ENHANCING CONSTRUCTION TRANSPARENCY AND DISPUTE RESOLUTION USING BLOCKCHAIN-BACKED BIM MODELS

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Thesis Titled

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In the name of Allah, Most Gracious Most Merciful. We are grateful to Allah Almighty first and foremost for allowing us to complete our design project; without His willingness, we could not have ever imagined completing such a monumental task. Peace and blessings be upon Prophet Muhammad (P.B.U.H) and His Progeny (P.B.U.H). Our parents' and teachers' efforts and sacrifices over the course of our lives to get us to where we are today are widely acknowledged.

We highly respect and appreciate our supervisor, Dr. Khurram Iqbal Ahmad Khan. His valuable fatherly advice and first-hand involvement motivated us immensely. Throughout the design project, his unwavering support and willingness to take time out of his busy schedule for mentorship kept us on track.

DEDICATION

Our parents who have played a foundational role in our upbringing by doing an amazing job. They have never left any stone unturned to provide us with the best opportunities possible. We are grateful for our parents' support, as this project would not have been finished without their prayers and continuous encouragement, and we would like to dedicate this document to them.

Abstract

Blockchain has been on the rise since its advent in 2008 and is finding its way into all kinds of use cases. In civil contracts management, the record keeping of documents is a decades old system which requires storing of information on paper. This paper based information can easily be tampered with and destroyed. Thus, this decades old system provides several loopholes for bad agents to escape from accountability.

Since these paper based documents can easily be tampered with, a rigorous system must be put in place to verify the truthfulness of these documents. In usual arbitration proceedings, this is done by allowing both parties to cross-examine the evidence submitted by the party they oppose. This process makes arbitration proceedings all the more cumbersome.

Nowadays, new technologies are continuously being adopted in different industries to make processes more efficient, and with much success. Blockchain is one of such technologies, that has caught the world by storm.

A blockchain is a way of storing data, such that the data cannot be tampered with and can never be deleted. This property of blockchain has given it opportunities for various uses from banking, medical record keeping, supply chain management, electronic voting, copyright management, etc.

In this design project, blockchain has been used to streamline the record keeping process and secure it using the fool-proof immutability of the blockchain. A smart contract has been developed which allows stakeholders of a project to share documents through the blockchain. The smart contract permanently saves the documents on the blockchain and retrieves them on demand.

A user-friendly interface was also developed to help users navigate the system. This allows for a tamper-proof storage system which can also be leveraged by the arbitrators to resolve disputes efficiently. The proposed system can reduce record-keeping costs as well as provide novel support for BIM models to be uploaded directly on the blockchain. The developed prototype promises to make the whole process more transparent and efficient.

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INTRODUCTION

1.1 General

The construction industry forms the backbone of global infrastructure development, relentlessly striving to meet the ever-increasing demand for modern and sustainable structures. It serves as a catalyst for economic growth, fostering job creation and propelling urban development. Despite its undeniable contributions, the industry grapples with persistent challenges that hinder its efficiency and long-term sustainability. Issues surrounding transparency, dispute resolution, and stakeholder trust remain pervasive, jeopardizing project success and eroding confidence in construction practices.

In Pakistan, for instance, the construction market witnessed a significant boom, reaching a valuation of USD 17.4 billion in 2022 (Pervez, 2022). Fueled by rapid urbanization and a growing appetite for modern infrastructure, the industry boasts an estimated annual growth rate of 5% from 2022 to 2027. However, this growth trajectory is threatened by the limitations of traditional methods employed for dispute resolution. These methods, often reliant on paper-based documentation and manual processes, are susceptible to errors, inefficiencies, and a lack of clear audit trails. Disputes concerning project specifications, timelines, and costs are commonplace, leading to project delays, cost overruns, and strained relationships among stakeholders (Chaudhry et al. 2022). The absence of a secure and immutable record-keeping system creates difficulties in tracking changes, verifying information, and holding stakeholders accountable. Traditional litigation can be a lengthy and costly process, further hindering project progress and eroding trust within the industry.

This intricate web of challenges necessitates a paradigm shift in construction practices. The industry demands innovative solutions that foster transparency, streamline communication, and establish a foundation of trust among stakeholders. Blockchain technology, with its core principles of decentralization, immutability, and transparency, emerges as a potential game-changer. By leveraging the power of blockchain, the TruView project proposes a novel approach to project management, aiming to revolutionize the construction industry and pave the way for a more efficient, transparent, and trustworthy future.

This thesis delves into the intricate workings of the construction industry, highlighting its current shortcomings and the transformative potential offered by blockchain technology. It establishes the problem statement, outlining the critical challenges hindering project success and stakeholder trust. Subsequently, the chapter presents the goals and objectives of the TruView project, detailing the specific aims that it seeks to achieve.

1.2 Problem Statement

The construction industry, both in Pakistan and globally, faces a multitude of obstacles that impede project success and erode stakeholder trust:

1.2.1 Disputes and Inefficiencies

Disputes concerning project specifications, timelines, and costs are commonplace, leading to project delays, cost overruns, and strained relationships between stakeholders (Chaudhry et al. 2022). These disputes often stem from misunderstandings, miscommunication, and a lack of clear documentation. Traditional methods of communication, often relying on paper-based documentation and siloed information systems, can lead to inconsistencies and conflicting interpretations.

1.2.2 Lack of Transparency

Fragmented communication, information silos, and a dearth of clear audit trails make it difficult to track project progress accurately, verify information, and ensure accountability among stakeholders. The absence of a centralized platform for project data can create confusion and hinder collaboration. Stakeholders may lack access to real-time updates and struggle to verify the authenticity of information, hindering trust and collaboration.

1.2.3 Inadequate Dispute Resolution

Traditional methods for dispute resolution in construction projects are often time-consuming, expensive, and lack efficiency. The absence of a secure and immutable record-keeping system creates difficulties in tracking changes, verifying information, and holding stakeholders accountable. Litigation can be a lengthy and costly process, further hindering project progress and straining relationships.

1.2.4 Cost Overruns and Delays

Ineffective project management, unforeseen circumstances, and a lack of transparency often result in significant cost overruns and project delays. Traditional methods of project management can be susceptible to human error and miscommunication, leading to missed deadlines and budgetary constraints. Additionally, the lack of real-time data on project progress can make it difficult to identify and address potential issues proactively.

1.2.5 Erosion of Trust

The absence of a reliable system for recording and verifying project transactions breeds mistrust among stakeholders. This lack of trust hinders collaboration and communication, ultimately impacting project efficiency and success. Without a secure and transparent platform for information exchange, stakeholders may be hesitant to share critical data or raise concerns, ultimately hindering project outcomes.

These challenges highlight the critical need for innovative solutions that enhance transparency, improve communication, and establish trust in construction projects. Traditional dispute resolution mechanisms, while partially effective, lack the efficiency and immutability offered by blockchain technology.

1.3 Objective

The TruView project aims to leverage the transformative potential of blockchain technology to address the critical challenges faced by the construction industry. The specific objectives are:

1.3.1 To Develop a Blockchain-Backed BIM System

Create an integrated system that seamlessly combines blockchain technology with BIM to ensure the transparency, immutability, and secure storage of project data throughout the entire project lifecycle. This integration will provide a secure and tamper-proof platform for recording all project activities, including design changes, material specifications, financial transactions, and communication logs.

1.3.2 To Enhance Dispute Resolution Mechanisms

Implement features within the TruView system that facilitate quicker and more efficient dispute resolution by providing a clear and tamper-proof record of all project activities. Stakeholders will have access to an immutable audit trail of all changes, decisions, and communication, enabling them to resolve disputes swiftly and efficiently based on verifiable data.

1.3.3 To Increase Stakeholder Trust

Foster an environment of trust and accountability among all project stakeholders by providing a secure and transparent platform for communication and information sharing. TruView will eliminate information silos and facilitate real-time collaboration, allowing stakeholders to access and verify critical project data readily. This increased transparency will foster trust and collaboration among.

1.4 Targetted SDGs

The TruView project transcends the boundaries of mere technological innovation. By addressing the critical challenges plaguing the construction industry, TruView aligns itself with several key United Nations Sustainable Development Goals (SDGs), contributing to broader objectives for sustainable and inclusive development. Here's a detailed exploration of how TruView intersects with these specific SDGs:

1.4.1 SDG 9

Industry, Innovation, and Infrastructure: By introducing innovative technologies like blockchain and BIM into the construction industry, TruView fosters the development of resilient infrastructure and advancements in construction practices. The secure and transparent record-keeping facilitated by TruView allows for improved project management, leading to more efficient resource allocation and reduced environmental impact. Additionally, the immutability of blockchain data ensures the integrity and traceability of materials used in construction, contributing to sustainable infrastructure development.

1.4.2 SDG 11

Sustainable Cities and Communities: Enhancing transparency and efficiency in construction projects directly contributes to the development of sustainable and resilient buildings and infrastructure. TruView promotes sustainable practices by facilitating better communication and collaboration among stakeholders, leading to more informed design choices that prioritize energy efficiency and resource conservation. The improved record-keeping and streamlined dispute resolution mechanisms offered by TruView can also expedite project completion times, minimizing disruptions to communities and fostering sustainable urban development.

1.4.3 SDG 16

Peace, Justice, and Strong Institutions: The TruView project directly supports the development of effective, accountable, and transparent institutions at all levels. The secure and immutable record-keeping system offered by blockchain technology provides a reliable platform for dispute resolution, reducing reliance on lengthy and costly litigation processes. Additionally, the increased transparency fostered by TruView promotes accountability among stakeholders, deterring corruption and ensuring adherence to regulations and best practices within the construction industry.

By targeting these specific SDGs, the TruView project demonstrates its commitment to not only addressing immediate industry challenges but also contributing to broader global objectives for sustainable and inclusive development. The project's potential to promote transparency, efficiency, and trust within the construction industry can have a ripple effect, fostering sustainable infrastructure development, strengthening institutions, and ultimately contributing to a more equitable and prosperous future.

1.5 Research Design Protocol

The research methodology of this project can be broken down into three parts. In the first part, studies and surveys were conducted. A plethora of research papers were studied to find out the extent of the work that has been done in the field. Moreover, this helped us to gather the tools and skills required to build this application. A survey of the market was conducted in which builders and constructors were approached. They were asked about the problems they faced during the life cycle of a project and what kind of solution they were willing to adopt. After preparing for the development of the application, we moved on to the second step. The decentralised application is the main part of this project. Several use cases of BIM-blockchain interoperability were tried and the best one was selected. Moreover, intricate details were taken care of when writing the clauses for the smart contract. Lastly, the economic and security benefits of this application were gauged to find out the impact which such a system will have on the industry.

The development of the decentralied application was carried out in these three steps

1) A stand-alone smart contract was developed which had the ability to store data regarding the documents and stakeholders and allowed us to retrieve this data on demand. All data stored in this smart contract is permanent and can never be removed.

2) A backend server application was constructed to allow the users to interact with blockchain in a user-friendly manner. Moreover, this backend server application served as a connection to IPFS which stores the large sized files on the blockchain.

3) A frontend application was finally developed to allow the users to interact freely with the decentralised application. It was made aesthetically pleasing and easy-to-use keeping in mind the industry gap.

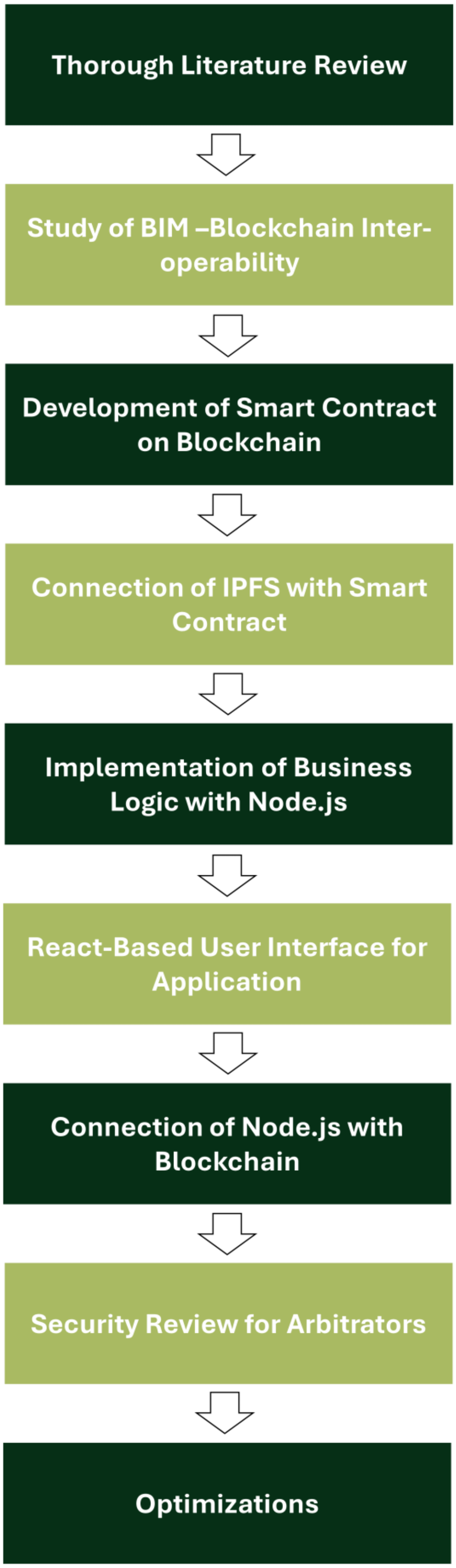


Figure 1*: Steps involved in the building process*

1.6 Organization of Report

This thesis is organized in 5 chapters. The present chapter is an introduction to blockchain, its impacts and applications in the construction sector, needs and objectives of study. Chapter 2 lay down the basic concepts and brief literature review. Chapter 3 discuss the methodology adopted to achieve defined objectives. The conclusions based on findings of this design and recommendations for further studies are presented in Chapter 5.

CHAPTER 2

LITERATURE REVIEW

2.1 Inefficiencies of Traditional Record Keeping Systems

A review of research papers under the genre of problems in record keeping and solutions showed that traditional practices of record keeping in the construction industry are prone to irregularities and inefficiencies which are preventing the industry from reaching its true potential (Yap and Lim, 2022). One of the most concerning security concerns was the record keeping of documents which can be easily destroyed or tampered with (Opoku et al. 2023). The construction industry is highly centralized which results in a lot of human intervention and beureaucratic procedures making it vulnerable to abuse (Zhang and Li, 2023). As all information is mostly stored at one single point of access, any accidental or intentional mishap can result in incomplete records which causes problems in the later stages of the project (Kinnunen et al. 2020). The current system is also time-intensive and requires a lot of necessary paperwork to be processed (Cunill, 2020). Construction contracts and documents are vulnerable to information asymmetry, leaving the interpretation and handling of the contents at the discretion of the dominant party (Padroth et al. 2017).

2.2 Blockchain

Blockchain is a new technology with huge untapped potential. The existence of blockchain implies the existence of an internet of value where interaction with the system requires monetary spending and all users control the system as one. This leaves the giants at the discretion of the masses as opposed to conventional internet (Lacity, 2022). The blockchain is a train of blocks that are mathematically connected with each other.Each block is represented by a unique number called the hash. This number is obtained by enctypting all the data in a block and considering the hash of the previous block. A copy of this blockchain is present with everyone who uses the blockchain while they try to verify that all copies are the same. Tampering with any data will result in a changed hash which will ultimately notify the system of a corrupted node (Wang and Liu, 2021). So, this hashing phenomenon coupled with the proofing mechanism along the decentralized nature of blockchains makes the data secure, immutable, and impossible to tamper with.

The integration of smart contracts with blockchain technology commenced the era of the second generation of the blockchain (Szabo, 1996). He defined the term smart contract as a

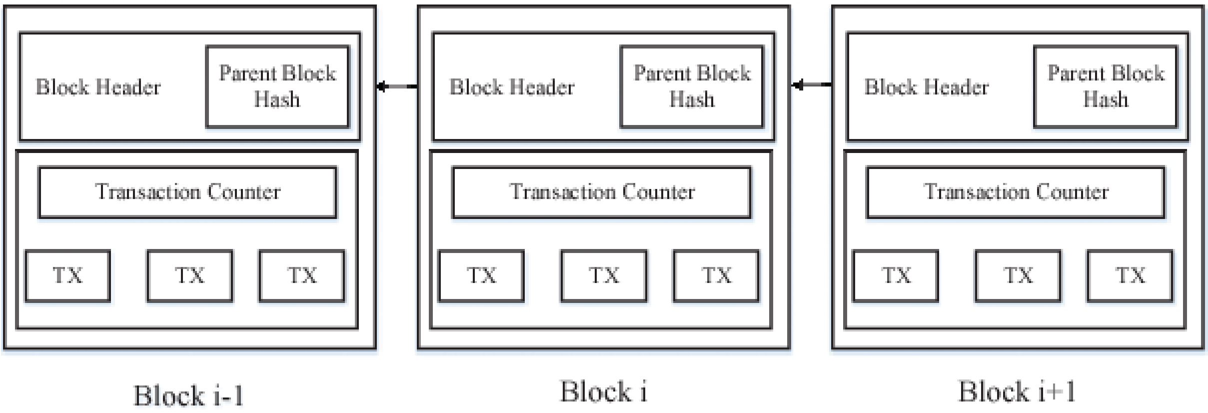


***Figure 2**: Block Formation in Blockchain (Zheng et al. 2017)*

computerized transaction protocol that seeks to replicate legally binding contracts through a code. Currently work is in progress on the third generation of blockchain and on layer 2 solutions which address the limitation of the second generation of blockchains such as scalability, high gas fee, and interoperability.

2.3 Blockchain in Construction

Many studies have been done on creating blockchain-based use cases and information management frameworks for the construction industry, since the industry faces difficulties with data management and storage. Owing to its inherent qualities, blockchain can assist with data and information management during the life cycle of a building project (Li et al. 2021). It can act as a universally consistent database and ensures the integrity of the data inside it.

Wang suggested utilizing blockchain technology to create a notarization tool that would foster trust (Wang et al. 2017). Hamida proposed that the land record be kept up to date via the blockchain's immutable distributed ledger (Hamida et al. 2017). Data loss can be minimized by employing blockchain technology for data management(Ganter and Lützkendorf, 2019). Nawari and Ravindran provide a framework for automated design examination and underline the potential benefits blockchain will have for the BIM workflow. Zheng creates a blockchain-based system for storing and organizing high-quality information documents (Zheng et al. 2019).

2.4 Smart Contract

A smart contract can be defined as a self-executing contract. The concept of the smart contract is not new. Firstly, it was introduced by the scientist Nick Szabo in 1994. He defined the term smart contract as a computerized transaction protocol that seeks to replicate legally binding contracts through a code (Szabo, 1996). Vitalik Buterin created the Ethereum chain by fusing the blockchain with the idea of a smart contract. Blockchain only functions as a money transfer system prior to the integration of smart contracts, however smart contracts enable users to customize payments by linking the release of cash to specific conditions (Buterin, 2013). Vitalik Buterin created the Ethereum chain by fusing the blockchain with the idea of a smart contract. Blockchain only functions as a money transfer system prior to the integration of smart contracts, however smart contracts enable users to customize payments by linking the release of cash to specific conditions. To code, smart contracts certain high-level programming languages are being used such as solidity, Plutus, rust, etc.

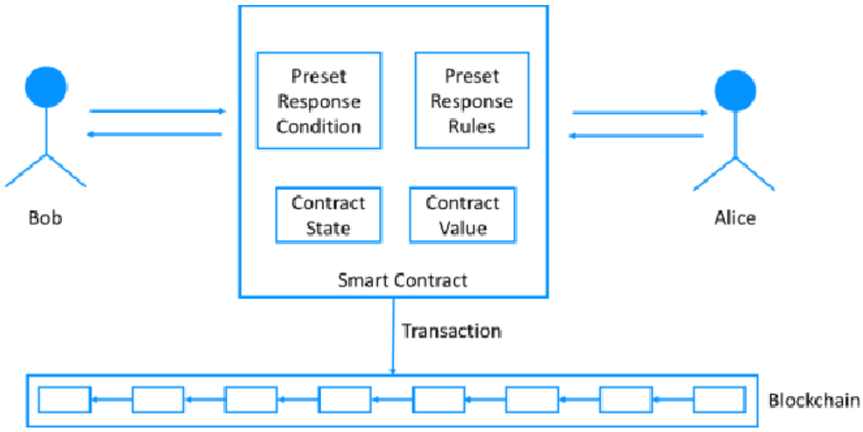


Figure 3: *Working of a Smart Contract (Wang et al. 2018)*

2.5 Types of Blockchain

Blockchains can broadly be categorized into two types:

2.5.1 Public Blockchain

This blockchain is freely available for everyone to use and interact with. No special permissions are required, and anyone can become a validator to verify transactions (Yang et al. 2024).

2.5.2 Private blockchains

These are normally very small blockchains developed for a very special purpose. Organizations mostly create such blockchains for the benefit of privacy. An example of such a blockchain is the HyperLedger Fabric (Ebrahimi et al. 2023).

2.6 Hash

A hash is a one-way cryptographic function in the context of cryptography, which means it can't be decrypted and accepts any size input to produce an output of a fixed size. A hash is a unique number that is resistant to collisions and is used to ensure the data's integrity. The hashing algorithm SHA-2 is one example; the bitcoin blockchain uses it as well to calculate hashes (Sharma and Mittal 2019).

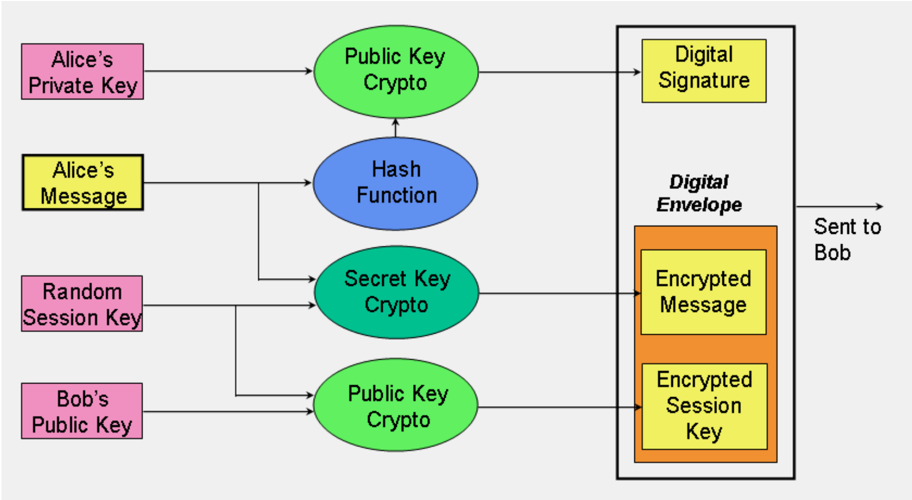


Figure 4: *Working of a Hash Function*

2.7 Cryptocurrencies

Blockchain is the underlying technology of cryptocurrencies (Chan et al. 2020). Cryptocurrencies are digital currencies. Traditional currencies are controlled by banks and governed by the state. However, cryptocurrencies are not controlled by any single entity. Pear-to-pear cash, or cryptocurrency, eliminates the need for middlemen to conduct transactions.

As of right now, the total market value of cryptocurrencies is around $2.42 trillion. Because cryptocurrencies have many benefits over conventional money, their use and demand are increasing daily. It is utilized as a method of value preservation and as a hedge against inflation in several nations. Countries are progressively adopting them and using them as legal tender. Right now, two nations that have proclaimed bitcoin to be legal tender are El Salvador and Japan. However, despite all of these advantages, cryptocurrencies remain speculative assets and often volatile.

2.8 Blockchain Explorer

A distributed, decentralized ledger serves as the blockchain's core. When it comes to transactions, the blockchain explorer provides access to transaction data. Live transaction broadcasting and data tracing and filtering based on wallet address are features of the blockchain explorer. The capacity to closely examine the movement of assets makes it possible to track and audit the money. Every blockchain has an explorer, such as the Ethereum chain's explorer, which is available at https://www.etherscan.io. The Arbitrum blockchain can be explored at https://arbiscan.io/.

2.9 Decentralised Application

A Dapp is an application that enables a user to interact with the blockchain, send, retrieve and analyze data for a specific use case. Like any conventional application, the Dapp requires a full stack. The back end of a Dapp is usually a smart contract which also acts as the database for the application. The smart contract consists of two important components necessary for deployment, i.e, ABI and bytecode.

A blockchain address is a special address which contains some cryptocurrency and can be used to send or receive currencies. A public and a private key are required to execute a successful transaction.

For deploying the smart contract on the blockchain, a connection with a node that exists inside the blockchain is required. Alchemy is a service which allows us to connect to a blockchain node and access the blockchain.

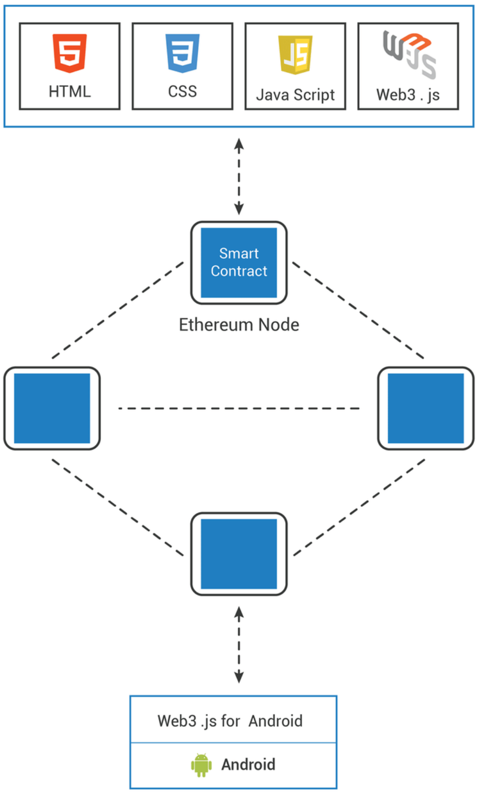


Figure 5*: A schematic diagrom of a decentralised Application (Jabbar et al. 2020)*

2.10 Building Information Modelling

Building information modeling (BIM) is the process of assembling graphical and non-graphical data into information models or data sets in a shared digital environment (Azhar, 2021). Coordination is the primary component of BIM. It facilitates visualisation and collision detection and improves teamwork among participants. When it comes to the automation and digitization of the AEC sector, BIM is crucial. BIM allows stakeholders to come together on platform and have easy access to information.

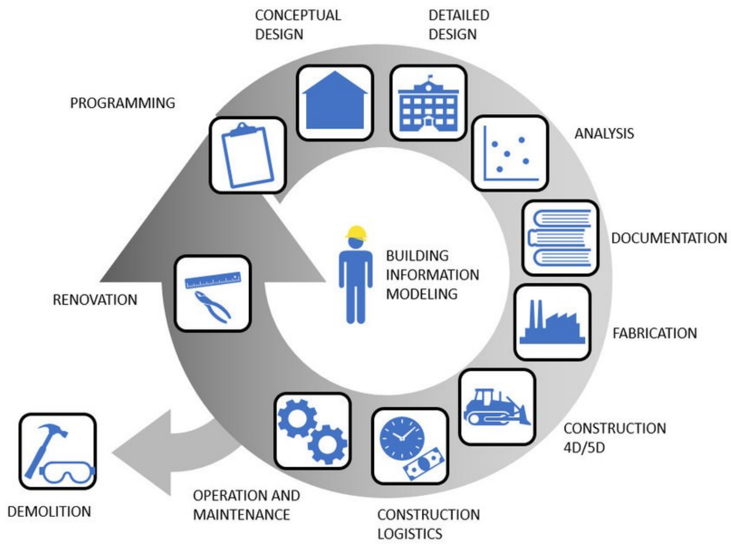


Figure 6: *Different aspects of Building Information Modelling (Alhamami et al. 2020)*

2.11 Cloud-based Database

Cloud-based databases run on cloud computing platforms, offering scalable and flexible storage and computing power without the need for physical hardware. Accessible over the internet, they adapt to varying business needs efficiently. These databases are centralised which means that there is only one point of access and with special permissions, it is easy to manipulate (Rabii et al. 2022).

2.12 BIM 360

BIM 360 is a cloud-based construction management software that facilitates collaboration and project management for construction teams. It offers tools for design, coordination, documentation, and field management, enhancing communication and efficiency throughout the project lifecycle. One of the primary advantages of BIM 360 is real-time collaboration. Teams can access and update project data from anywhere, ensuring that everyone works from the latest information. This reduces errors and rework, saving time and money. BIM 360 also improves project visibility and control. Managers can track progress, identify issues early, and make informed decisions with comprehensive data insights. The software supports various workflows, from design reviews to quality inspections, streamlining operations and ensuring consistency. Security is robust, with features like data encryption and user authentication, protecting sensitive project information. The platform's scalability allows it to handle projects of any size, adapting to the needs of both small firms and large enterprises. BIM 360 enhances construction project management with real-time collaboration, improved visibility, robust security, and scalable solutions, making it an invaluable tool for modern construction teams.

2.13 Autodesk Vault

Autodesk Vault is a data management software that helps design and engineering teams organize, manage, and track their design data. It streamlines workflows, enhances collaboration, and ensures data integrity throughout the project lifecycle. A key advantage of Autodesk Vault is version control. It keeps a comprehensive history of design changes, allowing teams to track revisions and access previous versions easily. This feature prevents data loss and ensures that everyone is working with the most up-to-date information. Vault also facilitates collaboration by enabling team members to share and access data from a centralized location. It supports concurrent engineering, where multiple users can work on the same project simultaneously, improving efficiency and reducing project timelines. Security is a significant benefit of Autodesk Vault. It includes robust access controls, data encryption, and user authentication, ensuring that sensitive project information is protected. Additionally, Vault integrates seamlessly with other Autodesk products, enhancing its utility in design and engineering workflows. In summary, Autodesk Vault improves data management for design and engineering teams with its version control, enhanced collaboration, robust security, and seamless integration, making it an essential tool for efficient project execution.

2.14 Dispute Resolution

Dispute resolution in the construction industry involves methods to address and resolve conflicts that arise during construction projects (Agapiou, 2023). These disputes can stem from contract issues, delays, cost overruns, or quality concerns. Effective dispute resolution is crucial to maintain project timelines, budgets, and relationships.

A common method is negotiation, where parties directly communicate to reach a mutually acceptable agreement. It's the simplest and least formal approach, often used to resolve minor issues quickly.

Arbitration is a more formal method where a neutral arbitrator hears both sides' arguments and makes a binding decision. It's faster and less costly than litigation, but the arbitrator's decision is usually final and not subject to appeal. Alternative dispute resolution (ADR) methods like mediation and arbitration are increasingly favored for their efficiency and cost-effectiveness. They help preserve business relationships by promoting collaborative solutions. In summary, dispute resolution in the construction industry includes negotiation, mediation, arbitration, and litigation. Each method varies in formality, cost, and time, providing various ways to address conflicts and maintain project continuity.

2.15 Stakeholder

In the construction industry, stakeholders are individuals or groups with an interest or investment in a project. These stakeholders influence the project and are affected by its outcome. Understanding the roles and needs of each stakeholder is crucial for successful project management and completion.

Key stakeholders include:

2.15.1 Client

They fund the project and define its scope, budget, and timelines. Their satisfaction is paramount as they are the end users of the project.

2.15.2 Contractors

Responsible for executing the construction work, contractors manage day-to-day operations, labor, and materials to meet project specifications.

2.15.3 Subcontractors

Hired by the main contractor to perform specific tasks or supply certain materials. Their work is essential for specialized components of the project.

2.15.4 Engineers

These professionals handle the technical aspects of the project, including structural, electrical, and mechanical systems, ensuring safety and functionality.

2.15.5 Consultants

They oversee the project's progress, coordinate between various parties, and ensure that the project stays on schedule and within budget.

2.15.6 Suppliers

Provide the necessary materials and equipment for the construction project. Timely delivery and quality of materials are crucial for project success.

2.16 Contract

A construction contract is a legally binding agreement between the project owner and the contractor, outlining the terms and conditions under which construction will be carried out. It establishes the framework for the project's execution, providing a clear understanding of each party's responsibilities and expectations (Wong et al. 2024).

At its core, a construction contract serves as a roadmap for the project. It defines the relationship between the owner and the contractor, specifying the roles and obligations of each party. This helps ensure that both sides are aligned on project goals, timelines, and deliverables, minimizing the potential for misunderstandings and conflicts.

One of the primary functions of a construction contract is to manage risk. By clearly outlining the scope of work, deadlines, and payment terms, the contract helps allocate risks appropriately between the owner and the contractor. This can include risks related to project delays, cost overruns, and quality of work. Having these terms in writing provides a reference point for resolving disputes and claims that may arise during the project.

Moreover, construction contracts often include provisions for dispute resolution, such as mediation or arbitration, which can provide more efficient and less adversarial means of resolving conflicts than litigation. This helps maintain working relationships and keeps the project on track.

In summary, a construction contract is essential for successful project execution. It defines the terms of engagement, manages risk, enhances communication, and provides mechanisms for dispute resolution. By setting clear expectations and responsibilities, it helps ensure that construction projects are completed on time, within budget, and to the required standards.

2.17 Dispute

Construction disputes refer to disagreements or conflicts that arise between parties involved in construction projects. These disputes can occur at any stage of a project and may involve issues such as contract interpretation, delays, defective work, payment disputes, or changes in project scope. They often require resolution through negotiation, mediation, arbitration, or litigation.

Effective dispute resolution mechanisms and clear contract clauses can help minimize the impact of disputes on construction projects, ensuring timely completion and maintaining positive relationships between project stakeholders.

2.18 Arbitration

Arbitration is a dispute resolution method where parties involved in a construction project agree to submit their disagreement to a neutral third party, the arbitrator, rather than going to court. The arbitrator reviews evidence and arguments from both sides and renders a binding decision, known as an award. Arbitration offers advantages such as confidentiality, flexibility in procedure, and potentially faster resolution compared to litigation. It allows parties to choose an arbitrator with expertise in construction matters, promoting a better understanding of technical issues. However, arbitration decisions are usually final and can only be challenged under limited circumstances. Despite its benefits, arbitration can also be costly and may lack the formalities and protections of a court proceeding, necessitating careful consideration of its suitability for resolving construction disputes (Wong et al . 2024).

2.19 Inter-Planetary File System

The InterPlanetary File System (IPFS) is a decentralized protocol designed to create a peer-to-peer method of storing and sharing hypermedia in a distributed file system. Unlike traditional web protocols that rely on centralized servers, IPFS enables files to be stored across a network of nodes, allowing for greater redundancy, availability, and resistance to censorship. IPFS uses content-addressed hyperlinks to uniquely identify and retrieve files, making it resilient to changes in network topology and enabling efficient distribution of content. It aims to revolutionize how data is accessed and shared on the internet by providing a more robust and decentralized alternative to traditional HTTP-based protocols. IPFS has applications beyond traditional web browsing, including content distribution, data archiving, and building decentralized applications (dApps) that leverage its distributed storage and retrieval capabilities (Benet 2014).

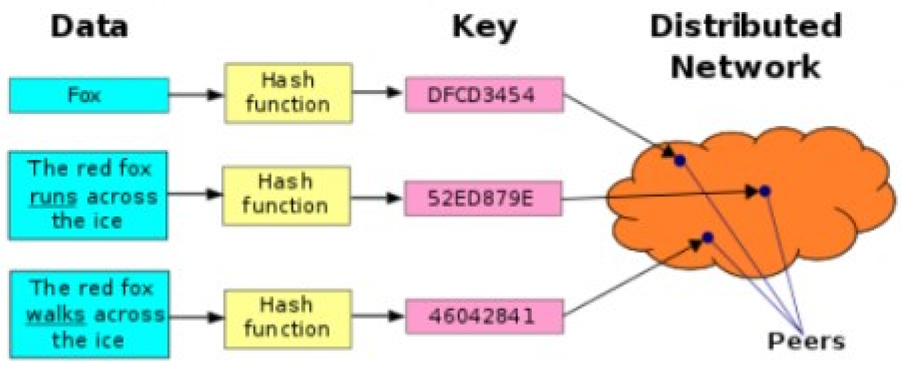


***Figure** 7: Working of IPFS with Hash*

CHAPTER 3

METHODOLOGY

The main methodology adopted for this design project involved utilization of advanced tools and techniques to resolve the existing concerns of transparency and data security in the construction industry. For this purpose, an advanced methodology was adopted to develop an innovative solution for the problem at hand.

3.1 Introduction:

In traditional construction, documents are sent via letters or emails. Such a method results in manual tracking of time, senders, recipients, etc. Smart contracts are used to integrate blockchain with record keeping systems. Smart contracts are the backbone of programmable blockchains. They act as the point of contact with the blockchain and contain all the logic which executes on the blockchain. The smart contract here is developed to ensure that data can be received, stored and then retrieved to help maintain an immutable record that is always available. The development of a smart contract involves intricate research about the way documents can be efficiently tracked and then used by arbitrators to solve disputes and extract information.

3.2 BIM Models and Documents

In a project management setting, several types of documents are exchanged between different stakeholders. These include but are not limited to BIM models, change orders, etc. These documents are required to be stored either digitally or physically. In both cases, the risk of having a document tampered, destroyed or misplaced is relatively very high. Such a risk gives rise to an environment where disputes can easily arise and become a cause of inefficiency in the whole system. Hence, all these documents and BIM models are required to be stored on a platform which prevents any kind of irretrievable changes made to these documents.

The blockchain is such a platform which can resolve this issue. A blockchain permanently saves data in its immutable ledger once it has been uploaded. If any changes are to be made, another instance of the data is created and only the changes are recorded and added to the original file.

BIM models and other related documents are uploaded directly on the blockchain which ensures that all files are secured and tamper-proof.

3.3 Uploading Documents

The documents and files are uploaded on the Inter-Planetary File System. The IPFS stores files in nodes which can be access by the user anytime. These distributed nodes are responsible for keeping the data safe and secured. The app asks the user to imput their document and it uploads them directly to IPFS.

3.4 IPFS Hash

Cryptographic hashes are functions that take some arbitrary input and return a fixed-length value. The value depends on the given hash algorithm in use. Typically, the algorithm SHA-256 is used. A given hash algorithm always returns the same value for a given input.

As an example, the input:

Hello world

The output using SHA-256 would be represented as:

0x64EC88CA00B268E5BA1A35678A1B5316D212F4F366B2477232534A8AECA37F3C

For any given input, there will be a very specific output which cannot be replicated if the input is changed. This hash or cryptographic function allows any length or type of data to be represented using a unique identification number. This identification number can be used to retrieve the data from IPFS whenever required.

For security reasons, if anyone changes the contents of a document or a BIM model, the hash will also change. This change in the hash number identifies that the document has been changed or tampered. This system allows IPFS to be a secure platform for storing valuable documents.

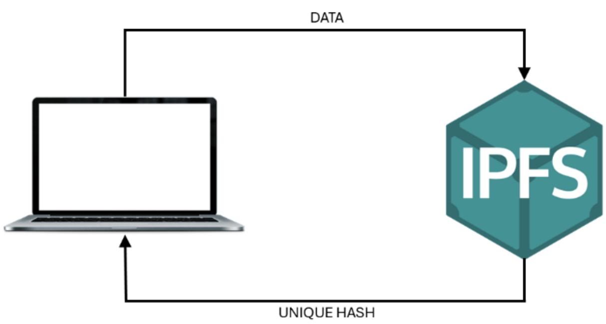


***Figure 8**: Working of IPFS*

3.5 Smart Contract

The smart contract has been created by keeping in mind the security concerns related to sharing of documents.

All the stakeholders are recognized by a special identification number called the blockchain address. The smart contract holds all the information about the stakeholders. When any stakeholder interacts with the smart contract, they use their blockchain address which can not be duplicated by anyone. This ensures that whenever a certain blockchain address is used, only the stakeholder registered against the blockchain address is accessing the files.

The storage of files on the blockchain is done through the IPFS Hash. The hash is stored against the type of file required. The sender of the file is recorded, and the receiver is also recorded.

Only the intended receiver can see the documents received and no one else can see the documents. If a certain file was intended to be received by the contractor, only the contractor has the access to view those files.

On the contrary, the arbitrator can view all the files sent and received by everyone in the organization.

This allows for a safe access by the intended parties which is crucial to protect the privacy of each stakeholder.

The smart contract logic has been provided below.

```
/**
 *Submitted for verification at Sepolia.Arbiscan.io on 2024-05-03
*/

// SPDX-License-Identifier: MIT

pragma solidity 0.8.25;

contract TruView {

    struct StakeHolder {
        string name;
        string password;
        string userRole;
        address userAddress;
    }

    struct ConsultantDocs {
        string documentType;
        string ipfs;
        int timestamp;
        string receivedBy;
        string receivedAddress;
    }

    ConsultantDocs[] ConsultantDocsArray;

    struct ContractorDocs {
        string documentType;
```

```
        string ipfs;
        int timestamp;
        string receivedBy;
        string receivedAddress;
    }

    ContractorDocs[] ContractorDocsArray;

    struct ArbitratorDocs {
        string documentType;
        string ipfs;
        int timestamp;
        string receivedBy;
        string sentBy;
        string receivedAddress;
    }

    ArbitratorDocs[] ArbitratorDocsArray;

// Called by Contractor
    struct SentConsultantDocs {
        string documentType;
        string ipfs;
        int timestamp;
        string receivedBy;
        string sentBy;
        string receivedAddress;
    }

    SentConsultantDocs[] SentConsultantDocsArray;

//Called by Consultant
    struct SentContractorDocs {
        string documentType;
        string ipfs;
        int timestamp;
        string receivedBy;
        string sentBy;
        string receivedAddress;
    }

    SentContractorDocs[] SentContractorDocsArray;


    struct ClaimData {
        string stakeholder;
        string sentBy;
        string  typeOfClaim;
        string fidicClauses;
        string claimTitle;
        string details;
    }

    //GLOBAL STRUCT

    StakeHolder[] stakeholderArray;
    ClaimData[] ClaimDataArray;

    address public clientAddress;

    function  registerUser(string  memory  _name,  string  memory
_password, string memory _user) public {
        // Create a new StakeHolder struct and add it to the array
        stakeholderArray.push(createRegistrationStruct(_name,
_password, _user));
    }

    function createRegistrationStruct(string memory _name, string
memory  _password,  string  memory  _user)  internal  returns
(StakeHolder memory) {
        // Create a new StakeHolder struct and return it
        if (
            keccak256(abi.encodePacked(_user)) ==
```

```
            keccak256(abi.encodePacked("client"))
        ) {
            clientAddress = msg.sender;
        }
        StakeHolder memory _stakeholder = StakeHolder({
            name: _name,
            password: _password,
            userRole: _user,
            userAddress: msg.sender
        });

        return _stakeholder;
    }



    //to access the transaction hash, use JS
    //hash cannot be accessed inside the contract
    function  sendTransaction(address  payable  _recipient)  public
payable {
        // Attempt to send the payment
        bool success = _recipient.send(msg.value);

        //  If  the  send  function  returns  false,  revert  the
transaction
        require(success, "Payment failed");

        timeStamp = block.timestamp;

        //extract txnhash from JS and call storeTxnHash() function
        //check  sender  and  recipient  and  hash  and  store  ing
TransactionHistory
    }

    uint256 private timeStamp;



/*//////////////////////////////////////////////////////////////
//////////////////////
\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\
\\\\\\\\\\\\\\\\\\\\\\*/

/*
THIS FUNCTION STORES CLAIM DATA ARRAY
*/

        function storeClaimData (
            string calldata _stakeholder,
            string calldata _sentBy,
            string calldata _typeOfClaim,
            string calldata _fidicClauses,
            string calldata _claimTitle,
            string calldata _details)
            public {
        ClaimDataArray.push(createClaimDataStruct(_stakeholder,
_sentBy, _typeOfClaim, _fidicClauses, _claimTitle, _details));

    }
    //these two functions can be nested
    function createClaimDataStruct(
        string calldata _stakeholder,
        string calldata _sentBy,
            string calldata _typeOfClaim,
            string calldata _fidicClauses,
            string calldata _claimTitle,
            string calldata _details
    ) internal pure returns (ClaimData memory) {
        // Create a new TransactionData struct and return it

        ClaimData memory _claimData = ClaimData({
            stakeholder: _stakeholder,
            sentBy: _sentBy,
```

```
            typeOfClaim: _typeOfClaim,
            fidicClauses: _fidicClauses,
            claimTitle: _claimTitle,
            details: _details
    });

        return _claimData;
    }

/*
THIS FUNCTION STORES CONSULTANT DATA
*/
    function storeConsultantDocs (
            string calldata _documentType,
            string calldata _ipfs,
            string calldata _receivedBy,
            string calldata _receivedAddress)
            public {

ConsultantDocsArray.push(createConsultantDocsStruct(_documentType
, _ipfs, _receivedBy, _receivedAddress));

    }
    //these two functions can be nested
    function createConsultantDocsStruct(
        string calldata _documentType,
        string calldata _ipfs,
        string calldata _receivedBy,
        string calldata _receivedAddress
    ) internal view returns (ConsultantDocs memory) {
        // Create a new TransactionData struct and return it

        ConsultantDocs memory _consultantDocs = ConsultantDocs({
            documentType: _documentType,
            ipfs: _ipfs,
            timestamp: int(block.timestamp),
            receivedBy: _receivedBy,
            receivedAddress: _receivedAddress
    });

        return _consultantDocs;
    }

/*
THIS FUNCTION STORES CONTRACTOR DATA
*/

    function storeContractorDocs (
            string calldata _documentType,
            string calldata _ipfs,
            string calldata _receivedBy,
            string calldata _receivedAddress)
            public {

ContractorDocsArray.push(createContractorDocsStruct(_documentType
, _ipfs, _receivedBy, _receivedAddress));

    }
    //these two functions can be nested
    function createContractorDocsStruct(
        string calldata _documentType,
        string calldata _ipfs,
        string calldata _receivedBy,
        string calldata _receivedAddress
    ) internal view returns (ContractorDocs memory) {
        // Create a new TransactionData struct and return it

        ContractorDocs memory _contractorDocs = ContractorDocs({
            documentType: _documentType,
            ipfs: _ipfs,
            timestamp: int(block.timestamp),
            receivedBy: _receivedBy,
            receivedAddress: _receivedAddress
```

```
    });

        return _contractorDocs;
    }

/*
THIS FUNCTION STORES ARBITRATOR DATA
*/

    function storeArbitratorDocs (
            string calldata _documentType,
            string calldata _ipfs,
            string calldata _receivedBy,
            string   calldata   _sentBy,   //   hard   code   either
"consultant" or "contractor"
            string calldata _receivedAddress)
            public {

ArbitratorDocsArray.push(createArbitratorDocsStruct(_documentType
, _ipfs, _receivedBy, _sentBy, _receivedAddress));

    }
    //these two functions can be nested
    function createArbitratorDocsStruct(
        string calldata _documentType,
        string calldata _ipfs,
        string calldata _receivedBy,
        string calldata _sentBy,
        string calldata _receivedAddress
    ) internal view returns (ArbitratorDocs memory) {
        // Create a new TransactionData struct and return it

        ArbitratorDocs memory _arbitratorDocs = ArbitratorDocs({
            documentType: _documentType,
            ipfs: _ipfs,
            timestamp: int(block.timestamp),
            receivedBy: _receivedBy,
            sentBy: _sentBy,
            receivedAddress: _receivedAddress
    });

        return _arbitratorDocs;
    }

/*
THIS FUNCTION STORES DOCS SENT TO CONSULTANT/STAKEHOLDER
*/

    function storeDocsSent (
            string calldata _documentType,
            string calldata _ipfs,
            string calldata _receivedBy,
            string   calldata   _sentBy,   //   hard   code   either
"consultant" or "contractor"
            string calldata _receivedAddress)
            public {
                if(keccak256(abi.encodePacked(_receivedBy))     ==
keccak256(abi.encodePacked("Contractor"))){

SentContractorDocsArray.push(createSentContractorDocsStruct(_docu
mentType, _ipfs, _receivedBy, _sentBy, _receivedAddress));
                }
                if(keccak256(abi.encodePacked(_receivedBy))     ==
keccak256(abi.encodePacked("Consultant"))){

SentConsultantDocsArray.push(createSentConsultantDocsStruct(_docu
mentType, _ipfs, _receivedBy, _sentBy, _receivedAddress));
                }
    }
    //these two functions can be nested
    function createSentContractorDocsStruct(
        string calldata _documentType,
        string calldata _ipfs,
```

```
        string calldata _receivedBy,
        string calldata _sentBy,
        string calldata _receivedAddress
    ) internal view returns (SentContractorDocs memory) {
        // Create a new TransactionData struct and return it

        SentContractorDocs    memory    _sentContractorDocs    =
SentContractorDocs({
            documentType: _documentType,
            ipfs: _ipfs,
            timestamp: int(block.timestamp),
            receivedBy: _receivedBy,
            sentBy: _sentBy,
            receivedAddress: _receivedAddress
    });

        return _sentContractorDocs;
    }

    function createSentConsultantDocsStruct(
        string calldata _documentType,
        string calldata _ipfs,
        string calldata _receivedBy,
        string calldata _sentBy,
        string calldata _receivedAddress
    ) internal view returns (SentConsultantDocs memory) {
        // Create a new TransactionData struct and return it

        SentConsultantDocs    memory    _sentConsultantDocs    =
SentConsultantDocs({
            documentType: _documentType,
            ipfs: _ipfs,
            timestamp: int(block.timestamp),
            receivedBy: _receivedBy,
            sentBy: _sentBy,
            receivedAddress: _receivedAddress
    });

        return _sentConsultantDocs;
    }
/*/////////////////////////////////////////////////////////////////
///////////////////////
\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\
\\\\\\\\\\\\\\\\\\\\\\\*/

/*
THIS FUNCTION RETURNS STAKEHOLDER ARRAY
*/

    function   getStakeHolderArray   ()   public   view   returns
(StakeHolder[] memory) {
        return stakeholderArray;
    }

/*
THIS FUNCTION RETURNS CONSULTANT ARRAY
*/

    function   getConsultantArray   ()   public   view   returns
(ConsultantDocs[] memory) {
        return ConsultantDocsArray;
    }

/*
THIS FUNCTION RETURNS CONTRACTOR ARRAY
*/

    function   getContractorArray   ()   public   view   returns
(ContractorDocs[] memory) {
        return ContractorDocsArray;
    }

/*
```

```
THIS FUNCTION RETURNS ARBITRATOR ARRAY
*/

    function   getArbitratorArray   ()   public   view   returns
(ArbitratorDocs[] memory) {
        return ArbitratorDocsArray;
    }

/*
THIS FUNCTION RETURNS DOCSSENTTOCONSULTANT ARRAY
*/

    function  getSentConsultantDocsArray  ()  public  view  returns
(SentConsultantDocs[] memory) {
        return SentConsultantDocsArray;
    }

/*
THIS FUNCTION RETURNS DOCSSENTTOCONTRACTOR ARRAY
*/

    function  getSentContractorDocsArray  ()  public  view  returns
(SentContractorDocs[] memory) {
        return SentContractorDocsArray;
    }
/*///////////////////////////////////////////////////////////////
////////////////////////
\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\
\\\\\\\\\\\\\\\\\\\\\\\\*/


/*
THIS FUNCTION RETURNS CLAIM DATA ARRAY
*/

     function getclaimDataArray () public view returns (ClaimData[]
memory) {
        return ClaimDataArray;}}
```

3.6 Backend

The backend is the bridge that connects the blockchain with the frontend. It is responsible for receiving information from the frontend, uploading files on the blockchain and then storing all the information on the blockchain. Moreover, it retrieves information from the blockchain, accesses files from the IPFS and then displays all the information on the frontend.

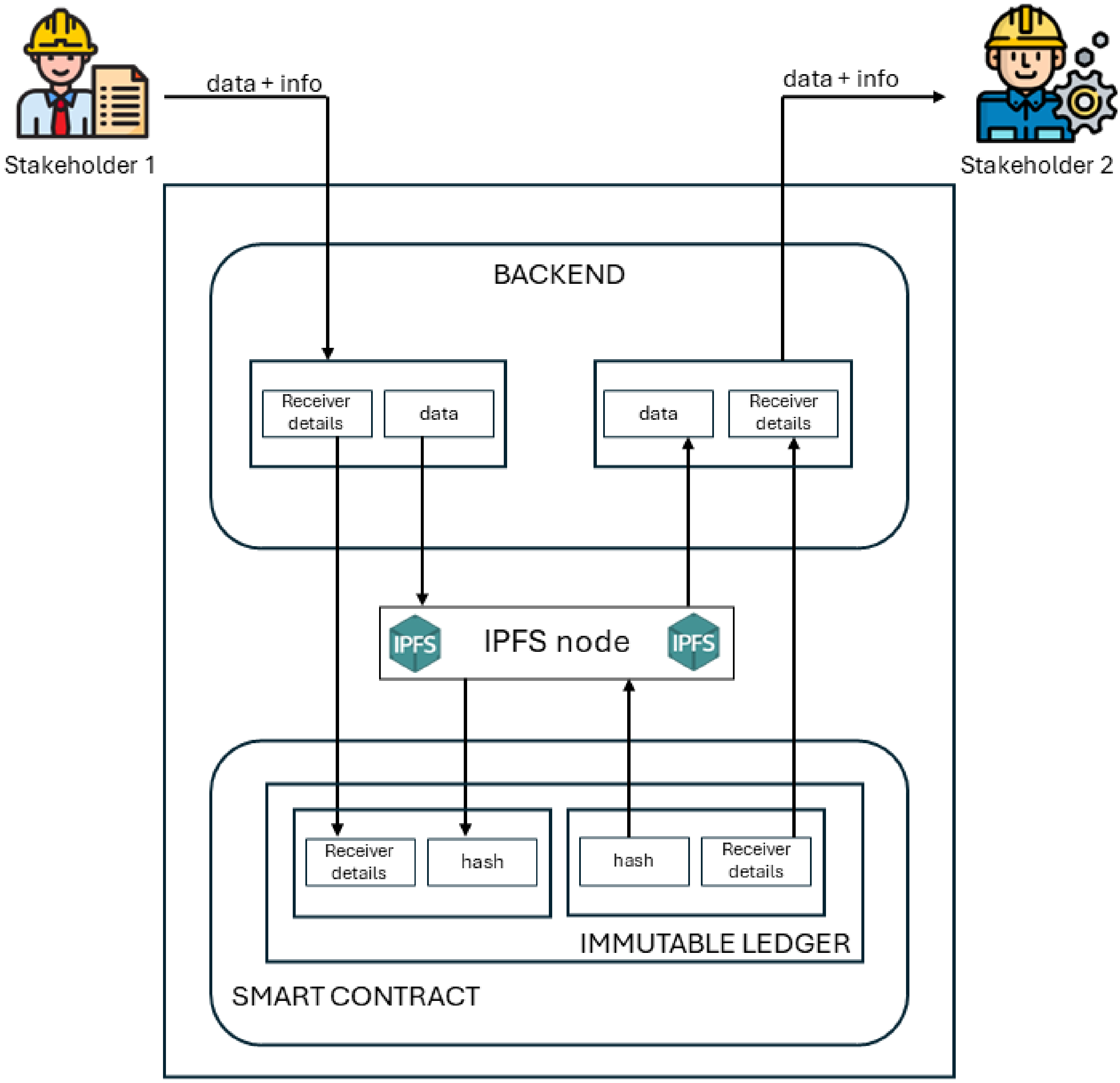


***Figure 9**: Backend working of decentralized application*

3.7 Frontend

The frontend is a user-friendly interface through which the users can freely interact with the decentralized application.

3.7.1 Stakeholders

A dedicated page showing all the stakeholders registered in the project is there to cross-check the blockchain addresses of each stakeholder.

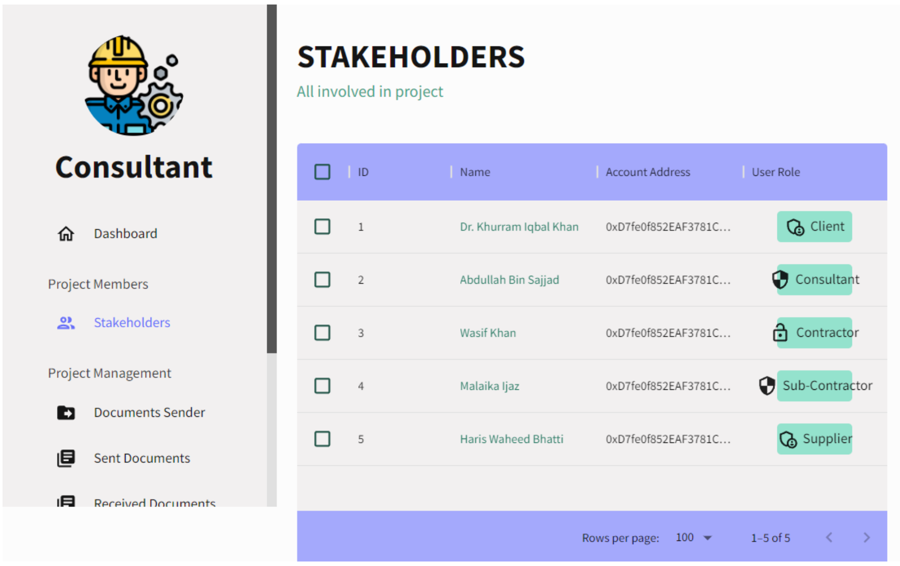


***Figure 10**: Stakeholders page*

3.7.2Documents Sender

A tab which allows stakeholders to send documents to other stakeholders

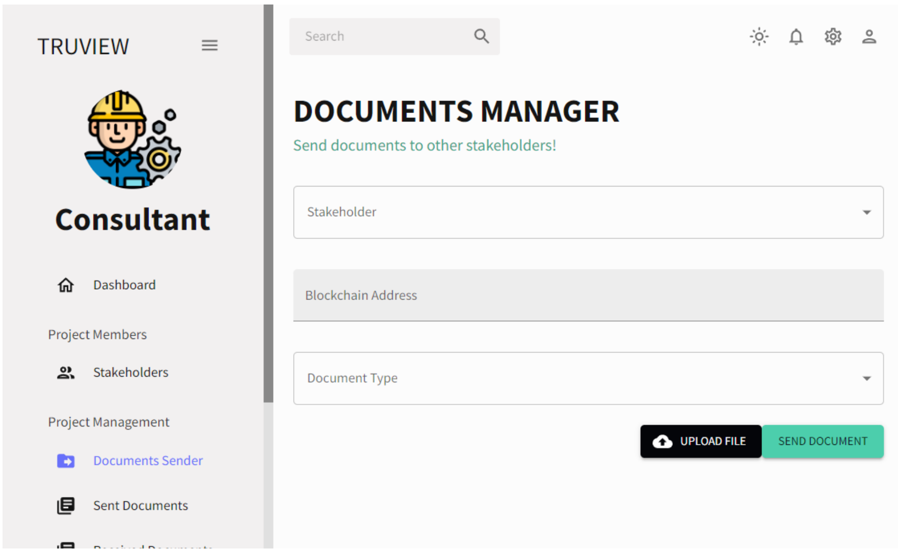


***Figure 11**: Documents Manager page*

3.7.3 Sent Documents

This tab allows a logged in stakeholder to see all the documents which he has sent to other stakeholders

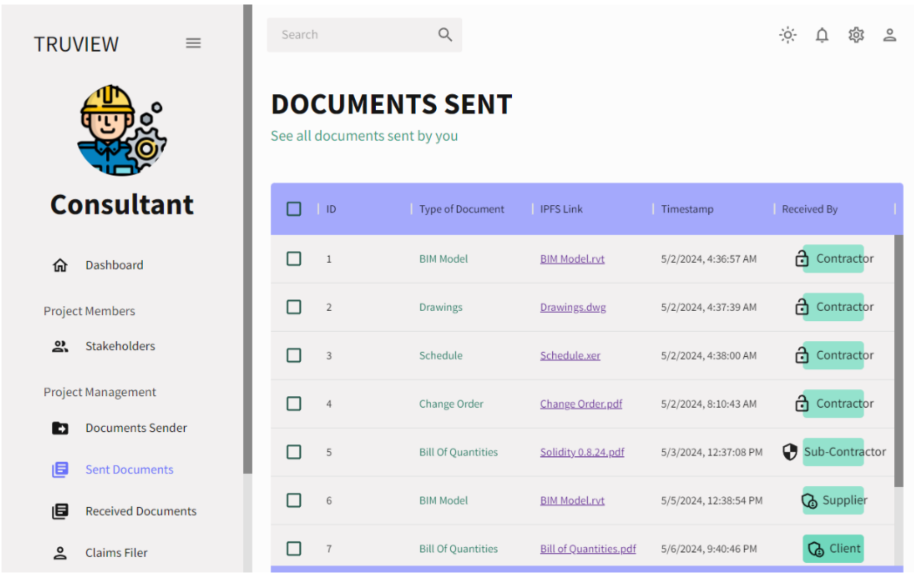


Figure 12: *Documents Sent page*

3.7.4 Received Documents

This tab allows a logged in stakeholder to see all the documents which he has received from other stakeholders

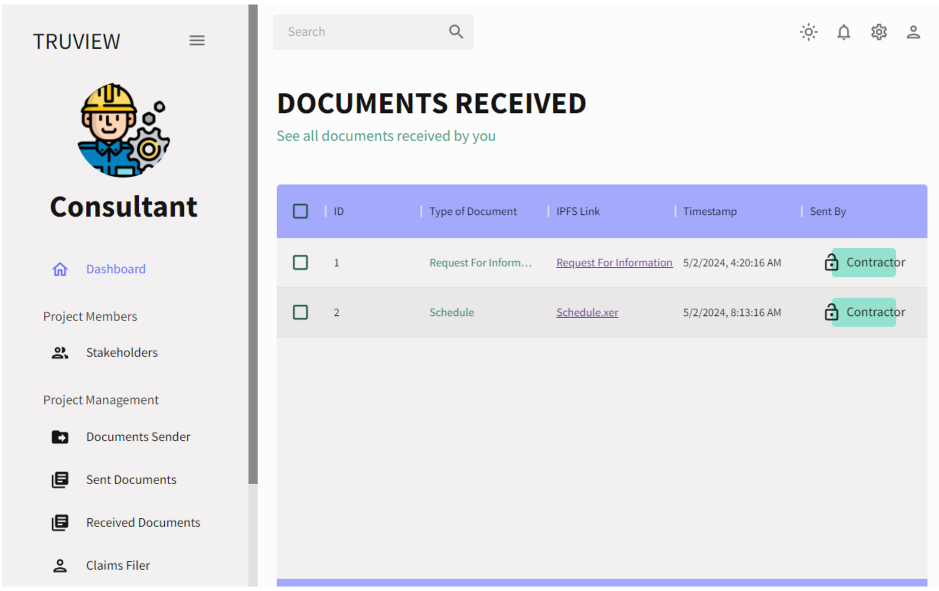


Figure 13: *Received Documents page*

3.7.5 Claims Filer

A tab which allows stakeholders to file a claim against any other stakeholder

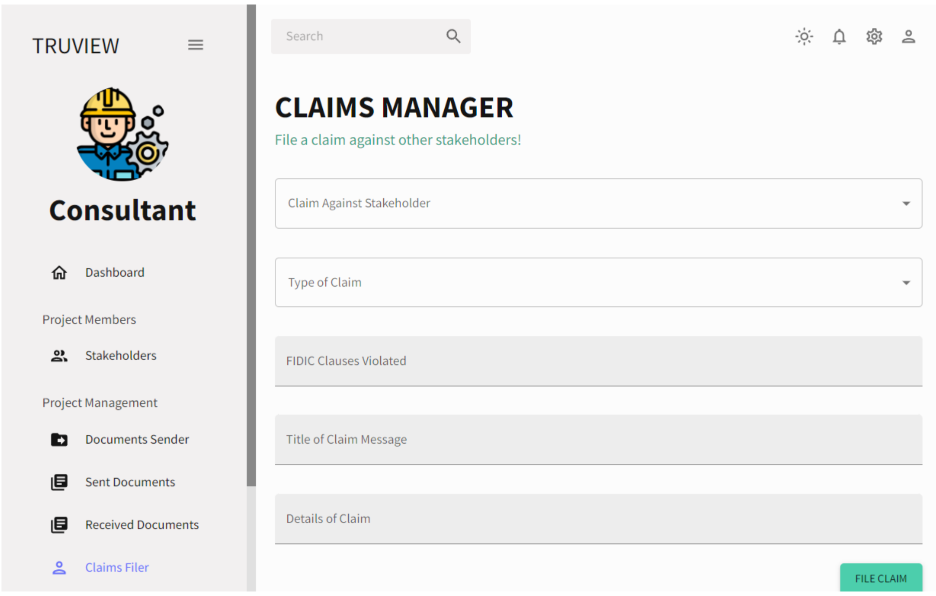


Figure 14: *Claims Filer page*

3.7.6 Dispute Ledger

A dispute ledger is accessible only by the arbitrator assigned to the project by mutual agreement and allows the arbitrator to view and access all the claims within the project.

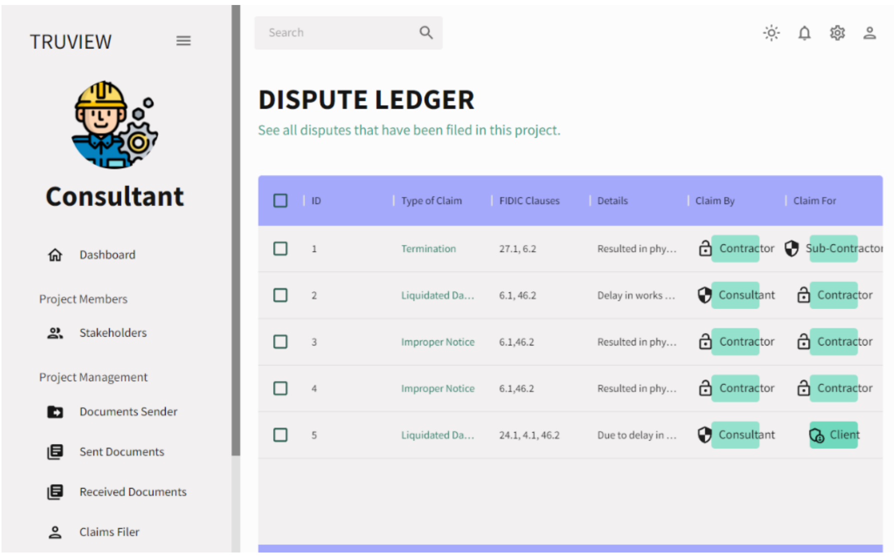


Figure 15*: Dispute Ledger page*

3.7.7 Arbitrator's Ledger

The arbitrator's ledger allows the arbitrator to view all the files that have been shared by all the stakeholders among each other.

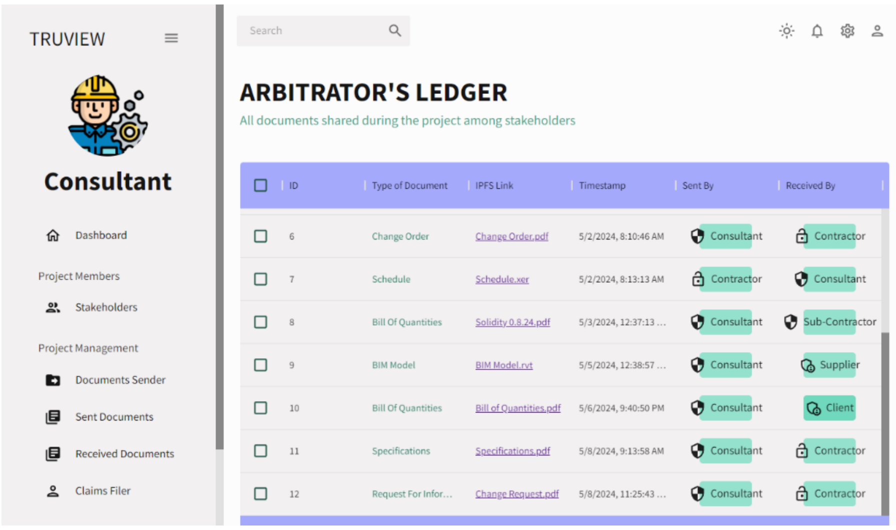


Figure 16: *Arbitrator's Ledger page*

CHAPTER 4
RESULTS AND DISCUSSIONS

4.1 BIM Support

The construction industry has huge demand for BIM and BIM managers need a secure method to exchange information. From the above studies, we have seen that blockchain can provide a very secure method to protect information exchange. BIM models can easily be uploaded to the blockchain using this application. The presence of BIM models secures the whole digital asset inside the blockchain system which helps to promote the security of the system. Once a BIM model is uploaded on IPFS, it can be accessed directly from the blockchain.

Figure 17*: IPFS hash for uploaded BIM model*

4.2 Cost Analysis

In conventional construction practices, record keeping is mostly paper based. This involves many types of costs involved. These include printing, storing, retrieving, maintenance, sending, etc. Even if in some cases, it doesn't involve paper, it is quite cumbersome to keep a record and protect its integrity throughout the lifecycle of a project. The costs involved with the record keeping process as well as the risks is too much (Koehn and Jones, 1983).

Here we are presenting an analysis of the low-cost approach we have adopted by using an Ethereum Layer 2 called Arbitrum.

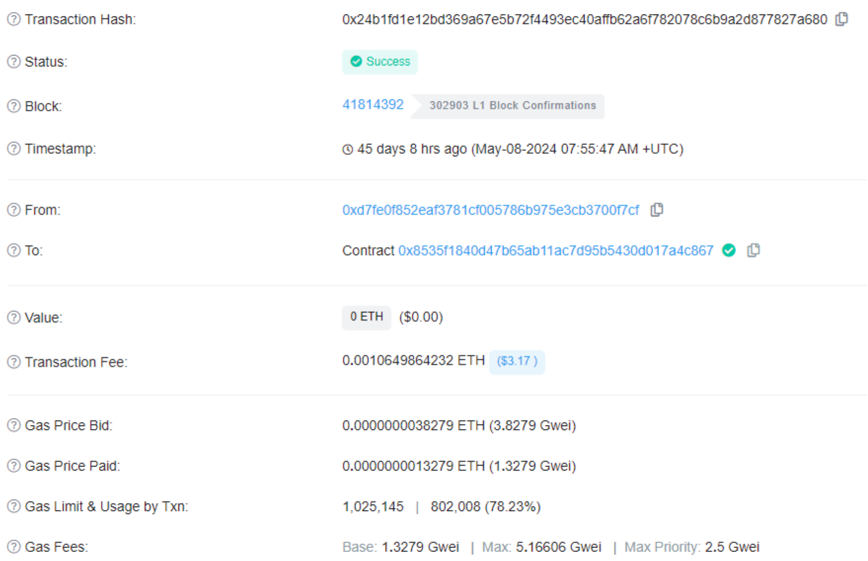
Some terms and conditions need to be clarified before we proceed further.

4.2.1 Gas

Gas is a unit of computational power expended by the blockchain to process a request. The blockchain is like a processing unit which takes commands and provides output by doing calculations just like a computer. Hence, it uses several units of gas depending on how many calculations were performed. For example, to send and store a document a total of 800,000 gas units were used.

4.2.2 Gas Fee

Each unit of gas comes with a fee represented in a value of the cryptocurrency being used for the specific transaction. The gas fee of Arbitrum Sepolia as of May-08-2024 07:55:47 AM +UTC is 0.0000000013279 ETH. This price can be converted to USD by conversion rates. At the time mentioned above, this transaction with 800,000 gas units cost around $3.17.



Transaction Hash:	0x24b1fd1e12bd369a67e5b72f4493ec40affb62a6f782078c6b9a2d877827a680
Status:	Success
Block:	41814392 302903 L1 Block Confirmations
Timestamp:	45 days 8 hrs ago (May-08-2024 07:55:47 AM +UTC)
From:	0xd7fe0f852eaf3781cf005786b975e3cb3700f7cf
To:	Contract 0x8535f1840d47b65ab11ac7d95b5430d017a4c867
Value:	0 ETH ($0.00)
Transaction Fee:	0.0010649864232 ETH ($3.17)
Gas Price Bid:	0.0000000038279 ETH (3.8279 Gwei)
Gas Price Paid:	0.0000000013279 ETH (1.3279 Gwei)
Gas Limit & Usage by Txn:	1,025,145 | 802,008 (78.23%)
Gas Fees:	Base: 1.3279 Gwei | Max: 5.16606 Gwei | Max Priority: 2.5 Gwei

Figure 18: *Blockchain Explorer showing public transaction details*

Once a document has been stored, it can be retrieved without cost until eternity. Hence, it eliminates the cost to keep paper-based records and hire labor to maintain them.

As this system allows for a tamper-proof record system, arbitrators do not need to expend a lot of energy into trying to figure out when and how certain correspondences occurred. Arbitrators will know exactly when a document was sent and what were the contents of that document. This allows easier arbitration and can reduce the service cost for arbitrators.

4.3 Digital Signatures and Timestamps

As documents are marked with a digital signature of the person sending them, hence there is always a proof of who sent the documents. Moreover, an exact timestamp is attached with every document which ensures that the time and date at which the document was sent can be immediately recognized.

***Figure 19**: Blockchain Explorer showing digital signature and timestamp*

CHAPTER 5

CONCLUSIONS & RECOMMENDATIONS

5.1 Discussion

The integration of blockchain technology with Building Information Modeling (BIM) through the TruView project represents a significant step forward in addressing the persistent challenges faced by the construction industry. The traditional methods of legal communication and dispute resolution have long been marred by inefficiencies, lack of transparency, and erosion of trust among stakeholders. The proposed solution not only aims to streamline these processes but also introduces a new paradigm of construction contract management that is secure, transparent, and immutable.

5.1.1 Enhancing Transparency and Trust

Blockchain technology's decentralized and immutable nature ensures that all project-related data, including design changes, material specifications, financial transactions, and communication logs, are securely stored, are easily verifiable and forever immutable. By providing a clear and tamper-proof audit trail, TruView allows stakeholders to track project progress in real-time, verify information authenticity, and hold each other accountable for their actions.Thus, TruView has the ability to improve security, trust and transparency between stakeholders in a construction project[1].

5.1.2 Cost Overruns and Delays

The total cost of sending one letter or adding one stakeholder or basically storing one record on the blockchain is 3 mulitiplied by 10 raised to the power -8 dollars, which is even less than a rupee. Thus, using TruView provides a cheaper and more efficient legal communication and contract management system for construction projects

5.1.3 Improving Dispute Resolution Mechanisms

Traditional dispute resolution methods in construction projects involve:

1. Using the postal service for communication
2. Keeping paper forms of all construction documents, contract and letters

3. Requiring the use of original documents as evidence during arbitration

When arbitration is called, the arbitrator summons all parties to a single place where he asks both parties to submit their proofs which are then cross-checked by the other parties. This way of substantiaton of proofs breeds a system of dispute resolution which is slow and in-effiecient. The use of the TruView blockchain allows

1. Online arbitration, significantly improving the ease of the process
2. Substantiation of proof using the immutability of the blockchain. This means that there is no requirement for the other party to cross-check the submitted proofs.

Thus, TruView, using de-centralization, offers a digital, cheaper, convenient and a more secure system for dispute resolution.

5.2 Recommendations

5.2.1 Adoption of TruView in Pilot Projects:

To demonstrate the effectiveness of TruView, it is recommended to implement the system in a series of pilot projects. This will provide practical insights into its benefits and challenges, allowing for refinement before wider adoption.

5.2.2 Policy and Regulatory Support:

Collaboration with regulatory bodies is essential to ensure that the use of blockchain technology in construction complies with existing laws and regulations. Policies should be developed to support the adoption of innovative technologies in the industry.

5.2.3 Scalability:

Develop methods for efficiently storing and displaying large volumes of construction data. Given that construction projects involve multiple extensive BIM files, it is essential to create a system capable of managing these files without compromising user experience or necessitating high-end hardware.

5.3 Practical Implementation

The practical implementation of the TruView project involves several key steps:

5.3.1 System Development:

Develop the integrated blockchain-backed BIM system, ensuring it meets the specific needs of construction projects. This includes creating user interfaces, establishing data protocols, and integrating blockchain technology with BIM software.

5.3.2 Pilot Testing:

Implement the system in selected pilot projects to test its functionality and effectiveness. Collect feedback from stakeholders and make necessary adjustments.

5.3.3 Full-Scale Deployment:

Once the system has been refined through pilot testing, proceed with full-scale deployment across multiple projects. Monitor its performance and continuously improve the system based on user feedback.

5.3.4 Ongoing Support and Maintenance:

Provide ongoing technical support and maintenance to ensure the system operates smoothly. Regular updates and enhancements should be made to keep up with technological advancements and changing industry needs.

5.4 Future Research

The implementation of blockchain-backed BIM models in construction projects opens numerous avenues for future research. One of these avenues is the inclusion of AI into blockchain backed BIM model system. Basically, making a fully automated progress tracking and legal communication system that can automatically track building components, update them on a BIM software, generate IPCs from BIM documents and store all this information the blockchain for use in dispute resolution.

5.5 Conclusion

The construction industry is at a critical juncture, where traditional methods of project management and dispute resolution are no longer sufficient to meet the demands of modern infrastructure development. The TruView project presents a revolutionary approach by integrating blockchain technology with BIM, offering a solution that enhances transparency, improves dispute resolution, and fosters trust among stakeholders. By addressing the critical challenges of inefficiencies, lack of transparency, and erosion of trust, TruView has the potential to transform the construction industry and contribute to the broader goals of sustainable and inclusive development. The successful implementation of this system can lead to more efficient, cost-effective, and trustworthy construction practices, ultimately benefiting all stakeholders involved. As the industry continues to evolve, embracing innovative solutions like TruView will be essential in overcoming persistent challenges and achieving long-term success.

REFERENCES

Pervez, A., 2022. Impact of Sustainable Supply Chain Management in the Construction Industry: Sustainable Supply Chain Management and Construction Industry. *South Asian Journal of Social Review*, *1*(2), pp.16-33.

Chaudhry, N., Ayaz, M. and Usman, M., 2022. Exploring the Factors Causing Delays in Project Completion on Time: An Evidence-based Study from Pakistan. *Empirical Economic Review*, *5*(2), pp.01-26.

Yap, J.B.H. and Lim, S.Y., 2023. Collaborative project procurement in the construction industry: investigating the drivers and barriers in Malaysia. *Journal of Construction in Developing Countries*, *28*(1), pp.171-192.

Opoku, D.G.J., Perera, S., Osei-Kyei, R., Rashidi, M., Bamdad, K. and Famakinwa, T., 2023, January. Barriers to the adoption of digital twin in the construction industry: A literature review. In *Informatics* (Vol. 10, No. 1, p. 14). MDPI.

Zhang, B. and Li, Y., 2022. A user profile of tendering and bidding corruption in the construction industry based on som clustering: a case study of china. *Buildings*, *12*(12), p.2103.

Kinnunen, U.M., Kivekäs, E., Palojoki, S. and Saranto, K., 2020. Register-based research of adverse events revealing incomplete records threatening patient safety. In *Digital Personalized Health and Medicine* (pp. 771-775). IOS Press.

Cunill, C., 2020. Margins of documents, center of power: a case study on the Consejo de Indias' annotated paperwork and the construction of legality in an imperial archive. *Archival Science*, *20*(4), pp.381-400.

Padroth, C., Davis, P.R. and Morrissey, M., 2017. Contract information asymmetry: Legal disconnect within the project team. *Journal of legal affairs and dispute resolution in engineering and construction*, *9*(3), p.04517015.

Lacity, M.C., 2022. Blockchain: From Bitcoin to the Internet of Value and beyond. *Journal of Information Technology*, *37*(4), pp.326-340.

Wang, S. and Liu, J., 2021, May. Blockchain based secure data sharing model. In *2021 IEEE 24th International Conference on Computer Supported Cooperative Work in Design (CSCWD)* (pp. 464-469). IEEE.

Szabo, N., 1996. Smart contracts: building blocks for digital markets. *EXTROPY: The Journal of Transhumanist Thought,(16)*, *18*(2), p.28.

Li, W., Duan, P. and Su, J., 2021. The effectiveness of project management construction with data mining and blockchain consensus. *Journal of Ambient Intelligence and Humanized Computing*, pp.1-10.

Wang, J., Wu, P., Wang, X. and Shou, W., 2017. The outlook of blockchain technology for construction engineering management.

Hamida, E.B., Brousmiche, K.L., Levard, H. and Thea, E., 2017, July. Blockchain for enterprise: overview, opportunities and challenges. In *The Thirteenth International Conference on Wireless and Mobile Communications (ICWMC 2017)*.

Ganter, M. and Lützkendorf, T., 2019, August. Information management throughout the life cycle of buildings–Basics and new approaches such as blockchain. In *IOP Conference series: Earth and environmental science* (Vol. 323, No. 1, p. 012110). IOP Publishing.

Ganter, M., & Lützkendorf, T. (2019). Information management throughout the life cycle of buildings - Basics and new approaches such as blockchain. IOP Conference Series: Earth and Environmental Science, 323(1). https://doi.org/10.1088/1755-1315/323/1/012110

Zheng, R., Jiang, J., Hao, X., Ren, W., Xiong, F. and Ren, Y., 2019. bcBIM: A Blockchain-Based Big Data Model for BIM Modification Audit and Provenance in Mobile Cloud. *Mathematical problems in engineering*, *2019*(1), p.5349538.

Buterin, V., 2013. Ethereum white paper. *GitHub repository*, *1*, pp.22-23.

Yang, H., Kim, D., Lee, D. and Park, S., 2024, January. Blockchain-based reliable and secure file access control for distributed public node. In *2024 IEEE International Conference on Consumer Electronics (ICCE)* (pp. 1-6). IEEE.

Ebrahimi, E., Khamespanah, E., Sirjani, M. and Mohammadi, S., 2023, September. Model checking of hyperledger fabric smart contracts. In *2023 IEEE 28th International Conference on Emerging Technologies and Factory Automation (ETFA)* (pp. 1-8). IEEE.

Zheng, Z., Xie, S., Dai, H., Chen, X. and Wang, H., 2017, June. An overview of blockchain technology: Architecture, consensus, and future trends. In *2017 IEEE international congress on big data (BigData congress)* (pp. 557-564). Ieee.

Sharma, A.K. and Mittal, S.K., 2019, January. Cryptography & network security hash function applications, attacks and advances: A review. In *2019 Third International Conference on Inventive Systems and Control (ICISC)* (pp. 177-188). IEEE.

Chan, S., Chu, J., Zhang, Y. and Nadarajah, S., 2020. Blockchain and cryptocurrencies. *Journal of Risk and Financial Management*, *13*(10), p.227.

Azhar, S., 2011. Building information modeling (BIM): Trends, benefits, risks, and challenges for the AEC industry. *Leadership and management in engineering*, *11*(3), pp.241-252.

Rabii, K.B., Javaid, W. and Nabeel, I., 2022. Development and implementation of centralised, cloud-based, employee health contact tracing database and predictive modelling framework in the COVID-19 pandemic. *The Lancet Digital Health*, *4*(11), pp.e770-e772.

Agapiou, A., 2022. Briefing: The role of the Technology and Construction Court in alternative dispute resolution. *Proceedings of the Institution of Civil Engineers-Management, Procurement and Law*, *177*(2), pp.61-64.

Wong, S., Zheng, C., Su, X. and Tang, Y., 2024. Construction contract risk identification based on knowledge-augmented language models. *Computers in Industry*, *157*, p.104082.

Benet, J., 2014. Ipfs-content addressed, versioned, p2p file system. *arXiv preprint arXiv:1407.3561*.

Koehn, E. and Jones, M.W., 1983. Benefits and costs of EEO rules in construction. *Journal of Construction Engineering and Management*, *109*(4), pp.435-446.

Ebekozien, A., Aigbavboa, C., Adekunle, S.A., Samsurijan, M.S., Aliu, J., Arthur-Aidoo, B.M. and Amadi, G.C., 2024. Smart contract applications in the built environment: How prepared are Nigerian construction stakeholders. *Frontiers of Engineering Management*, *11*(1), pp.50-61.

Faraji, A., Homayoon Arya, S., Ghasemi, E., Rashidi, M., Perera, S., Tam, V. and Rahnamayiezekavat, P., 2024. A conceptual framework of decentralized blockchain integrated system based on building information modeling to steering digital administration of disputes in the IPD contracts. *Construction Innovation*, *24*(1), pp.384-406.

Chung, I.B., Caldas, C. and Leite, F., 2022. An analysis of blockchain technology and smart contracts for Building Information Modeling. *Journal of Information Technology in Construction*, *27*.

Wang, R., Tsai, W.T., He, J., Liu, C., Li, Q. and Deng, E., 2018, December. A medical data sharing platform based on permissioned blockchains. In *Proceedings of the 2018 International Conference on Blockchain Technology and Application* (pp. 12-16).

Jabbar, R., Kharbeche, M., Al-Khalifa, K., Krichen, M. and Barkaoui, K., 2020. Blockchain for the internet of vehicles: A decentralized IoT solution for vehicles communication using ethereum. *Sensors*, *20*(14), p.3928.

Alhamami, A., Petri, I., Rezgui, Y. and Kubicki, S., 2020. Promoting energy efficiency in the built environment through adapted bim training and education. *Energies*, *13*(9), p.2308.