Enhancing the Sustainable Supply Chain in Nigeria's Real Estate Sector: A Blockchain Perspective for Transparency and Traceability

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Abstract

This study investigates the impact of blockchain technology on sustainable real estate supply chain management, specifically focusing on material traceability and transparency . The findings highlight the importance of considering blockchain as a viable solution for enhancing material traceability and transparency in sustainable real estate supply chains as panacea for preventing incessant building collapse in Nigeria. The study contributes to the understanding of blockchain technology's role in real estate supply chain management and provides insights for industry practitioners, policymakers, and researchers. In this study, a quantitative approach was employed, which included distributing a questionnaire to 300 participants representing various sectors within the real estate industry. Out of the total, 235 responses were received. A regression analysis was conducted to examine the impact of blockchain technology on material traceability and transparency in real estate supply chain. The regression analysis showed a statistically significant positive relationship ($\beta = 0.347$, $p < 0.005$), and ($\beta = 0.358$, $p < 0.005$) indicating that the adoption of blockchain technology has significant impact on improving material traceability and transparency respectively. While challenges exist in the use of blockchain, such as scalability, future work should focus on practical implementation through pilot projects and the development of standardised protocols. It is recommended that industry stakeholders collaborate with regulatory bodies to establish guidelines and standards specific to blockchain implementation in the real estate sector in Nigeria.

1. Introduction

The real estate industry has been identified to foster economic growth and prosperity in Nigeria. The growth in the sector has been unprecedented such that there is a considerable return on investment in the sector . For instance, the Nigerian real estate industry was reported to contribute over UK £84,031.22bn to the economy between 2016 to 2020 , accounting for 24.5% increase in compound annual growth rate (CAGR) [1].

Despite notable developments in the real estate sector, the housing market has been undersupplied, with a large gap between the demand for housing and the number of available units. According to [2], Nigeria needs more than 700,000 housing units annually to offset the housing deficit and provide suitable accommodation for the populace. This has resulted in high demand for housing , increase in property development, which in turn has led to an increased demand for building materials. Unfortunately, the high costs of building materials, combined with the lack of government support for housing development, have made it difficult for developers to obtain financing for their projects[3]. As such, some real estate companies use cheaper and lower quality building materials to reduce costs, resulting in structural deficiencies and safety hazards in buildings.

The lack of material traceability mechanism to verify origin, movement and quality of building materials within the real estate supply chain process directly impacts the sustainability and safety of building in Nigeria. In addition, the insufficient transparency and traceability practice in the sector encourages unauthorised alteration of approved building plans, contributing to building collapse in Nigeria. Most importantly, the inadequate government policies and law enforcement further exacerbates the challenges of unauthorised modification to building plans, production, importation and usage of substandard building materials in Nigeria [4]. Consequently, an average of 167 buildings collapsed between 2000 and 2021. This has caused displacement of over 6000 residents with a total estimated loss of £2.5million assets (see Figure 1) [5].

This implies that the challenges in the real estate supply chain in Nigeria demands a novel technology that can ensure material quality, sustainability and traceability. In retrospect, [6] identified blockchain as a novel technology suitable to enhance traceability and transparency for supply chain management. Blockchain technology is a decentralised and distributed ledger system that can be utilised in web 4.0 applications. It has the potential to promote compliance with approved building plan and sourcing building materials that could meet industry standards on quality and sustainability [7].

 | DOI: 10.20533/ijicr.2042.4655.2024.0150

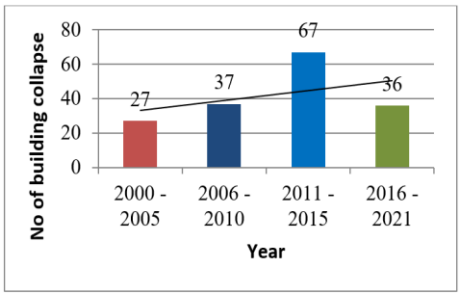

Figure 1. Record of Building Collapse in Lagos state

Empirical studies [8], [9] have examined potential ability of blockchain technology in promoting traceability and transparency in supply chain management . For instance, [10] used Delphi technique to examine the efficiency of blockchain technology in promoting material traceability and transparency in supply chain management . The authors opined that blockchain technology has the integrated features that could minimise risk exposure emanating from material quality deficiency in the supply chain loop which invariably could mitigate building collapse if adopted in the real estate sector.

However, closer assessment of most studies on blockchain technology shows that many researchers focused more on tokenization, land registration, benefits and challenges in real estate sector with limited studies on the use of blockchain for material traceability and transparency in real estate supply chain management. Moreover, considering the potential capability of blockchain technology , there is a need to examine its application in preventing building collapse with peculiarity to transparency and traceability features of the technology. Thus, this study examines the traceability and transparency capabilities of blockchain to enhance real estate sustainable supply chain process as a way to mitigate building collapse and enforce compliance with government policy on sustainable building materials and design in Nigeria. The research questions are as noted below:

R1: Does blockchain technology have impact on material traceability ?

R2: Does blockchain have any effect on sustainable supply chain transparency?

R3: can adoption of blockchain technology in sustainable supply chain prevent building collapse in Nigeria?

2. Blockchain adoption theory

There are various proposed theories on blockchain technology adoption in supply chain management. Some prominent theories include Technology Adoption Model, Diffusion of Innovation and Unified Theory of Acceptance Model . This paper adopts the Technology-Organisation-Environment (TOE) Framework developed by [11] because of its comprehensive analysis of internal and external factors and its suitable application to the real estate sector.

2.1. Technological dimension

The technology dimension attributes adoption of a new technology by users to the technical specifications, compatibility to organisation's operations, complexity of deployment, security concerns, relative advantage and potential benefits [12]. In order words, a simplified user interface, the ease of use and ability of stakeholders to achieve enhanced traceability, reduce cost, improve decision making and transparency in supply chain can facilitate the adoption blockchain technology. In contrast, the user's perception that blockchain application is complicated and non-user friendly may have a significant negative effect on the adoption.

In Nigeria, most real estate actors have knowledge about the perceived usefulness of blockchain technology, however, the adoption level is low because of the technology complexity, security concerns and high technical requirements.

2.2. Organisational dimension

The organisation dimension assesses internal factors like upper management support, managerial obstacles, upper management commitment and cost consideration. As noted, the degree to which top executives understand the functionality, importance and application of blockchain in SSCM would determine the adoption [13]. With this understanding, executives are likely to be committed by releasing resources to achieve the desired goal . In contrast, top executives may not adopt the blockchain technology if the capital outlay is high or the adoption will cause disruption to organisation's strategic business process and goals [14].

In Nigeria, the high cost of deploying blockchain technology in real estate sector has been a major obstacle in outright adoption. Nonetheless, organisations like HouseAfrica, and Purple Real Estate are disrupting Nigeria's real estate ecosystem using blockchain technology.

2.3. Environmental dimension

The environmental component of the TOE framework considers external factors in blockchain technology adoption. In this context, government policies, regulations, carbon budgets, consumer pressure for safety of lives and property are constructs for this dimension [15]. For instance, policies mandating the use of blockchain technology for

 | DOI: 10.20533/ijicr.2042.4655.2024.0150

property construction and traceability of building material could foster blockchain technology adoption.

3. Overview of real estate sector in Nigeria

The Nigeria real estate has been characterised as an economic catalyst for more than a decade. According to [16], the real estate sector contributed an average share of 7.6 % and 7.2% to the average Gross Domestic Product (GDP) between 2009 -2009 and 2010 to 2018 respectively (See Figure 2). Aside the contribution to GDP in Nigeria, the real estate sector has been identified as a main source of job creation. The real estate sector created jobs for more than 7 million young people across the value chain between 2010 to 2017 [17].

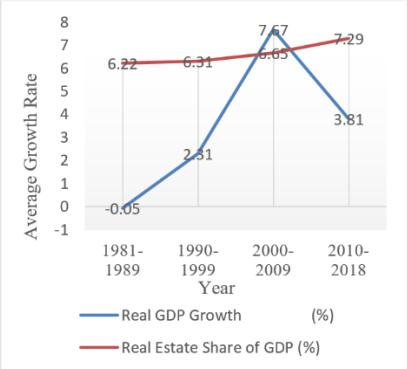

Figure 2. Real Estate Share of Nigeria GDP (%) from 1981 -2018

However, Nigeria's housing deficit is estimated to be 22 million while the sector is underfinanced since 1982 [18]. To boost the sector growth and reduce the prominent housing deficit , the real estate private players such as Purple Urban Limited and UACN Property Development Company PLC (UPDC) are filling the gap with a combined estimated value of £500million Real Estate Investment Trust and bonds issued in 2022. In addition, the Nigeria government assigned N1.4 trillion naira (£1.4 billion) to infrastructural development with a special focus on low-cost housing to bridge the housing deficit gap [19]. Consequently, the increase in demand for housing due to urbanisation and shortfall in financing are creating a wave of unscrupulous activities in the sector such as selection of unqualified lowest bidders to reduce cost and alteration of approved designs, predisposing all parties within the sector to unprecedent dangers.

Most times, all stakeholders including regulators in the real estate sector are aware of the aforementioned issues but tend to distort the supply chain process because of personal gains and conflicting interest. For instance, Fourscore Heights Limited, a real estate firm in Nigeria altered an approved plan for a 4- storey building to construct a 21-story building at Gerrard, Ikoyi, Lagos state in Nigeria without equivalent restructuring and structural reinforcement. The 21- storey building (A in Figure 3), approved by dubious government officials, collapsed on the 1st of November 2021 (B in Figure 3) killing over 46 people including the chief executive officer on site. The rubbles emanating from the collapsed building caused environmental degradation while other buildings by same company failed structural diagnostic test conducted by the Lagos State government [20].

As a safety precaution, the government mandated people in the vicinity to stay at least 45m radius away from the site, causing disruption to social network and community cohesion.

Figure 3. 21-Story Building Collapse in Lagos State

Therefore, it could be deduced that the real estate sector in Nigeria is promising but proactive measure with proven technology must be deployed to ensure safety to life and property.

3.1. Government efforts to promote blockchain technology in Nigeria

To pave way for a thriving digital economy in Nigeria, the federal government inaugurated the National Digital Economy Policy (NDEPS) on the November 28, 2019, focusing on eight (8) pillars: Developmental Regulation, Digital Literacy & Skills, Solid Infrastructure, Service Infrastructure, Digital Services Development & Promotion, Soft Infrastructure, Digital Society & Emerging Technologies and Indigenous Content Development & Adoption.

The Federal Ministry of Communications and Digital Economy has been instrumental in implementing the N-DEPS, developing twenty national policies and laws. These include significant policies such as the National Policy on Fifth Generation (5G) Networks for Nigeria's Digital Economy, the National Policy for the Establishment and Management of the National Centre for Artificial Intelligence and Robotics (NCAIR); and the National Digital Innovation & Entrepreneurship Policy.

 | DOI: 10.20533/ijicr.2042.4655.2024.0150

In line with the seventh pillar of the N-DEPS, the Nigerian government established the first National Centre for Artificial Intelligence and Robotics (NCAIR) in Africa in 2021. The centre is dedicated to providing capacity building for individuals and organisations in Nigeria, a crucial step towards fostering unprecedented digital economy.

Furthermore, on May 3, 2023, the National Blockchain Policy received federal government official approval. The policy acknowledges the transformative potential of blockchain technology across various sectors including finance, governance and supply chain management.

Specifically highlighted in Paragraph 4.3.2 : Government and Corporate Digital Services is the emphasis on adopting blockchain technology to address challenges in land registration and procurement. Sub section (ii) proposes the utilisation of blockchain technology for land registry to prevent single entry and fraudulent practices within the real estate sector. Similarly, subsection (iii) focuses on the integration of blockchain technology in ensuring supply chain transparency, traceability and accountability [21].

3.2. Concept of sustainable supply chain

Supply chain involves network of goods and services including intermediaries such as suppliers, manufacturer, distributor, retailer and even the customers. The cluster of intermediaries within the supply chain network usually induce process complexity. [22] using the 12,000 Burj Khalifa construction workers from approximately 100 countries established that the complexity of the supply chain network made it difficult for stakeholders to manage material, cash and information flows in supply chain network (see Figure 4).

The complex nature of the supply chain creates challenges in ensuring material quality and sustainability, which exacerbates the procurement and use of substandard materials in building construction. In response to these challenges, organisations are indeed encouraged to adopt sustainable supply chain practices in the real estate sector [23].

By implementing SSC principles such as responsible sourcing, real estate actors have been geared towards promoting building sustainability and enhancing the social well-being of all stakeholders.

According to [24] , sustainable supply chain (SSC) is a ‘strategic, transparent integration and achievement of an organization’s social, environmental, and economic goals in the systemic coordination of key inter-organisational business processes for improving the long-term economic performance of the individual company and its supply chains’’. Essentially, SSC incorporates the design, measurement, control, and improvement of environmental and social performance of all the organisational activities, resources, and processes that comprise the system of suppliers, contractors, manufacturers, and distributors selected during pre and post construction in real estate sector. Based on the definitions, it could be ascertained that more emphasis is placed on achieving sustainability in real estate supply chain.

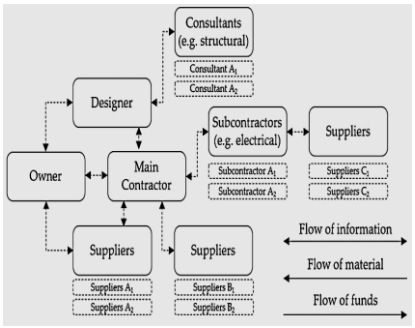

Figure 4. The complexity of real estate supply chain

Sustainability encapsulates the use of organisation’s resources to meet the present needs without jeopardising the future generations’ abilities to meet their own needs [25]. To put it in perspective, [26] asserts that sustainability in supply chain management hinges on a triple bottom line (environmental, social and economic performance) with supporting facets of risk management, transparency, strategy and culture (see Figure 5).

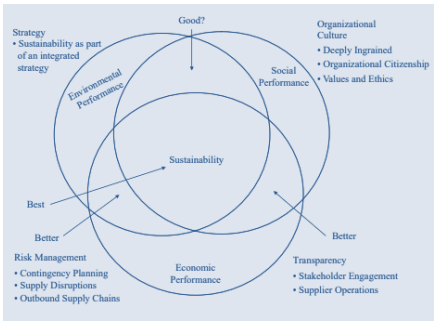

Figure 5. Sustainable supply chain framework

With the integration of the SSC’s bottom line and facets, real estate actors have the tendency to effectively manage risk, foster culture of sustainability, develop strategic approaches and ensure transparency across all the business units and processes.

4. Concept of blockchain technology

Blockchain technology is a decentralised and distributed ledger that records transactions across multiple computers known as nodes. To function on the nodes, blockchain is segregated into blocks to carry transaction data and each block is linked

 | DOI: 10.20533/ijicr.2042.4655.2024.0150

together with a cryptographic hash function (see Figure 6). A cryptographic function is mathematical algorithm that takes an input (data) and converts it into a fixed string of character known as hash value or hash code. The hash function is designed to be a one-way character making it computationally impossible to reverse- engineer the input from the output. The hash function is used to produce a unique identifier for each block in order to reinforce the security and immutability of the data stored on blockchain [27].

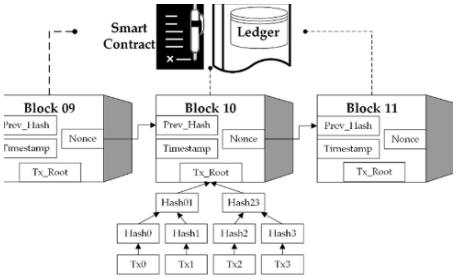

Figure 6. A diagram of blockchain technology

To understand the functionalities of blockchain in SSC, types, challenges features and benefits are examined below based on the work of [28], [29], [30].

4.1. Types of blockchain technology

Blockchain technology is classified based on openness, participation, access control and scalability. The blockchain technology categorised based on openness and participation are *public, consortium and private* blockchain while *sidechains, permissioned and hybrid* blockchains are categorised based on access control and scalability as discussed below;

4.1.1. Public blockchain. This is a blockchain that provides a decentralised, and non-restrictive access to participants of a network. Public blockchain is permissionless, allowing anyone to join the network, participate in the consortium mechanism, access and authorise transactions. This is suitable for sustainable supply chain management because of its open access for all real estate stakeholders. Examples include Ethereum and bitcoin.

4.1.2. Private blockchain. This is a blockchain that provides restricted access to selected actors by an organisation. Private network is usually permissioned and requires approval of system administrator to participate in the network. It is mostly deployed and tailored to a business need, providing a control mechanism and optimising business processes.

4.1.3. Consortium blockchain. This is a blockchain established by a group of organisations with predefined access and maintenance rules for compliance by all the participants.

4.1.4. Permissioned blockchain. Permissioned blockchain requires participants to obtain approval from the blockchain administrator to join and participate in the network. The restricted access provides more control and privacy compared to the public blockchain.

4.1.5. Hybrid blockchain. Hybrid blockchain is the combination of private and public features to enhance flexibility and control. Hybrid allows interoperability of various blockchain networks and exchange of data and digital assets for SSC management. Hybrid provides combined benefits of permissioned and permissionless solutions depending on the business need per time.

4.1.6. Sidechains. Sidechains are independent blockchains connected to a main blockchain. Sidechains often operate alongside the main network to solve scalability issues or perform a specific task without disrupting the main blockchain's performance.

4.2. Limitations to blockchain technology adoption in Nigeria

While blockchain technology has numerous benefits, it also has some challenges. Some of the challenges are discussed below.

4.2.1. Privacy issue. The decentralised nature of blockchain technology allows all stakeholders to access sensitive data transactions within the network. However, this openness may also exposes the system to risk such as competitors disguising as a customer or vendor to gain access to privileged information and potential data breaches leading to manipulation and unethical practices.

This privacy issue could discourage real estate actors from providing consistent information within the network, thereby undermining the effectiveness of blockchain technology in fostering traceability and transparency.

4.2.2. Corrupt practices. Corruption remains a significant obstacle to the integration of innovative technologies in African countries, including Nigeria.

In a case study conducted by [31], officers (actors) overseeing the inspection and approval of agricultural products within the supply chain from Africa to Europe were found to frequently demand facilitation fees and manipulate the blockchain system by inputting inaccurate figures. The authors identified three key issues: skepticism about the security of electronic systems leading to reliance on paper documents, fragmented data impeding judicial effectiveness, and the coexistence of digital and paper practices creating blind spots in data collection.

 | DOI: 10.20533/ijicr.2042.4655.2024.0150

This manipulation, involving inaccurate figures in the blockchain system, driven by corruption, directly threatens the integrity of the supply chain process, raising concerns about the quality and safety of materials and the system. These issues highlighted in the case study can impact the real estate sector in Nigeria. Similar challenges may arise in the procurement of building materials, where actors, including suppliers and inspectors, could engage in corrupt practices, affecting the quality and safety of real estate projects.

Importantly, it is crucial to acknowledge that blockchain technology, like any other technology, follows the principle of 'garbage in, garbage out.' This emphasises that the quality of the input data - free from corruption and inaccuracies- is essential for the technology to produce reliable and meaningful results. If corrupted data is fed into the blockchain system during the approval and compliance processes, it would undermine the blockchain technology's ability to fulfil its intended purpose of ensuring traceability and transparency in the real estate sector.

4.2.3. Epileptic Power Supply. Nigeria's inconsistent electricity infrastructure could significantly hinders the transparent deployment of blockchain technology. The issue of limited grid connectivity, with less accessibility, increases frequent shutdowns caused by failures and load shedding. The national grid reportedly collapsed forty-six times between 2017 to 2023 (see Figure 7) [32].

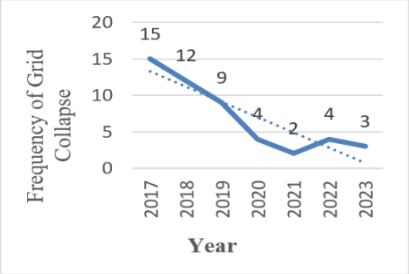

Figure 7. Nigeria grid collapse from 2017-2023

Due to power supply challenges in Nigeria, organisations may face difficulties in implementing complex ledger systems that rely on uninterrupted data flows. Power outages can disrupt essential processes like data capture, timestamping, and the creation of unified datasets necessary for maintaining immutable transparency records [33].

Similarly, the reliance on fossil fuel contingency measures incurs substantial costs. As of December 2023, the cost of one litre of diesel oil is estimated to be £1 (₦1,503), with the possibility of an increase in 2024. On average, organisations may consume more than £15,000 worth of diesel oil within a quarter to keep up with the use of generators and avoid power outages.

In the same vein, there are limitations in the use of solar energy, such as the cost of installation, storage challenges, import dependencies, and, notably, decentralised governance capabilities. For instance, managing and coordinating diverse solar energy installations in a decentralised manner can be challenging and capable of potentially impacting the efficiency and effectiveness of the overall energy system.

4.2.4. Cost Implications. Implementing blockchain technology demands a substantial financial investment. The cost of a blockchain project can vary widely, ranging from an average of £400,000 to several million pounds. The variation is based on project complexity, required features, scale of implementation, chosen technology stack, and other considerations [34].

Beyond the initial setup, ongoing costs involve ensuring data security and personnel training. [35] noted that blockchain transactions may require additional verification processes, such as audits in response to emerging issues. These audits, conducted by auditors or through internal processes, incur labour and capital costs and may involve third-party mediation.

Moreso, blockchain data storage could cost up to £78.56 per gigabyte. In an Hyperledger environment with substantial transactions, annual storage needs for blockchain alone may exceed 197 terabytes i.e. a whooping sum of £15,714,144 per annum [36].

While deploying blockchain for real estate supply chain challenges is feasible, the associated complexities and financial burdens may impact adoption in Nigeria's real estate sector.

4.3 Features and benefits of blockchain technology in real estate sustainable supply chain

4.3.1. Decentralisation. Decentralization refers to the distribution of power and control among multiple stakeholders in the blockchain network, eliminating the need for a central authority. In real estate sector, decentralisation will ensure no single actor has approval capability and control over material sourcing, building plan, regulatory compliance, bill of quantity, structural design, payment and other resources in the supply chain. This will promote trust, eliminating the risk of manipulation or fraudulent activities by providing a shared and transparent platform for all stakeholders [37].

4.3.2. Smart Contract. Smart contracts such as Hyperledger Fabric and Ethereum are self- executing contracts with a pre-defined terms and conditions which are automatically enforced once the conditions are met. To promote an effective SSC, a smart

 | DOI: 10.20533/ijicr.2042.4655.2024.0150

contract can be programmed to verify the authenticity and sustainability certification of a construction material using a pre-defined conditions such as quality, durability, sustainability compliance and texture [38]. If the pre-conditions are met, the smart contract can release the payment to the supplier, promoting the sourcing and use of sustainable building materials and reducing the use of substandard material causing building failure.

In addition, smart contract can be used to streamline and automate various processes in real estate supply chain such as vendor payment, request for quote, vendor qualification, carbon budget, carbon offset, contract agreement, project management, building plan approval, sustainability reporting, structural design, waste disposal and management. With the elimination of intermediaries in the supply chain, a real estate firm will most likely harness relevance advantages such as cost reduction, material efficiency, transparency and accountability [39].

4.3.3. Immutable Ledger. The concept of immutable ledger connotes that data recorded on blockchain is consistent, unalterable and tamper proof [40]. This feature provides high level of data security, integrity and will prevent fraudulent practices such as supplying substandard materials and altering building plans without approval.

4.4. Blockchain and material traceability

Traceability is the tracking of resources during the production and distribution phase of goods and services by different stakeholders including consumers and regulators in supply chain network. The essence of traceability in real estate is to give stakeholders accurate and timely access to information related to the components, originality and status of the building material and other resources in pre- and post -construction. To foster traceability, blockchain technology essentially tracks and verifies the production time, origination and movement of goods in the supply chain . All the data are coded with a time stamp and unique identifier making data immutable for any actor in the supply chain [41].

In addition, blockchain uses a consensus process to confirm the originality , durability and quality of resources in the supply chain. The consensus mechanism ensures that all the stakeholders agree on the accuracy and integrity of the data. Using the consensus mechanism, blockchain helps prevent consistent damage to life and property by ensuring that only verified and trusted information is recorded and used within the system [42].

[43] demonstrated potential of blockchain technology in material traceability. The authors proposed a system with distributed ledger to store and authenticate transactions among partners. The findings connote that blockchain has the feasibility to support traceability and sustainable supply chain.

Furthermore, [44] used a Radio Frequency Identification(RFID) integrated into blockchain technology for proof-of-object-based authentication protocol in food supply chain traceability.

However, material traceability may not be feasible because of the fractional and fragmented components of real estate projects; and if the blockchain tags or identifiers are directly associated with a specific property or project, it can limit their reusability [45]. To overcome this challenge, an RFID can be assigned to an individual component or materials and then assigned a hierarchical structure to trace their assembly into different products. By this, the reusability of identifiers can be sustained while still ensuring effective traceability throughout the supply chain

4.5. Blockchain and transparency

The real estate sector often faces challenges related to poor collaboration, trust issues, delay in payment and fraudulent documentation. These issues have been attributed to regulatory circumvention and lack of quality oversight. Transparency plays a crucial role in addressing these challenges and ensuring seamless real estate supply chain process. Transparency is the degree to which information is consistent between parties involved in the exchange of construction materials and other resources. Transparency is a fundamental factor in assessing the performance of construction resources and individual stakeholders within the supply chain [46].

Blockchain technology can be a powerful tool in achieving transparency in the real estate supply chain. With blockchain, stakeholders can maintain a shared ledger which will record and verify the whole supply chain process. The distributed ledger will allow information about sustainable materials sourcing, certification, originality, payment, waste management, contractual agreement, sustainability and regulatory compliance, and other prominent resources to remain transparent and accessible to all authorised participants [47].

A study by [48] with a sample size of 1000 participants found that transparency plays a crucial role in implementing blockchain within real estate sector in Kosovo as it eliminates information asymmetries.

Nevertheless, it is important to address the challenges of blockchain data interoperability and poor collaboration as they can impact the transparency protocol of blockchain technology. To mitigate these issues, organisations should involve all stakeholders from the design to the implementation of the blockchain technology to foster commitment and collaboration. This inclusive approach can help overcome trust barriers and ensure successful

 | DOI: 10.20533/ijicr.2042.4655.2024.0150

implementation of transparent blockchain system in the real estate sector in Nigeria.

Based on the above reviews, the following hypotheses are formulated:

$\boldsymbol{H_1}$: Blockchain technology has a positive impact on material traceability.

$\boldsymbol{H_2}$: Blockchain technology has a positive impact on supply chain transparency?

$\boldsymbol{H_3}$: Adoption of Blockchain in real estate sustainable supply chain has a potential ability to prevent building collapse?

5. Methodology

The methodology employed for this paper is quantitative design. A total of 300 questionnaires were distributed and 235 correctly filled questionnaires were returned, resulting in valid response rate of 83%. The questionnaire was designed to gather data relevant to the hypotheses testing, using a five Likert scale point ranging from strongly disagree (1) to strongly agree (5). Regression analysis was conducted to establish the relationship between blockchain technology and material traceability and transparency in SSC using SPSS.

6. Discussions and Findings

Figure 8 presents the age distribution of the respondents. The majority of respondents fall into the age groups of 20-30years (29%) and 31-40years (40%) while 41-50years (20%) and above 50years (11%) represent the minority group.

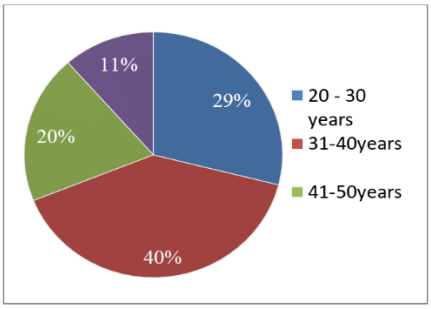

Figure 8. Frequency Distribution By Age

Figure 9 presents the profession distribution information of the respondent. The frequency distribution of the respondent are real estate developers (66) 28%; architect (53) 23%; contractor (42) 18%; material supplier (31) 13%; government official (18) 8%; IT Specialist (14) 6% and others (11) 5%.

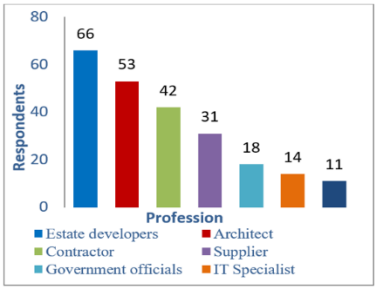

Figure 9. Frequency Distribution by profession

In Table 1, we present the frequency distribution of H_1 hypothesis. The table shows that (14) 5.96% strongly disagree, (19) 8.09% disagree, (24) 10.21% were neutral, (97) 41.28% agree and (81) 34.47% strongly agree that Blockchain technology has positive impact on real estate material traceability.

H_1: Blockchain technology has positive impact on real estate material traceability

Table 1. Frequency analysis of question 1

	Frequency	Percentage
Strongly Disagree	19	8.10%
Disagree	29	12.30%
Neutral	37	15.70%
Agree	75	31.90%
Strongly Agree	75	31.90%
Total	235	100%

In Table 2, we present the frequency distribution of H_2. The distribution shows that (15) 6.38% strongly disagree, (25) 10.64% disagree, (14) 5.96% were neutral, (105) 44.68% agree and (76) 32.34% strongly agree that Blockchain technology has a positive impact on real estate supply chain transparency.

H_2: Blockchain technology has positive impact on real estate supply chain transparency

Table 2. Frequency analysis of question 2

	Frequency	Percentage
Strongly Disagree	20	8.50%
Disagree	35	14.90%
Neutral	27	11.50%
Agree	83	35.30%
Strongly Agree	70	29.80%
Total	235	100%

In Table 3, we present the frequency distribution of H_3. The distribution shows that (12) 8.00% strongly

 | DOI: 10.20533/ijicr.2042.4655.2024.0150

disagree, (23) 15.33% disagree, (9) 6.00% were neutral, (78) 52% agree and (28) 18.67% strongly agree that the adoption of Blockchain technology in real estate sustainable supply chain have a potential ability to prevent building collapse.

H_3: Adoption of Blockchain in real estate sustainable supply chain has potential ability to prevent building collapse

Table 3. Frequency analysis of question 3

	Frequency	Percentage
Strongly Disagree	**17**	**7.20%**
Disagree	**34**	**14.50%**
Neutral	**41**	**17.40%**
Agree	**72**	**30.60%**
Strongly Agree	**71**	**30.20%**
Total	**235**	**100%**

Table 4. Regression analysis

Regression Statistics	
Multiple R	**.900[a]**
R Square	**.811**
Adjusted R Square	**.808**
Standard Error	**.3328**
Observations	**235**

a. Predictors: (Constant), H3, H1, H2

The regression results above established that blockchain has a significant positive impact on material traceability, sustainable supply chain transparency and prevention of building collapse. The multiple R value of 0.900 signifies a strong positive relationship among the variables while the R square value of 0.811 indicates that 81.1% of the variable's variance is explained by the selected factors. The adjusted R square, closely mirroring R square at 0.808, highlights the model's efficacy without undue complexity. The low standard error (0.3328) establishes the model's accuracy in predicting outcomes.

ANOVA[a]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	109.690	3	36.563	330.174	.000[b]
	Residual	25.581	231	.111		
	Total	135.271	234			

a. Dependent Variable: Blockchain
b. Predictors: (Constant), H3, H1, H2

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.782	.072		24.780	.000
	H1	.208	.027	.347	7.755	.000
	H2	.212	.030	.358	7.074	.000
	H3	.170	.032	.280	5.319	.000

a. Dependent Variable: Blockchain

Note: Standardized Coefficient (β) & Standard Error (Std. Error)

The ANOVA results, with a high F-statistic of 330.174 and significant low p-value (<0.005) suggest that the inclusion of predictors (H1, H2, H3) significantly contributes to explaining the variance in blockchain technology. This supports the hypotheses that the blockchain adoption in the real estate sustainable supply chain has a preventive potential on building collapse. Also, the regression coefficients present intriguing insights into the examined model. The significant intercept at 1.782 (t = 24.780, p-value < 0.005) indicates that in the absence of predictor variables, there is a substantial positive baseline impact. Meanwhile, H1 has a regression coefficient (B) of 0.208, a standard error (SE) of 0.027, β-value of 0.347 and a t-value of 7.755 (p-value <0.005) implying a potential impact therefore indicates that blockchain technology impact material traceability. H2, has a regression coefficient (B) of 0.212, standard error (SE) of 0.030, β-value of 0.358 and a t-value of 7.074 (p-value <0.005), this indicate that blockchain technology impact supply chain technology.

Similarly, for H3, the regression coefficient (B) is 0.170, standard error (SE) of 0.032, β-value of 0.280 and a t-value of 5.319 (p-value <0.005) indicating that the adoption of blockchain in real estate supply chain has a potential ability to prevent building collapse.

These findings indicate that the adoption and use of blockchain technology has a significant positive impact on real estate materials traceability and supply chain transparency which is similar to the finding of [49] who asserts that blockchain technology has a significant impact on material traceability and transparency.

The coefficients suggest that increased use of blockchain technology in real estate may likely result in a corresponding increase in traceability and supply chain transparency. These findings have significant ramifications for Nigeria's real estate market and through the use of decentralized, irreversible ledgers, stakeholders can increase the tracking and monitoring of construction materials, increase transparency and encourage accountability with the use of automated verification processes and smart contracts.

 | DOI: 10.20533/ijicr.2042.4655.2024.0150

7. Conclusion

Blockchain technology holds great promise for enhancing sustainable supply chain management and preventing building collapse in Nigeria. The key features of transparency, immutability, smart contracts, and consensus mechanisms provide a solid foundation for improving traceability and transparency in the real estate sector. However, the actualization of this technological potential is contingent upon the robustness of surrounding institutional structures, prevailing behavioural practices, and infrastructure readiness. In isolation, blockchain runs the risk of being a peripheral digital remedy, potentially concealing rather than transforming deep-seated issues related to governance and ethics.

8. Recommendations

The Nigerian government's 3 Million Technical Talent (3MTT) programme, aimed at training 3 million individuals for the digital economy, is commendable. However, recognizing the potential challenges faced by service providers in Nigeria lacking the capacity to support blockchain technology, we recommend a collaborative effort between the Federal Government, state governments, and key institutions to establish National Centres for Artificial Intelligence and Robotics across states. These centres should operate on renewable energy to reduce energy costs and ensure uninterrupted operations during development and maintenance processes.

Fully equipped with state-of-the-art infrastructure, the centres could offer shared access to cutting-edge technologies as a way to mitigate upfront costs for developers and promote a collaborative learning environment. Most importantly, the centralised nature of these facilities would also facilitate resource-sharing especially in terms of storage infrastructure, offering cost-effective solutions for data storage and management.

Moreover, by providing aspiring young developers with training opportunities at a centralised location, the centres can offer a more cost-effective approach to learning blockchain development.

To address corruption, it is recommended that industry stakeholders collaborate with regulatory bodies to establish guidelines and standards specific to blockchain implementation in the real estate sector. This will foster consistency, promote widespread adoption, and create a supportive ecosystem for the successful integration of blockchain technology in sustainable supply chain management and building safety in Nigeria. Most importantly, the government should introduce oversight similar to the practices adopted in accounting audits. To assess full compliance with global accounting standards and internal policies, many government bodies and organisations employ the services of international audit firms such as PricewaterhouseCoopers and Ernst & Young.

To enhance transparency and accountability, the government could engage external independent auditors to conduct physical audits. These audits would involve validating information logged on the blockchain technology by real estate actors against the physical assessments of compliance with building plan approvals, structural tests, and material standards.

The awareness of potential oversight will encourage compliance among various stakeholders. Auditors from countries like the UK, Europe, Canada, or Asia should be considered to enhance impartiality. This is crucial as internal malpractices due to corruption may remain unaddressed if conducted solely by Nigerian entities.

9. Future work

In proposing future research, we plan to conduct a longitudinal impact assessment that will involve tracking transparency and accountability improvements. Pilot blockchain platforms deployed among large- and small-scale real estate organisations in Lagos and Abuja will be scrutinised using metrics focusing on structural integrity, material quality, information exchange and government approvals. This assessment aims to provide insight into the sustained impact of blockchain traceability and transparency capabilities.

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