving disputes that may arise during a project (Cinko et al. 2023). Efficient claim management can minimize the impact of claims on project schedules and budgets and improve the relationships between the parties involved in the project (Asuquo et al. 2020).

Despite many studies to determine the success factors in developing a claim management system, managing claims remains a challenge. The problems in claim management systems include a lack of communication and trust among parties, unavailability of documents, ambiguity regarding roles and responsibilities, a lack of standardized procedures, inadequate record-keeping, inaccurately recorded information, and insufficient evidence to assert a claim or defend against it (Asuquo et al. 2020; Bakhary et al. 2015; Cinko et al. 2023).

Blockchains utilize distributed ledger technology to implement a distributed, transparent, and immutable record of transactions (Monrat et al. 2019). Blockchain technology has been applied in many cases in response to issues such as lack of trust (Qian and Papadonikolaki 2021), reliability of information (Turk and Klinc 2017), poor communication and collaboration (Yoon and Pishdad-Bozorgi 2022), standardizing procedures, and document management (Das et al. 2022). This research project aims to tackle three problems associated with existing claim management systems: the lack of cooperation among project parties and trust, unclear roles and procedures, and unavailability of reliable and trustworthy information.

The primary objective of this research is to develop a blockchain-based claim management system to address the issues identified in existing systems. The proposed solution enables clear roles and workflow to facilitate reliable updates and sharing of claim information among stakeholders. In addition, integrating blockchain technology can enhance the efficiency of the claim management process by providing trustworthy information gathered through consensus, improving collaboration among parties to capture claim information, and automating and enforcing the process governance through smart contracts.

Claims in Construction Project

The complexities and uncertainties present in construction projects (Asuquo et al. 2020; McCord et al. 2015), coupled with the involvement of stakeholders with conflicting interests (Soni et al. 2017), can result in unforeseen events that impede a project's advancement (Asuquo et al. 2020). Such occurrences can lead to disagreements and conflicts between stakeholders, ultimately escalating to litigation (Bakhary et al. 2015).

Construction claims arise when a party requests compensation due to a deviation from the original contract and conditions (Kululanga et al. 2001). Mishmish and El-Sayegh (2018) define claims as a mechanism for reimbursing losses incurred by any party in the contract. For submitting a new claim, contractors are typically bound by the conditions outlined in the contract, which entail fulfilling specific requirements such as providing relevant supporting documentation and a breakdown of claimed additional cost and time (Bakhary et al. 2017). Following the submission of a claim, the involved parties can either reach an agreement through issuing a change order or modification, or alternatively, they may disagree and pursue a dispute (Zaneldin 2020). Given the high cost, time-consuming process, and the risks of litigation, many dispute control mechanisms have been developed to help parties reach an agreement before it leads to a litigation (Gebken and Gibson 2006). Alternative dispute resolution (ADR) methods are usually mandated by contract as an alternative method to resolve disputes and avoid litigation (Alaloul et al. 2019; Yaskova and Zaitseva 2017). The resolution of disputes using ADR can take various forms, including arbitration, adjudication, negotiation, mediation, dispute resolution advisor system, dispute review board, and mini-trial (Lee et al. 2016).

In the worst cases, claims can negatively impact the progress and prolong the completion of a project (Enshassi et al. 2009; Mishmish and El-Sayegh 2018). The adverse effects of claims on project delays and cost escalation have been acknowledged and discussed by many scholars in the literature (Aibinu and Jagboro 2002; Gulezian and Samelian 2003; Iyer et al. 2012; Prasad et al. 2019). As a result, effective claim management is essential to avoid, mitigate, evaluate, and handle claims that may arise because of various reasons, such as unforeseen changes, delays in payments, varying site conditions, and design errors (Cinko et al. 2023; Do et al. 2022; Shaikh et al. 2020).

Claims management is the process of organizing and coordinating resources to handle a claim, from identifying and analyzing it to preparing and presenting, and ultimately negotiating and settling the claim (Kululanga et al. 2001; Zaneldin 2006). Management of the construction claims is one of the biggest challenges of contractors in a project (Abdul-Malak et al. 2020; Makarem et al. 2012). To address this issue, researchers have proposed approaches to enhance the efficiency of claim management processes and minimize the negative impacts of claims. For example, Parchami Jalal et al. (2021) introduced a building information modeling (BIM)-based claim management system to proactively manage and visualize the construction elements prone to claim. They identified ten claim types where the elements of construction are assessed to determine their susceptibility to claims. Niu and Issa (2012) proposed an ontology-based system for automatically generating construction claim documents. The system leverages software agents to extract claim knowledge from various sources and facilitate data collection and generation, thereby enhancing the efficiency and reliability of claim documentation. Guévremont and Hammad (2021) proposed a new method for using 4D simulation and an integrated ontology to visualize and analyze delay claims in the construction industry. The proposed method can facilitate hearing procedures of construction delay claims by providing a multidisciplinary tool for quantification, impact assessment, and assigning responsibility for claims.

Previous research has emphasized the importance of understanding the causes of construction claims to develop effective claim management systems. Various studies have been conducted to identify common types and causes of claims in the construction industry (Hashem M. Mehany and Grigg 2015; Hayati et al. 2019; Matseke et al. 2021; Parchami Jalal et al. 2019). For instance, Zaneldin (2020) identified twenty-six causes of claims based on a survey among participants in construction projects, with change orders and owner-caused delays emerging as the most severe causes. Similarly, a study by Al-Qershi and Kishore (2017) revealed that the most significant causes of claims included delays in site handover, variations between actual and original quantities, excessive change orders by the owner, delayed shop drawing approvals, and project scope changes. In another study, Mohamed et al. (2014) identified several critical causes of construction claim disputes, such as delayed interim payments from clients, teamwork qualifications, extensions of time, incomplete drawings and specifications, poorly written contract clauses, change orders, and cooperation and communication issues among project teams, as well as late supply of equipment and materials. In a more recent study, Do et al. (2022) identified forty-five claim causes, highlighting six key causes, namely contract-related problems, inappropriate actions by the owner, contractor's lack of competence, impediment issues from the owner/consultant, uncontrollable objective problems, and contractor's bidding issues.

Despite numerous studies on construction claims aimed at identifying the success factors in the effective claim management (Cinko et al. 2023) and the primary causes of construction claims (Do et al. 2022; Parchami Jalal et al. 2019; Parikh et al. 2019), claims administration remains a challenge in construction projects (Asuquo et al. 2020; Cinko et al. 2023). According to Cinko et al. (2023), communication and feedback, conflict resolution capability, mutual trust and confidence, and clarity of roles and responsibilities are the most critical factors in successful claim management in construction. Two main identified issues of the claim management process are: 1) unavailability of accurate and reliable information for supporting the claims; and 2) lack of collaboration and unclear roles and procedures in claim management. These two problems are discussed in more detail throughout the following sections.

Integrity and Accuracy of Claim Documentation

A thorough and appropriate claim documentation can increase the chance of successing a claim for contractors (Stamatiou et al. 2019). Conversely, poor documentation of claims can lead to denial of legitimate claims and forfeiture of a favorable position by contractors (Stamatiou et al. 2019). Claim documentation contains supporting facts related to the history of a construction claim (Kululanga et al. 2001). According to Kululanga et al. (2001), the documented facts are critical for the success and validity of the claim legal framework. In addition, dated and signed communications between participants can be served as a strong backup for claims (Stamatiou et al. 2019). Documentation must include general parts, contract citations, quantification of financial claims and time claims, and claim evidence (Yang and Xu 2011). In addition, images, invoices, and impacted schedules can also be used to support claims (Stamatiou et al. 2019).

The construction industry has a reputation for lacking consistency and accuracy in the documentation of its procedures and transactions (Bakhary et al. 2015; Shahhosseini and Hajarolasvadi 2018). Claim management is a data-intensive process. Access to accurate, reliable, and trusted data efficiently and on time is one of the biggest challenges in the claim management systems (Shahhosseini and Hajarolasvadi 2018). Verifying the authenticity and accuracy of information is crucial in providing justifications for claims (Vidogah and Ndekugri 1998). Niu and Issa (2012) indicate that the inconsistency and unreliability of claims history and inefficient manual works during the production of claims documentation weakens the robustness of claim arguments (Niu and Issa 2012). A survey conducted by Hayati et al. (2019) identified the unavailability and inaccuracy of recorded information as well as the time and cost associated with retrieving related information, as significant issues during the identification and preparation of claims. Thus, it is vital to proactively organize and maintain relevant information and documents in a traceable manner for effective claims management. Such preventive activities can prevent disputes and minimize potential claims by providing precise and easily retrievable records (PMI, 2016).

Collaboration, Roles, and Responsibilities in Claim Management Systems

Adversarial relationships among project parties, often caused by lack of cooperation, limited trust, and ineffective communication, can significantly impact construction projects, such as delays, cost overruns, and ineffective claim resolution (Chan et al. 2004). To address these issues, collaborative practices have effectively improved project efficiency and reduced disputes (Chan et al. 2004). In addition, studies have found that collaborative information management is a crucial success factor in construction projects (Wuni and Shen 2022), that can improve communication and enhance trust and teamwork, leading to early identification and resolution of problems, which can greatly benefit claim management (Elhag et al. 2020).

Collaborative problem-solving approaches have been identified as one of the most efficient ways to deal with construction project claims (Shaikh et al. 2020). However, clear definitions of responsibilities and regular monitoring of the partnering process are essential for successfully implementing collaborative practices (Chan et al. 2004).

A clear definition of responsibilities and regular monitoring of the partnering process have been discussed as requirements of a successful partnering (Chan et al. 2004). Ambiguity in claim procedures and unclear responsibilities can be critical issues in claim management, hindering the claim's efficient and timely resolution (Abdul-Malak et al. 2020; Hayati et al. 2019; Semple et al. 1994). Therefore, it is necessary to establish accountabilities, expectations, roles, and responsibilities, identified as critical success factors for the sustainable delivery of construction projects (Banihashemi et al. 2017).

Blockchain

Blockchain is a distributed ledger technology that enables multiple parties to maintain a shared database to record transactions without requiring a central authority or intermediary. In the blockchain, transactions are recorded securely and transparently on a distributed ledger. Each block contains a cryptographic hash of the previous block, creating a tamper-proof record of transactions. In blockchain, transactions, after being cryptographically signed, will be validated through the consensus mechanism and will be stored on blockchains. The consensus mechanism in blockchain facilities collaborative decision-making to ensure consistency on the state of the distributed ledger in a in a trustless environment (Zheng et al. 2018). Based on the consensus method, blockchains can be categorized into permissioned and permissionless. Permissionless blockchains are open networks where any user can participate in adding new blocks, and anyone can read the ledger data. In contrast, permissioned blockchains restrict participation to authorized users, and access to the ledger data may also be restricted based on policies set by the network administrators. Permissioned blockchains can be public or private, depending on whether the ledger data is visible to the public or restricted to a specific set of users or organizations (Yaga et al. 2019). One of the applications of blockchain is smart contracts which are self-executing digital contracts that are coded on a blockchain network (Vacca et al. 2021). They are designed to automatically enforce the terms of an agreement between two or more parties without the need for intermediaries or third-party validation (Zou et al. 2019).

Blockchain technology has been adopted in many industries for creating a reliable and trustworthy record of data or information in a decentralized, tamperproof, and transparent manner. In the construction industry, blockchain has been utilized to tackle problems such as trust and province of BIM objects (Celik et al. 2023), lack of design liability control (Erri Pradeep et al. 2021), security and integrity of construction documents and records (Das et al. 2022), decentralization and transparency in construction projects tendering process (Torkanfar et al. 2023), information sharing accuracy for the onsite assemble of modular construction (Wu et al. 2022), delays in construction payments (Luo et al. 2019), manipulation and fraud in managing construction quality information (Wu et al. 2022), and fragmentation and poor traceability of information construction supply chain management (Wang et al. 2020).

The three main identified shortcomings of current practices are: 1) lack of collaboration and trust among parties in managing claims; 2) ambiguity in roles and procedures; and 3) unavailability of accurate, trustworthy, and traceable records of information for claim prevention and claim justification. Blockchain technology has been proposed as a solution to these issues, offering a trustless and decentralized environment for parties to interact with each other. Furthermore, through the use of blockchain and smart contract technologies, it is possible to ensure the security, integrity, and validity of recorded information by enforcing the governance rules of the claim management process. Moreover, the features of blockchain technology can enable the creation of a traceable and trustworthy record of information that is validated and trusted by all parties involved. Thus, this research proposes a blockchain-based claim management system as a solution to the identified shortcomings of traditional claim management systems.

Methodology

The primary goal of this study is to improve the availability of reliable and trustworthy information, which can facilitate identifying claims and providing credible documentation to support them in the event of disputes. To accomplish these objectives, a blockchain-based claim management system is proposed. The proposed method, depicted in Figure 1, consists of a blockchain data ledger which records the documents and communications of events that have the potential to result in claims. A claim management system is also incorporated, which utilizes the recorded information to identify the claims and generate robust documentation in case of disputes. The blockchain transactions are securely timestamped and recorded, serving as solid evidence to support claims.

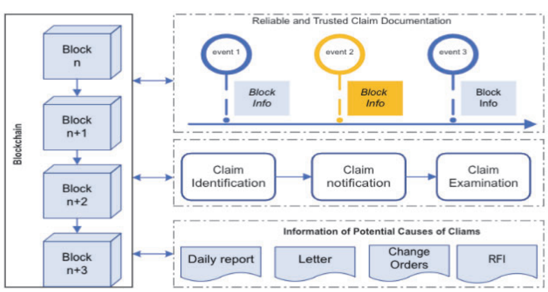

Figure 1: The proposed system architecture.

To develop the proposed system, as shown in Figure 2, three steps are identified. These steps include: 1) determining the claim management workflow with clear roles and responsibilities of parties, 2) determining the type of blockchain and designing the blockchain network based on the established workflow, and 3) creating the smart contracts.

Claim Workflow

As previously discussed, construction projects are prone to various events that can give rise to claims. To improve the availability of accurate information, the transactions and documentation related to the events that have the potential to lead to various claim causes need to be captured. Change orders, requests for information (RFI), daily reports, and correspondences are documents used in most construction projects (Shahhosseini and Hajarolasvadi 2018). For example, in the case of owner delay in payments, documents such as payment applications, previous invoices of the delivered material, the payment application of the delivered job, communications between parties, and inspectors' daily reports can support the claim. Delay in payments is the most important cause of construction claims, usually followed by change orders and variation orders by owner (Shaikh et al. 2020). As a result, documenting the change order process proactively is critical. The change order process usually initiates by an RFI submitted by the contractor (Du et al. 2016). The RFI is an essential communication tool between the contractor and the owner or its consultant (Shim et al. 2016). It is a formal request submitted by the contractor seeking clarification or information on issues related to design, construction, or contract documents (Hanna et al. 2012). This research uses blockchain to manage cost claims caused by two main potential communication sub-systems: change management and RFI. To prove the concept of using blockchain for managing claims, a conceptual case study has been developed for a design-bid-build project involving a contractor, consultant, and owner.

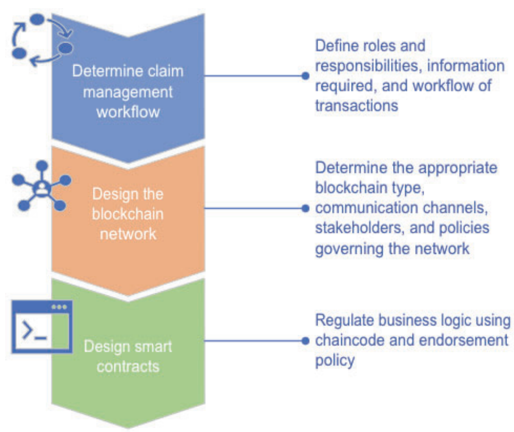

Figure 2: Proposed Methodology Workflow.

As shown in Figure 3, an RFI is initiated by the contractor when an issue is observed. The RFI will then be sent to the owner or consultant for a response. The result of the evaluation of RFI can be either a change in the scope or a clarification on the topic. The change in the scope is usually requested under a formal change order request by the owner or consultant. In this process, the owner requests a proposal from the contractor, and the contractor provides a quoted price and time for the additional work. After the consultant reviews the proposed change, it might go through negotiation on the cost and time requested. If they can reach an agreement, a change order request will be issued to the contractor to proceed with the work;

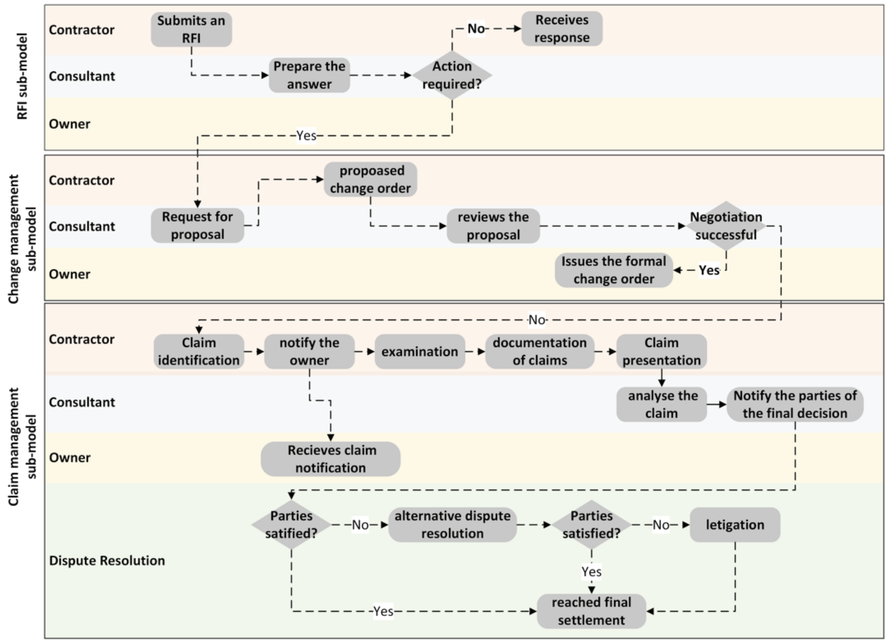

Figure 3: The studied case study's claim management workflow.

otherwise, the claim management process will be initiated (Charoenngam et al. 2003).

Appropriate Type of Blockchain

It is important to determine which type of blockchain is most suitable for developing a network with desired capabilities, such as collaborative information management, managing authorities, and access control. A claim management system involves sensitive information related to claims and thus requires strict access control and data privacy measures. A permissioned blockchain is the most suitable for such a system, as it allows for secure access and data visibility control. In this research, Hyperledger Fabric technology has been used. Hyperledger Fabric is a widely used permissioned blockchain network that employs key concepts such as peers, channels, ordering service, chaincode, policies, and membership service provider (MSP) (Androulaki et al. 2018; Fabric 2023).

Peers play a central role in any Hyperledger Fabric network. They are network nodes that host a copy of the ledger and execute transactions. In addition, peers are responsible for maintaining the blockchain ledger and ensuring that transactions are accurately validated before being recorded. Channels enable secure communication and collaboration among network members. The ordering service coordinates the sequence of transactions and ensures consensus. Chaincode, also known as smart contracts, executes business logic and enforces rules on the ledger data. Policies determine network members' access control and data visibility, while MSP provides secure identity and authentication for users.

An endorsement policy is a protocol in a blockchain network that specifies the requirement for transactions generated by smart contracts to be validated. This is accomplished by signing transactions by designated organizations within the network.

Smart contracts and the ledger are the two main components of blockchain-based applications using Hyperledger Fabric. Hyperledger Fabric, like other blockchain networks, utilizes a distributed ledger to record transactions among network participants. Smart contracts, also known as chaincode, are used to define the business logic and rules for how data can be accessed and updated on the blockchain. Smart contracts in Hyperledger Fabric ensure the consistency of recorded information based on defined rules and access controls. They can also be used to automate business transactions when certain predefined requirements are met. By encoding the business logic into a set of executable codes, smart contracts cover the common terms of business, governance rules, concept definitions, and processes.

The preceding section introduced a case study that demonstrated the potential workflow for the claim management process. The roles and responsibilities of the participants, the subsystems involved, and the common types of transactions between parties were identified. In the following section, the Fabric network will be designed by considering the necessary channels, policies, peers, and ordering service. Lastly, the chaincode package and required policies must be created to handle the business logic and update the ledger accordingly.

Hyperledger Fabric network configurations

The first step in the Hyperledger Fabric blockchain network configuration is to identify the organizations involved. In this case, three organizations are identified: the owner, consultant, and contractor, denoted as R1, R2, and R3, respectively. Each organization contributes infrastructure and resources to the network, which is governed by policies agreed upon by all parties.

As shown in Figure 4, the network consists of two channels of communication: C1 and C2. C1 is designated for transactions between the contractor and the owner or consultant, while C2 is created for internal communications, i.e. between owner and its consultant, regarding evaluations of change requests and claims before final decisions are communicated with the contractor. The contractor utilizes a client application, A3 to conduct business interactions with channel C2, while the owner and consultant use client applications A1 and A2 to perform business interactions with channels C1 and C2. The channels C1 and C2 are governed based on channel configurations CC1 and CC2, respectively, with CC1 managed by the owner and consultant and CC2 under the control of all parties.

The owner manages the entire network configuration under the policies of NC1 which regulates network configurations. The ordering service, responsible for ordering transactions into blocks, is composed of one node and is configured based on NC4, which grants administrative rights to the owner.

Certificate authorities CA1, CA2, and CA3 assign identities to the administrators and network nodes of the owner, consultant, and contractor. These certificates are used for signing transactions by organizations and indicating endorsement of transactions by the relevant parties before being accepted to be added to the ledger.

It is important to note that only the parties responsible for channel configuration can add additional organizations to a channel. Moreover, the owner of the network holds the complete network administration rights, thereby enabling them to add other channels and consortia as required.

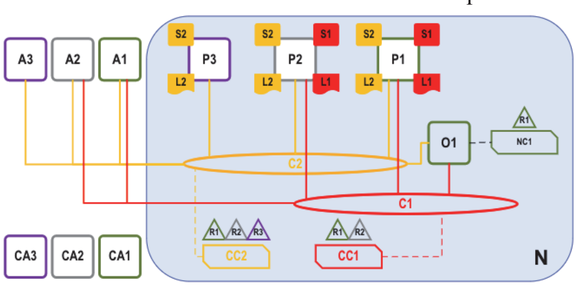

Figure 4: Designed Fabric network's configurations for a claim management system

Smart contract design

To establish a blockchain-based claim management system, a smart contract must be developed to enforce the governance of business objects. This smart contract enables the specification of the claim-management governance model, which comprises shared terms, processes, and rules that regulate interactions between the parties involved.

Based on the provided case study, the smart contract needs to define three main terms: RFI, change order, and claim. These terms can be defined in the smart contract as states of the ledger with appropriate information and relationships. Table 1 summarizes various information that should be captured for each class of terms to enable a consistent and accurate state of the claim information. However, the information in this table is not exhaustive and may vary based on the project and contractual requirements.

The defined information for these terms creates a world state for each concept. These states will be updated based on defined rules and policies and transparent and immutable records of changes will be recorded on the blockchain. This process ensures a reliable and auditable history of the system's interactions and enables parties to review and assess any claims that may arise.

Table 1: Common terms and information definitions required for a claim management system.

Term	Information	Definition
RFI	ID	A unique identifier for the RFI
	Initiator	The party who initiated the RFI
	Contract reference	Identify the relevant contract clause
	Design document	A reference to the design document
	Detailed question	A detailed description of the question
	Date submitted	The date of transaction
	Status	The status of the RFI (i.e., open, closed, pending, etc.).
	Response	The response provided to the RFI
	Action required	Are further actions required (i.e. yes nor no)
	Corresponding change order ID	The link to the possible change order following the RFI
Change order	Change order ID	A unique identifier for the change order
	Cost estimate	An estimate of the cost of the change
	Time estimate	An estimate of the time required to complete the change.
	Work item ID	The work item that the change order pertains to
	Contract reference	A reference to the original contract
	Date	The date that the change order was requested
	Description of change	A detailed description of the change being requested
	Status	The status of submitted change order including, initiated, proposed, reviewed, negotiated, finalized
	Documentation	Any additional documentation related to the change order, such as drawings or specifications.
Claim	ID	A unique identifier for the claim
	Claimant	The party initiating the claim.
	Respondent	The party against whom the claim is being made.
	Description	A detailed description of the claim and the issues being raised.
	Supporting documents	Any supporting documents or evidence to support the claim.
	Claim cost impact	The claim impact on project cost
	Claim time impact	The claim impact on the project schedule
	Cause of claim	Identified cause of the claim
	Consultant decision	The consultant's decision after reviewing the claim
	Status	The status of claim i.e., Initiated, owner notified, submitted
	Settlement status	The status of claim i.e., settled, negotiation, rejected
	Date	The date and time of transaction

Now that the standard terms and their relationships are defined, the required functions and policies to update the system states should be determined. The rules can be enforced using the smart contract and the Hyperledger fabric's endorsement policy. The smart contract can be utilized to enforce capturing required information when submitting a new claim, or to define timelines based on the contractual agreement. On the other hand, the endorsement policy can regulate the parties that must sign and approve the transactions to be valid and added to the ledger. Table 2 presents five functions identified for the transactions during the claim management process. In our case study, a claim is identified after an unsuccessful change order negotiation, so the contractor initiates a claim using *ClaimIdentification* function. The *ClaimNotification* and *ClaimEvaluation* functions are defined so the contractor can update the state of the identified claim by notifying the owner about the claim and estimated impacts. When the contractor submits the claim, the consultant must respond within the specified timeline. Any transaction involved should be endorsed by all parties to be considered valid.

Based on the defined system configuration and required functions, a Hyperledger Fabric application can be developed. The first step in developing the application is to lunch the network based on the predefined network configuration explained before. After the network is set up the smart contract (i.e. chaincode) written in Go language will be deployed on the ledger and installed on the network's peers. Due to space limitations, our discussion focuses on the claim management smart contract deployed on channel2 for communication among all stakeholders during the claim management process. While the system has different smart contracts for handling transactions regarding RFIs, change orders, and claims, we have narrowed our focus on the most important aspect of the system, which is managing claims; further research will delve deeper into the other areas.

Three main types of rules and policies were encoded into the smart contract. These policies include the information needed to accurately describe each term, the parties who must endorse the transactions invoking the smart contract functions, and the parties eligible to invoke specific functions of the smart contract.

Hyperledger fabric struct types can be used to define the blockchain's world state. Struct types can be used to represent complex objects that have multiple attributes or properties. For example, as depicted in Figure 5, the claim object is defined including all the characteristics of a claim such as ID, claim cause, impacts, etc. After defining an object, smart contract functions can be defined to update the state of the defined object. For example, the *SubmitClaim* function, shown in Figure 5, is used by the contractor to submit claims. Before a user can invoke this function, three conditions must be satisfied: 1) the user must be a member of the contractor's organization; 2) the claim has been previously identified and its ID exists in the ledger's state; and 3) claim submission's time must meet the specified timeline. Once the user initiates this transaction, the transaction must be endorsed by required parties based on the predefined endorsement policy (in this case, requiring validation and signature from all three parties); the transaction will be sent to the orderer node for inclusion in the ledger.

In addition to functions like *SubmitClaim* that are used to write information on the ledger, we can define functions to read data and query the ledger. For example, to retrieve the history of a specific claim, a function was designed to query the ledger and retrieve the complete history of a particular claim. As shown in Figure 6, this function, which can be called by any party, will retrieve a list of all the changes that the state of that specific claim has undergone since it has been identified.

```go
// Claim describes basic details of a claim
type Claim struct {
    ID                   string  `json:"ID"`
    Claimant             string  `json:"Claimant"`
    ClaimCause           string  `json:"ClaimCause"`
    ClaimCostImpact      string  `json:"ClaimCostImpact"`
    ClaimTimeImpact      string  `json:"ClaimTimeImpact"`
    ConsultantDecision   string  `json:"ConsultantDecision"`
    Description          string  `json:"Description"`
    Respondent           string  `json:"Respondent"`
    SettlementStatus     string  `json:"SettlementStatus"`
    Status               string  `json:"Status"`
    SupportingDocuments  string  `json:"SupportingDocuments"`
}
//SubmitClaim issues a new claim and updates the world state of a previously identified claim
func (s *SmartContract) SubmitClaim(ctx contractapi.TransactionContextInterface, id string,
    claimant string, respondent string, description string, supportingDocuments string,
    claimCostImpact string, claimTimeImpact string, claimCause, status string) error {
    exists, err := s.ClaimExists(ctx, id)
    if err != nil {
        return err
    }
    if !exists {
        return fmt.Errorf("the claim %s does not exist", id)
    }
    // Updating the original identified claim
    claim := Claim{
        ID:                  id,
        Claimant:            claimant,
        ClaimCause:          claimCause,
        ClaimCostImpact:     claimCostImpact,
        ClaimTimeImpact:     claimTimeImpact,
        Description:         description,
        Respondent:          respondent,
        Status:              status,
        SupportingDocuments: supportingDocuments,
    }
    claimJSON, err := json.Marshal(claim)
    if err != nil {
        return err
    }
    return ctx.GetStub().PutState(id, claimJSON)
}
```

Figure 5: Chaincode sample function, written in Go language, for updating the state of claims with given details.

```go
// GetAllClaims returns all Claims found in world state
func (s *SmartContract) GetAllClaims(ctx contractapi.TransactionContextInterface) ([]*Claim, error) {
    // range query with empty string for startKey and endKey does an
    // open-ended query of all claims in the chaincode namespace.
    resultsIterator, err := ctx.GetStub().GetStateByRange("", "")
    if err != nil {
        return nil, err
    }
    defer resultsIterator.Close()
    var claims []*Claim
    for resultsIterator.HasNext() {
        queryResponse, err := resultsIterator.Next()
        if err != nil {
            return nil, err
        }
        var claim Claim
        err = json.Unmarshal(queryResponse.Value, &claim)
        if err != nil {
            return nil, err
        }
        claims = append(claims, &claim)
    }
    return claims, nil
}
```

Figure 6: Chaincode sample function, written in Go language, for retrieving the history of a claim.

Discussion and Future Work

Claims are an inevitable aspect of construction projects, and their occurrence can result in numerous issues, including increased project costs and delays. Despite extensive research on this subject, managing claims remains a challenge. A robust claim management system that promotes stakeholders collaboration, provides reliable information, and establishes clear roles and procedures is essential for addressing these challenges. This study proposes a blockchain-based claim management system to tackle the aforementioned issues.

Blockchain has been proposed in many use cases as a solution to trust issues in collaborative environments (Mathews et al. 2017). In construction contracting, trust is classified into three types: system-based, cognition-based, and affect-based (Wong et al. 2008). System-based trust is established through formalized and procedural arrangements, and it is not based on personal attributes or characteristics (Lewis and Weigert 1985). Developing system-based trust necessitates the implementation of organizational policies, a robust communication system, and contractual agreements (Wong et al., 2008). System-based trust is founded on a structured and systematic approach that prioritizes procedural fairness, transparency, and accountability. This form of trust is primarily established through the implementation of reliable and trustworthy organizational policies, procedures, and contractual agreements, which serve to formalize the relationship between parties. Such measures are designed to facilitate cooperation and collaboration among project stakeholders by ensuring that all parties adhere to a consistent and agreed-upon set of standards and practices (Miller et al. 2009; Pishdad-Bozorgi and Beliveau 2016).

Developing an effective communication system is critical for enhancing system-based trust, as it enables timely and accurate information sharing among stakeholders through clearly defined communication procedures (Gayeski 1993). In addition to facilitating communications, a robust communication system can reduce the risks of arguments and enhance parties' reputations.

The proposed blockchain-based claim management system enhances system-based trust among participants in construction claims management. This system-based trust in the proposed system involves using smart contracts to automate and enforce claim management processes. By using a decentralized and transparent system, all stakeholders can have increased confidence in the integrity and fairness of the system. Additionally, because the system operates based on pre-programmed rules and protocols, it reduces the potential for human error or uncertainties. In addition, the proposed system can help reduce disputes and conflicts that may arise due to miscommunications or misunderstandings around roles and responsibilities, ultimately leading to more efficient and effective resolution of claims.

The proposed system can establish pre-defined rules and procedures, which can help reduce ambiguity and confusion around the roles and responsibilities of each stakeholder involved in the process. By using smart contracts, some aspects of the process can be automated and enforced. The system can ensure that all parties are held accountable for meeting their obligations and that any changes to the project scope or timeline are recorded and tracked transparently and auditable. Defining the parties' responsibilities was implemented during designing the network configurations and within the smart contract. The network configuration defines more overall roles in the system's administration and governance. However, smart contracts define more granular responsibilities.

The proposed blockchain-based system can potentially improve the reliability and quality of claim data by leveraging the properties of smart contracts and blockchain, such as consensus mechanism, transparency, immutability, traceability of records, and decentralization. Using blockchain ensures that data is transparent, immutable, and traceable, reducing the risk of errors or manipulations and increasing data reliability. The consensus mechanism in blockchain validates each block by multiple parties, ensuring that all stakeholders have validated and signed the transactions. Additionally, smart contracts enforce the capture of the necessary information and responsible parties. The endorsement policy further ensures that appropriate parties have signed and endorsed the transactions, creating a system where data is reliable and valid. Finally, the traceability of records in blockchain enhances the provenance of information, further increasing the trustworthiness of data.

In future work, it is important to consider the potential involvement of other participants in the system, as their inclusion can changes the system configuration and design. The current research focused on a specific type of claim. Further studies are needed to expand the developed smart contract to accommodate a broader data model encompassing a more comprehensive range of claim causes and related communications. Efficient data retrieval from the ledger is essential, and it is crucial to investigate the most efficient data models to enable streamlined information retrieval. Additionally, while the current research focused on design-bid-build projects, it is

Table 2: Functions and policies identified for updating the state of identified claims

Term	Function	Role	Rules
Claim	ClaimIdentification	Contractor	• The claim must be assigned a unique identifier for tracking purposes. • The claim should include a clear description • The claim identification should be initiate by contractor
	ClaimNotification	Contractor	• The contractor should notify owner and consultant within the specified time frame from its identification time
	claimEvaluation	Contractor	• The contractor must estimate the financial impact of the claim, including the cost of the additional work, time extension, and any other relevant costs
	SubmitClaim	Contractor	• The claim must include a detailed description of the issue. • The claim should include all the supporting evidence. • The claim must include the impact on the project cost and schedule. • The claim must be submitted within the time frame specified in the contract documents. • If the claim is rejected or not responded to within a specified time frame, the contractor can initiate the ADR process specified in contract
	ClaimResponse	Consultant	• The owner or consultant must conduct an evaluation of the claim and respond within a specified time frame. • The owner or consultant must provide a detailed explanation for any decision to accept or reject the claim. • If the claim is rejected, the owner or consultant must initiate the ADR process if necessary.

important to note that collaborative contracts, such as design-build and integrated project delivery method, may have different rules and policies regarding claim management. Further research requires addressing these varieties.

Conclusions

To address the current challenges in construction claim management, such as a lack of trust and collaboration, and the unavailability of reliable information for resolving disputes, a blockchain-based claim management process has been proposed. Utilizing Hyperledger Fabric technology, the proposed system aims to improve the construction industry's management, monitoring, and resolution of claims by fostering collaboration among stakeholders, providing reliable information, and establishing clear roles and responsibilities. The implementation of smart contracts holds the potential to automate and enforce several aspects of the claim management process. In addition, the proposed system improves system-based trust by providing a decentralized and transparent platform that is not controlled by any single party. The system can also establish trust between stakeholders by providing a secure platform for sharing information and collaborating on claim management process. Future work includes expanding the scope of this research to capture a broader range of claim causes, exploring efficient data models for retrieving information, and adapting the system for more collaborative construction project delivery methods.

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