

**THE BARRIERS TO ADOPTING BLOCKCHAIN TECHNOLOGY IN
CONSTRUCTION PROJECTS DELIVERY**

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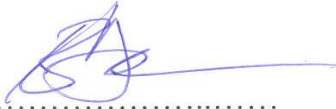
IN

PROJECT MANAGEMENT TECHNOLOGY

OCTOBER, 2023

CERTIFICATION

This is to certify that this work entitled “**THE BARRIERS TO ADOPTING BLOCK CHAIN TECHNOLOGY IN CONSTRUCTION PROJECTS DELIVERY**” was carried out by **Agbara, Victor Odinakachukwu** (Reg. No. **20194191478**) in partial fulfillment for the award of the Degree of Master of Science (M.Sc) in Project Management Technology in the Department of Project Management Technology of the Federal University of Technology, Owerri, Nigeria.



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DEDICATION

This work is dedicated to God Almighty for His Love.

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God bless you all!

Agbara, Victor Odinakachukwu

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ABSTRACT

This study is aimed at evaluating the barriers to adopting blockchain technology and its implementation in construction project delivery in Imo State, Nigeria. It specifically sought to identify the major barriers to adopting and implementing Blockchain technology in construction project delivery, develop causal relationships among the finalized barriers to adopting Blockchain technology in construction project delivery, prioritize the barriers according to how to manage them based on their cause-and-effect relationship using feedbacks from experts in Imo State, Nigeria. This research was guided by the theory of reasoned action (TRA), technology acceptance model (TAM) and diffusion of innovation (DOI) theory. The study used an exploratory and multi-method (qualitative and quantitative) research design methods of investigation, and a simple random sampling technique was used to select a sample size of 123 from a population of 194 people using the Krejcie and Morgan's method of sample size determination, and five (5) construction projects from the sampled practitioners in Imo state. The data collection and survey instrument included a well-structured questionnaire, focus group interviews/discussion and personal observations and visits to elicit information from respondents/construction project locations. The collected data was presented in the form of frequency distribution, figures, and charts using descriptive statistical tools using IBM SPSS Statistics version 25.0. While the Interpretive Structural Modeling (ISM) with the aid of ISM diagraph Model and MICMAC analysis was used to analyse the study's main topic of discourse. The study's findings indicate a general low level of utilization/application of Blockchain technology in the delivery of construction projects in Imo state. This is due to the fact that none (0.00%) of the respondents have heard of Blockchain technology as applicable to construction projects-related activities, 9 (10.47%) have used Blockchain technology sparingly, 35 (40.70%) have never heard of Blockchain technology and 42 (48.84%) have heard of Blockchain technology, but never applied it on any construction project-related activity out of the eighty-six (86) responses used for the study. This research also reveals that amongst the eight (8) identified barriers to Blockchain technology application, the most influential barriers militating against the application of Blockchain technology are: Bandwidth and Connectivity (BC), Absence of regulations, legislation and global standard (AR) and Blockchain technology characteristics (BT). While the study further revealed the interaction and convergent relationships amongst the Blockchain technology barriers impeding against the application of Blockchain technology are: Security (SE), Resistance to Change (RC), Scalability and transaction capability of Blockchain systems (ST) and Immature application of Blockchain technology (IA). This study recommends that, a united front is needed to make Blockchain technology awareness-raising and encourage practitioners to embrace it. Blockchain can provide a dependable infrastructure for information management throughout all stages of the construction project life cycle, as well as secure storage of sensitive sensor data.

Keywords: Barriers, Blockchain, Technology, Construction Projects, Imo state, Interpretive Structural Modeling.

CHAPTER ONE

INTRODUCTION

1.1 Background Information

The construction industry will continue to be a vital engine of economic growth for all nations. It secures and maintains critical assets, promotes growth, and protects the infrastructure framework for long-term economic and social development. Construction is one of the largest industries in the world, contributing significantly to Nigeria's annual GDP.

Nonetheless, the industry's productivity and effectiveness have frequently been called into question. According to McKinsey research, building productivity has been static for decades, whereas manufacturing productivity has nearly doubled and continues to rise over the same period. Undoubtedly, the building sector is very different, but a more efficient business is required to maintain the global economy's phase. Digitalization is a component of this evolution, and the variety of modelling tools and software available makes the design process more efficient and project and document control more interactive. According to Amade, Ogbonna, Raphael, Obodoh, and Okore (2022), a Research and Markets report stated that more than 80% of new construction activities will include at least one form of emerging technology or related smart building technologies.

Over the next five years, the commercial smart building market is expected rise nearly double to more than \$51 billion globally by 2023. Arguably the most significant shift is the use of Building Information Modelling (BIM), which makes the design process more integrated and aids in the creation of a digital description

of every part of the built asset. The industry anticipates that within five years, 61% of enterprises will use BIM on the majority of their projects.

Technical advancements have occurred at an almost unfathomable rate in recent years. Artificial intelligence, robotics, cloud computing, and the internet of things are just a few examples of how technology is changing our way of life and how we work. The prospective changes in the commercial and social economy are not yet fully understood, but one thing appears certain: those who can use these technological developments on their company model can adapt fast, gain market competitive advantages, and give better service to clients and users.

Another of these groundbreaking technologies is Blockchain technology. Several advisors have identified its potential to transform sectors, business models, and operational processes like as payment settlement, accounting, administration, supply chain, customer interactions, funding, and so on. Blockchain is a sort of distributed ledger technology (DLT) that was publicly introduced as the underlying technology of Bitcoin about ten years ago. Blockchain is an information technology that is designed to adapt to structural issues. It can provide a comprehensive platform where project design and management take place in a Blockchain-backed building information model, integrated with a self-enforcing smart contract supplied by vendors chosen by a Blockchain network and managed by a Blockchain network on a larger scale of circular economy. This technology has the potential to bridge the trust gap between stakeholders (Mathews et al., 2017), automate many currently manual processes, provide a secure and reliable infrastructure for collaboration and information exchange, increase transparency, and provide a reliable chronological record keeping.

Blockchain is a distributed ledger technology implementation in which peers serve as data storage nodes. With such a system, information is totally and verifiably shared with everyone, with complete traceability and chronological order. The technology is free and establishing a Blockchain system is significantly less expensive than implementing any other shared database system, such as conventional cloud solutions. So far, Blockchain has gone through three generations: Blockchain 1.0 for digital currency, Blockchain 2.0 for digital banking, and Blockchain 3.0 for digital society. Blockchain 1.0 is only concerned with the decentralization of money and payments. Blockchain 2.0 operates on a broader scale, covering transactions involving any type of asset. Smart contracts and smart properties are two examples of the consequences of the second generation. Blockchain 3.0 extends beyond asset transaction tracking to include domains such as government, health, science, and culture. Blockchain implementations in supply chain management and banking systems demonstrate its high security and dependability (Morabito, 2017). Depending on the level of openness and access required, public, consortium, and private Block chains provide diverse information management system frameworks that can serve different demands (Morabito, 2017). A public Blockchain is open to anybody, and data may be read or written by any user, whereas a private system is only accessible to a chosen few. A hybrid Blockchain, also known as a consortium Blockchain, enables exchange between various Blockchain networks. The source of Blockchain's power is the lack of administrative power and the power of the crowd over data validity.

Wang et al. (2017) identify Blockchain as one of the methods that can assist in overcoming the acknowledged lack of trust and poor information exchange technologies in the Architecture, Engineering, and Construction (AEC) business

(Lau & Rowlinson 2010). Because of the way Blockchain works, it eliminates the requirement for trust between parties as well as the need for adversarial contractual agreements owing to a lack of confidence. This study looks into three areas of Blockchain technology's potential in the built environment sector. Payment and project management, procurement and supply chain management, building information modelling, and smart asset management are the four categories. Lastly, the difficulties associated with adopting Blockchain technology in construction projects are highlighted.

1.2 Problem Statement

The adoption and implementation barriers of Blockchain Technology necessitate careful consideration from both the construction industry and academia. Conducting an investigation into the barriers associated with Blockchain Technology is imperative in order to identify those that may significantly impede its adoption and implementation. Hence, it is imperative to recognize these hindrances to ensure seamless and efficient assimilation and execution. In addition, it is imperative for managers to comprehend the structural interdependencies that exist among the identified obstacles to the adoption and implementation of Blockchain Technology, with the aim of achieving optimal and proficient management. Consequently, this research is being conducted to fulfill these requisites.

The potential application of Blockchain can reduce the issues we have in construction projects, which can be divided into three major elements. Payment and project management challenges; A construction project involves a web of hundreds of procedures, participants, products, and materials. Money transactions and/or data exchange are commonly carried out in tandem with project progress. During the construction process, there are several disagreements and lawsuits.

Although payment terms and data confidentiality are established in a contract or agreement, disagreements over the agreed-upon standards frequently arise (Taylor, 2017). Aside from being incredibly productive, one of the main benefits of such a platform is the high level of openness for all parties involved. For example, (Johnston et al., 2004) discovered that the level of trust in the buy-supplier relationship of construction engineering management is associated to some inter-organizational cooperative behaviours, such as shared planning and flexibility. Complex contracts, terms, and conditions are frequently used in capital construction projects. It might be difficult to secure collaboration on every level between all contract parties throughout the lifecycle of a project. A higher level of trust is believed to improve project performance while managing project interactions, particularly in a cross-disciplinary environment. With such a system and smart contracts, it is possible to ensure that all actions are carried out in accordance with the terms agreed upon. Many parts of a building project might benefit from increased transparency and better collaboration. In this section, we will look at how Blockchain can help to alleviate payment problems and improve project management efficiency.

Procurement and supply chain management delivery challenges; the possibilities of Blockchain technology do not end with payment applications. Several research in the field of construction engineering management have focused on increasing supply chain management performance among manufacturers, distributors, contractors, and customers (Simatupang & Sridharan, 2005). It can also transform the construction industry's present supply chain management by assuring structural material provenance and creating a verified chain of custody that is transparent to all parties in the supply chain. The ultimate goal of supply chain management is to develop a seamless and agile supply chain in order to meet the needs of customers

at the lowest possible cost. Yet, due to the competing interests of many supply chain partners, achieving this ultimate goal is extremely challenging. The larger the project, the more moving parts, information, and people there are. It allows for blunders and confusion. A distributed network of information tracking supplies, designs, and transactions between project owners, contractors, and subcontractors will reduce or prevent errors from occurring.

Construction project delivery challenges, by utilizing a building information model and smart asset management. BIM is widely employed in the contemporary construction sector to increase collaboration, data interchange, information flow, and project delivery (Wang et al., 2015; Wang et al., 2016). BIM, in its most basic form, is a technique that works with digital representations of real-world objects. Such applications necessitate the use of a centralized company to record and handle data, which other players may be unwilling to offer. The degree to which shared information can be trusted and used to meet the needs of the supply chain is referred to as information quality. It can be measured in terms of precision, frequency, credibility, and accessibility. At its heart is a computer model that contains a wealth of asset information such as 3D geometry, construction management data such as time schedules and budgets, and operation and maintenance indicators. Smart contracts can account for real-time project implications; such as change orders or schedule revisions. They can also be partially or completely self-executing and self-enforcing, expediting payment and claim procedures and allowing for simple contract verification and management.

1.3 Objectives of the Study

The aim of this study is to evaluate the barriers to adopting and implementing Blockchain Technology on construction projects delivery. The specific objectives are:

- i. To identify the major barriers and extent of adoption of Blockchain technology in the delivery of construction projects in Imo State.
- ii. To develop causal relationships among the most influential barriers hindering the adoption of Blockchain technology on construction projects in Imo State.
- iii. To prioritize these barriers according to how to manage them based on their cause-and-effect relationship using feedbacks from experts in Imo State.

1.4 Research Questions

The underlisted research questions would guide the study;

- i. What are the major barriers impeding the adopting and implementing of blockchain technology on construction project delivery in Imo State?
- ii. How can the causal relationship amongst the identified barriers impeding the adopting and implementing of Blockchain technology on construction project delivery in Imo State be developed?

- iii. To what extent can these barriers be prioritized according to how to manage them based on their cause-and-effect relationship using feedbacks from experts in Imo State?

1.5 Justification of the Study

Most construction project information is lost during the transition to the first owner of the completed project. Blockchain's distributed ledger may contain lifespan information about every asset in a construction project, such as warranties, certifications, and replacements. Building Information Management (BIM) technology is used to create an immutable digital replica of the construction project within the Blockchain. This serves as a model to guarantee that the project stays within its scope, as well as a virtual home for assets, allowing them to be quickly searched and quantified. Monitoring the lifecycle of a single asset and scheduling maintenance become automated operations, especially when integrated with artificial intelligence (AI).

In necessity for contract proactiveness, this study with regards to contracts, will be required to be one step ahead. Given that smart contracts are written agreements that incorporate Blockchain technology. The necessity for document duplication is reduced because data is decentralised and readily available throughout the network. This study would further create the much-needed requirement for proactive third-party oversight, as it would create awareness for dozens of subcontractors and the contracting parties to accomplish their duties and job functions with ease. Given that Blockchain is an emerging technology that has permeates the nooks and crannies of different sectors/industries, its application on construction project delivery would aid in closing the gap that exist in technological driven construction

project delivery. This study would further be of paramount importance to construction project managers who would be enriched with recent tools and techniques which blockchain technology avails in the delivery of modern day construction projects.

1.6 Scope of Study

The study is delimited by geographic, scale, and sectorial parameters. The study's geographical focus was Imo State, Nigeria. The adoption of the Blockchain technology approach in the construction sector is being actively promoted the world over, with substantial investments being made towards enhancing its capacity and its deployment in the delivery of construction projects. Thus, the study was effectively studied within the context of construction projects who are involved in the delivery of their projects by deploying modern day emerging technologies such as Blockchain within Imo state, Nigeria.

The study primarily centered on construction projects with specifics on building construction projects, specifically those with an evidence of application of information and communication related tools. The applicability of the research findings may be limited to the public and private sector building construction projects, which are characterized by temporary construction and have a maximum 5 years life span.

CHAPTER TWO

LITERATURE REVIEW

2.1 Conceptual Review

2.1.1 Historical Development of Blockchain

Blockchain technology is one of the ground-breaking innovations in decentralised information technology (Abeyratne et al., 2016). The concept of this technology dates back to 1991, when Stuart Haber and Scott Stornetta published the first work on a cryptographically safe chain of blocks. Despite the fact that the technology's concept was revealed, it did not acquire traction until 2008. (Crosby et al., 2016). The technology debuted alongside the popular cryptocurrency Bitcoin. Satoshi Nakamoto, an anonymous author, presented a paper titled "Bitcoin: A Peer-to-Peer Electronic Currency System" in 2008. Because the author wished to remain unknown, this article was released under the author identity Satoshi Nakamoto. Nobody knows who the author is since he chose to stay unknown. The article described a peer-to-peer electronic cash system that would allow internet payments to be transmitted directly from one party to another without going through a financial institution. The goal was to eliminate the necessity for a third party in all financial transactions. (Crosby et al., 2016). Satoshi demonstrated a practical application of blockchain technology and solved the major difficulty of avoiding double spending in a paper published in 2008. To explain the double spending issue, one could remark that the system prevents a situation in which a party transfers an asset twice (Drescher, 2017a). Since 2008, blockchain technology has been firmly associated with Bitcoin, and some claim that it was invented as part of the underlying infrastructure of Bitcoin. The technology, however, extends far beyond digital money and financial assets. As the technology received wider

exposure in recent years, there have been important advances, new cases to employ and applications for the technology (Abeyratne et al., 2016).

2.1.2. What is a Blockchain?

Blockchain is an interconnected set of data "blocks" that constitute a distributed ledger, which is a fancy word for a collection of accounts—similar to a self-balancing cheque book. This ledger is where transactions or contracts that define a project are stored.

A Blockchain is a distributed ledger technology that is a consensus of shared and synchronized digital data geographically spread across various sites, regions, or institutions. In other words, there is no centralized administrator or data storage (Wu et al., 2017). The name Blockchain comes from the fact that this distributed ledger features a chronological sequence of "blocks," each of which holds a record of valid network activity, documents, or transactions (Abeyratne et al., 2016). The goal is for the majority of system members to validate the content of each block. After a block has been inserted and verified, it cannot be deleted or changed (Wang et al., 2017). Each block could well be defined as a chunk of encrypted data. Anybody within the system can, in theory, add data to the chain of blocks and review the data at any moment, but no one can change the data without proper authority (Abeyratne et al., 2016). As a result, each "block" generates a complete and immutable history of the network's operations, which is shared with all system participants. As a block is authenticated, it is added to a chronological chain of other blocks, hence the name Blockchain. As a result, the Blockchain is a chain that holds verifiable records of every single transaction, document, and so on that has ever occurred in the system.



Figure 2.1: A Simple Example of how the Blockchain technology works with a transaction of money (Crosby et al., 2016).

Blockchain technology is a game-changing tool for recording transactions and connecting them to build a "chain" known as a distributed ledger. Businesses are utilising blockchain to seize control of supply chains and contracts in ways that were not feasible even five years ago—but is widespread use of blockchain in construction realistic?

Even very huge building projects will become easier to handle as more construction businesses utilise Blockchain. Continue reading to understand further about Blockchain and the improvements it proposes for the construction sector, or visit our animated infographic for a visual breakdown.

a. A block addition's transaction, verification, block addition, and continuation steps

It is analogous to a literal chain, with each link representing a separate transaction in a project. If one provider completes a delivery and satisfies their contract, the completed contract is finalized and added as a new "block," or link in the chain. This provides block chains a natural order that is easy to follow while looking for information.

b. The three Blockchain concepts characterize it as secure, decentralized, and scalable to any size project.

i. Safeguard: Multilayer encryption employs mathematical functions to conceal data in a difficult-to-crack coded string of characters.

ii. Decentralization: Transactions are automatically checked by connections known as "nodes," resulting in a digital paper trail of validated records.

iii. Scalability: Because the information isn't centralised, Blockchain can be scaled to accommodate very huge projects.

Because Blockchain projects are distributed, they eliminate the normal hierarchy of information in a project, making them secure, decentralised, and scalable. This increases project transparency by decreasing the need for back-and-forth discussion about simple goals. As a result, Blockchain technology can be used to improve the efficiency of any project.

2.1.3 Transparency

A thorough account of transactions is kept in a Blockchain and is available to all network users at the same time. All subscribers involved in a transaction are aware of any actions done on data or transactions, leading in improved transparency

(Baiod, Light & Mahanti, 2021). The implementation of Blockchain in the global supply chain enabled open collaboration and trade. Traceability and transparency were two words that were frequently used in supply chains. Clarity is defined as the degree of openness or accessibility of supply-chain activity to participants and the network. Bannor and Kyire (2021) demonstrated how Blockchain enabled member tracking through its decentralised record approach, resulting in a transparent supply chain and enhanced overall efficacy. Blockchain technology was created to hold evolutionary algorithm time-stamp data validated by subscribers along the supply chain while also seeking to make the validated transactions or documents public to maintain transparency. Similarly, past studies backed up the earlier claim that Blockchain technology was the ideal answer for boosting transparency, autonomy, and efficiency in global supply chains. This implies that the core potential of Blockchain was to make supply chains transparent. In practise, agri-product transportation between countries might be facilitated by blockchain technology, with producers, intermediaries, and end users confirming transactions before making a choice. The adoption of Blockchain technology in agri-supply chains can boost transparency while decreasing the bullwhip effect. Furthermore, it was suggested that clear transactions provided by Blockchain were particularly beneficial to farmers by eliminating trade middlemen, improving channel efficiency and producer and buyer profit margins. Blockchains were proposed as an important option to examine if governments wanted to encourage short supply chains in agriculture. Furthermore, multiple studies have found that Blockchain usage contributes to accountability in farming and other industries.

The construction sector is attempting to shift towards integrating procedures between clients and executive parties, where transparency is critical. Transparency

in this study strives to provide insights on questions that are important to the parties involved. This knowledge will aid the parties' decision-making process while carrying out certain transactions. Many various stakeholders are involved in the supply chain, including suppliers, manufacturers, distributors, and customers. This creates a network of businesses that affect one another from raw resources to completed goods. According to Muskat et al. (2012), one component of improved transparency in the construction industry is the importance of quality assessment. In the early phases, the sector must focus on developing more robust and transparent methods of assessing quality. This study focuses mostly on transparency prior to the construction phase. The reputation system is critical for improving the operation of the market in this business. It can be improved by enhancing transparency and the ability to demonstrate previous project quality controls. To improve the reputation mechanism, keep in mind that measuring quality is challenging, especially between projects due to the uniqueness of each project. Yet, generic transparency standards can be employed to keep bad apples out of a pre-selection of available data from past results. This could help to improve the construction industry's image.

With a public blockchain network, all transactions are visible and public. The records of activity can be made public so that all market players can see them, or the amount of transparency can be restricted as appropriate (Rodrigo, Perera, Senaratne, & Jin, 2019). Creating a land register on a blockchain, for example, promotes openness, which is tremendously useful to the general public (Rodrigo et al., 2019). On public blockchains, data privacy is lacking (Perera, Nanayakkara, Rodrigo, Senaratne & Weinand, 2020). Because there are no privileged users, every node in the blockchain has access to all of the blockchain's information, and anybody is free to join and participate in the public blockchain network. As a

result, with public blockchains, data privacy is a big concern. Those who are concerned about data privacy might prefer private blockchains. Private blockchains, data encryptions, membership management, channels, and a variety of other methods have been proposed and deployed to address data privacy problems. On the other hand, even on a public blockchain, private or sensitive details can be stored off-chain to ensure that all nodes do not have access to them, which benefits the construction industry because highly classified data can be stored off-chain to prevent data privacy problems.

2.1.4 Business Continuity

Every business must guarantee that their facilities are and will stay operational. The lack of a single vulnerable failure point in blockchain technology ensures that the network is never down, even if certain failures occur, guaranteeing operational continuity (Baiod et al., 2021).

2.1.5 Disintermediation

Because blockchain infrastructure is truly decentralised, it allows for significant disintermediation. Because of decreased trust, technology protocols and elements can replace intermediaries, increasing efficiency and lowering friction-related direct and indirect costs between individuals and organisations (Baiod et al., 2021). The blockchain tries to avoid central control and continues to operate in a peer-to-peer network with no intermediaries, lowering operational costs and increasing the efficiency of the sharing service. Blockchain technologies can eliminate the necessity of third parties to be involved in data management while also addressing the issue of trusting the intermediaries (Rodrigo et al., 2019).

2.1.6 Intelligent Contracts (smart contracts)

Another important feature of blockchain is smart contracts, which are digitalized contracts that operate instantly once certain agreements are met (Duan, Zhang,

Gong, Brown & Li, 2020). Smart contract can significantly accelerate transactions while also increasing trust. Payment, for example, can be automatically sent to manufacturers once products arrive at the warehouse. When compared to the traditional supply chain, the programmed contract can save paperwork, accelerate processing time, and reduce human labour efforts. Because most blockchain applications include scripting languages, some functionality can be added to ledgers. For example, bitcoin contains a simple pile language, whereas Ethereum provides a similar language to JavaScript, a Turing-complete imperative language. These programs, referred to as smart contracts, are computer codes/software developed to electronically enable, confirm, and implement the negotiating process or achievement of business rules. As long as the terms of agreements are met, smart contracts self-execute and automate the execution of credible transactions and actions (e.g., the exchange of property, money, shares, or anything of value) without a middleman. Smart contracts can be used in previous ways, but blockchain is the best technology platform for leveraging smart contracts due to data integrity and data availability to all parties (Baiod et al., 2021).

For example, when exporting a container of roses and avocado from Kenya to the Netherlands in 2014, Maersk discovered that over 30 people and organisations were involved (Duan et al., 2020). It also took 34 days, including 10 days for data handling, to complete the entire shipping activity, not including missing papers that caused delays and time extensions. Because smart contracts are based on the agreement of all partners, no single user can make changes to them. In other words, it can serve as a substitute for "the letter of credit" and protect the partnerships. When all of these features are combined, blockchain can eliminate the risks of transactions in a low-trust environment, boost supply chain transparency and

visibility, increase performance, and safeguard the advantages of all interested parties.

Under this case, blockchain can help maximize digitalization while also saving process time, increasing efficiency, and lowering unnecessary expenses.

Smart contracts, according to Li, Greenwood, and Kassem (2019), instantly satisfy contractual terms upon having met pre-set commitments. Construction contracts drafted using code will alter how businesses operate, increase speed payouts, decrease disputes, and so on.

2.1.7 Fast Processes

Processes become streamlined and therefore faster (Li et al., 2019). Reduces the need for multiple verifications as they can be accessed by all participants on the Blockchain technology, especially in design and planning.

2.1.8 Decentralization

The lack of centralised control increases robustness and avoids many-to-one traffic flows, minimizing delays and a single point of failure. According to Rodrigo et al. (2019), "the purpose of Blockchain technology is to establish a decentralised environment where no third party is in control of the transactions and data."

2.1.9 Anonymity

Because blockchain transactions are recorded using public and private keys, persons can choose to remain anonymous to safeguard their privacy while allowing third parties to authenticate their identity. To avoid identity vulnerability in a blockchain network, each user will connect with a randomly generated address. This signifies that a certain level of privacy on transactions is maintained (Rodrigo et al., 2019).

2.1.10 Security

The encryption technology employed in a blockchain assures the legitimacy of the information saved and prevents fraud. To preserve virtual security, blockchain employs strong encryption including public and private keys. Encryption keeps private data private, while digital signatures provide authenticity, data integrity, and non-repudiation (Rodrigo et al., 2019).

2.1.11 Immutability

Blockchain keeps immutable records of data that are protected by a network of peer-to-peer participants. Transactions cannot be undone once they are added to a blockchain, making the ledger an immutable record of all prior transactions (Rodrigo et al., 2019).

2.1.12 Auditability

Because each transaction on the blockchain is validated and logged with a timestamp, any user may easily trace the previous records by accessing any node in the distributed network (Rodrigo et al., 2019).

2.1.13 Veracity

Several copies of the ledger's history records are maintained in the network of nodes, and each record is checked by consensus, enhancing veracity at a higher level when fake entries are recognized and destroyed by failure to attain consensus (Rodrigo et al., 2019).

2.1.14 Traceability

Traceability is an important aspect of global supply chains. Yet, blockchain technology has been widely recognized as a solution for achieving efficient traceability (Bannor & Kyire, 2021). Hence, blockchain technology enables the

tracking of agricultural and manufacturing products from their origin to the end customer. For example, it is emphasized that food traceability was made feasible by the evolution of blockchain technology, and as a result, items could be easily monitored from the point of manufacture to the ultimate customer. Furthermore, they said that the rising use of fertilizers and pesticides, along with other chemicals, significantly harms consumers, necessitating the implementation of blockchain technology to assist food traceability.

Coupled with transparency, the ability to trace specific materials is critical. This can be accomplished via a traceability system. This system should maintain track of items and chain partners so that each unit of a product may be traced throughout the supply chain. This type of technology is critical in supply chain management for quality control, product recall, reverse logistics, and other functions. These types of traceability technologies are not widely used in supply chains today (Duan et al., 2020). Some industries have made some attempts, using a method known as RFID tagging. This method was developed to replace earlier barcode scanning and to allow for more effective product tracking. Yet, the implementation has not been a success. The method was rejected by the majority of suppliers since they had to pay for the tags and the advantages did not justify the expenses. To integrate a new system in the supply chain, one must improve the benefits for all players, which might be tough in practise (Duan et al., 2020). According to Duan et al. (2020), there are two primary concerns to consider when implementing a traceability system in any form of supply chain. To begin with, the complexity of the systems makes it difficult for chain partners to understand and assess the costs and advantages of a traceability system. To address this issue, one must identify crucial decision variables analytically, explain costs, and describe benefits for each party. Second, traceability system design, implementation, and maintenance are

frequently decentralised. To preserve the effectiveness and efficiency of the traceability system, particulate participants must be driven to fulfil their commitments.

When you generate a cryptographically hashed value of some type of data, the hash value is expected to remain constant. Digital footprints are used by this technology to determine whether or not data has been tampered with (Wang et al., 2017). To check whether the data has been tampered with, for example, all that is required is to generate the cryptographic hash value again and compare it to the previous one. If these two hash values are the same, the data has not changed since the first hash value was generated (Drescher, 2017b). When it comes to delivering data to someone, this form of technology is also useful. If the sender generates a hash value before providing the data, the receiver can easily generate a hash value of the data received, ensuring that the data was not altered during the transmission (Drescher, 2017b). Hash references are another key aspect of blockchain technology (Crosby et al., 2016). Hash references are a type of reference that makes use of the power of cryptographic hash values (Drescher, 2017 a). These data references can be explained by comparing them to cloakroom tickets. A cloakroom ticket represents the physical location where your jacket is stored. You will be able to retrieve your jacket later using the cloakroom ticket. Consider the hash reference to be a cloakroom ticket that displays hash values rather than conventional integers. The hash reference ensures that the data to which it refers has not changed since the reference was generated. If the data to which the reference is made has changed, the reference is considered broken or invalid. This is like to having a cloakroom ticket for a certain hook that no longer holds your jacket. In other words, the cloakroom worker cannot hand over your jacket any longer (Drescher, 2017 b). The whole point of generating hash references is to

safeguard users from retrieving material that has been modified intentionally without alerting the receiver or changed without one's consent (Wu et al., 2017). They are also designed to safeguard consumers against data changes that occur unintentionally due to technical failures. As a result, hash references are used and produced anytime users need to ensure that the data remains unmodified once created and that users cannot obtain updated data (Drescher, 2017 b).

Furthermore, it was stated that implementing Blockchain in agribusinesses may reduce or eliminate food fraud by monitoring the entire production, processing, and distribution process until it reached ultimate consumers. Blockchain enabled the tracking of the origins of all food ingredients and raw materials. Interestingly, in terms of traceability, Bannor and Kyire (2021) stated that food safety risks might be tracked using an effective traceability system provided by blockchain. This means that suppliers and consumers would be informed about the manufacture date, nation of origin, and inputs used via the blockchain system, potentially resolving food safety and food fraud issues.

For example, Zhong An, a technical startup, launched "Bu bu chicken" to follow the chicken supply chain from farm to customer using blockchain and the internet of things. As a result, it was a perfect opportunity for global supply chains to incorporate blockchain technology to improve product traceability. Furthermore, the yearly national cost of food-borne diseases in the United States was projected to be between \$55.5 billion and \$93.2 billion, and as such, rapid traceability of the source of contaminated food products was critical for eradicating or reducing that cost. As a result, blockchain adoption was highlighted as a solution to that problem. In terms of blockchain possibilities for agribusinesses, blockchain technology is being used to monitor wood from standing trees to the eventual user via RFID sensors and open-source technologies. Similarly, Canada was

establishing permissioned and regulated blockchain networks to trace the cannabis supply chain at the time.

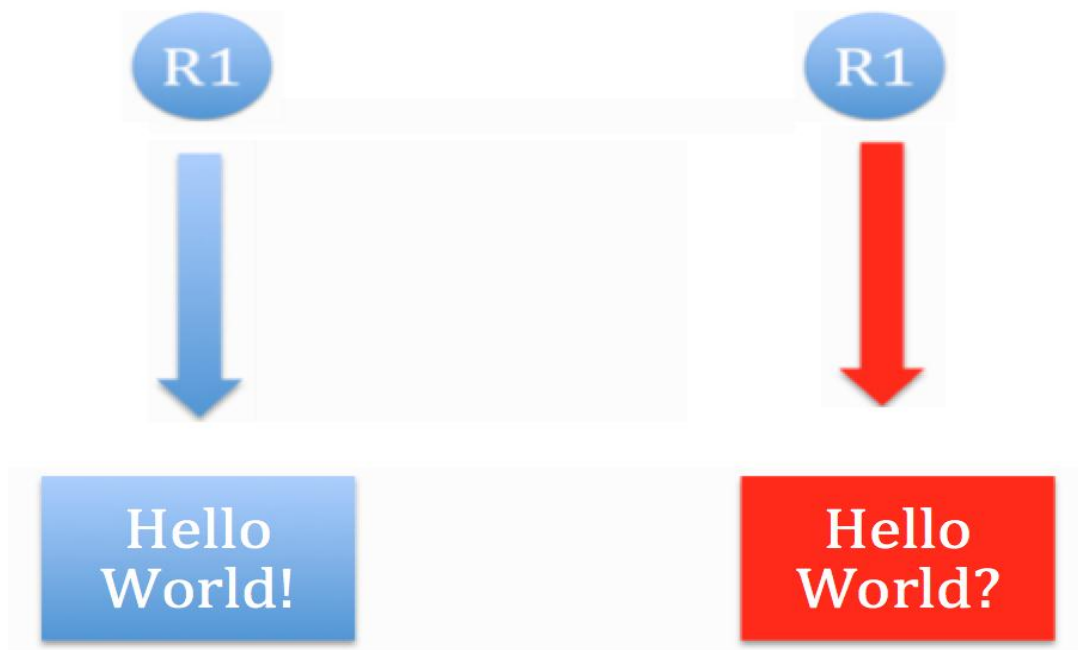


Figure 2.2: A Symbolic example of an invalid hash reference (Drescher, 2017; Hultgren & Pajala, 2018).

When a block is recorded, authenticated (see next part), and later added to a chain of blocks, it contains some of the hashes of the previous blocks. The chain of blocks will then include more work or hashes (Abeyratne et al., 2016). To alter a block in the chain (which can only be done by creating a new block containing the same predecessor), one must regenerate all successors and perform the work contained in the blocks. By connecting all blocks in a chain and integrating the work from each block, the blockchain is protected from tampering (Drescher, 2017 b). Figure 2.2 shows a symbolic example of an invalid hash reference (Drescher, 2017; Hultgren & Pajala, 2018).

2.1.15 Transaction Validation

Using bitcoin as an example once more, one of the primary concerns is the problem of double-spending, or avoiding a circumstance in which a person can

transfer an asset twice. The blockchain technology handles this through the verification or validation procedure (Crosby et al., 2016). To begin with, it is critical to recognize that being a part of a distributed network does not obligate you to disclose personal information with everyone in the system. This issue is addressed by developing a secure digital identity. The principle behind blockchain technology is that each member in the system has a public- and a private cryptographic key (Bauerle, 2017a).

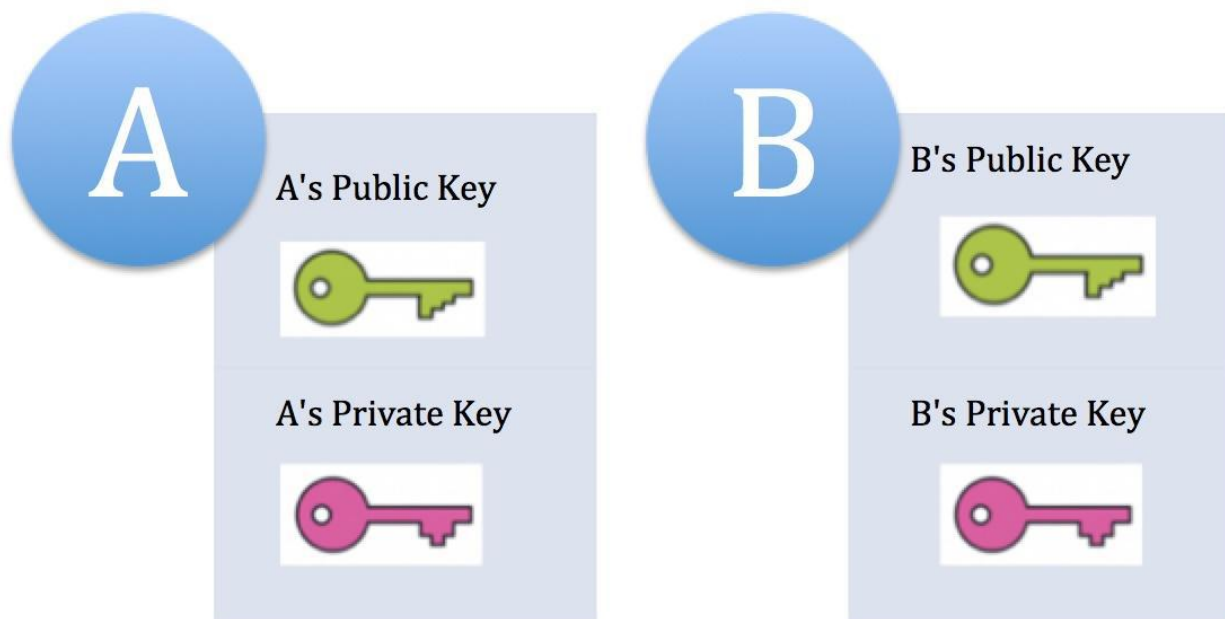


Figure 2.3: A Sample of two different cryptographic keys. (Bauerle, 2017a; Hultgren & Pajala, 2018).

The public key is used to access the distributed system, while the private key serves as a powerful ownership tool that satisfies authentication needs (Wang et al., 2017). The reason for keeping these distinct is to limit the risk of hackers. Yet, the combination of these keys might be viewed as a type of agreement, or in other words, a useful digital signature (Bauerle, 2017a). Figure 2.3 depicts a sample of two different keys.



Figure 2.4: Public- and the private key and digital signature (Bauerle, 2017a; Hultgren & Pajala, 2018).

Digital interactions originate from the combination of cryptographic keys and distributed systems (Crosby et al., 2016). In the case of bitcoin, the procedure begins with A taking their private key and making an announcement in the system. If A declares that he or she will send Bitcoin to B, he or she will simply attach it to B's public key. When this is done, the time is recorded and appended to the block (which has already been hashed) in the form of a time stamp (Bauerle, 2017b). Figure 2.4 depicts a public and private key and digital signature.

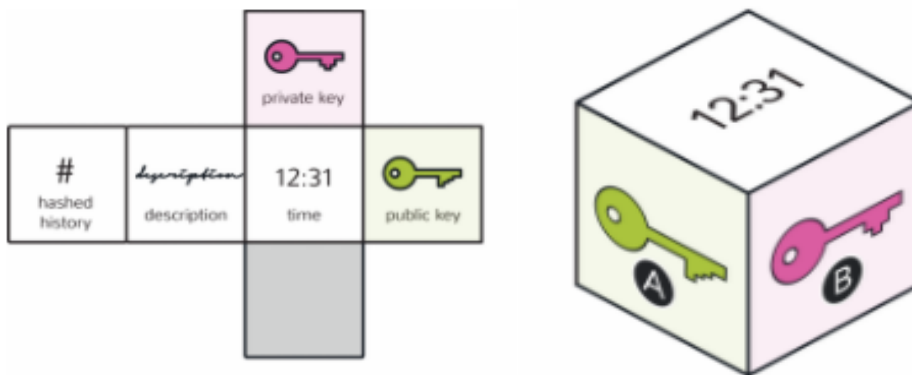


Figure 2.5: An example of what the block contains when broadcasted to the distributed system. Source: (Bauerle, 2017a; Hultgren & Pajala, 2018).

The block is again transmitted to the decentralized system, where the system members must agree and ratify the block's order. In order for the block to be

approved, the majority of the system's members or nodes must agree (Heiskanen, 2017). Because each member of the system independently updates the record or validation, they all construct their own updated version. The most "popular" record is made the official record and master copy. Blockchain technology eliminates the requirement for a trusted third to facilitate digital relationships by using this form of validation and technology (Bauerle, 2017 b). There are numerous methods for creating incentives to validate these types of blocks depending on whether the system is public or private (the differences will be explained in the next section). For public blockchains, mining is required (Bauerle, 2017a). When someone verifies or validates a block, they receive a form of remuneration. Using Bitcoin as an example, whomever validates a block will be rewarded with a set amount of Bitcoins. This type of labour is frequently referred to as "proof of work," which means demonstrating that the algorithm is correct and the transaction is legal (Wu et al., 2017). In some ways, this is equivalent to offering one's computer processing power to the network. The reward exists to generate incentives for people to act in their own self-interest in order to help meet societal needs (Bauerle, 2017a).

2.1.16. Trust Building (establishing trust)

The underlying concept of the blockchain mechanism is the creation of a trustable record among untrustworthy parties. The nice concept of blockchain-embedded procedure and cryptography properties reinforce trust and make verification easier (Baiod et al., 2021).

Another important benefit of Blockchain adoption that has been extensively discussed in the literature is trust. In today's world, where everyone is concerned with business and profit, trust is essential for forming partnerships between supply-chain actors (Bannor & Kyire, 2021). People prefer online trade because suppliers and consumers are not easily found, which typically results in merchandise fraud,

under-supply, defective products, and other issues. However, because of the system's transparency and visibility, traders gained trust through the use of blockchain technology. According to Bannor and Kyire (2021), blockchain architecture facilitates trustbuilding and supply networks by sharing information via smart contracts and distributed ledger. Before data can be added to a blockchain, the majority of participants in the blockchain must agree on it. Because blockchain is based on shared common understanding among various parties, the information stored on it is trustworthy. Intermediation can be avoided due to the trust that has been established (Rodrigo et al., 2019).

2.1.17. The Distinction between Public and Permissioned Blockchains

As noted earlier, there are several techniques to construct the distributed system. In short, there are two ways or systems for Blockchain technology: public and permissioned (private) (Bauerle, 2017c).

2.1.17.1 The Public System

Anyone can join the network in the public system. Miners, as previously stated, are incentivized to validate blocks in the system. Anyone in the public system can become a miner and seek the prize. It also allows a miner to walk away from being a node in the system and later return if they change their mind and receive a full report of all network activities (Wu et al., 2017). Anyone with a computer may basically join the system, read the chain, validate new blocks, and make legitimate changes as long as they follow the system's regulations. The system will be entirely decentralised if these elements are present (Bauerle, 2017c).

2.1.17.2. System with Permission (Private)

The goal of this system is to build a permission function for reading information in the Blockchain. It also restricts who can make changes to the Blockchain and who can serve the network by validating blocks and adding new blocks to the chain.

One example is the cryptocurrency Ripple, which operates on a permissioned Blockchain. The startup, unlike any other public system, decides who can participate as a validator in their network. CGI, MIT, and Microsoft are some of the validators for this cryptocurrency. Aside from these validators, the firm also develops its own nodes in various locations throughout the world. These permissioned Blockchains may or may not include the "proof of work" mining method. There is debate among Blockchain developers on whether private Blockchain that do not use proof of work (Blockchain without mining) should be regarded and viewed as Blockchain at all, but rather as simply shared ledgers (Bauerle, 2017c).

2.1.17.3. System Integration (semi-private)

Some Blockchain developers have recently begun experimenting with the two solutions mentioned above. In summary, a developer can make the system public for everyone to read, but they can limit who can be a node, validating blocks, or mining in the system. This allows the Blockchain to be adjusted in a variety of ways, making it more usable in new industries and applications (Bauerle, 2017c).

Blockchain, like a mobile phone, provides multi-dimensional stacking to ensure a number of critical elements. Most IT security practises are focused on protecting systems from loss of confidentiality, integrity, and availability. These three are known collectively as the security triad, the CIA triad, and the AIC triad." The security triad consists of the following:

1. Confidentiality: a set of regulations that restricts information access.
2. Integrity: assurance that the information is correct and reliable.
3. Availability: authorised individuals or users have consistent access to information.

Software architecture refers to how system components are related to one another and arranged. Szmigielski (2015) is frequently credited as being the first to describe the three major architectural approaches for software systems: centralised, decentralised, and distributed. As Szmigielski shows in his centralised network: A star represents a centralised network. Each node is linked to a central node. It is obvious that removing the centre node causes the network to fail. Any arrangement in which there is a central authority and everyone reports to it is an example (Prowse, 2017; Szmigielski, 2015).

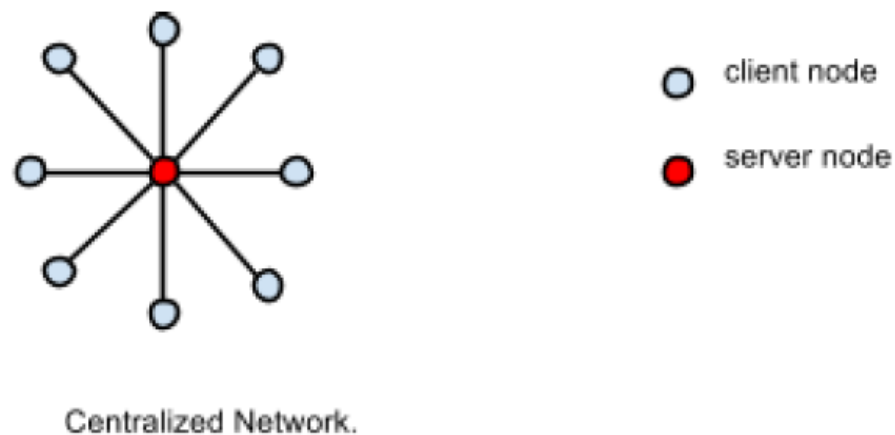


Figure 2.6: Centralized network Szmigielski (2015)

Szmigielski (2015) goes on to describe decentralised networks in further detail. There is no clear core in a decentralised network. To completely disrupt this network, the four red nodes must be removed. Alternatively, the marked communication links would have to be removed. It should be noted that removing the links divides the network up into smaller sub – networks, see figure 2.7

(Prowse,2017;Szmigielski,2015).

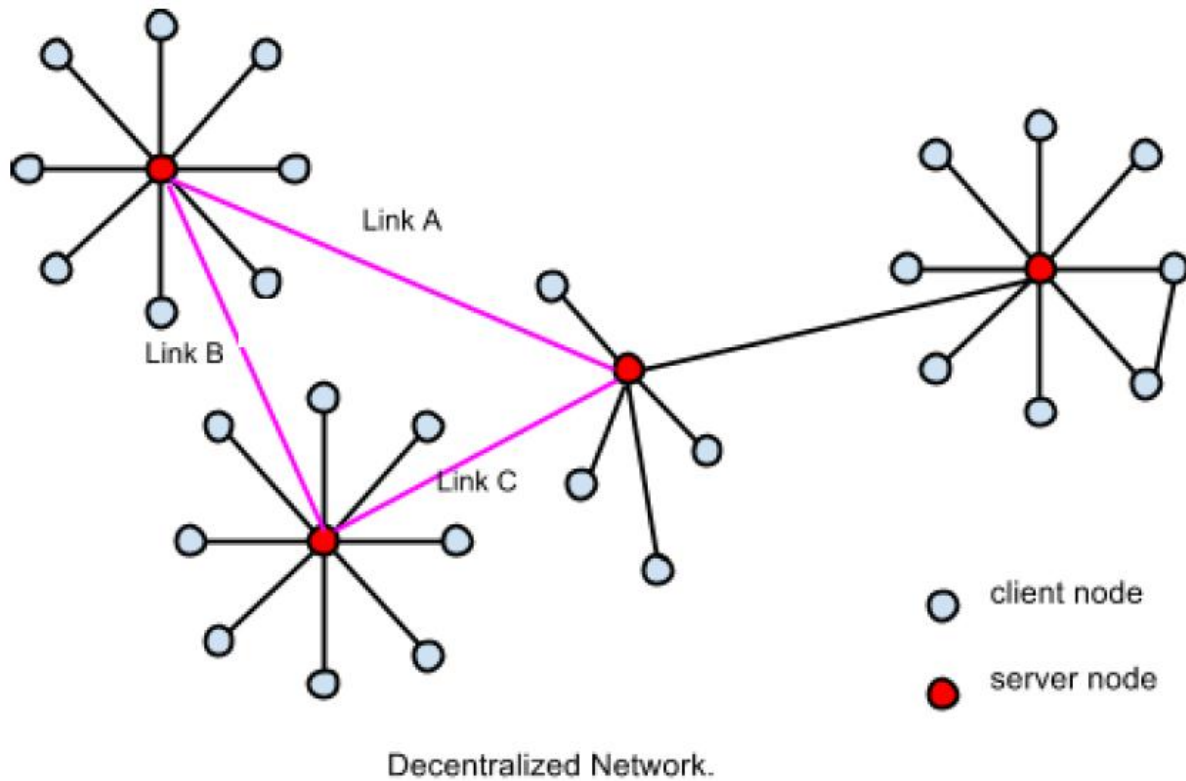


Figure 2.7: Decentralized network Source: Szmigielski (2015)

According to Drescher (2017), decentralised networks have advantages in terms of fault tolerance, efficiency in constructing network linkages, and difficulty in shutting down the entire network. Lastly, as seen in Figure 5, Szmigielski considers distributed systems: But what if we want to build a network that is nearly difficult to destroy? All that is required is for each node to have as many connections to other nodes as feasible, as well as the ability to forward traffic on its way to a destination. As a result, a network connection will be created. A node in a distributed network has as many connections to other nodes as possible. As a result, disrupting communication is equivalent to nearly destroying every node or

link. Every node can now forward communications from other nodes. It serves as a server for others while also serving as a user on its own (Szmigielski, 2015).

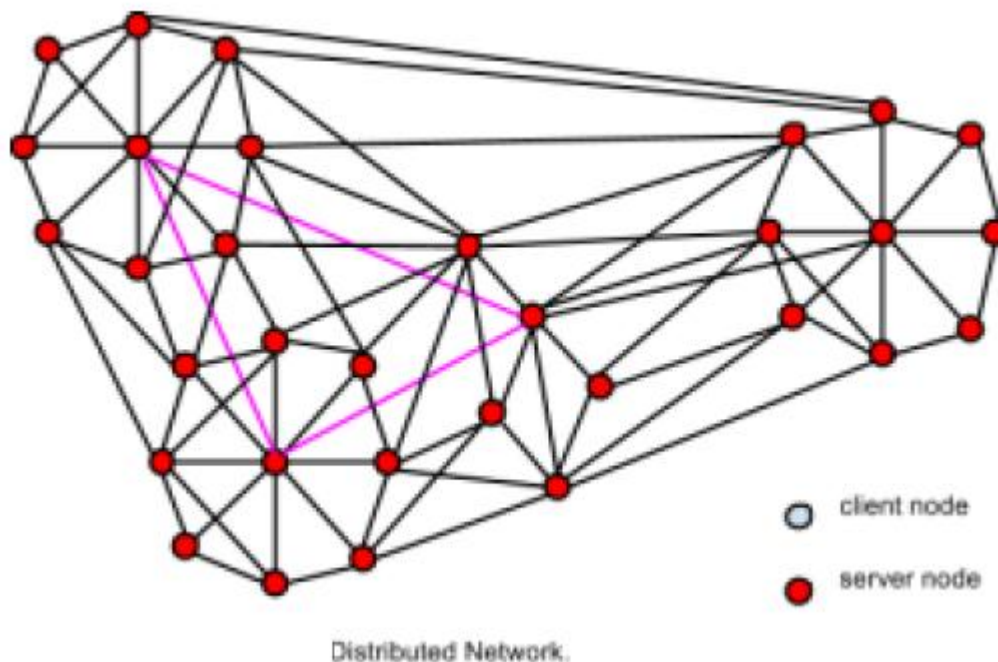


Figure 2.8: Distributed System. Source: Szmigielski (2015)

According to Szmigielski (2015), there's often ambiguity when addressing distributed versus decentralised systems: "The major difference is that in fully distributed networks, each node has several connections and can act as a server." With this in mind, the Blockchain functions on a distributed basis, which provides various benefits like greater computational power and the capacity for the system to evolve organically? Computation power is a product of all linked computers on the system, which contributes to reliability because the network may continue to run even if a single point of failure occurs. As more computers are added to the system, power can be adjusted incrementally, allowing the system to naturally expand in scope.

A peer-to-peer (P2P) network is a form of distributed system that allows individual computers to share computational resources with other network users without the

need for a central point of coordination (i.e. - decentralised). Individual computers are also known as nodes, and each node serves as both a supplier and a consumer of resources inside the system. Architectural models can also be mixed in nature, including aspects of both a centralised and distributed system. Software architecture can be chosen based on available resources, intended implementation to an existing system, or as an inventive way of change. Figure 2.9 depicts a distributed system's core component as well as an internal distributed system linked to an external centralised system (Drescher, 2017).

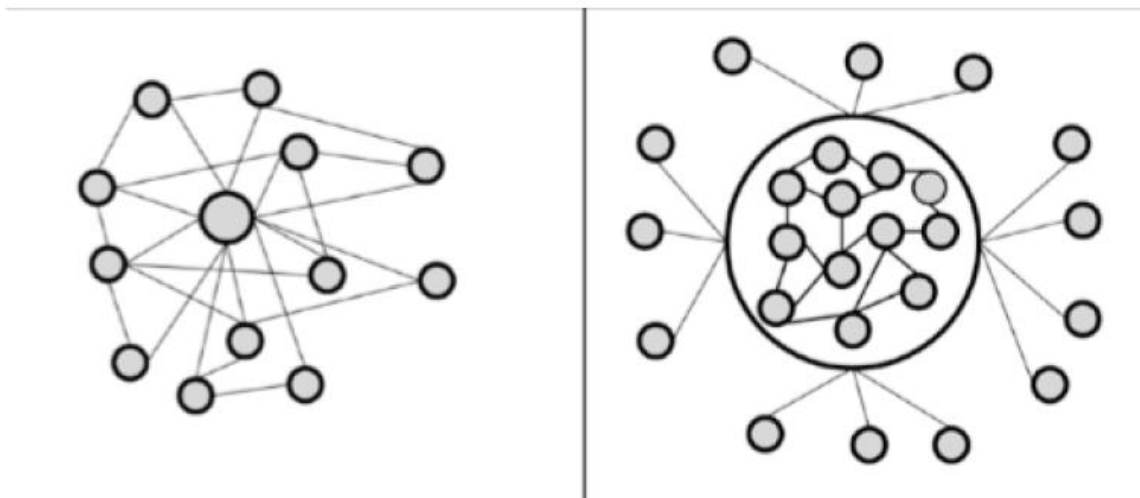


Figure 2.9: Central component of a distributed system and internal distributed system. Source: (Drescher, 2017).

Remember security triangle, which says that when a system loses privacy, information is given to people who aren't supposed to have it. Someone who wasn't supposed to has changed or deleted data or an IT system, which means that the integrity has been lost. Availability makes sure that systems and data are up and running when they are needed.

Trust must be present in both the users and the system for the security triangle to work and stay in place. "The main problem that the Blockchain has to deal with is getting and keeping integrity in a peer-to-peer system with an unknown number of peers whose reliability and trustworthiness are unknown," writes Drescher (2017, p. 31). Byzantine Generals' Dilemma, which was written by Lamport, Shostak, and Pease in 1982, is a well-known metaphor for this situation.

In this scenario, a group of Byzantine generals surround a city or citadel. Each general is in charge of a different part of the army. Some generals might want to attack, while others might want to get out of the way. Traitors who vote for a bad strategy selectively (e.g., by giving a vote to retreat to one group of parties and an attack vote to another) make the situation even worse and could lead to bad results because there is no clear strategy. The generals are also physically far apart, so they have to rely on messengers who may or may not be reliable. For example, they might forget to pass on votes or give wrong information. This metaphor shows how hard it is to coordinate actions and make decisions over networks or channels of communication that are not reliable or are not good.

Proof of work is an idea that can be used with the Blockchain to solve the Byzantine Generals' Dilemma. Proof of work is used to verify transactions that miners send to the Blockchain. Before a new block can be added to the chain, the miner must solve a maths puzzle based on the header of the transaction. Szmigielski, (2015) shows how the Blockchain method works. As transactional blocks are made, miners "apply a mathematical formula to the information in the block, coming up with a much shorter, seemingly random string of letters and numbers called a hash". This unique hash is kept with each block, and it also includes the hash of the block before it in the chain. This makes for a very accurate

way to mark the time. The most popular secure hash algorithm, or SHA, is SHA-256. It makes a unique 256-bit hash with a fixed size.

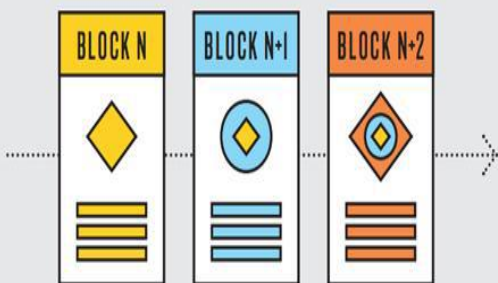
Hashes are used to link transaction information because they are one-way functions that can't be decrypted. This makes it "hard to change the blockchain without those changes being immediately obvious". Hashing is a one-way function that only shows that data exists, not that it does. Hashing, which is sometimes called a "digital fingerprint," shrinks inputs of any length into outputs of a fixed size. Each block on the blockchain is hashed, and if the block was changed, the hash value would also change.



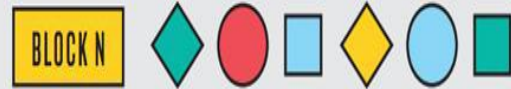
1 TRANSACTION Two parties exchange data; this could represent money, contracts, deeds, medical records, customer details, or any other asset that can be described in digital form.



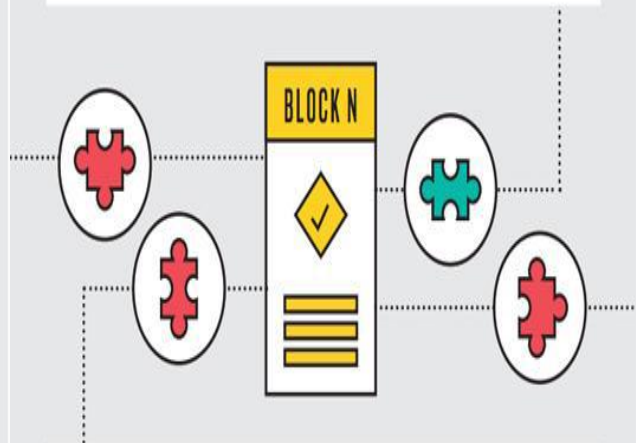
2 VERIFICATION Depending on the network's parameters, the transaction is either verified instantly or transcribed into a secured record and placed in a queue of pending transactions. In this case, nodes—the computers or servers in the network—determine if the transactions are valid based on a set of rules the network has agreed to.



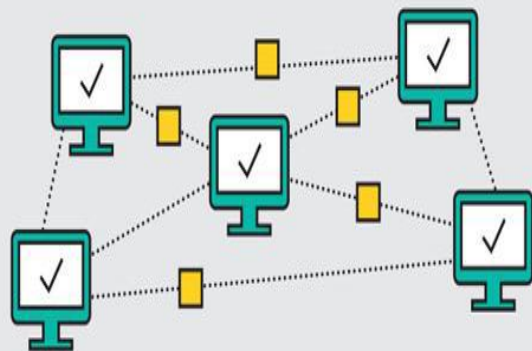
3 STRUCTURE Each block is identified by a hash, a 256-bit number, created using an algorithm agreed upon by the network. A block contains a header, a reference to the previous block's hash, and a group of transactions. The sequence of linked hashes creates a secure, interdependent chain.



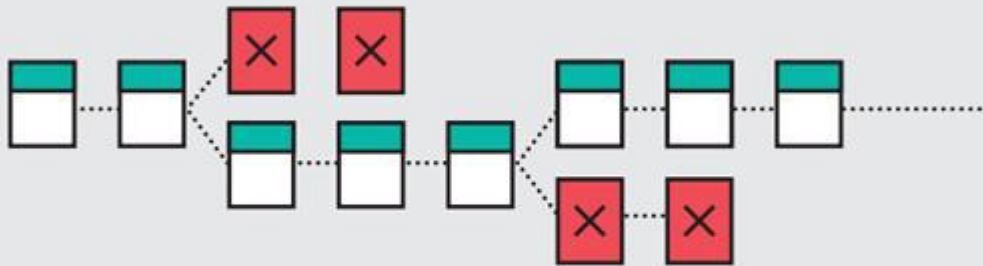
4 VALIDATION Blocks must first be validated to be added to the blockchain. The most accepted form of validation for open-source blockchains is proof of work—the solution to a mathematical puzzle derived from the block's header.



5 BLOCKCHAIN MINING Miners try to “solve” the block by making incremental changes to one variable until the solution satisfies a network-wide target. This is called “proof of work” because correct answers cannot be falsified; potential solutions must prove the appropriate level of computing power was drained in solving.



6 THE CHAIN When a block is validated, the miners that solved the puzzle are rewarded and the block is distributed through the network. Each node adds the block to the majority chain, the network's immutable and auditable blockchain.



7 BUILT-IN DEFENSE If a malicious miner tries to submit an altered block to the chain, the hash function of that block, and all following blocks, would change. The other nodes would detect these changes and reject the block from the majority chain, preventing corruption.

Figure 2.10 Blockchain process, Keyser (2017)

2.1.18 Conceptual Framework

2.1.18.1 Areas of Application and Opportunities of Blockchain Technology on Construction Projects.

In this section, we'll talk about how blockchain technology could be used in building projects. Blockchain technology has already been used successfully in

many different industries. But in this work, we only talk about how Blockchain can be used for things related to construction projects.

2.1.18.2. Real Estate Applications

Real estate transactions are complicated, opaque, and costly because numerous parties are involved, including brokers, government property databases, title companies, escrow companies, inspectors, appraisers, and notaries public (Baiod, Light & Mahanti, 2021). According to the FBI, scammers are increasingly targeting real estate transactions. In 2017, for example, 9,645 victims of real estate fraud were reported. Blockchain in real estate provides efficient and dependable workflows, increasing transparency and visibility at all stages and, ultimately, providing safer investments for everyone. However, these scams represent only a small portion of the transactions that blockchain can affect and strengthen. Aside from addressing fraud, distributed ledger smart contracts simplify transaction processes, eliminate unnecessary intermediaries, lower costs for main parties, and speed up deal closing.

Blockchain can speed up the registration and transfer of property ownership, especially in less-developed countries with legal systems in which public authorities dealing with real estate registers lack the trust and transparency principle, or where land registry systems are untrustworthy. With the help of blockchain, it is now possible to collect all property information and provide access to those who require it.

Furthermore, each property can have a corresponding digital address that contains occupancy, finance, legal, building performance, and physical attributes and transmits and maintains all historical transactions in perpetuity. The real estate industry is poised to use blockchain to solve current issues and change the way transactions are completed. These changes are already taking place in the real estate industry. In the Netherlands, for example, the Municipality of Rotterdam is

collaborating with Deloitte to develop the first Blockchain application in real estate to document rental contracts.

Their projects include: (1) digitizing building data; (2) digitizing the ownership situation; (3) transferring ownership; (4) contract closure; and (5) unlocking contract information for third parties. A blockchain-based real estate transaction platform has been proposed. The platform, which aims to realize the real estate transaction information release and transaction, makes use of the Hyper Ledger Fabric platform to effectively connect purchasers, sellers, financial institutions, and government departments. It can also look up past transactions.

Baiod et al. (2021) provided valuable information on 17 blockchain companies that are revolutionizing the real estate industry. Propy17, for example, is a global real estate marketplace that uses smart contracts to facilitate international real estate transactions. Propy connects buyers, sellers, brokers, agents, and notaries through a set of blockchain-based smart contracts that streamline the real estate process. Shelter Zoom is another example; it is a secure online platform that manages all offer and acceptance processes in real estate transactions. Brokers, agents, buyers, and sellers can transact in a more transparent and efficient environment by utilising blockchain technology and its mobile tools and dashboards. Ubiquity is another real estate blockchain use case. Ubiquity offers a simple solution for storing and searching for real estate titles by combining a SaaS platform with blockchain technology. The platform receives property data via a distributed ledger, which makes it transparent, incorruptible, and encrypted.

2.1.18.3. Building Management System

Preventive and planned maintenance are critical during the operational phase of a building for both safety and occupant satisfaction (Perera et al., 2020). A Blockchain-enabled automated system can aid in the monitoring of building

maintenance procedures. Smart contracts allow for the easy and accurate management of maintenance requests, procurement processes, product delivery, payments, and other similar tasks. Because of the transparency provided by blockchain, the occupant and all other parties are aware of the status of the maintenance request from start to finish. It allows maintenance managers to determine who supplied and installed which building components and at what cost at any given time.

2.1.18.4. Combining Blockchain with Internet of Things (IoT) Devices

IoT, which includes RFID (Radio-Frequency Identification), GPS (Global Positioning System), GIS (Geographic Information System), and WSN (Wireless Sensor Network), is an intelligent, dependable, and high-speed information network that connects objects (Duan, Zhang, Gong, Brown, and Li, 2020). Instead of manual recording, IoT sensors can automatically capture information such as temperature and humidity. This ability to capture real-time information is especially important for frozen and fresh food products, as quality is closely related to the external environment]. IoT automation can improve the efficiency of monitoring and data collection while reducing manual errors. However, there are some issues with IoT deployments, such as data confidentiality, vulnerability, data integrity, and stakeholder privacy. As a result, when using IoT devices in supply chains, which can be developed by combining with the Blockchain protocol, protection and security are critical.

Many studies have combined blockchain technology and IoT, claiming that blockchain can help manage IoT and improve supply chain efficiency. Six propositions on the combination of blockchain and IoT can improve the scalability, security, auditing, efficiency, interoperability, and quality of IoT solutions.

The Internet of Things (IoT) is an opportunity to build an intelligent environment enabled by the integration of the physical and network worlds, which emerged as a result of modern civilization's steady progress in science and technology (Zhou, 2023). The Industrial Internet is a subset of the Internet of Things that focuses on the interaction and transfer of information between devices and people. It has very broad development and application prospects. With the rapid rise of a new round of scientific and technological innovation revolutions around the world, it not only promotes the long-term development of the manufacturing industry, but its transformation to digitalization and intelligence has also been elevated to a national strategic level. There has been a lot of talk about using Blockchain technology to solve information asymmetry problems in the instrument leasing platform. Combining blockchain technology in the leasing platform enables lessor and lessee nodes to build a decentralised Blockchain network and install a smart contract in it to complete the leasing process, allowing transaction information generated during leasing and data generated when the instrument is used to be uploaded to the blockchain and a consensus to form a block record in the network to be reached. Zhou (2023) proposes a general framework for restricted authentication and authorization. To ensure the platform's security, access to terminal devices requires authentication and authorization. By protecting application-layer paid payloads, this protocol addresses a major limitation of the datagram transport layer security protocol. He also proposed blockchain-based distributed ledger management technology to enable the sharing of IoT data and address the issue of trust in traditional centralised institutions.

The Internet of Things can provide accurate and timely data collection (Wu, Lu, Xue, Li, Zhao & Tang, 2022). Many core components of the IoT, such as RFID (Radio Frequency Identification) tags, NFC (Near Field Communication) tags, and

GPS sensors, have been proposed by practitioners and scholars to help realise its concept. Furthermore, researchers have proposed smart construction objects (SCOs), an IoT model with sensing, processing, and communication capabilities to facilitate information exchange among construction resources.

2.1.18.5. Intelligent Contracts

In a nutshell, smart contracts are made up of if/then commands that eliminate the need for intermediaries, reduce the amount of physical paperwork, and can help to reduce potential attacks and fraud, arbitration, and enforcement costs (Li et al., 2019). Smart contracts are "contracts that are fully executable without human intervention" (McNamara & Sepasgozar, 2020) or "self-enforcing, monitoring external inputs from trusted sources to settle according to the contract's stipulations."

The implementation of blockchain necessitates the creation of smart contracts, which are regarded as the primary software artefact of most Blockchain technology-based solutions (Jurgelaitis, Ceponiene, Butkus, Burkina & Drungilas, 2023). Smart contracts are programs that run on a specific blockchain platform network. They can be used to cover parts or all of a business process by implementing software components that are hosted on a peer-to-peer network and allow data sharing among network participants through the use of a public blockchain ledger.

Smart contracts are programs that are stored on a blockchain and are only activated when certain criteria are met (John William, Rajendran, Pranam, Berry, Sreedharan, Gul & Paul, 2023). They are frequently used to automate the implementation of an agreement in order to allow all parties to ensure an immediate conclusion without the need for an intermediary or additional delay.

They can also automate a workflow by triggering subsequent actions when certain criteria are met. A network of computers performs the required activities when the predefined conditions are met and validated.

Blockchain also empowers resources by embedding autonomous agents in provenance records, quality control, and transactions via virtual smart contracts. Smart contracts are computer programs that can be customized to regulate ledger writing laws. Smart contracts are executable programs that can be executed automatically if a predetermined condition is met, such as the parties to a transaction honoring their agreement. Along with the contract terms, legal restrictions and agreement conditions are encoded in computer language. Smart contracts are self-enforcing and tamper-proof, which results in significant benefits such as the elimination of middlemen and the reduction of transaction, contracting, enforcement, and compliance costs. Low-value transactions may be more cost-effective, and blockchain may facilitate transaction system interoperability (Ahmad Termizi, Wan Alwi, Manan & Varbanov, 2023).

Smart contracts are one of the most important aspects of Blockchain for construction. Smart contracts are self-executing pieces of code that execute contract terms when pre-defined obligations are met (Li et al., 2019). Because some elements may still require human input and control, smart contracts can also be thought of as automatable traditional contracts. According to the Winfield-Rock Report, blockchain combined with smart contracts can solve some of the problems associated with BIM adoption, such as increasing trust and collaboration, because the availability of a real-time, change-resistant, and hack-resistant record of data with trustworthy time entries improves the data's reliability, integrity, and transparency. The report also notes that many issues remain to be addressed, such as untested legal issues and the ongoing need for clear and express contract terms,

as well as mitigating measures that reduce the risk that parties enter into unintended obligations and disputes.

Smart contract technology may provide a more dependable way to track contracts via a decentralised network (Mohammed, Almousa, Ghaithan & Hadidi, 2021). The goal is to create a self-executing electronic digital agreement between two or more parties. The smart contract could be a technique for forming and monitoring construction contracts. A smart contract must be triggered in order to achieve the desired result. Smart contracts, on the other hand, must interact with real-world objects and building components if they are to be used in construction projects. Here is where Blockchain oracles could help overcome the barrier of engaging with the non-digital world.

2.1.18.6. Construction Management with Building Information Modeling

Building Information Modelling (BIM) introduced to the AEC sector created a shared data environment in which all information is saved in a common project file. The location and upkeep of this shared data environment was a new difficulty. Blockchain technology appears to be a possible answer to this problem (Turk & Klinc 2017). An always-updated distributed ledger system with excellent security that may be utilised as an infrastructure for keeping up-to-date BIM models between project stakeholders throughout the project Lifecycle. BIM provides a single project environment in which all project information is developed and stored. Adoption of BIM has typically been viewed as a progression including growing levels of capacity maturity across technological, process, and policy areas (Li et al., 2019). Although it is widely acknowledged that BIM can benefit from integration with Blockchain technology, there is agreement that the level of collaboration enabled by Level 2 BIM is insufficient and that this must progress into more networked and integrated forms, such as those envisioned in Level 3,

before this can be realized. Level 2 BIM is a collaborative approach to working in which 3D models with the necessary data are created in separate discipline models in accordance with a set of guidelines, standards, and specifications. Level 3 BIM, also known as iBIM (integrated BIM), refers to a "fully open" process and data integration enabled by web services that is compliant with the Industry Foundation Classes (IFC) and building SMART Data Dictionary (bsDD) standards. Level 3 BIM also emphasizes working with a new contractual framework that promotes consistency, clarity, openness, and collaboration in a cooperative, learning-and-sharing culture. The integration of BIM, Blockchain, smart contracts, and the Internet of Things (IoT) can have a significant impact on construction activities and facility management, particularly where component tracking is useful and there is duplication of work; IoT tracking devices will automatically collect data about an item or a process and update the Blockchain Technology accordingly. Blockchain has the potential to solve many of the issues that have slowed BIM adoption, such as limited collaboration and information sharing. In the event of a single [shared-access] BIM model, ownership and rights (e.g. responsibilities, liabilities, and intellectual property rights) can be made explicit and transparent to all project parties on the Blockchain, leading to increased trust.

In the case of project design and management in a Blockchain BIM integrated with a self-imposing intelligent contract supplied in a larger circular economy and by selected suppliers controlled via a Blockchain network, Blockchain may provide a direct solution to each of these problems or a comprehensive framework for Blockchain application on construction projects (Amade et al., 2022).

A smart contract can be programmed to process a self-executing contract by converting the rules from the agreement's terms into lines of code using a "Generalized Adaptive Framework" (GAF) for a neutral data standard, such as the

"International Foundation Class" (IFC) (Hijazi, Perera, Alashwal & Calheiros, 2023). This enables the automation of code verification procedures for data routing in the blockchain network. The proposed GAF concept for automated processes includes the development of a computable representation of predefined laws, as well as methods for transferring data between the framework's various components (Blockchain network) and BIM data. A smart contract that ensures the enforceability of transparency by executing the CSC data, making the CSC data immutable and accurate, could be another approach.

BIM is currently the most visible manifestation of digital innovation in the construction industry, serving as the primary enabler for promoting collaboration, information sharing, and data management. Blockchain-based intelligent contracts (iContracts) are one possible solution for removing the trust element associated with massive data transactions (McNamara & Sepasgozar, 2020). It is widely assumed that it was created as a means of distributing crypto-currency in a way that keeps a public and multi-person record of the transaction. Blockchain is one possible solution for removing the trust element associated with the massive data transactions that an iContract would both rely on and generate. Trust is built into the technology due to its decentralised nature and consensus-based nature, representing a paradigm shift from trust to a "trust less" system in which third parties are rendered obsolete.

Blockchain provides a centralised platform for maintaining and updating that project environment, as well as connecting it to the reality of site work. This would result in time-stamped and tampered proof data. The peer-to-peer structure of Blockchain aligns well with the collaborative way that different stakeholders develop a BIM model, and it would ultimately improve collaboration. The tampered proof track record of each user's changes to the model can be used to

identify a party at fault in design or miscommunication. Any changes to the model are documented and communicated to others in the Blockchain network. As a result, BIM-related claims during the project lifecycle can be handled much more naturally.

To connect a project's BIM model to a smart contract, an information system would be required to link project elements to reality and reflect project progress on the model. Blockchain can be used independently or in conjunction with smart contract governance to link the BIM model to the smart contract and update the BIM model as the project progresses. The smart contract programme can be applied to the elements of the BIM model and linked to the project's reality via Blockchain. As a result, in order to be compensated, the actual construction must match the model. If the contractor discovers a discrepancy or an error, he can issue a change order or RFI, which will be securely time stamped and recorded. The model can track granular work progress with or without reality capture technologies. The inspection procedure can be carried out manually or automatically using reality capture technologies such as 3D laser scanning or Lidar. The end result would be improved project governance and streamlined contract administration.

2.1.18.7. Blockchain Technology for Governmental Construction Work Supervision

Due to the benefits of traceability, immutability, and transparency, Blockchain technology has been investigated for governmental supervision of construction work (GSCW). However, its decentralised nature appears to be incompatible with GSCW, which is a type of centralised governance in and of itself (Lu, Wu, Zhao, Li & Xue, 2021).

In the construction industry, governmental supervision of construction work (GSCW) is typically carried out to provide an independent view on quality, safety, progress, and other compliance issues. This mandatory governmental supervision of projects, including privately owned projects, is based on public interest concerns (Li et al., 2019) and is governed by a variety of statutory and non-statutory arrangements, such as national standards, construction ordinances, building codes, and professional codes of conduct. China's Regulations on Safety Production Management of Construction Projects, for example, require all building owners to submit project quality and safety documents as well as apply for local government construction permits.

2.1.18.8. Construction Using Smart Energy

Until recently, Major Power Producers (MPPs) led the market and set prices; they still account for 94% of the electricity production market. However, as the cost of renewable technologies falls and consumer behavior improves (Li et al., 2019), this market is opening up to provide more opportunities to individual, residential producers of electricity, primarily those who use solar photovoltaic panels on their home and produce an excess to that which they need to run their home, to sell to the grid or to their neighbors. Currently, trades are conducted through MPPs; however, micro grids managed by DLT make this possible in a decentralised manner, directly from prosumer to consumer.

IoT devices combined with smart contracts running on DLT are reducing distribution congestion and faults, and demand management is being revolutionized through monitoring using sensor technologies that automatically regulate power usage through smart contracts and/or inform homeowners of their

usage, allowing them to make sustainable changes to their energy consumption and lifestyle choices.

Automated auction mechanisms based on DLT enable multiple buyers and sellers to purchase energy from one another, transforming the way users buy energy and making it more passive through automation. Individuals and/or communities can become more self-sufficient from the grid by utilising micro-generation, which benefits the environment and allows consumers to generate higher profits based on demand and supply. Because so much depends on the ability to manage energy usage and ensure supply, energy efficiency is critical to achieving many "smart" goals such as smart city, smart home, and smart government. The construction industry must consider this when designing new assets and renovating and/or repairing existing assets. The main challenges mentioned in these papers are the lack of regulation and the emergence of DLT.

2.1.18.9 Management of the Construction Supply Chain

The decentralised and fragmented structure of the construction industry's supply chain is an excellent match for Blockchain's decentralised ledger system. Blockchain can provide the infrastructure required to advance material traceability in a secure and reliable manner (Hultgren & Pajala 2018; Petersson & Baur 2018) and promote the circular economy (Rudolphi, 2018). The construction industry has a significant impact on the global economy and global construction industry output, which was worth more than 10 trillion USD in 2017 and accounts for approximately 13% of global GDP (Perera et al., 2020). The construction industry creates the most complex and large objects, and it has difficult, lengthy supply chains with a large number of internal and external suppliers. As a result, implementing an information and communication technology solution in project-

based industries is more difficult than in process-based industries. Although information technology (IT) applications can improve information flow efficiency, they cannot eliminate uncertainty in construction supply chains. The complexity of the construction supply chain, combined with low transparency, is eroding trust and payment security, particularly for suppliers and subcontractors at the top of the supply chain. In a construction project, each item could be tracked from the extraction/production stage until it is delivered to the site and incorporated into a building or structure, similar to the method of tracing products in supply chain management. Blockchain-based supply chain management can improve product authenticity and compliance, ultimately leading to higher quality assurance of the final product. In this way, an immutable record of data can be stored and maintained throughout the project's entire life cycle. Furthermore, such data can be retrieved during the post-construction phase. Blockchain-based supply chain management improves payment security, ensures product compliance and authenticity, streamlines payment processing and reduces finance costs, fosters trust among suppliers and clients, and provides transparency for auditing purposes. According to Agi and Jha (2022), blockchain technology has the potential to significantly improve supply chain management and achieve supply chain performance goals by providing a platform for direct interaction between supply chain members to exchange credible and tamper-proof data. One of the primary advantages of this technology is that it allows for full product traceability and increases visibility throughout the various supply chain stages.

Smart contracts can help with supply chain management and material tracing. By using a smart contract, both the supplier and the buyer can be assured that they will be compensated for their money/product. As a result, without the need for local suppliers, the purchase could take place more directly between the source and the

end user. Payments can be made in a sequential and proportionate manner based on the status of material/product delivery, with the final payment tied to the final inspection/commissioning of the material/product.

There is also significant potential for combining the internet of things or RFID tags with blockchain to provide a real-time material monitoring system, resulting in better site management practises and increased construction efficiency. Using a blockchain network for supply management would allow vendors to easily demonstrate their identity certification to authorities. Buyers can easily validate those identity certifications and also see the vendor's track record to check their reputation and capacity from previous works. As a result, a buyer and a vendor can enter into a transaction without knowing or trusting each other.

A true circular economy is possible on a larger scale thanks to blockchain. When a raw material is extracted, its information, including its source and characteristics, can be stored on a blockchain network. The network can then be used by producers to order and obtain raw materials. Each order is also saved, and it is possible to trace which raw materials went into which product. This information chain continues to the end user, who purchases the product and installs it in their project, increasing material transparency in the construction industry. Furthermore, during a product's lifetime, when maintenance is required or there is a question about its source or the source of its materials, it is clearly traceable. From the raw material source to the factories, vendors, subcontractors, contractors, and the final project, there will be a chain of information. This would allow for fully transparent material usage in the industry, with pre-planning and current knowledge of material status and background allowing for material reuse planning.

2.1.18.10 The Use of Blockchain in Project Management

Blockchain technology has been applied in the field of construction project management and construction management, primarily in various aspects such as construction bidding, construction quality control, construction cost control, construction safety management, construction contract management, construction information management, green construction (environmental protection), and engineering insurance, and has achieved better practise and experience in the field of blockchain technology in re (Wei, Qian, Ma & Cao, 2023).

2.1.19 Limitations/challenges of Blockchain on Construction Project Realization

Because Blockchain is a new technology, there are various difficulties in implementing and utilising it. One issue that needs to be addressed is that people simply do not know enough about this technology or how it works (Baiod et al., 2021). The utter lack of Blockchain competence in many firms is a major impediment to Blockchain growth and acceptance. There are still unresolved Blockchain issues. One is Blockchain scalability. Concerns about security and regulations are other obstacles to overcome. From the body of literature analyzed, an exhaustive list of the obstacles and opportunities associated with the deployment of Blockchain on building projects was developed. Furthermore, the non-construction-specific difficulties mentioned are equally applicable to the construction business; however, particular instances were not provided to provide context. The difficulties are mentioned below.

Blockchain technology is still in its early stages, and much work is being done to uncover and improve its utility (Peck, 2016). There are numerous unknowns in the current state of technology development, and the following are some of the concerns about the application of Blockchain technology. In its most generalized

form, Blockchain may run any type of software imaginable. Applications operate automatically on Blockchain and are accessible to internet users (Peck, 2016). They are also essentially autonomous and difficult for governments to control. A lack of effective government regulations can pose a serious threat by increasing corruption and money laundering to finance criminal activities in the building industry.

2.1.19.1 Security

Although Blockchain is distinguished by a collection of security features that make it resistant to attack, it is not totally impenetrable, and so some Blockchain security issues exist (Baiod et al., 2021). Baiod et al. (2021) conducted an end-to-end investigation into the Blockchain's security threats. We describe three common risks: 51% assaults, privacy leaks, and private key security. According to Oye-Bangbose (2019), cybersecurity is an ongoing threat, particularly to any system that relies on the internet network. The distributed nature of blockchain raises security concerns since the more members in the network, the more points of attack for cybercriminals to target. If thieves successfully steal a user's information, they will invariably create irreversible fraudulent transactions on the network.

The Majority Attack (51% Attacks): The blockchain uses a distributed consensus technique to generate mutual confidence. This consensus process has a 51% vulnerability. Attackers could use this flaw to take control of the entire blockchain. In basic terms, if a user controls more than 51% of the network, they can influence and modify the blockchain. They can impose their will on the network since they control the majority of it.

Furthermore, this dominating user(s) can choose which transactions are accepted; hence, they can refuse other transactions while allowing their own coins to be spent numerous times, which is known as the double-spend issue. Cryptocurrencies

with tiny communities of miners are particularly vulnerable to this type of assault since a single user can have a large degree of control in the early phases of blockchain. As a result, cryptocurrencies with large communities of miners, such as Bitcoin, are highly immune to such attacks (Baiod et al., 2021).

Privacy leaking: Blockchain is regarded a fairly safe system because users connect with pseudonymity, only making transactions using generated addresses rather than their true identities, and can generate several addresses to prevent against information leakage (Baiod et al., 2021). Because it is feasible to trace users' behavior in the blockchain, blockchain takes safeguards to preserve users' transaction privacy. For example, with Bitcoin and Zcash, one-time accounts are used to hold the received bitcoin. Furthermore, users assign a private key to each transaction, making it hard for attackers to determine if cryptocurrencies in different transactions are received by the same user. Yet, despite all of the privacy protection mechanisms in blockchain and proposed approaches to augment blockchain anonymity, perfect privacy cannot be attained. According to Oye-Bangbose (2019), trust issues, such as privacy, are some of the major issues confronting Blockchain. According to Oye-Bangbose (2019), some organisations may be concerned about the secrecy and information transmission in the blockchain and may be hesitant to engage in a shared database in case of information leakage that could jeopardize the firm's business. Despite the buzz surrounding Blockchain technology, some developers believe that it can be used anonymously and that someone can explicitly construct a programed to penetrate private information/databases and therefore infringe on privacy (Peck, 2016).

According to Baiod et al. (2021), transactional privacy is not guaranteed in the blockchain because, while participants can establish new pseudonymous public keys to increase their anonymity, the values of all transactions and balances for

each (pseudonymous) public key are publicly viewable. They also developed an effective approach for DE anonymizing Bitcoin users, allowing user pseudonyms to be linked to IP addresses. They claimed that their system is reliable even when users are behind network address translation (NAT) or firewalls. The core principle is that each client can be uniquely recognized by a group of nodes to which he or she connects known as "entry nodes," which can be learned at the time of connection and later used to determine the provenance of a transaction. Furthermore, they empirically analyzed two link ability flaws in Monero's mixin sampling mechanism. Monero is a "privacy-centric cryptocurrency that allows users to obscure their transaction graph by including chaff coins, called 'mixins,' along with the actual coins they spend." First, the majority of Monero transaction inputs do not include any mixins. Transactions with zero mixins do not ensure privacy to the users who send them. Second, the mixins are not selected randomly, allowing them to be distinguished from real coins by their age distribution easily; Users' private keys are considered the identity and security credentials in blockchain systems. These keys are generated and maintained by users and used to prove ownership of a crypto asset (i.e., bitcoin). However, if private keys are lost, criminals can manipulate users' blockchain accounts (Li et al., 2019).

Bitcoin and Ethereum use the Elliptic Curve Digital Signature Algorithm (ECDSA) for payment authorization; nevertheless, the ECDSA system has a flaw in that there is insufficient randomization in the signing process, allowing attackers to recover the users' private keys (Baiod et al., 2021).

2.1.19.2. Immature Application of Blockchain Technology

Throughout the early stages of blockchain development, the topic of inadequate understanding and ignorance of blockchain adoption was addressed in research. Despite the fact that blockchain was frequently listed as a top priority in the food

industry, numerous industries' management lack Blockchain expertise, which may postpone deployment, making large-scale blockchain implementation hard (Bannor & Kyire, 2021). According to Oye-Bamgbose (2019), a crucial element of blockchain is the immutability of records, which means that once a transaction is recorded to the blockchain, it is permanent and cannot be altered. This would provide a significant issue if regulators demanded a reversal of trade transactions, as it would imply that an equal and offsetting trade would have to be initiated, which all parties engaged in the original trade would have to approve. As a result, it is a complicated technology with immutable properties.

2.1.19.3. Blockchain Technology Characteristics

The characteristics of blockchain technology refer to the features that may make it difficult to embrace and implement in businesses. Blockchain data is unchangeable. Nevertheless, there were no protocols in place to confirm the raw data's accuracy. Additionally, changing incorrect or inaccurate blockchain entries is difficult (Tan, Yan, Chen & Liu, 2018). An abundance of openness to information would jeopardize privacy protection. Sensitive information, such as production techniques, may be included in products. As a result, striking a balance between secrecy and transparency will be difficult (Bannor & Kyire, 2021).

2.1.19.4. Scalability and Transaction Capability of Blockchain Systems

According to Perera et al. (2020), Blockchain is not ideal for storing Big Data because to the massive volumes of data and the slow rate at which data is processed. The quantity of data that may be stored on a public Blockchain is limited. The point describes the characteristics that prevent widespread Blockchain application owing to the actual block size limitation and the time interval for manufacturing new blocks. Blockchain can only handle seven transactions per second and cannot handle millions of real-time queries at the same time. As a

result, Blockchain applications were constrained by the time required to complete each transaction. Furthermore, as data volumes expanded, the storage and computational strain became increasingly difficult. Data synchronization took a long time and caused problems for the client when the system was in operation. Additionally, each transaction in the Blockchain necessitates the approval of more than half of the nodes, resulting in inefficient transaction capacity (Bannor & Kyire, 2021).

A transaction, on the other hand, must be validated and accepted by the majority of nodes in order to be recorded. When a big amount of data is saved, the mining/block creating process is also delayed (Perera et al., 2020). As a solution to this problem, only the most critical data that must be on the Blockchain will be on-chain, while all other data will remain off-chain. A construction project generates a large amount of data. Yet, just the data essential for Blockchain processing can be stored in the Blockchain ledger.

For the purpose of consensus and block validation, the full Blockchain must be present; hence, all previously approved transactions must be stored for validating new transactions, which requires a huge amount of storage (Baiod et al., 2021). The original block-size restriction and the delayed consensus process are important contributors to the scalability issue. Each transaction generates data, and with a maximum size of 1MB per block, only a limited number of payments may be handled at once. The Bitcoin Blockchain can only handle a maximum of six to seven transactions per second.

If crypto were to replace traditional currency, it would need to execute hundreds of thousands of transactions per second to ensure the economy could keep moving without significant delays for consumers and companies. In comparison, Visa and MasterCard's networks process "more than 5,000 transactions per second, with the

ability to process quantities multiple times that number; Bitcoin, on the other hand, takes 10 minutes to clear and settle a single transaction, whereas Ethereum takes 15 seconds." Furthermore, miners may postpone tiny transactions because to the short block size, as they prefer transactions with a high transaction fee. But, increasing the size of the blocks would slow down block propagation.

Some proposed solutions, which are connected to optimizing Blockchain storage or rebuilding Blockchain, solve the Blockchain's scalability challenge. For example, Baiod et al. (2021) proposed a novel cryptocurrency scheme. Under this method, the network can forget about old transactions, and the suggested database, known as the account tree, is used to store every unique, non-empty address and the balance of all those addresses. As a result, not all transactions must be stored in order to validate a transaction, which reduces the requirement for long-term data storage. Bitcoin-NG (Next Generation), a new scalable Blockchain protocol, was introduced. The core concept of this new protocol is to break standard blocks into two halves in order to reduce propagation size. This updated Blockchain version addresses the tradeoff between block size and network security. Furthermore, the Lighting Network is a potential Blockchain implementation that can handle millions of transactions per second across its network.

2.1.19.5 Bandwidth and Connectivity

Sufficient server capacity is essential for system stability and uninterrupted internet connectivity. Parts of the supply chain delivery system may fail due to a lack of connectivity (Mohammed, Almousa, Ghaithan & Hadidi, 2021). Adequate server capacity is necessary for system stability, as well as constant internet access (Li et al., 2019). Due to a lack of connectivity, elements of the supply chain delivery system may fail. The compatibility of blockchain platforms with existing business internal systems may provide a hurdle (Oye-Bamgbose, 2019). Several firms are

interested in seeing how Blockchains from different companies interact with one another.

2.1.19.6. High Investment in Blockchain-based Systems

One of the requirements for using Blockchain technology is that every participating provider utilise a digital device to record their manufacturing information. Several small suppliers, though, continue to utilise pen and paper to keep track of their data. It was costly and time-consuming for them to replace paper and pen with digital devices. To integrate all firms into the Blockchain system, financial and infrastructure help was required. Nowadays, most businesses utilise Blockchain to track food; nevertheless, the fee for tracking food was greater than the item's price (Bannor & Kyire, 2021).

2.1.19.7. Absence of Regulations, Legislation and Global Standard

Blockchain was incredibly complicated and rapidly evolving. Blockchain technology was neither standardized nor regulated at the time. There were both large and small vendors in food supply systems. If there were no common standards in existence, these suppliers would be unable to share data and ensure technological compatibility. There were no regulations governing Blockchain technology at the time, as well as a lack of relevant standards. Presently, 20 states in the United States are considering similar laws. This was a problem because most countries had yet to pass Blockchain-related legislation. When supply chains became more global, providers in different countries would use Blockchain in different ways because there was no internationally recognised standard. Because the global supply chain operates in a complex global setting, it is subject to a number of laws, rules, and regulations. Overlapping and inconsistent requirements from multiple national governments throughout the world make drafting

Blockchain-related legislation and rules even more difficult (Bannor & Kyire, 2021).

Because Blockchain is an open database, policies will be required to protect users' rights and trading secrets. Duan et al. (2020) used PEST analysis to investigate the uncontrollable external environment for Blockchain deployment, which comprises political, economic, social, and technological variables. They proposed that governments use Blockchain to acquire supply chain information and eliminate food risks. A few countries and authorities have also expressed interest in and support for Blockchain development, such as China, which has issued the Blockchain White Book and started Blockchain-related projects. ISO Blockchain (TC307) was also collaborating to create global Blockchain standards. Thus far, there is no formal Blockchain policy in the food supply chain. They also proposed that norms and procedures be created to protect users, such as what data should be submitted, who owns the data, how to use and keep the data, and so on. A lack of policy could be a hurdle to widespread Blockchain use. As a result, from the standpoint of preserving users' rights, it is difficult to urge all companies or individuals to adopt Blockchain before some completed standards and policies are established. Firms, particularly those that operate in many jurisdictions, do not now have clarity on the laws and regulations that would apply to Blockchain implementations in circumstances of failure, fraud, and bankruptcy (Oye-Bangbose, 2019).

There is a paucity of legal precedents and rules because construction is highly reliant on legally binding contracts and has difficulty implementing laws (Li et al., 2019). One of the biggest challenges for many firms in integrating blockchain is a lack of legislation and standards. According to a Deloitte poll of blockchain-savvy CEOs, regulatory challenges were regarded as major hurdles to greater investment

in blockchain technology (Baiod et al., 2021). Several components of this technology, such as cryptographic signatures and smart contracts, are supported, but they are not addressed by present rules. Furthermore, a survey of senior executives who attended the Ernst & Young Global Blockchain Summit in New York discovered that regulatory complexity is having a substantial influence on mainstream blockchain implementation.

Using Bitcoin as an example, Baiod et al. (2021) stated that the characteristics of this decentralised system will limit the central bank's power to manage economic policy and the amount of money, making the government wary of blockchain technologies. As a result, authorities must address this new issue and accelerate the development of new policies to mitigate its potential impact on the market. Because blockchain is still in its early stages, governments are constantly modifying legislation as it evolves. For example, over 17 U.S. state legislatures reviewed and adopted numerous laws relevant to blockchain technology deployment in 2018. These laws cover a wide range of topics, including "the recognition of digital signatures, the definition and usage of smart contracts, and the use of Blockchains for company record keeping."

2.1.19.8. Resistance to Change

Implementation necessitates changes to processes at all levels of the company. Because the sector has historically been averse to change, it is probable that Blockchain will not realize all of its potential benefits. Process changes at all levels of the organization are required for implementation (Mohammed et al., 2021). Because the sector has historically been resistant to change, it is probable that not all of the potential benefits of Blockchain technology will be realized (Li et al., 2019). Table 2.1 summarizes the relevant barriers to blockchain technology adoption on construction project delivery as extracted from the literature.

Table 2.1: Barriers to Blockchain Technology Adoption on Construction Project Delivery

S/N	Barriers to Blockchain Technology Adoption	Sources								
		A	B	C	D	E	F	G	H	I
1	Security	√	√	√	√					
2	Immature Application of Blockchain Technology		√			√				
3	Blockchain Technology Characteristics		√				√			
4	Scalability and Transaction Capability of Blockchain							√		
5	Bandwidth and Connectivity	√	√		√	√			√	
6	High Investment in Blockchain-based Systems					√				
7	Absence of Regulations, Legislation and Global Standard	√	√		√	√				√
8	Resistance to Change				√				√	

A=Baiod et al. (2021); B=Oye-Bamgbose (2019); C=Peck (2016); D=Li et al. (2019); E=Bannor and Kyire (2021); F=Tan, Yan, Chen and Liu (2018); G=Perera et al. (2020); H=Mohammed, Almousa, Ghaithan, and Hadidi (2021); I=Duan et al. (2020)

Source: Authors Construct

2.2. Theoretical Framework

Over the last 35 years, information system researchers have developed a variety of models and theories to explain and predict user adoption and acceptance (Nnaji, Okpala, Awolusi & Gambatese, 2023). At the individual level, researchers have consistently and satisfactorily applied the Technology Acceptance Model (TAM)

and other theories of blockchain/IT as it relates to construction projects. The under listed theories are discussed herewith.

2.2.1. Theory of Reasoned Action (TRA)

First-time TRA was developed by Fishbein and Ajzen for psychological and sociological research, but it is now used to study how people behave when using IT (Taherdoost, 2022). The three components listed below form the basis of this model. Whether someone chooses to engage in a behaviour or whether the earlier factors have an impact on this one is determined by their intentions; attitudes, including the degree to which people feel favourably about an attitude or how they themselves feel about it; Social influence is discussed in terms of social norms.

The theory of reasoned action, as originally proposed, is one of many well-known persuasive psychological models that contribute to information systems (IS) research. It emphasizes the importance of attitudes and subjective norms in determining people's behavioral intentions (Wu, Ishfaq, Hussain, Asmi, Siddiquei & Anwar, 2022).

Individuals' actions can be classified as either intentional or systematic. In addition to these components, three boundary factors, including intention stability over time, volitional control, and intention measurement taking context, target, time, specificity, and auction terms, are defined for testing and evaluating the TRA model. This model also employs techniques such as time horizon and generality to strengthen the robustness between attitude and corresponding intention. Some terms, however, remain unaddressed in this framework. For example, there are still gaps in our understanding of how habits, moral considerations, survey misinterpretations, cognitive deliberation, and issues resulting from the use of voluntariness in the validation process affect the validation process.

According to Hewavitharana, Nanayakkara, Perera, and Perera, (2021), TRA does not take into account external conditions, which are the performance of behaviour, such as specific opportunities, skills, conditions, and resources. Furthermore, when cognitive effort is low, attitude and behavioral intention are always directly related to the behaviours that are performed. Because of certain circumstances, the attitude does not always match the behaviour. Because it is critical to consider ingrained human beliefs as well as other external factors such as perceived other benefits, skills, and conditions when implementing within construction organisations, the conceptual model was created with two additional variables in mind: "Perceived Personal Benefits" (POB) and "Attitudes Towards Digitalization" (AD).

This theory is relevant to the current study because it attempts to explain the benefits of using Blockchain technology, as well as the limiting factors for the adoption and deployment of Blockchain technology among indigenous construction players.

2.2.2 Technology Acceptance Model (TAM)

Davis created this model, which is based on the TRA framework, to address the ambiguous status of psychometric and theoretical in TRA by removing subjective norms (Taherdoost, 2022). The TAM framework, one of the most widely used adoption frameworks, places a strong emphasis on perceived usefulness and ease of use. Although attitude towards technology use is an important consideration when using the TAM framework (Figure 2.1), TAM also considers the impact of two important beliefs (perceived usability and perceived ease of use) on users' attitudes, which are measured as favorability and unfavorability towards the system.

In order to use independent variables (causal influences) to explain technology acceptance (behavioral intention or actual use), the prediction must be accurate, as

inaccurate predictions may result in questionable decision-making and a failed technology integration process (Nnaji et al., 2023).

The TAM model has recently been used in studies to assess how well blockchain-based technologies are accepted (Amade et al., 2022; Taherdoost, 2022; Saputra & Darma, 2022; Wang, Liu, Liu & Huang, 2022). It implies that the TAM model accurately predicts the adoption of new technologies.

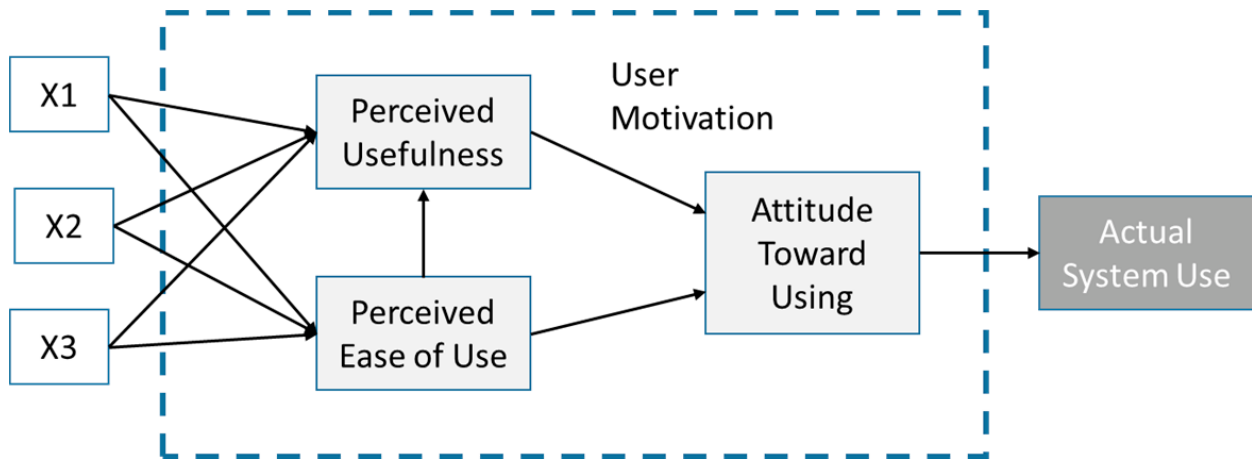


Figure 2.11: Original TAM.

In this model, the influence of perceived ease of use and perceived usefulness on the attitude and BI are direct and indirect, respectively, and the perceived ease of use impacts the perceived usefulness directly.

Despite the fact that numerous research models have been developed and various factors have been tested in the field of information technology, various authors agree that the TAM is the most popular research model (Mondego & Gide, 2022). TAM can forecast information technology use and factors influencing acceptance, according to the explanation. The research combines TAM constructs with additional factors that pose challenges for blockchain, such as trust, social influence, user interface, government regulation, and security.

As a result, predictive and explanatory technology acceptance models enable researchers and professionals to generate reliable and relevant contextual data on

potential technology acceptance (Nnaji et al., 2023). As illustrated in Figure 2.1, this model also considers external factors such as system characteristics, user training, user participation in design, and so on.

This theory is key to this study in the sense that its attempt to explain the impact of adopting Blockchain technology, on its perceived use and favorability for adoption and application on construction project delivery.

2.2.3. Diffusion of Innovation (DOI) Theory

Rogers' theory of innovation diffusion is the first example of persuasive psychological modelling for technology or innovation adoption (Wu et al., 2022). Rogers defines the process of adopting an innovation as beginning with knowledge, then moving on to persuasion, decision-making, implementation, and confirmation of whether an innovation should be accepted or rejected.

The diffusion of innovation theory has been used in the literature to analyze the diffusion and uptake of information technology such as cloud computing, green IT, virtual technology, and Web 2.0 services (Grover, Kar & Janssen, 2019). According to the theory of technological diffusion, each industry may experience a different rate of technological diffusion. Furthermore, different industries can cross-pollinate.

The diffusion of innovation (DOI) theory, according to Woodside, Augustine, and Giberson (2017), explains how an idea, good, or service is adopted by a system over time. People or groups in an organisation adopt innovation at different rates, ranging from early adopters to late laggards.

When considering the diffusion of innovation, five critical factors, including compatibility, observability, complexity, trial ability, and relative advantage, are taken into account as effective variables in the acceptance of innovation in the characteristics of the innovation step (Taherdoost, 2022). In the following step,

known as the adopter characteristics step, the categories are considered as innovators, early adopters, late majority, early majority, and laggards.

The implementation, knowledge, persuasion, confirmation, and decision phases culminate the innovation-decision step, which occurs over time and through communication channels established between participants in related social systems. In this model, four additional factors are introduced to determine a wide range of innovations that can affect the growth of a new concept. Social systems, time, innovation, and communication channels are examples of these elements. The DOI framework employs a theoretical foundation to address organisational, individual, and even global adoption levels. This acceptance model incorporates the innovation-decision process, the characteristics of an innovation, and the characteristics of adopters. The DOI also discusses organisational features, system features, and environmental factors. Furthermore, the explanatory analysis receives less attention.

The DOI theory is one of the most well-known theories that has attempted to investigate the variables that influence a person's decision to adopt an innovation or new technology. It denotes a link between the characteristics of innovations and their adoption (Hewavitharana et al., 2021). Adoption is measured using compatibility, relative advantage, complexity, compatibility, trial ability, and observability. It explains the methods, reasons, and rates at which new concepts and technologies spread across cultures. The measures are explained briefly below.

-Compatibility: The degree to which an innovation is thought to be somewhat difficult to understand and apply.

-Relative advantage: How much an innovation is thought to be superior to the concept it replaces; -Complexity: The degree to which an innovation is perceived as relatively hard to understand and use;

-Relative advantage: The extent to which an innovation is perceived as being better than the idea it supersedes;

-Trialability: The extent to which an innovation may be experimented with on a limited basis;

-Observability: The extent to which the innovations are observer able by others.

Consequently, compared to other acceptance frameworks, this method has also shown less power in the practical prediction of outcomes.

The goal of this study is to chart the spread of Blockchain technology across various industries.

This theory is important to this work as its attempt to explain the factors that influences practitioner's intention to adopt Blockchain technology as an enabling factor to drive and adopt an innovation or new technology such as Blockchain in delivering construction projects to fruition.

2.3 Empirical Review

The theoretical and empirical literature show that the existing literatures on the reviewed uses of blockchain technology on construction project practise in Africa, and particularly in Imo state, is limited. The majority of studies on the use of Blockchain technology in construction procedures are common in many developed countries such as Europe, America, and Canada. But Blockchain has numerous distinguishing qualities that encourage its use in various businesses. This section examines a handful of these linked works.

Baiod et al. (2021) conducted a technology evaluation on Blockchain technology and its applicability across many domains. The paper provides an overview of Blockchain technology by bringing together all of the essential design aspects, qualities, and benefits of blockchain that make it a superior and unique technology, as well as presenting common consensus protocols and blockchain system

taxonomy. The study looked at blockchain-based applications in finance, insurance, supply chain management, energy, advertising and media, real estate, and healthcare. The report identifies three broad constraints of blockchain technology: scalability, security, and regulation, and demonstrates how these issues may effect blockchain application and adoption. Baiod et al. (2021) did not specify the methodology used to get their conclusions. Amade et al. (2022) conducted research on the primary elements that influence construction project practitioners' desire and intention to accept and use Blockchain technology in Nigeria. The study applied the UTAUT2 paradigm to the issues mentioned in the general literature as inherent in a developing country such as Nigeria. A quantitative methodology was used, as well as data gathered from information and communication technology-savvy practitioners, in relation to construction projects in Imo state, Nigeria. The data was analysed using IBM SPSS Statistics 25.0 and Structural Equation Modeling (SEM). The study's findings give a framework for depicting practitioners' "intention to utilise and adopt" behaviours in the Nigerian construction industry. As a result, this research identifies trust, habit, perceived security, price value, and effort anticipation as the primary constructs impacting users' desire to employ Blockchain technology in construction projects. This paper presents an experimentally based model of the elements that influence people's intentions to utilise and adopt Blockchain technology. The study's findings provide impetus for decision-making in the public and private construction project service sectors in terms of policy development and practical implementation as a catalyst for achieving better project outcomes in developing country scenarios where project performance remains critical to economic development and growth. The study did not particularly look at the obstacles and prospects of Blockchain implementation on construction projects, which was the goal of this work from the

start. Lu et al. (2021) investigated the aspect of governmental supervision of construction work (GSCW) in China using Blockchain technology. The study's goal was to discover a network topology with an appropriate level of (de)centralization and, based on that topology, to construct a Blockchain-based model for GSCW. To identify issues in GSCW, a literature review was undertaken. Then, GSCW and digital currency electronic payment systems collaborated on cross-sectoral learning. A dual-layer Blockchain-based GSCW model with an incentive mechanism was built using a design science research method. The study created a model that may be used as a beneficial reference for policymakers, practitioners, and researchers when developing governance policies or Blockchain applications that do not take into account the key problems and opportunities of Blockchain application on building projects. Li et al. (2019) conducted research on Blockchain applications in the built environment and construction business. The study's primary goal was to analyse the existing state of DLT in the built environment and construction sector in order to establish a cohesive approach to assist its adoption, particularly in the construction industry. The research shows that there is real potential for DLT technologies to support digitalization in the construction industry by identifying seven application areas and enabling solutions to many of its challenges using a systematic review, conceptual models, and practical use cases, and two conceptual models were developed. Nevertheless, the study did not specify where it was conducted (in terms of geographical coverage). Xu, Chong, and Chi (2021) conducted research on the Blockchain adoption hurdles in the AEC business. According to the authors, in the digital age, Blockchain has the ability to profoundly disrupt the workflow, trust, and procurement environments in the architecture, engineering, and construction (AEC) industry. Using a two-stage integrated interpretative structural modelling (ISM) and

decision-making trial and evaluation laboratory (DEMATEL) method, eleven (11) impediments to Blockchain adoption were identified based on a survey of the literature, industry reports, and expert comments. The findings helped practitioners in this field gain a better grasp of relevant barriers and potential solutions. The study established an important research basis for the effective acceptance and usage of Blockchain in the AEC industry, but no indication of where the study was done was made. The literature does not explicitly indicate how the barriers/challenges were identified specifically and comprehensively in the study.

2.3.1 Research Gap

The available literature on the potential application of Blockchain technology on construction projects was discussed in this chapter. The conceptual framework, theoretical framework, empirical literature, critical review, and research gaps were all explained in this chapter. The approach used to conduct the study is discussed in the following chapter. In filling the gap, this study will deploy the use of ISM to delineate the barriers to adopting blockchain technology in construction project delivery in Imo state, Nigeria where it has been proven to the best of our knowledge a study of this nature has not been conducted.

CHAPTER THREE

METHODOLOGY

3.1 Research Design

The research method consists of both the quantitative, qualitative and exploratory type used in this study. In order to determine the opinions, attitudes, and perceptions of interest in this research, questionnaires with the aid of focused group interviews were typically used. This study will have an exploratory study approach. The main idea of an exploratory study in particular is to find out what is happening; to seek new insights; to ask questions and to assess phenomena in a new light (Hultgren & Pajala, 2018). In this study, this will be particularly useful since we are striving to clarify the understanding of a problem even if it is difficult to specify the problem (Hultgren & Pajala, 2018; Saunders et al., 2009). According to Saunders et al. (2009), there are three different ways to carry out an exploratory research namely viz; a search of the literature, interviewing “experts” in the subject and conducting focus group interviews.

3.2 Study Area

The study was carried out in Imo state where there are numerous ongoing infrastructure construction projects with a main emphasis on construction projects and practitioners applying emerging technologies such as Blockchain technology in the delivery of their projects. The essence of deploying this approach is to enable the researcher get ample information that would aid in arriving at the desired objectives of the study. The practitioners consulted in the course of conducting this study were those who are information technology (IT) savvy and complaint. The professionals include project managers, consultants, contractors,

engineers (structural, civil and service engineers), architects, builders, quantity surveyors and other construction practitioners.

3.3 The Study Population

This consists of all the elements or group of persons that possess the requisite knowledge needed for the purpose of achieving the study’s objectives (Kothari, 2004). The targeted population which would constitute the unit of analysis for the study will comprise of selected professionals and registered construction project management stakeholders in Imo state. The details of the professionals were gotten from the database of their professional bodies. They include project managers, consultants, contractors, engineers (structural, civil and service engineers), architects, builders, quantity surveyors and other construction practitioners who are principally involved in the business of managing construction project using Blockchain technology and related technologies. The table below describes the details of professionals (targeted population) for study.

Table 3.1: Study Population

S/N	Targeted Professionals	Population Size
1	Engineers	63
2	Project Managers	32
3	Consultants	23
4	Quantity Surveyors	28
5	Architects	12
6	Builders	25
7	Others	11
	Total	194

Source: Field Survey, 2022

3.4 Sample Size and Sample Selection

There are currently four clear distinctions of professions playing an active role in the construction industry namely: Engineering (civil, structural, mechanical and

electrical), Quantity surveying, Project management Architects, Builders; all the aforementioned constitute the Design team. Whereas, the project promoters/Clients and Consultants are the other key players. Other than the above mentioned we also have subcontractors and material suppliers. The sampling frame refers to the source of the population. It is a means of representing the elements of the population (Gwaya, 2015; Mugenda & Mugenda, 2004). The sampling unit is the basic unit containing the elements of the population to be sampled. It may be the unit itself or the unit in which the element is contained. This study covers the clients, design team and consultants as the sampling frame. Due to the difficulty of establishing the number of individual clients; they were surveyed subjectively through ongoing projects for this study. The questionnaires for the design teams were designed for the most technical person in the clients' organizations.

These are the processes or tactics utilised by the researcher to choose sample representatives from the designed demographic information. There are two sorts of sampling procedures: probability sampling techniques and non-probability sampling techniques (Egwi, 2022). In order to fulfil the goal or purpose of this research, the researcher chose respondents using a probability sampling approach known as the simple random sample technique. In addition to "pure random sampling," the method of chance was utilised to choose responders from the sample frame. This provides all respondents the same opportunity to pick. As a result, the basic random selection technique is acceptable for achieving the necessary generalizability of the study's conclusions.

The sample size was determined using the Krejcie and Morgan Method of sample size determination. The sample size using the Krejcie and Morgan Method (Krejcie & Morgan 1970) is 123. See Krejcie and Morgan table for sample size determination at the appendix.

3.5 Method of Data Collection

The method used to collect the data consists of both research instruments and focus group discussion. In other words, the study used information from a primary source. The primary data came from site surveys and focus group interviews at project locations. Thereafter, the instrument was used to design and collect well-structured questions for purposes of collecting primary data. To accomplish the objectives of the study, a number of questions were included in the questionnaire. This includes all of the various aspects that have to do with the issue in context. Subject-matter specialists in the construction industry who are IT savvy and conversant with Blockchain Technology as it relates to the construction project and the industry were contacted. In analyzing the main issues of discuss using the ISM approach, 23 respondents participated in this aspect of the study.

3.6 Instruments for Data Collection

The questionnaire facilitated the possible collection of required information. The first section of the questionnaire's questions would be from demographic information, with close-ended questions and responses expected from the respondents. Semi-structured interviews in the form of focus groups with selected industry experts 23 (twenty-three) of them were used to acquire relevant information for that aspect of the study. The various approaches for conducting the ISM analysis include some focus group discussions or interviews were deployed.

3.7 Method of Data Analysis

The data collected via the administered questionnaires was checked for accuracy and relevance before being coded and entered into an IBM SPSS Statistics version 25.0. In order to reach a more dependable and reliable conclusion, the demographic results were presented using tables, charts and figures.

Based on the study objectives, the following data analysis methodologies were used.

First Objective: To identify the major barriers in the adoption and implementation of Blockchain technology in the delivery of construction projects in Imo State. Content analysis using literature search was used in identifying the barriers for purposes of further analysis and achieving the stated objective.

Second Objective: To develop a causal relationships among the most influential barriers hindering the adoption of Blockchain technology on construction projects in Imo State. The methodology for interpretive structural modeling (ISM) was developed by J. Warfield in 1973 to study complex and subjective problems (Azevedo, Sequeira, Santos, & Mendes, 2019). ISM is a mapping theoretic method that belongs to the causal mapping approach family. ISM is useful when a multilevel research design is required and the research outcome cannot be predicted based on existing research. Its basic concept is to use and incorporate experts' practical experience, opinions, and knowledge to decompose a complex system into several subsystems and create a multilevel structural model (Azevedo et al., 2019; Khan & Rahman, 2015). In this sense, ISM is used to identify and summarise relationships among specific variables that define a problem, as well as to analyse the impact of those relationships.

Using a structural self-interaction matrix (SSIM) scale, respondents were asked to rate each Blockchain barrier as identified via a review of literature from various research. The use of SSIM analysis was adopted for the analysis and ranking of questionnaire responses based on the initial reachability matrix by replacing V, A, X, O associations with the binary values 1 and 0 as appropriate (See table 4.4). And thereafter, a digraph was drawn and the transitive links were removed using

the connections given in the reachability matrix and the defined levels for each Blockchain barrier.

The various procedures for carrying out the ISM analysis with a view to achieving the second objectives is as follows.

Step 1. From the native functions of Blockchain, different Blockchain barriers were identified and listed as variables.

2. Step 2: A contextual relationship between these barriers was established.

3. Step 3. A structural self-interaction matrix (SSIM) was created for Blockchain barriers to indicate pair-wise relationships between them. For analysis, a contextual relationship of the type "leads to" was chosen, which means that one variable leads to another variable. To indicate the direction of the relationship between the elements i and j , the following four symbols have been used (Agrawal, 2019):

V: Blockchain barrier i contributes to Blockchain barrier j . A: The ability to use Blockchain barrier j contributes to Blockchain barrier i . X: i contributes to Blockchain barrier j as well as Blockchain barrier j contributes to Blockchain barrier i . O: Blockchain barrier i and j are unrelated to one another.

Step 4: Again when the SSIM was concluded, it was transformed into a binary matrix known as the initial reachability matrix by replacing V, A, X, O associations with the binary values 1 and 0 as appropriate. The initial reachability matrix was then reviewed for transitivity, resulting in the creation of the 'final reachability matrix'.

Step 5: The final reachability matrix that was generated in Step 4 was split into multiple levels.

Finally, the final reachability matrix was created in its conical form, with the majority of zero (0) variables in the upper horizontal half of the matrix and the majority of unitary (1) variables in the lower portion.

6. Step 6. A digraph was drawn and the transitive links were removed using the connections given in the reachability matrix and the defined levels for each Blockchain barrier.

7. Step 7. In the final step, the ISM model, as shown in Figure 4.4, was developed and reviewed to eliminate any inconsistencies, and any necessary changes were made.

After removing the indirect links from the final reachability matrix, the final ISM-based model for Blockchain barriers was obtained.

Third Objective: To prioritize these barriers according to how to manage them based on their cause-and-effect relationship using feedbacks from experts in Imo State. Responders were requested to rate the aspects from various studies on a satisfaction scale, as described from the focus group discussion. The MICMAC (Matrice d’Impacts Croisés Multiplication Appliquée á un Classement) systematic analysis was used to describe the system and categorise variables based on their interactive and convergent relationships (Ahuja, Sawhney & Arif, 2017). Under the MICMAC analysis, each Blockchain barrier was classified into four clusters based on the driving and dependence power, as shown in figure 4.5. The MICMAC is a systematic analysis that uses a matrix to describe the system and categorizes variables based on their driving and dependant power. The ISM diagram is drawn based on the determined levels and final matrix. Each level is specified by repeating the equation below (Maybodi, Dehnavi, Rabbanib & Ashkezari, 2023);

$$R(CJ) \cap A(CJ) = R(CJ), \quad \forall CJ \in C \dots\dots\dots(31.)$$

Where R, C, J , represents row, column and joint variables, n , the intersection.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Analysis of Questionnaire

The study population consists of 194 personnel from construction firms selected around Imo State, Nigeria. Questionnaires were self-administered to the professionals in the construction firms. The number of questionnaires distributed based on the sample size as determined by the Krejcie and Morgan's method of sample size determination which was 123 and those retrieved as well as those found useable for the analysis and projects involved by the professionals are shown in table 4.1.

Table 4.1 Response from Questionnaire

S/N	Targeted Professionals	Population Size	Sample Size	Sample Returned	Number Used	Projects Involved in
1	Engineers	63	34	23	21	Road construction Owerri – Orlu road
2	Project Managers	32	21	18	17	
3	Consultants	23	15	12	12	
4	Quantity Surveyors	28	16	11	9	Construction of Hotel building at Hospital Junction, world bank.
5	Architects	12	10	7	7	
6	Builders	25	19	15	13	Flood Control projects at FHA Estate Egbeada Imo State.
7	Others	11	8	7	7	
	Total	194	123	93	86	

4.2. Demographic Characteristics of Respondents

In the first section of the questionnaire the respondent's characteristics as regards their discipline, years of experience, qualifications, sector of operation etc are presented.

4.2.1. Discipline of Respondents

Table 4.2 shows the discipline of all the respondents who participated in the study. Of note, 21, majority (24.42%) are engineers, while 17 (19.77%) are project managers. Other professionals have also contributed (12) and (9) like consultants and quantity surveyors. Also, the highest response rate was from engineers (21 responses), while the least is by procurement officers and land surveyors with a response rate of 2 and 2 respectively.

Table 4.2: Discipline of Respondents

Targeted Professionals	Frequency	Percentage
Engineers	21	24.42
Project Managers	17	19.77
Consultants	12	13.95
Quantity Surveyors	9	10.47
Architects	7	8.14
Builders	13	15.12
Estate Surveyors	3	3.49
Land Surveyors	2	2.33
Procurement Officers	2	2.33
Total	86	100.00

4.2.2. Years of Experience of Respondents

Figure 4.1 shows the years of experience of all the respondents who participated in the study. Of note, 18 (20.93%) have spent 20 years and above in the industry, while 19 (22.09%) have spent between 6 to 10 years. Others have also spent between 16 to 20 years 13 (15.12%). Also, the highest response rate was from 11 to 15 years 21 responses (24.42%), while the next to the least is between 1 to 5 years with a response rate of 15 and (17.44%).

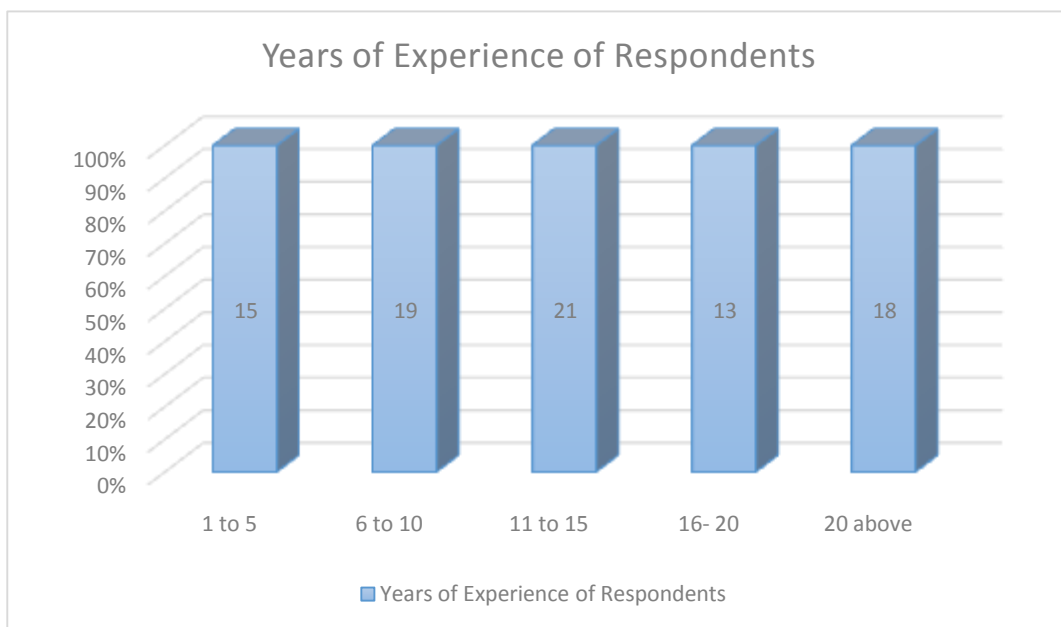


Figure 4.1: Years of Experience of Respondents

4.2.3. Qualifications of Respondents

Table 4.2 shows the qualifications of all the respondents who participated in the study. The highest response rate was from B.Eng/B.Tech/B.Sc/HND holders with 45 responses (52.33%), while the next to the least is PhD holders with a response rate of 4 and (4.65%). While those with M.Eng/M.Sc/MBA had a response rate of 37 (43.02%).

Table 4.2: Qualifications of Respondents

Qualifications	Frequency	Percentage
B. Eng/B.Tech/B.Sc/HND	45	52.33
M. Eng/ M.Sc./MBA	37	43.02
PhD	4	4.65
Total	86	100

4.2.4. Sector of Operation of Respondents

Figure 4.2 shows the response percentage related to personal information. The result obtained showed that (24.42%) 21 of participants in this survey worked in the public sector while, 54 (62.79%) worked in private, while 11 (12.79%) worked in both Private and Public Sectors.

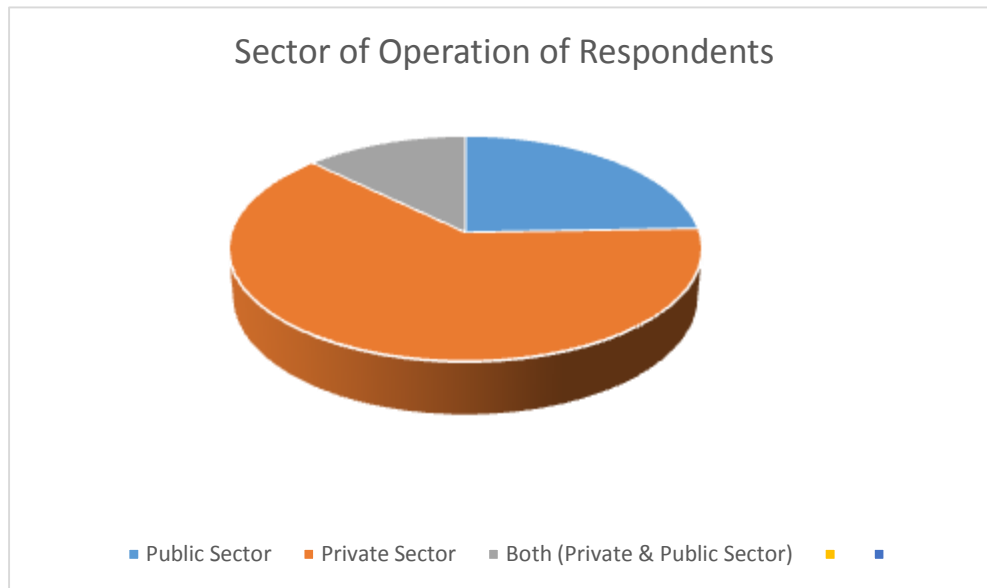


Figure 4.2: Sector of Operation of Respondents

4.3. Status and Extent of Utilization of Blockchain Technology

In a bid to achieve the first research's objective, respondents were provided with the following set of questions. The status and extent of utilization of Blockchain technology on construction projects is depicted in figure 4.3, and the results show that 42 (48.84%) of the respondents have heard of Blockchain Technology but it has never been used on construction projects. In contrast, 35 (40.70%) of the respondents have never heard of Blockchain Technology, while 9 (10.47%) had only used it sparingly, such as in electronic and procurement related functions. While none of the respondents (0.00%) had used/applied Blockchain Technology on their construction projects.

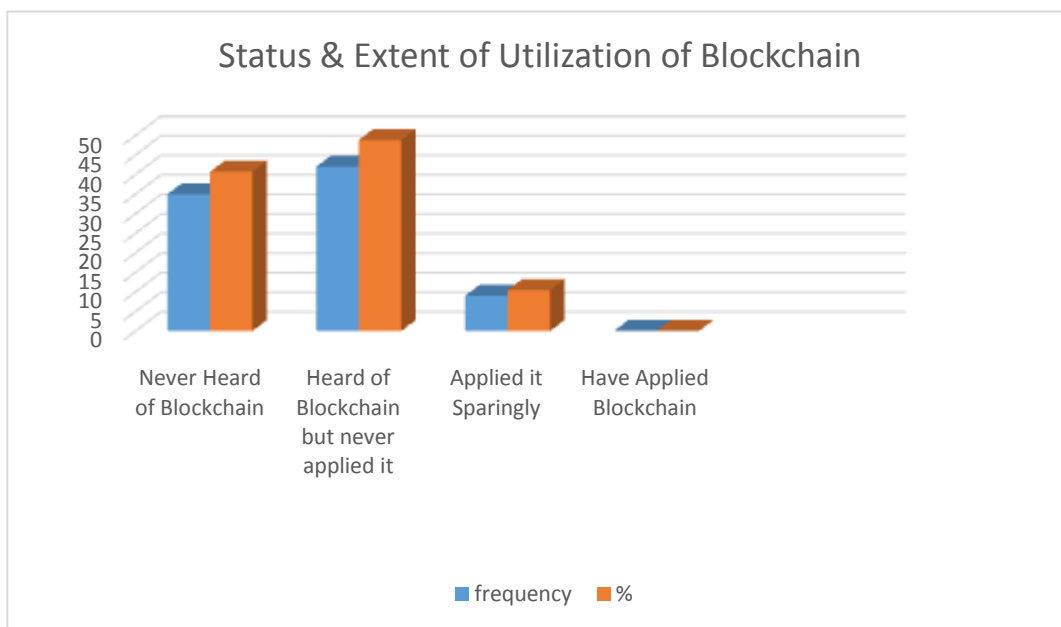


Figure 4.3: Status and Extent of Utilization of Blockchain Technology

Table 4.3: Some of the Construction Projects visited for the purpose of this study (ongoing, abandoned and completed)

S/N	Project Name	Project Description	Partners	Capacity	Status	Remarks
1	Construction of 2Nos 16 Man Rank & File block for officers of Nigerian Customs Service	Accommodation for Nigerian Customs officers	SEA KEN Nigeria Limited	2floors Semi-detached blocks	Completed	Contract awarded in 2020
2	Road construction Owerri – Orlu road	Dual carriageway road construction	CRANEBURG CONSTRUCTION COMPANY	37 kilometers	Ongoing	Flagged off on 30 th Nov' 2020
3	Flood Control projects at FHA Estate Egbeada Imo State.	Flood control & storm water discharge linkage	Federal Housing Authority/ Asfrank Nigeria Limited	Flood control	completed	No information
4	Construction of Hotel building at Hospital Junction, world bank.	6 floors Hotel building	Ice Associates Nigeria limited	60 guest room capacity	Ongoing	No information
5	Construction of warehouse Okigwe	Tiles Storage and distribution warehouse	Janox Projects and Design Ltd	2,400 sqm area	Ongoing	No information

Source: Author's compilation, 2023

Details of the interaction from the semi-structured interview with the respondents on the barriers of blockchain technology adoption on construction project delivery in Imo State

Basically, the barriers identified amongst others to include:

1. Lack of Awareness

- Lack of awareness about the concept of blockchain as is applicable on construction project delivery. Most of the respondents were not conversant with its application. This situation seems to agree with the outcome of our findings, in that there's tendency of a resistance to change occurring.

2. Lack of access to connectivity was also envisaged by some of the respondent who showed evidence of being aware of the existence of blockchain technology. The respondent aver that he is aware of its existence and unfortunately raised concerns on issues bordering on access to internet, power and connectivity which are some of the problems impeding the adoption of such IT infrastructure nowadays.

3. Lack of existing regulations and law to support the deployment of such technologies in the delivery of construction projects as it is applicable in other advanced climes.

4. Other issues discovered in the course of the interaction with some of the respondents on site is that, there was an overall lack of the deployment of

modern IT facilities on those projects. Only a few personal computers and office accessories were noticed in some of the construction project sites visited.

4.4. Influential Barriers to Application of Blockchain Technology

In a bid to achieve the second research's objective, respondents were provided with the list of barriers identified from the literature (See table 4.3). Using the various procedures for carrying out the ISM analysis as stated in steps 1 through 7.

Table 4.4: Blockchain Barriers on Construction Projects

S/N	Blockchain Barriers	Codes
1	Security	SE
2	Immature Application of Blockchain Technology	IA
3	Blockchain Technology Characteristics	BT
4	Scalability and Transaction Capability of Blockchain	ST
5	Bandwidth and Connectivity	BC
6	High Investment in Blockchain-based Systems	HI
7	Absence of Regulations, Legislation and Global Standard	AR
8	Resistance to Change	RC

MICMAC analysis was applied to the various identified Blockchain barriers in order to focus on its implementation process and prioritise the Blockchain barriers with a view to achieve immediate high-end benefits such as faster construction, good quality, improved performance, cost savings, and so on.

Semi-structured interviews and focus groups with eighteen (18) industry experts, as well as an in-depth literature review, were conducted for this study. The various procedures for carrying out the ISM analysis with a view to achieving the second objectives is as follows.

1. Step 1. From the native functions of Blockchain, different Blockchain barriers were identified and listed as variables (shown in Table 4.4).

Table 4.5: Structural Self-Interaction Matrix for Blockchain Barriers

S/N	Variables	8	7	6	5	4	3	2	1
		RC	AR	HI	BC	ST	BT	IA	SE
1	SE	V	V	V	V	V	V	V	X
2	IA	A	V	V	V	X	V	X	
3	BT	A	V	A	V	A	X		
4	ST	A	V	V	V	X			
5	BC	A	X	A	X				
6	HI	A	V	X					
7	AR	A	X						
8	RC	X							

2. Step 2: A contextual relationship between these barriers was established.
3. Step 3. As shown in table 4.5, a structural self-interaction matrix (SSIM) was created for Blockchain barriers to indicate pair-wise relationships between them. For analysis, a contextual relationship of the type "leads to" was chosen, which means that one variable leads to another variable. To indicate the direction of the relationship between the elements i and j, the following four symbols have been used (Agrawal, 2019):

V: Blockchain barrier i contributes to Blockchain barrier j. A: The ability to use Blockchain barrier j contributes to Blockchain barrier i. X: i contributes to Blockchain barrier j as well as Blockchain barrier j contributes to Blockchain barrier i. O: Blockchain barrier i and j are unrelated to one another.

Table 4.6: Initial Reachability Matrix for Blockchain Barriers

S/N	Challenges	1	2	3	4	5	6	7	8
1	SE	1	1	1	1	1	1	1	1
2	IA	0	1	1	1	1	1	1	0
3	BT	0	0	1	0	1	0	1	0
4	ST	0	1	1	1	1	1	1	0
5	BC	0	0	0	0	1	0	1	0
6	HI	0	0	1	0	1	1	1	0
7	AR	0	0	0	0	1	0	1	0
8	RC	0	1	1	1	1	1	1	1

Step 4: Again when the SSIM was concluded, it was transformed into a binary matrix known as the initial reachability matrix by replacing V, A, X, O associations with the binary values 1 and 0 as appropriate (See table 4.6). The initial reachability matrix was then reviewed for transitivity, resulting in the creation of the 'final reachability matrix'.

Table 4.7: Final Reachability Matrix for Blockchain Barriers

S/N	Challenges	1	2	3	4	5	6	7	8	DrP
1	SE	1	1	1	1	1	1	1	1	8
2	IA	0	1	1	1	1	1	1	0	6
3	BT	0	0	1	0	1	0	1	0	3

4	ST	0	1	1	1	1	1	1	0	6
5	BC	0	0	0	0	1	0	1	0	2
6	HI	0	0	1	0	1	1	1	0	4
7	AR	0	0	0	0	1	0	1	0	2
8	RC	0	1	1	1	1	1	1	1	7
	DeP	1	4	6	4	8	5	8	2	

NB: DeP=Dependence power; DrP=Driving power

Step 5: As shown in table 4.6, the final reachability matrix that was generated in Step 4 was split into multiple levels.

Table 4.8: First Iteration/partition for Each Level of Blockchain Barriers

Barrier	Reachability Set	Antecedent Set	Intersection Set	Level
SE	SE,RC,IA,ST,HI,BT,BC,AR,	SE	SE	
IA	IA,ST,HI,BT,BC,AR,	SE,RC,IA,ST,	IA,ST	
BT	BT,BC,AR	SE,RC,IA,ST, HI,BT,	BT,	
ST	IA,ST,HI,BT,BC,AR,	SE,RC,IA,ST,	ST,IA	
BC	BC,AR,	SE,RC,IA,ST, HI,BT,BC,AR,	BC,AR	Level I
HI	HI,BT,BC,AR,	SE,RC,IA,ST, HI	HI	
AR	BC,AR,	SE,RC,IA,ST, HI,BT,BC,AR,	BC,AR,	Level I
RC	RC,IA,ST,HI,BT,BC,AR,	SE,RC	RC	

Finally, the final reachability matrix was created in its conical form, with the majority of zero (0) variables in the upper horizontal half of the matrix and the majority of unitary (1) variables in the lower portio

Table 4.9: Second Iteration/partition for Each Level of Blockchain Barriers

Barrier	Reachability Set	Antecedent Set	Intersection Set	Level
SE	SE,RC,IA,ST,HI,BT,BC,AR,	SE	SE	
IA	IA,ST,HI,BT,BC,AR,	SE,RC,IA,ST,	IA,ST	
BT	BT,BC,AR	SE,RC,IA,ST, HI,BT,	BT,	Level II
ST	IA,ST,HI,BT,BC,AR,	SE,RC,IA,ST,	ST,IA	
BC	BC,AR,	SE,RC,IA,ST, HI,BT,BC,AR,	BC,AR	
HI	HI,BT,BC,AR,	SE,RC,IA,ST, HI	HI	
RC	RC,IA,ST,HI,BT,BC,AR,	SE,RC	RC	

Table 4.10: Third Iteration/partition for Each Level of Blockchain Barriers

Barrier	Reachability Set	Antecedent Set	Intersection Set	Level
SE	SE,RC,IA,ST,HI,BT,BC,AR,	SE	SE	
IA	IA,ST,HI,BT,BC,AR,	SE,RC,IA,ST,	IA,ST	
ST	IA,ST,HI,BT,BC,AR,	SE,RC,IA,ST,	ST,IA	
HI	HI,BT,BC,AR,	SE,RC,IA,ST, HI	HI	Level III
RC	RC,IA,ST,HI,BT,BC,AR,	SE,RC	RC	

Table 4.11: Fourth Iteration/partition for Each Level of Blockchain Barriers

Barrier	Reachability Set	Antecedent Set	Intersection Set	Level
SE	SE,RC,IA,ST,HI,BT,BC,AR,	SE	SE	
IA	IA,ST,HI,BT,BC,AR,	SE,RC,IA,ST,	IA,ST	Level IV
ST	IA,ST,HI,BT,BC,AR,	SE,RC,IA,ST,	ST,IA	Level IV
RC	RC,IA,ST,HI,BT,BC,AR,	SE,RC	RC	

Table 4.12: Fifth Iteration/partition for Each Level of Blockchain Barriers

Barrier	Reachability Set	Antecedent Set	Intersection Set	Level
SE	SE,RC,IA,ST,HI,BT,BC,AR,	SE	SE	
RC	RC,IA,ST,HI,BT,BC,AR,	SE,RC	RC	Level V

Table 4.13: Sixth Iteration/partition for Each Level of Blockchain Barriers

Barrier	Reachability Set	Antecedent Set	Intersection Set	Level
SE	SE,RC,IA,ST,HI,BT,BC,AR,	SE	SE	Level VI

6. Step 6. A digraph was drawn and the transitive links were removed using the connections given in the reachability matrix and the defined levels for each Blockchain barrier.

7. Step 7. In the final step, the ISM model, as shown in Figure 4.4, was developed and reviewed to eliminate any inconsistencies, and any necessary changes were made.

After removing the indirect links from the final reachability matrix, the final ISM-based model for Blockchain barriers was obtained. Figure 4.4 depicts the final

ISM-based Blockchain barriers model. 'Bandwith and Connectivity' (barrier 5) and 'Absence of Regulations, Legislation and Global Standard' (barrier 7) were discovered to be at the top of the hierarchy, reflecting the effectiveness of all Blockchain barriers. All of the other Blockchain barriers control it. The ISM hierarchy's base barriers, 'Security' (barrier 1), 'Resistance to Change' (barrier 8), 'Scalability and Transaction Capability of Blockchain' (barrier 4) and 'Immature Application of Blockchain Technology' (barrier 2), were discovered to be interdependent. These Blockchain barriers had the most driving power, implying that they were the four most important Blockchain barriers that influenced the entire barriers. The following level barrier was the linkage cluster which was discovered to have no factor (barrier) in it. Variables in this cluster have a strong reliance power as well as a high driving power. They have a high system linkage.

These elements should be treated with greater care. Any change in the cluster has an influence on the system. No barrier in this study falls under this category. The next level Blockchain barrier discovered to be affected by the previous mentioned Blockchain barriers but directly affecting 'Blockchain technology characteristics BT' (barrier 3) in the second level, followed by ' High investment in blockchain-based systems HI' (barrier 8) in level three. In the fourth level of the diaphragm, two barriers viz; 'Immature application of blockchain technology IA (barrier 2) and Scalability and transaction capability of Blockchain systems ST (barrier 4) were recognized as the key Blockchain barrier requiring adoption on construction projects to produce effective results, forming the system core. In the fifth level, it was discovered that Resistance to Change RC (barrier 8) has a direct influence on a number of Blockchain barriers and to be controlled by other barriers as well. In addition, the sixth penultimate level Blockchain barrier was discovered from the diaphragm as Security SE (barrier 1).

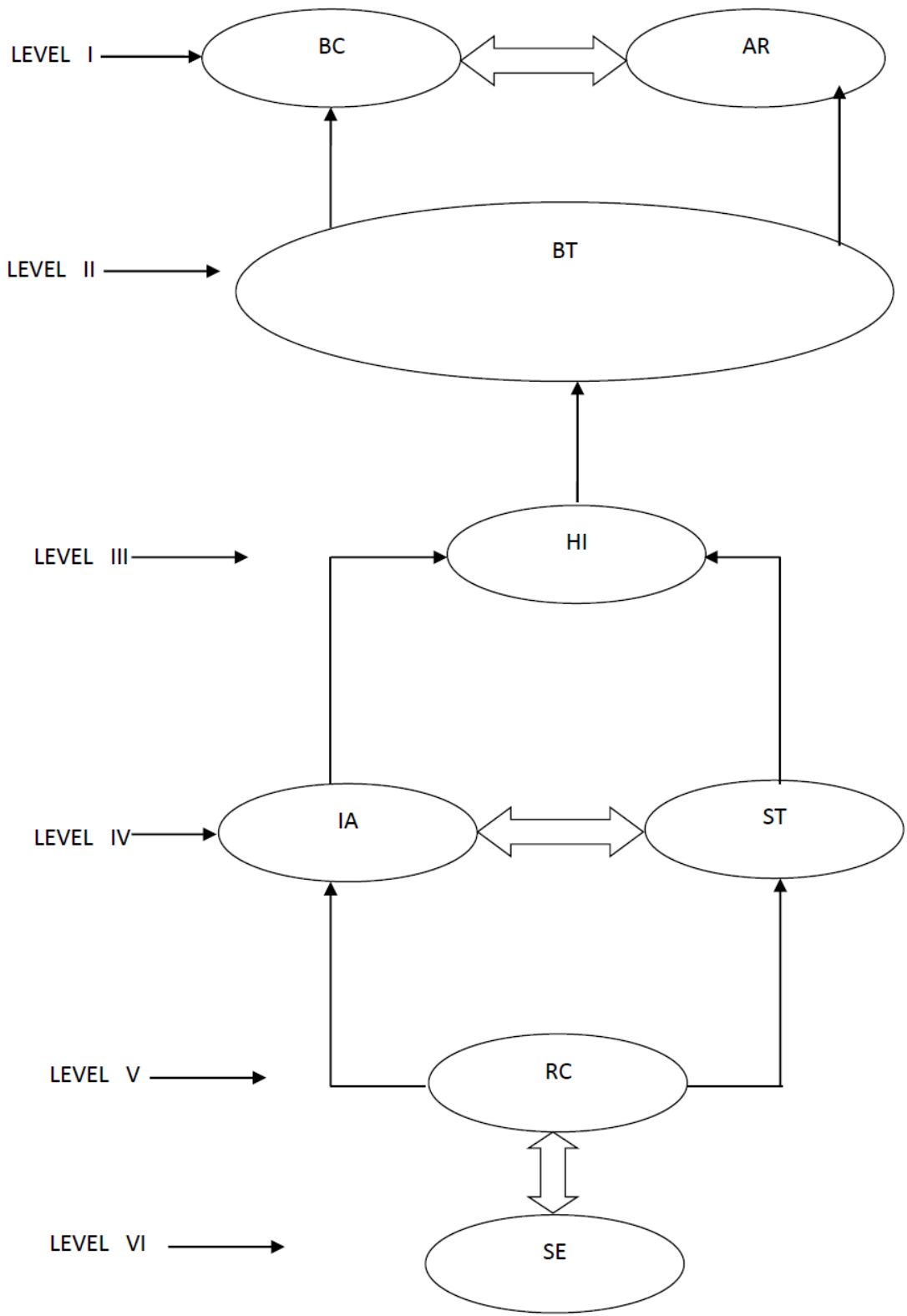


Figure 4.4: ISM Based Model for Blockchain Barriers

4.5. Interaction and convergent relationship amongst Blockchain Technology Barriers

MICMAC analysis is based on the multiplication properties of matrices, and one of its primary goals is to examine and categorize important variables in terms of driving power and dependence power, with all variables grouped into four designated clusters (Agrawal, 2019).

After assigning levels to various Blockchain barriers, the MICMAC analysis was used to determine the driving and reliance power of these Blockchain barriers, by providing valuable insights into their relative importance, nature, and interdependencies. Under the MICMAC analysis, each Blockchain barrier was classified into four clusters based on the driving and dependence power, as shown in figure 4.5, namely autonomous Blockchain barrier, dependent Blockchain barrier, linkage Blockchain barrier, and independent Blockchain barrier. The first cluster, situated in the southwest section, comprising of autonomous Blockchain barriers with low driving power and reliance. According to reports, these barriers are relatively disconnected from the model. There was no mention of such any barrier in the current study from that cluster. The second cluster comprised of dependent Blockchain barriers, which had little driving power but relied heavily on other capabilities. This category included factor 5 (BC), Bandwidth and Connectivity which took one of the top spot in the ISM model, factor 7 (AR), Absence of regulations, legislation and global standard which was second to take the top spot in the ISM model, factor 3 (BT), Blockchain technology characteristics, factor 6 (HI), High investment in Blockchain-based systems. This category of Blockchain barrier requires more thought and analysis from Blockchain users because successful construction project delivery is only possible if other barriers are adequately and fully identified.

The third cluster is the linkage barriers that demonstrate both high driving and high dependence power. Unfortunately, no barrier fell on this cluster. This category was reported to have an effect on other barriers as well as feedback on themselves, making them unstable. Barriers in this cluster were discovered to not only be dependent on other barriers, but also to drive the top-level Blockchain barriers. These Blockchain barriers from this cluster are critical and require the full attention of Blockchain implementers to achieve positive results. To achieve the desired result, Blockchain users must implement the components of these barriers with meticulous detail because they have the most ability to influence other Blockchain barriers and are also heavily reliant on other barriers. The fourth cluster consisted of independent Blockchain barriers, which were reported to have high driving power but low dependence power. Among these are factor 1 (SE), Security, factor 8 (RC), Resistance to Change, factor 4 (ST), Scalability and transaction capability of Blockchain systems, and factor 2 (IA), Immature application of Blockchain technology. These Blockchain barriers are primarily found at the base of the ISM model and condition the entire system. These are of the utmost importance because they can influence and aid in the achievement of other barriers to the greatest extent possible.

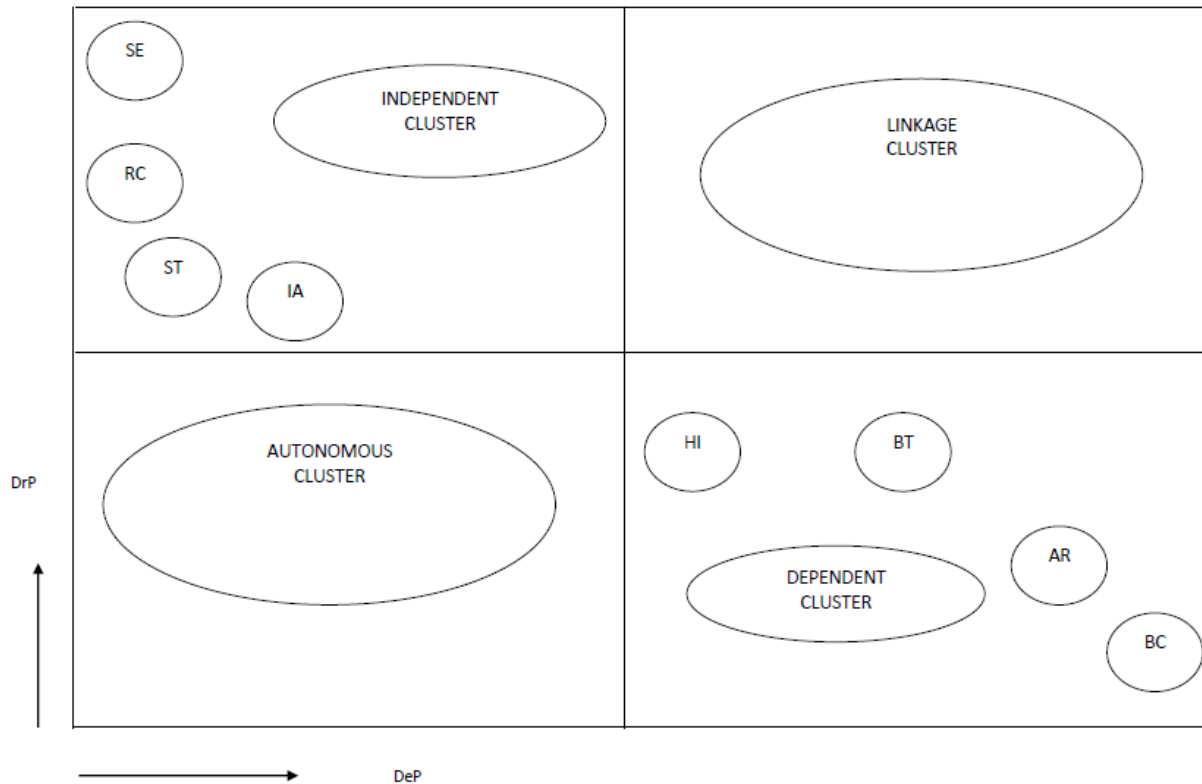


Figure 4.5: MICMAC Analysis of Blockchain Barriers

4.6 Results Discussion

The findings from the study depicts that, out of the eighty-six (86) responses on the status and extent of utilization of Blockchain Technology, 42 (48.84%) of the respondents opined that they have heard of Blockchain Technology but it has never been used on their construction projects. In contrast, 35 (40.70%) of the respondents have never heard of Blockchain Technology, while 9 (10.47%) have only used it sparingly, such as in electronic and procurement related functions. While none of the respondents (0.00%) has used/applied Blockchain Technology on their construction projects. However, this could be an indication that awareness of Blockchain technology in Nigeria has not been encouraging. A cursory look at some of the studies conducted on Blockchain with regards to construction related

projects indicates that a handful of them were conducted in advanced climes with little or virtually none in developing countries and Nigeria in particular. Some of the researchers who did similar studies with regards to Blockchain technology include that of the two authors (Oye-Bamgbose, 2019; Amade et al., 2022).

The findings from this study indicates that, the most influential barriers to application of Blockchain technology on construction projects as opined by the respondents after the iterations and the drawing of the diagraph, the following barriers Bandwidth and Connectivity (BC), Absence of regulations, legislation and global standard (AR), and Blockchain technology characteristics (BT). The outcome of this finding can be substantiated with the statement from the Mohammed et al. (2021) and Li et al. (2019) who were of the view that parts of a supply chain delivery system might fail largely due to lack of connectivity. Hence, there's need for the provision of adequate server capacity that is necessary for system stability, as well as constant internet access that will boost the process. On the aspect of regulation, given that Blockchain is an open database, policies will be required to protect users' rights and trading secrets. According to Duan et al. (2020), the use of PEST analysis to investigate the uncontrollable external environment for Blockchain deployment is imperative. Hence, there is need for a proposed standard by government to help check the menace of unauthorized entry and access into the cyberspace.

The findings from this study indicate that, the interaction and convergent relationship amongst the barriers to application of Blockchain technology on construction projects as opined by the respondents after the iterations and the application of the MICMAC analysis in determining the driving and reliance power of these Blockchain barriers, four (4) barriers were found to have a distinct form of interdependencies. Among these are Security (SE), Resistance to Change

(RC), Scalability and transaction capability of Blockchain systems (ST), and Immature application of Blockchain technology (IA).

Successful Blockchain adoption and implementation on construction projects in Nigeria and Imo state in particular is expected to improve the industry's current situation, prospects, and achievement. It is vital to determine and assess critical Blockchain barriers at the organisational level in order to increase Blockchain adoption in Nigeria. Several existing Blockchain functions were examined in this study in order to develop eight Blockchain barriers that are responsible for the challenges impeding its adoption. Among these Blockchain barriers, each is classified based on its driving and dependent power, giving Blockchain adopters a clear understanding of their significance in terms of utilisation and implementation to achieve better outcomes. ISM provides this evaluation, which identifies the hierarchical system of barriers to be adopted by Blockchain users so as to resolve various challenges faced by the construction project managers in the industry and to use Blockchain to its full potential. The outcome this study agreed with that of Baiod et al. (2021) and Oye-Bamgbose (2019) who opined that an end-to-end investigation into the Blockchain's security threats most times gives rise to three common risks; viz; assaults, privacy leaks, and private key security. Furthermore, there is need for users to assign a private key to their transactions, thus making it difficult for attackers to determine if crypto-currencies in different transactions are received by the same user. These Blockchain barriers must be implemented concurrently on the project in order to achieve a data-rich information model that can contribute to efficient "construction project delivery" and use in the AEC industry in general.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

This chapter summarizes the findings, as well as the study's objectives and the outcome of the findings emanating from this research. Furthermore, based on the findings and discussions, the study reached conclusions and made recommendations. The chapter concludes with a discussion on the study's contribution to knowledge.

5.2 Summary of Findings

The broad objective of this study is to evaluate the barriers to Blockchain Technology application on construction projects. The study specifically identified the status and extent of utilization of Blockchain technology, identified and evaluated the most influential barriers to application of Blockchain technology, examined the interaction and convergent relationships amongst the Blockchain technology barriers impeding the delivery of construction projects in Imo State.

In the course of conducting the research, the status and extent of utilization of Blockchain Technology on construction projects was determined. Thereafter, eight (8) barriers to Blockchain technology's adoption and application on construction projects have also been identified and evaluated. The key results from the three (3) objectives set out *ab ini tio* are described underneath.

The study sought to identify the status and extent of utilization of Blockchain technology on construction projects in Imo State. The study found out that, out of the eighty six (86) responses on the status and extent of utilization of Blockchain Technology, 48.84% of the respondents opined that they have heard of Blockchain

Technology but it has never been used on their construction projects. In contrast, 40.70% of the respondents have never heard of Blockchain Technology, while 10.47% have only used it sparingly, such as in electronic and procurement related functions. While none of the respondents 0.00% has used/applied Blockchain Technology on their construction projects.

The study sought to identify and evaluate the most influential barriers to application of Blockchain technology on construction projects in Imo State. The study found out that, the most influential barriers to application of Blockchain technology on construction projects in Imo as opined by the respondents after the iterations and the drawing of the diagraph, barrier 5 (BC), Bandwidth and Connectivity which took one of the top spot in the ISM diagraph, and barrier 7 (AR), Absence of regulations, legislation and global standard which was second to take the top spot in the ISM diagraph, while barrier 3 (BT), Blockchain technology characteristics, came third in the second level of the ISM diagraph.

The study sought to examine the interaction and convergent relationships amongst the Blockchain technology barriers impeding the delivery of construction projects in Imo State. The study found out that, the interaction and convergent relationship amongst the barriers to application of Blockchain technology on construction projects in Imo as opined by the respondents after the iterations and the application of the MICMAC analysis in determining the driving and reliance power of these Blockchain barriers, four (4) barriers were found to have a distinct form of interdependencies. Among these are barrier 1 (SE), Security, barrier 8 (RC), Resistance to Change, barrier 4 (ST), Scalability and transaction capability of Blockchain systems, and barrier 2 (IA), Immature application of Blockchain technology.

5.3 Conclusions

Given the outcomes of the results emanating from this study, we now conclude that;

1. In terms of the status and extent of utilization of Blockchain technology's deployment in the delivery of construction projects, there is a general low level on the extent of utilization of Blockchain technology in the delivery of construction projects in Imo state, Nigeria, given the fact that none of the respondents 0.00% has used/applied Blockchain Technology on their construction projects in recent time. And that 48.84% of the respondents opined that they have heard of Blockchain Technology but it has never been used on their construction projects. 40.70% of the respondents have never heard of Blockchain Technology, while 10.47% have only used it sparingly and mostly in the form of electronic procurement related functions.
2. The most influential barriers to application of Blockchain technology on construction projects in Imo are (BC), Bandwidth and Connectivity barrier, (AR), Absence of regulations, legislation and global standard barrier, and (BT), Blockchain technology characteristics barrier.
3. The interaction and convergent relationship amongst the barriers to application of Blockchain technology on construction projects in Imo is (SE), Security barrier, (RC), Resistance to Change barrier, (ST), Scalability and transaction capability of Blockchain systems barrier and (IA), Immature application of Blockchain technology barrier.

5.4 Recommendations

1. In order to grasp the utilization of Blockchain technology as one of the key essential elements for construction project realization, there is need for a united front to make the necessary information available through Blockchain technology awareness-raising among construction project stakeholders in the Nigerian construction industry. Given that Blockchain technology is a life-saving program, an enormous amount of information will need to be created through professional association meetings, workshops, and conferences, among other venues, to help raise Blockchain technology awareness and encourage practitioners to accept it whole heartedly as it has the much-needed magic wand to change the tide of construction project delivery to the right destination.
2. Since it is critical to use Blockchain technology efficiently in the delivery of construction projects. There's need to encourage government on one hand to create the much needed environment by enacting the enabling laws that will give the necessary backing to the enthronement and utilization of Blockchain technology where access to bandwidth and connectivity will be a thing of past. This will aid in fast-tracking the adoption of Blockchain technology on construction project delivery in Imo state and Nigeria in general.
3. Again, given that Blockchain technology allows for distributed, encrypted, and secure digital transaction logging process, there's need for both public and private sector practitioners to revolutionize its existence in a myriad of areas, particularly those areas where centralization is critical and privacy, as well as security is given the outmost/desired attention. Furthermore, we

recommend that practitioners within the AEC industry should allow technology to be useful in the industry. The industry is dynamic in nature, hence there's need for all and sundry to embrace change as a critical ingredient of modern day liberalization. We are inspired by the fact that construction projects require a dynamic collaboration of several entities particularly during information-intensive phases; centralization of information management is required. When unrestricted technology is used, communication patterns among participants reveal a peer-to-peer nature of the relationships. In such an environment, Blockchain can provide a reliable infrastructure for information management throughout all stages of the construction project life cycle. Blockchain can improve the reliability and trustworthiness of construction logbooks, works performed, and material quantities recorded on the job site. The main potential of Blockchain in the facility maintenance phase is that it will help in securing, storage of sensor data that is sensitive to privacy and security.

5.4 Contribution to Knowledge

This paper advances knowledge in the following ways:

1. The research identified the key barriers of Blockchain technology in the built environment by categorizing and analyzing results from a state-of-the-art and literature review, highlighting eight categories which is first of its kind conducted in Imo state, Nigeria.
2. The study further contributes to the body of knowledge by incorporating its findings into the creation of a framework (ISM model) that includes multi-dimensional conceptual models that will serve as the foundation for a roadmap for Blockchain technology implementation on construction projects.

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APPENDIX I

Dear respondents,

REQUEST FOR RESEARCH DATA

My name is Victor Odinakachukwu Agbara, and I am a Master of Science Degree Student in Project Management Technology at the Federal University of Technology, Owerri in Imo State, Nigeria. I am presently focusing on my dissertation, which is a necessary component for the degree. "THE BARRIERS TO ADOPTING BLOCKCHAIN TECHNOLOGY ON CONSTRUCTION PROJECTS DELIVERY" is the title of my research.

Given the nature of the research, I've chosen your company to be one of the organisations that will help me collect data. As a result, the need for this letter requesting your approval and assistance in conducting the survey among your participants.

You have my assurance that I will strictly adhere to the ethics that govern the research process. This study will have no negative consequences for any of your employees who participate.

Thank you in advance for taking the time to consider my request.

With Regards,

Victor Odinakachukwu Agbara.

+2348037509138.

QUESTIONNAIRE

SECTION A: Demographic Information of Respondents

1. Please check just one box indicating why you consent with the given answers.
2. What is your discipline? Engineer Project manager consultant
Quantity Surveyors Architects Builders Estate Surveyors Others
3. What is your Years of Experience as practitioners in the construction industry? 1- 6years 7-11 years 11- 15years 16- 20years Above 20years
4. What is your Educational Qualification? HND/BSc/B.Tech/B.Eng
MBA/MSc/M.Eng PhD
5. What is your Sector of Operation? Public sector Private sector
Public/Private sector

SECTION B: Status and Extent of Utilization of Blockchain Technology

What is the extent of you utilizing Blockchain technology in the delivery of construction projects in your organisation?

1. Never heard of Blockchain
2. Heard of Blockchain but never applied it
3. Applied Blockchain Sparingly
4. Have Applied Blockchain

SECTION C: Barriers Militating against the Adoption and Application of Blockchain technology

To what extent do you agree that the following barriers are militating against the adoption and application of Blockchain technology on construction project delivery?

S/N	BARRIERS	RESPONSE				
		SA	A	N	D	SD
1	Security					
2	Immature Application of Blockchain Technology					
3	Blockchain Technology Characteristics					
4	Scalability and Transaction Capability of Blockchain					
5	Bandwidth and Connectivity					
6	High Investment in Blockchain-based Systems					
7	Absence of Regulations, Legislation and Global Standard					
8	Resistance to Change					

Thank you for your time and patience.

APPENDIX II

KREJCIE AND MORGAN TABLE

Table for Determining Sample Size for a Given Population									
N	S	N	S	N	S	N	S	N	S
10	10	100	80	280	162	800	260	2800	338
15	14	110	86	290	165	850	265	3000	341
20	19	120	92	300	169	900	269	3500	246
25	24	130	97	320	175	950	274	4000	351
30	28	140	103	340	181	1000	278	4500	351
35	32	150	108	360	186	1100	285	5000	357
40	36	160	113	380	181	1200	291	6000	361
45	40	180	118	400	196	1300	297	7000	364
50	44	190	123	420	201	1400	302	8000	367
55	48	200	127	440	205	1500	306	9000	368
60	52	210	132	460	210	1600	310	10000	373
65	56	220	136	480	214	1700	313	15000	375
70	59	230	140	500	217	1800	317	20000	377
75	63	240	144	550	225	1900	320	30000	379
80	66	250	148	600	234	2000	322	40000	380
85	70	260	152	650	242	2200	327	50000	381
90	73	270	155	700	248	2400	331	75000	382
95	76	270	159	750	256	2600	335	100000	384

Note: "N" is population size
"S" is sample size.

Source: Krejcie & Morgan, 1970

APPENDIX III

Raw Data Set in A,X,V,O that Transformed into that of Appendix IV

S/N	Variables	8	7	6	5	4	3	2	1
		RC	AR	HI	BC	ST	BT	IA	SE
1	SE	V	V	V	V	V	V	V	X
2	IA	A	V	V	V	X	V	X	
3	BT	A	V	A	V	A	X		
4	ST	A	V	V	V	X			
5	BC	A	X	A	X				
6	HI	A	V	X					
7	AR	A	X						
8	RC	X							

APPENDIX IV
Raw Data Set for ISM

S/N	SE	IA	BT	ST	BC	HI	AR	RC
1	1	1	1	1	1	1	1	1
2	0	1	1	1	1	1	1	0
3	0	0	1	0	1	0	1	0
4	0	1	1	1	1	1	1	0
5	0	1	0	0	1	0	1	0
6	0	0	1	0	1	1	1	0
7	0	0	0	0	1	0	1	0
8	0	1	1	1	1	1	1	1
9	0	1	1	1	1	0	1	0
10	0	0	0	0	1	0	1	1
11	0	0	1	0	1	0	1	0
12	0	0	0	0	1	1	1	0
13	0	1	1	1	1	0	1	0
14	0	1	1	1	1	1	1	0
15	0	0	0	0	1	0	1	0
16	0	1	0	0	1	1	1	0
17	0	1	1	0	1	1	1	1
18	0	1	0	0	1	0	1	0
19	1	1	1	1	1	1	1	0
20	0	1	0	0	1	1	1	1
21	0	1	1	0	1	0	1	0
22	1	1	0	0	1	0	1	1
23	1	1	1	1	1	1	0	0

