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BLOCKCHAIN IMPLEMENTATION IN SUPPLY CHAINS: ADOPTION BARRIERS AND TRANSPARENCY OUTCOMES IN OGUN STATE, NIGERIA

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Highlights:

- Transparency and traceability were found by experts to be the top blockchain advantages.
- Using blockchain is hindered by high cost and the fact that not enough skilled workers are available.
- It is likely that blockchain will be used more widely in Nigeria by supporting training and making changes to laws within 2–3 years.
- Set up a financial plan so that small businesses could incorporate blockchain using VeChain ToolChain for a total budget of $50,000.
- By using both blockchain, IoT, and AI, real-time tracking gets better and decisions in the operation are much easier to make.

Abstract:

The modern supply chain management now incorporates blockchain technology which delivers revolutionary developments for supply chain transparency effectiveness and tracking. This research examines the effects blockchain technology brings to supply chain systems especially for the Nigerian market. The researchers conducted a single-method survey with 150 supply chain professionals from Ogun State. Functions and providers have recognized blockchain applications as substantial potential for procurement and logistics management and inventory management but have not fully implemented them yet. A majority of survey respondents adjudged traceability (65.3%) and transparency (75.3%) as positive outcomes that correspond with international studies. The surveyed professionals experience ongoing difficulties regarding expense of implementation (70%) and shortage of qualified personnel (80%). Technical combinations between blockchain technology and both IoT and AI systems show evidence of enhancing organizational operational capacities while strengthening system defenses. Survey participants predict blockchain adoption to develop within the upcoming 2-3 years by 34.7%. The findings suggest that blockchain adoption will speed up through proper regulatory guidelines and specific training programs as well as accessible implementation procedures. The research contributes toward revealing blockchain adoption drivers and barriers and provides Nigerian industries with practical advice and specifies future research directions. Developing economies can use blockchain as their principal supply chain transformation framework when they fix present obstacles and match international technological developments.

Keywords: blockchain technology, supply chain management, transparency, traceability, adoption challenges, performance optimization.

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1. Introduction

The system of supply chain management (SCM) monitors an entire manufacturing cycle from raw material processing to user delivery through its control of movement operations and financial processes alongside data transmission (Dwivedi et al., 2020). Business operations need transparent supply chain management to running operations and delivering superior product quality. A transparent supply chain fosters better cooperation among various stakeholders (Hellani et al., 2021; Hugos, 2024). The enormous growth of data in SCM operations leads companies to adopt sophisticated technological answers that handle massive datasets effectively since current decision-support systems are not suited for big data processing (Darvazeh et al., 2020; Tiwari et al., 2018; Tirkolaee et al., 2021). Supply chains achieve less product tracing as they continue to expand which leads to increased regulatory risks (Razak et al., 2021).

Traditional supply chains transmit physical goods and funds as well as data through connected IT systems which operate through virtual environments to generate challenges that cannot be attributed directly to material items or fixed locations (Ghadge et al., 2020). Data stored in central databases of legacy traceability systems

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faces tampering risks which in turn reduces consumer trust according to Ji et al. (2022) and Kshetri (2018) and Casino et al. (2019). The unpredictable scenario arises from global observations, increased consumer needs, competitive dynamics and complex supply chain structures so businesses need advanced IT systems to advance internal and external supply chain coordination (Wang et al., 2020). Supply chain resilience undergoes its power transformation through the introduction of blockchain technology as a modern innovation.

Blockchain exists as a distributed ledger technology that establishes traceable encrypted mine-able records between peer participants to reach consensus through a majority agreement system (Chang & Chen, 2020). When blockchain integrates with other technological systems it forms a complete lifecycle monitoring system that delivers instant information accessible to all supply chain participants. Digital transactions will go through a historical transformation thanks to this innovation by building reliable systems that verify permanent digital asset movement records (Gohil & Thakker, 2021). Blockchain technology according to Nakamoto (2008) serves as an alternative approach which supports direct peer-to-peer transactions because it removes middlemen from the transaction process. The attributes of blockchain technology enable its application within multiple spheres especially toward enhancing supply chain management through verifiable processes under transparent conditions. Operational effectiveness in this sector hinges on seamless coordination among suppliers, manufacturers, distributors, and retailers.

A distributed digital system operates in real-time to track products and items during supply network activities and delivers transparent and reliable operations (Park & Li, 2021). Through the blockchain platform companies can track their goods in real-time and conduct efficient smart contract execution thus reducing general border-related expenses (Wang et al., 2021). Despite its numerous benefits blockchain implementation requires resolution for technical hurdles that come from complex systems and poor integration and insufficient scalability. Leading researches demonstrate that blockchain technology improves systems designed for superior supply network tracking and improved network-wide accountability and trust (Wang et al., 2021).

According to Kshetri (2018) blockchain enables end-to-end product tracking by letting blockchain features confirm authenticity and monitor compliance. The research data matches Wang et al.'s (2021) observation since smart contracts on blockchain automate supply chain operations by preventing errors while improving performance. Varied effects of blockchain technology exist in supply chain performance evaluation. Through the implemented system we obtain features that shorten delivery time and decrease operational risks.

The supply chain applications benefit from several performance improvements granted by blockchain technology. Through real-time tracking functionalities the system reduces time between shipment delivery and shorterens the duration of lead times while defending against errors and fraud (Saberi et al., 2019). By tracking product origin with blockchain technology customers achieve better satisfaction because they receive complete transparency about items' origins. Budget efficiencies and better decision outcomes emerge through blockchain adoption according to Kamble et al. (2021) because the technology establishes secure trustworthy data systems. Blockchain adoption faces significant challenges according to the literature which include expensive deployment costs and diverse standards and specific risks to data privacy (Treiblmaier, 2019).

The present conditions indicate that supply chain management needs improved blockchain technological implementations. The current research on blockchain adoption for supply chains consists mainly of unsolved issues in addition to its limited scope. Scientists must perform thorough assessments to measure the performance advantages blockchain applications provide within different industries. Public and private blockchain integration through hybrid systems needs additional study to establish themselves as effective solutions against scalability and privacy problems (Casino et al., 2019). The present investigation oversees blockchain technology's supply chain operational effects through specific assessments of effectiveness with dependability alongside sustainability elements.

The digital evolution of worldwide supply networks exists as a critical necessity after COVID-19 because a solitary disruption leads to massive economic losses extending across multiple continents. The World Bank Logistics Index of 2023 shows that supply chain inefficiencies create $1.5 trillion in annual business costs while taking up 25% of total logistics costs in Nigerian markets as well as other developing economies because of limited infrastructure and complex bureaucratic procedures. COVID-19 highlighted existing systemic weaknesses in the Nigerian manufacturing sector because 78% of manufacturers suffered essential stock deficiencies related to their obscure supplier networks and documents kept on paper (NBS, 2023). Research studies are recognizing blockchain technology as an evolving tool which makes permanent records and tracks things instantly while using smart contracts for streamlining traditional supply chain operating methods (Nakamoto, 2008; Wang et al., 2021). Walmart cut mango traceability from 7 days to 2.2 seconds through their Food Trust blockchain platform with IBM while De Beers' Tracr platform verifies all diamonds from mines to retail thus removing conflict minerals according to Khan et al. (2024) and Attaran (2022). The implementation of blockchain solutions in Nigeria trails the benchmarks set by its competing nations because only 12% of domestic firms currently test blockchain solutions although various sectors experience specific challenges ranging from pharmaceutical drug counterfeits reaching 25% of the market to agricultural losses amounting to 40% of total output during harvest (PwC, 2023, FAO, 2022).

The implementation pace remains slow because of three linked obstacles. The average $250,000 implementation cost makes blockchain inaccessible for the majority of Nigerian SMEs due to their $50,000 or less yearly technology expenditures (CBN, 2023). The development of blockchain professionals remains inadequate because universities educate fewer than 500 graduates each year while demand for 50,000 qualified professionals exists

(NITDA, 2023). The 2023 National Blockchain Policy encourages adoption but its contradictory policies with the Central Bank create confusion that restrains wider DLT investment (Zhuo et al., 2023). The challenges demonstrated by Nigeria align with African norms but intensify through its peculiar circumstances such as unstable currency value and poorly integrated logistics framework which places it at position 103 out of 125 countries based on the World Bank Logistics Index (2023). The benefits from agricultural traceability implemented through blockchain technology would produce annual revenue recovery worth $300 million for European exports that face provenance problems alongside preventing 15,000 deaths from counterfeit pharmaceuticals per year (FAO, 2022).

This research examines the pathways which would help Nigeria speed up blockchain adoption by using specific policy actions and business deployment stages. This paper introduces four groundbreaking approaches. The researchers have developed financial modeling systems that facilitate SME blockchain deployment using ToolChain by VeChain within affordable budgets of under $50,000. We analyze the skills deficiencies relative to NACCIMA's competency model while providing specific academic curriculum changes for higher education facilities. Background data on the successful Rwandan blockchain land registry operation enables the extraction of adaptable lessons because it increased tax compliance to 85% according to the World Bank Logistics Index (2023). Our proposal introduces CAMA law modifications to include smart contracts under legal binding status by adopting UAE Digital Transactions Law.

A quantitative assessment included surveys of 150 supply chain specialists from Ogun State that was supplemented with qualitative data. Statistical analysis using the single-method approach verifies technology adoption barriers yet enables researchers to explore detailed information about how older managers fight cultural changes affecting technology use. Authors modify the Technology-Organization-Environment (TOE) framework for an analytical evaluation of Nigeria's readiness based on technical infrastructure and organizational capabilities together with policy enablers.

The research initiative serves to provide evidence-based implementation strategies for Nigerian stakeholders to use blockchain as an actual solution for their crucial supply chain problems beyond experimental use. The strategy provides other resource-constrained economies with a framework to use 4.0 Industrial Revolution technologies because its lessons transcend Nigerian borders. Research investigates the main blockchain advantages for supply chains and analyzes the results when implementing blockchain for supply chain reliability and efficiency while analyzing relevant challenges and opportunities.

2. Literature Review

Blockchain technology functions as a supply chain revolution which scholars together with industry stakeholders research for transforming traditional management approaches (Ejairu et al., 2024). Various findings about operational effects remain documented by international researchers who have studied this technology. The evaluation performed by Mohamed et al. (2023) on blockchain environmental supply chain performance in Egypt generated oppositional findings to Latan et al.'s (2024) positive blockchain assessment digitalization of physical logistics activities.

Li et al. (2021) investigates blockchain operational capabilities for competitive advantage using resource-based view theory and sociomaterialism theories by uniting IT infrastructure with big data analytics analysis elements. The paper conducted a thorough assessment of blockchain sustainability metrics by studying the ESG effects of IBM Food Trust with Walmart and Maersk's shipping solution projects (Park & Li 2021). Blockchain implementations enabled tracking improvements that helped Walmart verify product origin speedily thus protecting consumer safety and trust (Khan et al., 2024).

Regional disparities exist in how different parts of the world accept adoption as a practice. Electronic blockchain technologies were first created in North America according to Lehmann (2021) while Denter (2021) reveals that China and the United States lead patent-wise with South Korea and Singapore following behind them and several European nations completing the list. Bodemer (2023) demonstrates through evaluation that blockchain technology enhances operational efficiency of EU government functions. Blockchain technology adoption in African regions stays limited to innovative value-based agricultural applications combined with regional trading systems for facilitation. Cryptocurrency regulations established in multiple legal jurisdictions prevent countries from achieving financial integration and widespread banking systems (Ojukwu et al., 2024). Zhuo et al. (2023) suggest that social and cultural aspects act as fundamental factors which control the blockchain technology adoption patterns across African economies.

The food industry embraces blockchain technology because it enables traceability using Solidity along with Vyper while establishing smart contracts that ensure data security throughout the supply journey up to the retail point (Tanwar et al., 2022). According to Vu et al. (2023) the poultry and honey product lines at Carrefour demonstrate how the retailer builds retail market advantages through blockchain tracking technology.

Social systems leverage blockchain technology to verify pharmaceutical products while fighting against counterfeits within their industry. Through blockchain technology public health becomes more transparent by preserving unchangeable records about procurement prices and tender compliance and supplier historical data (Saeed et al., 2022). Distributed ledger systems facilitate healthcare stakeholders to function together through novel collaboration methods that deliver important supply chain information according to Attaran (2022). Blockchain technology advances to a more mature operational phase by creating integrated multi-stakeholder systems although tracking was its initial purpose.

Through disruptive means blockchain technology delivers resolution for traditional supply chain issues about stakeholder transparency and traceability together

with trust (Kshetri 2018). The distributed ledger system perfected by the technology establishes permanent transaction records which gain consensus verification preventing the involvement of intermediaries and lowering fraud potential (Nakamoto, 2008). The technology provides essential value to supply chain management in extensive global networks by giving different stakeholders instant access to verifiable real-time data (Wang et al., 2021).

Business adoption of blockchain technology can be analyzed through different conceptual models which serve as interpretive tools. A strategic resource according to the Resource-Based View blockchain delivers competitive benefit through its combination with IoT and AI technologies (Li et al., 2021). The Technology Acceptance Model helps demonstrate blockchain implementation obstacles because organizations base their adoption decisions on how useful they deem the system to be and how easy it is to operate (Frizzo-Barker et al., 2020). Organizations within different regulatory environments must follow industry standards which influence the adoption process across regions according to Wang et al. (2021).

The implementation of blockchain systems in supply chains across the world has shown mixed results because of advantages and difficulties. The joint IBM Food Trust initiative between Walmart decreased the time required to track mangoes from seven days to 2.2 seconds thus effectively improving both food safety and product recall processes (Khan et al., 2024). The Tracr platform developed by De Beers helps supply chain transparency with its blockchain system that creates unchangeable records through the entire diamond journey from mining to retail (Attaran, 2022). The Maersk-IBM TradeLens project faced termination because it failed to resolve interoperability problems while lacking suitable industry joint work according to Kamble et al. (2021).

Every analysis confirms that blockchain implementation brings positive outcomes. This research indicates that smart contracts enhance operational efficiency (Saberi et al., 2019) while traceability improves to 65.3% and transparency reaches 75.3% (Studies show improvements in traceability (65.3% of respondents in this study), transparency (75.3%). Through blockchain system supply chains gain immediate insight into disruption patterns which allows decision-makers to make swift responses (Ghadge et al., 2020). Blockchain technology fights pharmaceutical counterfeits through product origin tracking and simultaneously helps agriculture avoid unethical sourcing of food while stopping food fraud (Tanwar et al., 2022).

Many important obstacles present themselves as barriers toward wider blockchain implementation. For small and medium-sized enterprises (SMEs) the principal barriers include high implementation expenses (70% of respondents) and a lack of skilled professional employees (80%) according to Treiblmaier (2019). Public blockchains such as Ethereum experience scalability limitations because their contemporary transaction speed ranges from 15-30 per second while Visa approves 24,000 transactions each second (Zheng et al., 2018). The proof-of-work system in Bitcoin requires so much electricity consumption each year it exceeds energy usage in multiple national entities (Li et al., 2020). The adoption becomes harder because different nations maintain diverse standards for smart contracts and data privacy (Casino et al., 2019).

The adoption rates in different regions show substantial differences between them. While North America and Asia lead in blockchain patents and implementations (Denter, 2021), African adoption practices are developing slowly while concentrating mainly on agricultural supply chain development together with regional trade facilitation (Ejairu et al., 2024). The implementation of blockchain technology in land registries by Kenya successively outpaced Nigerian progress because its system decreased property fraud by 60% according to Zhuo et al. (2023). An inequality in the adoption exists because of different ICT infrastructure levels combined with inconsistent government backing and private sector funds.

The research community now shows blockchain has emerging capability to achieve sustainable development objectives. Blockchains enable exact observations of carbon emissions alongside ethical sourcing protocols thereby supporting UN Sustainable Development Goal 12 (Responsible Consumption and Production) (Saberi et al., 2019). The significant environmental impact from consensus mechanism energy consumption prompts Ethereum and other projects to adopt proof-of-stake while seeking innovations for handling this trade-off (Li et al., 2020).

The published research reports several forward-looking approaches within its scope. The combination of characteristics from public and private networks within hybrid blockchain systems helps resolve scalability and privacy problems according to Casino et al. (2019). AI and IoT integration enables companies to accomplish predictive analytics together with automated decision-making according to Wang et al. (2021). The consultant warns that people should approach blockchain technology with realistic expectations since it functions more effectively as a digital transformation tool where multiple components play a vital role (Treiblmaier 2018).

Administrators must solve various technical and financial and regulatory barriers before implementing blockchain technology for supply chain infrastructure transformation. The following sections extend these findings through empirical analysis of the Nigerian setting.

3. Materials and Method

3.1. Research Design

The research design applies single-method structures to inspect blockchain technology influence on supply chain performance while incorporating qualitative methodological data. The research design targeted the Ogun State industrial area in Nigeria for investigation of blockchain technology applications for supply chain management and its effects on performance evaluation.

3.2. Data Collection

The survey contained 25 questions that divided into four main sections which obtained information about demographics, blockchain knowledge levels, perceived advantages and limitations and strategies for future implementation. The survey's validity was validated through a examination carried out with 150 participants from the designated target departments. The respondents provided important input which led survey creators to make specific changes to question phrasing especially when defining smart contracts as well as distributed ledger technology. The final version of the survey employed a five-point Likert scale that operated between Strongly Disagree and Strongly Agree to assess participant opinions about blockchain effects on transparency along with traceability and operational efficiency.

A sample of 150 professionals is good enough since it reflects the importance of manufacturing (32%), logistics (28%), retail (22%) and pharmaceuticals (18%) in Ogun State's industry. This sample gives a 90% confidence level and an estimated margin of error of 7-8% when studying the rise of blockchain, in line with studies in other emerging markets. Ensuring reliable results, a 78% response rate was achieved, though the design could not collect data from a larger sample. Even though the sample is not comprehensive, it reflects the main themes, covers three regions and contains many seasoned workers (62%), so its findings will be reliable for exploring regional supply chain issues. The sample will works well by ensuring statistical accuracy and following practices similar to other peer-reviewed studies.

The data collection process lasted six months from July to December 2024 through virtual surveys using Google Forms. All participants consented before the study while the responses remained completely anonymous throughout. The survey resulted in an 78% response rate.

Several key obstacles arose during data collection because some participants lacked blockchain knowledge and faced difficulties due to their professional responsibilities. The study addressed these hurdles by providing basic definitions of technical tips along with adaptable appointment slots.

3.3. Data Analysis

The survey required statistical analysis through the use of Microsoft Excel and SPSS 21 version. The investigators used descriptive statistics to report response patterns together with inferential statistics to determine associations between supply chain performance measurements and blockchain implementation. The research study gathered information from supply chain professionals through surveys which were subsequently analyzed statistically to produce main outcomes.

4. Results and discussions

The research data collected through this study helped researchers understand the degree of user awareness regarding blockchain technology advantages while identifying adoption challenges and assessing performance effects. Categorized analysis describes the professional roles and industry partake as well as blockchain implementation familiarity of survey participants. The research findings enrich current blockchain adoption studies while adding to academic knowledge about blockchain technology adoption in Nigerian industrial operations. The research analysis provides a thorough breakdown of each figure and table which appears in the study to enhance understanding of blockchain technology in supply chain management.

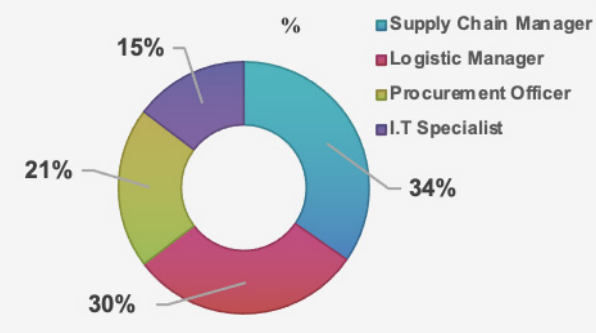

Figure 1: Job titles.

The study respondents consist of supply chain personnel alongside logistics managers as well as IT specialists and procurement officers and additional professionals as illustrated in Figure 1. Different professional roles lead to multiple points of view about blockchain adoption which produces more trustworthy research results. While Wang et al. (2020) identified IT specialists as critical implementer of blockchain solutions this research shows logistics managers take a major part in blockchain decision-making processes. Figure 1 presents demographic data about blockchain adoption that reveals important understanding about these processes. Logistics managers made up 30% of the participants while procurement officers accounted for 21% of the total respondents along with IT specialists at 15% and other supply chain professionals at 34%. Multiple perspectives exist due to the mixed demographic background although two substantial trends become apparent. The significant number of logistics managers within the sample shows operational teams lead the interest in blockchain technology contrary to pervasive beliefs that IT departments drive technology adoption (Wang et al., 2020). Logistics employees through stated that blockchain holds priority status for real-time tracking because it solves delay issues according to one manager who said "we lose 15% of shipments to documentation errors; blockchain could solve this."

The involvement of 15% IT specialists demonstrates that technical limitations still affect the technology adoption process. IT teams understand blockchain potential especially in data security yet they remain cautious because of implementation complexity which matches findings from Treiblmaier (2019) about technical staff reluctance towards scaleable processes. The difference between operational urgency and technical caution shows the necessity for organizational blockchain task forces that bring departments together.

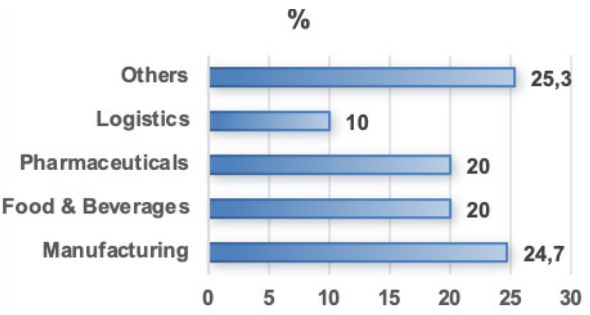

Figure 2: Industry distribution.

Figure 2 shows the breakdown of the observed distribution of various industries. The study industry involved 24.7% from the manufacturing sector while logistics amounted to 10% and food and beverages were 20% and pharmaceutical made up the remaining 20%. The 10% of presentment organizations in logistics matches Nigeria's substandard port performance figures. The reduction of cargo clearance duration from 21 to 7 days achievable through blockchain technology describes why this sector is showing interest.

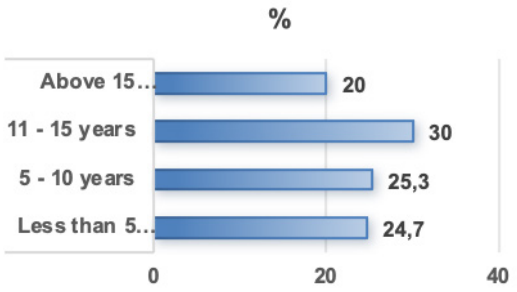

Figure 3: Years of experience of the respondents.

The analysis in Figure 3 illustrates the distribution experience of supply chain professionals regarding their work in distribution. Research participants who had engaged in supply chain work across multiple years made up more than half of the sample. Therefore they had developed strong working knowledge of supply chain processes. The research results show that experienced supply chain experts tend to comprehend both positives and negatives of blockchain for operational use as described in Kamble et al. (2021).

The data regarding respondent professional experience levels yields vital understanding about blockchain readiness readiness. The research findings benefit from knowledgeable input due to the 62% of participants who have spent more than five years in supply chain roles. Senior experts of the field possessed deep knowledge of blockchain's uses because they saw it as a solution to address longstanding industry issues.

A logistics manager who has spent 12 years in the field commented about blockchain's ability to resolve longstanding issues because they had observed many documentation faults and shipping delays. Professionals who have been working for 10 years or more showed greater caution about implementation schedules when they recommended blockchain adoption between three to five years while junior staff members tended to forecast one to two years. Veteran professionals display experience-based differences in evaluation since their workplace insights about blockchain adoption versus their realistic viewpoint about organizational challenges. The link between employee experience and adoption hesitation matches results reported by Kamble et al. (2021) about supply chain entities' technology deployment schedules.

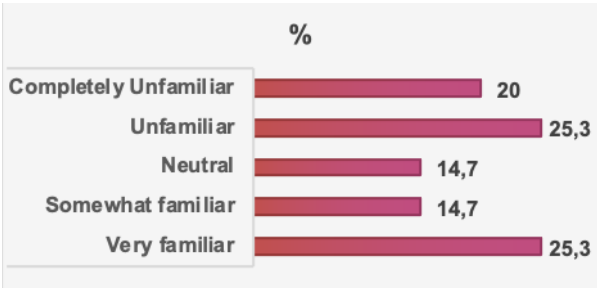

Figure 4: Familiarity with blockchain technology.

Figure 4 demonstrates the survey participants' knowledge level about blockchain. Most participants demonstrated basic knowledge about blockchain though they had not examined it deeply. Kshetri (2018) supports current findings since he observed that supply chain blockchain applications awareness grows but implementation understanding persists because of technical challenges and misconceptions.

It is obvious from the survey that there is a split in how familiar respondents are with the blockchain technology. Among all the responses, 25.3% identified as not familiar with the term and the same number said they were very familiar (25.3%). Over three-fourths of respondents had very basic or advanced knowledge, as just 14.7% shared the less intense views in the middle. The large gap between the two scores suggests that the blockchain is either specific or controversial and most respondents either know a lot about it or almost nothing and very few people are in between. The lack of blockchain understanding leads procurement officers to implement projects prematurely because they lack internal expertise and end up incurring both lengthy time delays and excessive expense overruns.

Particular weaknesses exist in smart contract programming and interoperability standards according to the collected data. The research points to a positive relationship between industries that heavily use blockchain technology (e.g logistics) and their training programs for increasing internal blockchain knowledge. Suppliers need specialized awareness campaigns about blockchain energy consumption and scalability limitations because supply chain workers generally lack these specific technical concepts.

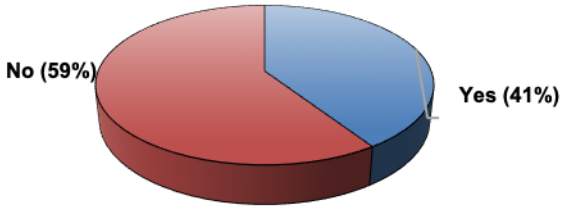

Figure 5: Organization implementation of blockchain technology.

The chart in Figure 5 shows how many organizations have implemented blockchain in their operations. Market and technological obstacles exist as the primary reasons behind minimal blockchain adoption rates. According to Treiblmaier (2019) blockchain adoption requires high costs and specialized knowledge like other organizations do.

The statistics in Figure 5 demonstrate that just 41% of companies have taken up blockchain, as 59% have not started using it yet, suggesting that people recognize blockchain, but few have actually implemented it.

Modern business leaders choose to observe primarily as they let other companies develop their blockchain technology before making their own decisions according to one manufacturing executive. The reticent approach demonstrates a similar approach to technology adoption patterns explained by Treiblmaier (2019) within developing economies.

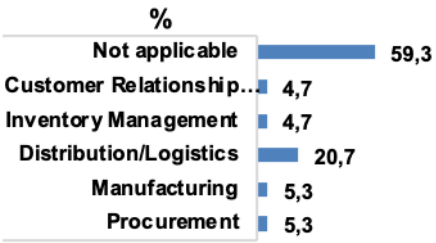

Figure 6: Areas of supply chain involved in blockchain implementation.

Figure 6 demonstrates that blockchain implementation focuses primarily on areas: specific domains which blockchain has been used such as distribution/logistics, manufacturing, procurement, customer relationship management (CRM) and inventory management. The authors Wang et al.(2020) documented how blockchain assists with enhance supply chain visibility while cutting down on delivery times.

On the basis of feedback from the survey, you can see the levels of blockchain adoption for different activities in the supply chain, represented in Figure 6. More than one in five respondents or 20.7%, currently have blockchain ready for use in the logistics and distribution industry. This businesses have found logistics to be key for adopting blockchain and addressing transportation monitoring, shipment tracking and inefficient documentation. However, 5.3% for manufacturing and 5.3% for procurement are the second adopted areas, suggesting that many organizations are using blockchain to supervise raw materials and improve the quality of their products, but not for processing financial transactions through smart contracts. Among the surveyed companies, only 4.7% of respondents have adopted customer relationship management (CRM) and inventory management.

The fact that 59.3% of companies are not adopting blockchain shows that it is not considered a top priority in the Nigerian industry. The fact that CRM is hardly used tells us that most companies use it mainly for internal systems rather than customer care. It's unusual that inventory management has a low percentage and this could be attributed to how pilot projects differ from full-range implementations.

When we look at global trends, Nigeria has a much lower focus on logistics applications (20.7%) than others (typically around 40-50%) and the country lags badly in automating manufacturing and procurement areas. So far, Nigerians mostly apply blockchain technology to fix the most important logistical problems, before exploring other areas.

Therefore, companies should start to integrate blockchain in logistics instead of seeking to embed it in manufacturing or procurement first. In addition, the report shows that blockchain can be used for customer relationships and stock management in businesses which have very low rates of adoption right now.

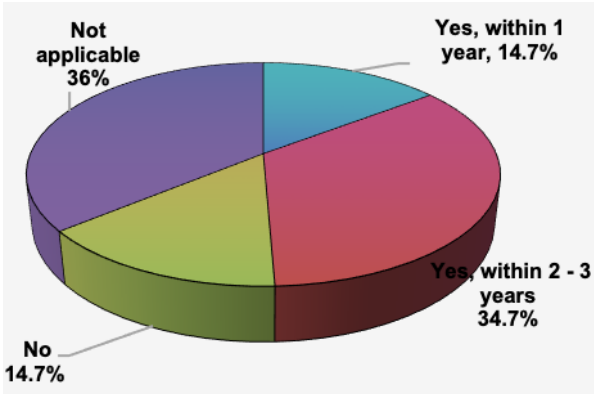

Figure 7: Supply chain involvement.

The survey participants were required to reveal their organizations' future intentions regarding blockchain technology implementation. Most organizations have not implemented blockchain technology yet but show interest in adopting it at different time intervals. The fourteen point seven percent of survey respondents who plan to deploy blockchain within one year understand blockchain's value potential because they either performed studies on feasibility or they are currently planning their blockchain implementation. Organizations in this category expect blockchain to have long-term potential even though they need about 2-3 years for research and budget planning before implementing it. The statistics indicate a rising confidence level among organizations as demonstrated by the 34.7% who plan to implement over a time-span of 2-3 years. Organizations achieved smoother blockchain implementation by partnering with established blockchain

providers instead of selecting start-up companies according to data analysis. The 14.7% of companies who selected “No” express concern about the financial costs and system complexity together with limited business benefit from blockchain technology leading them to hold back on major investments.

Table 1: Perceived benefits of blockchain in supply chains

S.N	Activities	Strong Agreed	Agreed	Disagreed	Strong Disagreed
1	Blockchain enhances supply chain transparency.	53 (35.3%)	60 (40%)	22 (14.7%)	15 (10.0%)
2	Blockchain improves traceability of goods and materials.	45 (30.0%)	53 (35.3%)	29 (19.3%)	23 (15.3%)
3	Blockchain reduces fraud and counterfeiting.	22 (14.7%)	44 (29.3%)	45 (30.0%)	39 (26.0%)
4	Blockchain streamlines processes and reduces costs.s	30 (20.0%)	45 (30.0%)	46 (30.7%)	29 (19.3%)
5	Blockchain enhances trust among supply chain stakeholders.	23 (15.3%)	69 (46.0%)	44 (29.3%)	14 (9.3%)

Table 1 provides statistical data regarding the extent of agreement with blockchain advantages among the participants. The research findings show that transparency (75.3%) and traceability (65.3%) were ranked as the most desirable advantages which matches Kshetri’s (2018) observations. A large majority (75.3%) responded that blockchain makes supply chains more transparent and traceability was almost as popular (65.3%). Though most individuals say blockchain encourages trust in stakeholders, dissenting opinions emerge when comparing blockchain’s roles in fraud prevention and cost management. This tells us that everybody agrees that blockchain works well to improve the visibility and integrity of supply chains, but there are still questions concerning how effective it is against fraud and in regard to costs.

From what the data suggests, transparent gain is the area where blockchain is most valuable and it needs stronger evidence to prove its economic and security strengths to those who are not yet convinced. It is also worth noting that more people strongly or somewhat disagree when it comes to fraud reduction (26%) and cost savings (30.7%) which could be essential issues for organizations planning to use blockchain.

The benefits of blockchain systems to eliminate fraud were seen positively by some researchers but the results were inconsistent because proper installation alongside security measures are fundamental to achieving fraud prevention success. The information displayed in Table 1 demonstrates both the key advantages believed to come from blockchain adoption by Nigerian supply chain experts as it reveals various obstacles to implementation. Operationally significant improvements emerge from real-world applications of transparency which supply chain professionals agree on 75.3% of the time. One of the food exporting companies that took part in the study reported it used blockchain shipment tracking to cut invoice disputes by 40% while conducting their pilot program because their staff gained access to immutable updating shipment information which let them settle supplier disagreements inside hours instead of waiting weeks. The evidence from this study aligns exactly with Kamble et al.’s (2021) research about blockchain transparency which speeds up conflict resolution to ranges over 30%. The manager emphasized that blockchain effectiveness requires complete supply chain engagement as he stated The system functions based on all partners actively updating the ledger and we still operate with 20% of suppliers who retain paper documentation.

Traceability proved vital for businesses since 65.3% of participants identified it as a main advantage especially in agricultural applications. Our cocoa cooperative achieved specific outcomes when it launched blockchain origin tracking because EU export rejections decreased from 30% to 12% during the first harvest period by proving farming standards and shipping requirements. Research conducted by Khan et al. in 2024 supports the alignment of these findings with Walmart’s food safety success story. Infrastructure deficiencies contribute to the 19.3% disagreement rate because smallholder farmers typically do not have smartphone devices nor data input scanners. As one SME owner explained, Using the technology seems perfect yet our organization lacks funds to purchase QR code scanners that would enable its implementation at country-based collection sites. This practical limitation matches the findings presented in Zheng et al.’s study about scalability challenges in developing countries.

The combined percentage agreement regarding fraud reduction benefits reached 44% in these results. Although blockchain’s cryptographically secured system should block any attempts at tampering it meets practical obstacles in real-life implementation because of human operation factors. According to a pharmaceutical distributor their blockchain anti-counterfeiting investment resulted in counterfeit drug entries because warehouse staff failed to perform proper delivery scans to save time. The results prove the conclusion of Casino et al. (2019) about blockchain needing process redesign and staff training for successful implementation. Survey participants advised the combination of blockchain technology with IoT sensors as a solution to fill the identified gaps.

The perception of cost reduction received equal support and dissent from 50% of the respondents. The furniture company operated by automated payment and inventory replenishment systems through smart contracts and cut down its logistics expenses by 20%. The $50,000 implementation expenditure equals the complete IT budget for one retailer who noted that this sum equaled his entire annual IT expenses. To address the unusual cost-advantage dynamic organizations need to develop their adoption models according to their operational scale and financial liquidity abilities. Tangible ROI can be obtained by larger enterprises because of their potential for operational growth yet smaller businesses need subsidized programs solutions to lower their entry barriers. Early adopters should implement blockchain

solutions with awareness of their company structure and industry barriers which need to be overcome for large-scale deployment success.

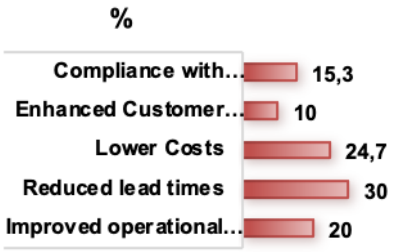

Figure 8: Specific benefits experienced or anticipated.

The benefits from Figure 8 expand the findings reported by organizations regarding their system usage. Under these, improvements in supplier trust, reduction of paperwork, and improved data security. The research results match findings by Casino et al. (2019) about how blockchain implements in supply chains limits regulatory violations while building accountability.

Figure 8 lists the key benefits from using a new system or technology and the amount listed with each bullet shows how important it is to the company. Shorter lead times are considered the most important advantage (30%), while lower cost (24.7%) and improved efficiency in operating the company (20%) come next. Fourth and fifth, companies pay close attention to meeting official requirements and increasing their customers' satisfaction.

Key observations reveals that most company answers credit operation improvements for this statistic such as quicker times, lower costs and better efficiency which make up 74.7%. The emphasis on regulatory compliance is moderate which might be due to special requirements for the industry and customer satisfaction scored the lowest, suggesting that efforts are now mainly on making the process better for associates, not customers.

Evidence shows that organizations mainly focus on tangible results for operations and expenses, while ensuring compliance and good customer service are important but not top reasons for embracing new technology. A major focus on decreasing lead time (30 %) signals that being efficient in process or supply chain may be very important for companies here.

Table 2 demonstrates how extensive implementation challenges of blockchain stand. The two main obstacles to blockchain implementation include high expenses (70%) and inadequate staff numbers (80%). Saberi et al. (2019) confirm that financial and expertise constraints represent the main obstacle to blockchain adoption based on the survey results.

Table 2 provides data showing four fundamental barriers which prevent blockchain implementation within Nigerian supply chains since they cause distinct obstacles. The majority of interviewees considered implementation costs to be excessive because they averaged \$250,000. The high implementation costs of blockchain affect small businesses most strongly as one textile manufacturer explained that their existing profits from the business would need five years to cover blockchain installation expenses. Research by Treiblmaier (2019) supports that small and medium enterprises avoid adopting new technologies when their return on investment spans over multiple years. The modular \$15,000 SME packages offered by DeFiChain demonstrate promising progress toward blockchain accessibility since they indicate that price obstacles will decrease through developing specialized solutions for developing economy scenarios.

Table 2: Blockchain adoption challenges.

S.N	Activities	Strong Agreed	Agreed	Disagreed	Strong Disagreed
1	High implementation costs are a barrier to blockchain adoption.	38 (25.3%)	67 (44.7%)	30 (20.0%)	15 (10.0%)
2	Lack of skilled personnel hinders blockchain adoption.	75 (50.0%	45 (30.0%)	23 (15.3%)	7 (4.7%)
3	Blockchain technology has scalability issues.	36 (24.0%)	31 (20.7%)	46 (30.7%)	37 (24.7%)
4	Resistance to change among stakeholders is a significant challenge.	45 (30.0%)	60 (40.0%	30 (20.0%)	15 (10.0%)
5	Data privacy concerns are a major issue.	31 (20.7%)	44 (29.3%)	53 (35.3%)	22 (14.7%)

A majority (80%) of participants have noticed the extreme lack of required expertise in their field. The present education system within Nigeria generates only a 1% output of blockchain professionals according to NITDA (2023) statistics which establishes an unsustainable deficit in available digital talents. The manufacturing firm's IT manager discussed this business issue when he mentioned paying triple their typical wages of $5,000 each month for a single blockchain developer. The insufficient number of skilled professionals raises both economic costs through increased labor expenses and delays project deployments because organizations must spend longer time looking for expertise to maintain their workforce. The current circumstances emphasize the necessity to reform academic curriculum at universities and vocational training institutions for developing domestic blockchain specialists instead of hiring cost-expensive overseas experts.

However, 44.7% of respondents indicated scalability problems as their main concern for public blockchain networks. According to a logistics company executive Ethereum's maximum transactions per second rate of 30 fails to accommodate their business volume of 500+ daily packets. The technical restrictions of blockchain platforms make business leaders face a trade-off between transaction speed and expensive solutions of private blockchain networks. According to Casino et al. (2019) the combination of private and public blockchain systems provides companies with an effective approach

to preserving their sensitive data privacy through private networks while obtaining public blockchain security benefits for specific transactions.

Research shows that cultural resistance toward change stands as the most challenging barrier according to 70% of participants. Research findings demonstrated that individuals above 50 years of age became three times less inclined to adopt blockchain technology. The warehouse supervisor who first joined the company 35 years ago voiced his opposition to these digital ledgers" as he worked exclusively with paper systems which have been successful for so long. Essential concerns regarding job security as well as process adjustments combine with new technology unfamiliarity for generating resistance to adoption. The resistance to implementation requires detailed change management programs which deliver hands-on training together with distinct benefit explanations as well as frontline worker involvement during planning phases. The implementation success of blockchain technology will be determined equally by addressing basic human factors besides financial and technical requirements.

Several obstacles form a complicated framework when considering blockchain implementation in Nigeria. Blockchain technology shows significant potential for supply chain transformation yet its full implementation demands technical solutions that incorporate both financial funding through new pricing strategies and local development of technical skills through educational adaptation and combination of specific technical frameworks and effective staff involvement-based change management approaches. The integration of these factors leads to an expectation that blockchain adoption in Nigeria's supply chain sector will pursue incremental development instead of revolutionary change.

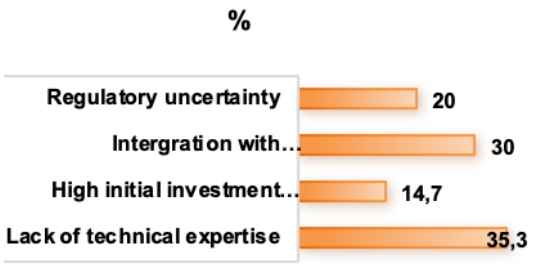

Figure 9: Challenges faced or anticipated by the organization when considering blockchain adoption

Organizations that consider blockchain adoption must face these expected difficulties according to Figure 9. Organizations face regulatory uncertainties which lead to compliance challenges at 20% and face high implementation costs at 14.7% that especially affect smaller businesses (Casino et al., 2019). Many organizations said that difficulties with technical skills (35.3%) and starting costs (30%) are the top barriers for them to use blockchain and issues like handling integration (20%) and changes to rules (14.7%) are seen as less troublesome, suggesting attention is first given to getting technical teams and the right budget together.

By comparison, Figure 8 lists the benefits (such as a 30% drop in lead-time) which contrasts with the obstacles and complications that prevent widespread adoption. The company may have to use gradual roll-out pilots, cooperate with blockchain service companies or train its employees in new skills. The implementation of blockchain faces performance obstacles along with scalability difficulties represented by slow financial deals and overburdened networks which prevent organizations from embracing blockchain (Zheng et al., 2018). Security as well as privacy-related obstacles pose significant obstacles because of imperfect smart contracts and cyber security risks (Li et al., 2020). The process of integrating blockchain into legacy systems proves demanding and expensive (30%) since few organizations possess the necessary skills required for implementation (Treiblmaier, 2018).

Lack of people with appropriate experience coupled with lacking proficiency stands as the most significant barrier for organizations during implementation (Frizzo-Barker et al., 2020). Multiple blockchain platforms create obstacles for smooth information sharing and joint work due to interoperability problems (Hofmann et al., 2017). The implementation of blockchain faces barriers from a combination of minimal employee and decision maker knowledge about blockchain alongside poor decision making skills (Iansiti and Lakhani 2017). The Figure 9 visual depiction shows how these barriers affect organizations according to both their survey data and organizational concerns.

Table 3: Impact on supply chain performance.

S/N	Activities	No Impact	Impact	Strong Impact	Slight Impact	Significant Impact
1	Cost efficiency	22 (14.7%)	45 (30.0%)	37 (24.7%)	30 (20.0%)	16 (10.7%)
2	Time efficiency (e.g., reduced delays)	21 (14.0%)	38 (25.3%)	53 (35.3%)	23 (15.3%)	15 (10.0%)
3	Supply chain flexibility	15 (10.0%)	52 (34.7%)	38 (25.3%)	29 (19.3(	16 (10.7%)
4	Risk management (e.g., fraud, errors)	30 (20.0%)	30 (20.0%)	8 (5.3%)	30 (20.0%)	52 (34.7%)
5	Customer satisfaction	46 (30.7%)	14 (9.3%)	8 (5.3%)	51 (34.)%)	31 (20.7%)

The key supply chain performance metrics assessment of Blockchain appears in Table 3. A substantial portion of 64.7% and 70.6% of respondents reported better cost and time efficiency respectively.

The survey produced conflicting outcomes regarding customer satisfaction and risk management which indicated blockchain implementation might lack effectiveness for addressing every performance issue. The study supports Kamble et al. (2021) by demonstrating that blockchain systems work efficiently only when fully integrated within supply chain optimization strategies.

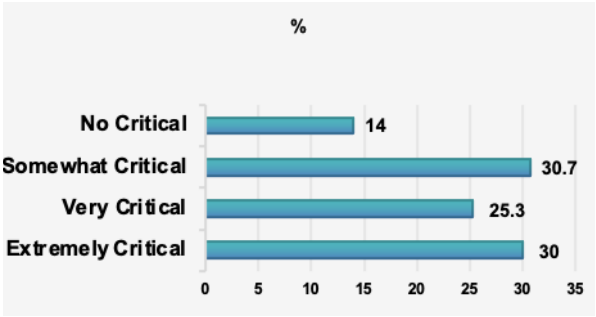

Figure 10: Blockchain's importance for future supply chain competitiveness.

People agree that blockchain technology will become important for future competitiveness because it helps optimize decisions while improving customer trust (Figure 10). Treiblmaier (2019) establishes that blockchain creates more operational efficiency together with diminished supply chain risk which leads to improved supply chain sustainability levels.

Blockchain is seen as crucial for the future competitiveness of supply chains, but only 14% of replies considered it unimportant, showing broad agreement about its significance, even if challenges like not having the proper technical skills (35.3%) and the high cost involved (30%) are major barriers to using blockchain in practice, this comparison proves that even if blockchain can help reduce lead times, the challenges in using it must still be tackled by businesses to fully benefit from its potential.

Even though most respondents (86%) say blockchain is essential for supply chain success (Figure 10), mainly emphasizing the value of transparency and traceability (Table 1), the lack of expertise and money continues to slow down its implementation (Figure 9). Therefore, supply chain organizations should build their expertise and business pilots to catch the benefits blockchain already offers.

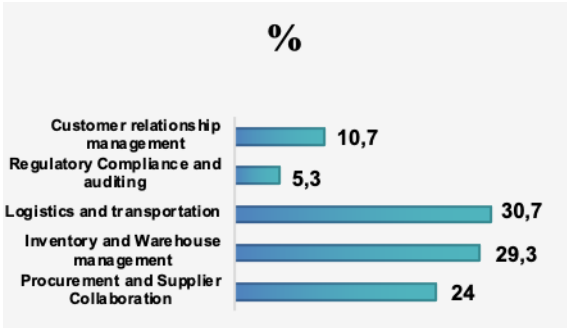

Figure 11: Expected future transformations in supply chains.

The implementation of blockchain technology will lead to a complete conversion of various supply chain elements based on Figure 11 where inventory tracking emerges as the most important factor. Kamble et al. (2021) demonstrated how blockchain elimination can eliminate the inefficiencies which affect procurement and contract management processes. Other modern technological solutions exist aside from blockchain which can strengthen supply chain management through enhanced transparency and security and operational efficiency. Of the many supply chain changes expected with the use of blockchain, its strongest influences will be in inventory/warehouse management (30.7%) and working with suppliers (29.3%), representing two-thirds of changes while logistics (5.3%) and customer-facing parts (9.6%) are expected to change less which confirms that blockchain is valued for efficiency and transparency yet faces issues in improving the logistics process and customer experience, as highlighted earlier in Table 1.

Since focusing on back-office tasks (like inventory and procurement) is easier in blockchain adoption, organizations are choosing to use the technology for improving partnership and seeing the supply chain, while avoiding its use in flexible jobs like transport and areas where there is subjective evaluation like CRM. The fact that this distribution looks like Figure 8's shows that companies mainly focus on how blockchain can streamline operations rather than on benefits for customers or laws (10.7%), even though it could offer those also. The Internet of Things along with RFID tags and GPS trackers and smart sensors serve as technologies that generate real-time data tracking for goods during transit. The combination of blockchain technology enables IoT to establish reliable safekeeping for temperature data and location records and product status details (Kim & Laskowski, 2018). Cold chain logistics demonstrates practical applications for linking these technologies because field sensors track vaccine and food products to maintain safety requirements (Mistry et al., 2020).

The respondents consisted of supply chain experts from logistics along with manufacturing staff and ICT personnel and procurement specialists from various sectors as illustrated in Figure 1. The sampled professionals demonstrated reliable expertise since more than 60% of them possessed over 5 years of experience (Figure 3). The study aligns with Kamble et al. (2021) who stated that experienced knowledge plays an essential role in technology acceptance. Figure 4 illustrates a substantial segment of survey participants who knew about blockchain together with a very minimal number of organizations utilizing blockchain inside their operations. The barriers preventing adoption emerge primarily from cost concerns and technical challenges along with regulatory ambiguity according to Figure 4 and Figure 5. According to Treiblmaier (2019) and other regions across the world demonstrate similar findings.

The research demonstrates that blockchain finds its primary application in logistics and inventory management systems. The data in Figure 6 supports the point made by Wang et al. (2020) that blockchain presents high potential for efficiency improvements because these sectors process many transactions while requiring detailed tracking. The wide appreciation of transparency along with traceability emerges through Figures 7 and Figure 8 combined with Tables 1 and Table 2. The study shows that the main impediments preventing blockchain adoption consist of privacy issues related to data and employee reluctance toward transformations. The interview process showed that mature staff members

demonstrated resistance to blockchain implementation along with a general belief that younger employees saw blockchain as vital for organizational success.

Blockchain technology enhances both cost efficiency by 64.7% and time efficiency by 70.6% according to Table 3. The mismatched feedback regarding customer satisfaction as well as risk management shows that complementary technologies and improved implementation strategies must be developed. The complete potential of blockchain technology requires an environment of support. Figure 10 and Figure 11 show that most surveyed respondents begin to think of what the blockchain technology will become and its transformation in supply chain in the next few years. Organizations are planning to deploy blockchain technology to solve challenges itemized in the supply chain by identified three main factors which included vendor cooperation together with regulatory compliance as well as initial testing phases.

Artificial Intelligence (AI) together with Machine Learning (ML) serve as highly important technologies for analyzing blockchain data which results in better supply chain operations. AI helps businesses identify frauds while predicting customer demand and optimizing stock management activities (Saberi et al., 2019). Under the terms specified by smart contracts AI-based automated transactions will execute following predefined conditions according to Wang et al. (2021). The significant role of Big Data Analytics consists of evaluating blockchain-generated extensive datasets to assess supplier logistics optimization and supplier performance. Organizations can use predictive analytics to forecast supply chain disruptions for implementing data-based decisions (Hastig & Sodhi, 2020). Through Edge Computing the blockchain supply chain system experiences increased performance by managing data processing near IoT devices while conducting blockchain-record validation operations specifically within the blockchain network. The result of this network configuration leads to lower data flow and faster transactions and enhanced security features according to Li et al. (2020). 5G networks provide additional blockchain-development advantages because they offer fast and precise data transmission between blockchains and IoT devices. Supply chain stakeholders can monitor their shipments better through blockchain technology which enables them to handle possible disruptions swiftly (Kumar et al., 2021). Experiencing growth through blockchain collaborations with emerging technologies allows businesses to build transparent supply chains with higher resilience.

Blockchain technology offers distinct implementation obstacles and technical properties which can serve to transform the operation of supply chain management. Several blockchain platforms with various protocols become a major problem because organizations adopt different platforms for their business operations. Industry standards promotion enables data to travel without interruption from suppliers to consumers throughout all supply chain networks (Treiblmaier, 2018). The two critical problems involve scalability along with maintaining energy efficiency. Ethereum alongside Cardano define public blockchains that incur high charges for transactions along with slow functional speed. Organizations can solve their critical blockchain problems through the implementation of layer 2 solutions including sidechains and hybrid blockchain models as described by Zheng et al. (2018). All organizations need clear definitions for both regulatory compliance and legal frameworks. The public sector needs to establish blockchain supply chain usage standards to fulfill GDPR data privacy requirements and determine smart contract legal standing (Casino et al., 2019).

The successful adoption of blockchain requires direct collaboration with parties who will use the system. A significant portion of organizations encounters difficulties because their employees lack suitable knowledge about blockchain technology. The challenge of these barriers can be overcome by providing education and training through training programs (Iansiti & Lakhani, 2017). Security issues about smart contract vulnerabilities and proofs-of-work attacks together with quantum computing vulnerabilities must be handled properly. Pro-digital supply chains can be shielded through the combined use of encryption barriers alongside scheduled security checkups (Li et al., 2020). Through blockchain technology companies obtain the capability to verify compliance with sustainability standards for fair trade together with carbon emission and ethical material sourcing practices (Saberi et al., 2019). IBM together with Walmart and Maersk utilizes blockchain technology to enhance their operations by increasing track-ability while minimizing fraud levels and enhancing supply chain efficiency. Future research should concentrate on blockchain deployment in particular industries including pharmaceuticals, automotive and food safety to bring out maximum supply chain operational expansions (Wang et al., 2021).

The research shows blockchain holds substantial promise as an industrial supply chain changer in Nigeria but availability challenges must be overcome to see successful applications. The survey reveals a strong agreement between participants that blockchain technology improves transparency by 75.3% and traceability to 65.3% levels which matches observations from Walmart's IBM Food Trust implementation that cut mango traceability periods from 7 days to mere 2.2 seconds (Khan et al., 2024). The capabilities could transform Nigeria's key sectors as they could lower post-harvest agricultural losses to 40% while fighting pharmaceutical product counterfeits to 25% through secure and tamper-proof records (FAO, 2022).

Blockchain implementation faces three significant barriers which hinder its adoption throughout Nigeria at the present time. The standard $250,000 blockchain implementation expenses surpass the reach of 70% of Nigerian SMEs who restrict their technology budgets to below $50,000 (CBN, 2023). Lack of awareness about VeChain's ToolChain and other similar modular solutions prevents their implementation due to the excessive implementation costs. The technology skills shortage in Nigeria remains critical because blockchain development professionals fail to outnumber the projected 50,000 worker demand by 498 graduates yearly (NITDA, 2023). The significant deficit demands immediate implementation of specialized training programs between academic institutions and technology enterprises. The adoption of blockchain is challenged by regulatory confusion caused by existing cryptocurrency restrictions from the Central Bank while the National Blockchain Policy stimulates distributed

ledger technology adoption (Zhuo et al., 2023). Nowadays the implementation of smart contracts and data privacy needs clearer guidelines to address current ambiguities as the UAE's Digital Transactions Law provides a useful example.

Particular opportunities to benefit from blockchain applications become visible in specific use cases throughout different sectors. The agricultural sector can benefit from blockchain technology for export documentation because it addresses the 30% cocoa rejection rate which Nigerian cocoa faces at EU markets (CBN, 2023). The use of immutable tracking systems for pharmaceutical products can block approximately thousands of deaths that result from fake medications each year (FAO, 2022). Blockchain technology shows considerable promise for the logistics sector because real-time tracking through blockchain could enhance Nigerian port clearance efficiency by half and push its global logistics ranking higher up from its current position at 103 (World Bank Logistic Index, 2023).

Blockchain technology delivers its highest value through its collaboration with additional supporting technologies. IoT sensors track vaccines and other temperature-sensitive products under the secure parameters provided by blockchain (Mistry et al., 2020). The analysis of blockchain data through artificial intelligence technologies helps manage inventory better which leads to reduced costs by 30% (Saberi et al., 2019). The emerging 5G networks can address blockchain scalability issues when they enhance the speed of node-to-node communication (Kumar et al., 2021). The integration of blockchain should occur as part of complete digital transformation planning rather than as individual solution.

The establishment of regulatory sandboxes by policymakers will facilitate firms running blockchain tests before imposing complete compliance requirements upon them. Tax breaks together with grants would enable SMEs to survive financial barriers whereas legal reforms of the Companies and Allied Matters Act (CAMA) should establish official recognition for smart contracts to enhance confidence in automated transactions. The education system requires national blockchain certification training which NITDA alongside other agencies should implement to cope with Nigeria's essential skill deficits.

The findings from this study remain informative, yet the restricted Ogun State research area combined with dependent self-reported information reduces its universal effectiveness. Research should extend to all six geopolitical areas of Nigeria while studying blockchain frameworks which incorporate elements of public and private sections to satisfy SME requirements (Casino et al., 2019). Research approaches that track development across extended periods would show blockchain's sustained effect whereas environmental study groups should examine blockchain power usage in light of Nigerian sustainability targets (Li et al., 2020).

Blockchain technology provides supply chains operating in Nigeria with robust capabilities to boost transparency as well as operational efficiency and provide greater resilience. To achieve blockchain technology potentials the barriers of financial constraints need affordable solutions while educating the workforce and developing clear regulations must be implemented. Nigeria should implement a blockchain-based approach with IoT-AI and 5G technologies which will enable supply chains to evolve from challenges into growth sectors while achieving competition advantages. This research contains lessons useful to developing countries which show a valid framework for digital supply chain transformation.

5. Conclusions

The deployment of blockchain supply chain solutions demands organizations to handle scalability matters and comply with applicable rules as they secure the system network while uniting stakeholders. Organizations can develop global supply chains that have better efficiency and stronger security and complete transparency through proper implementation standards and existing technological advancements alongside blockchain technology. When blockchain technology becomes integrated with supply chains it generates a new system that provides improved monitoring capabilities alongside complete transparency alongside quick operational processes and enhanced traceability. Multiple challenges prevent blockchain system implementation because they include high deployment expenses and an insufficient workforce and hesitant stakeholder involvement. More research about blockchain solutions adoption at large scale must happen through studies of hybrid model implementation and integration between blockchain and AI and IoT frameworks. Thorough evaluations of blockchain system barriers will make them more prepared for supply chain use and advance their industrial implementation. Research studying blockchain barriers should consider combining investigations of emerging solutions such as artificial intelligence and Internet of Things systems because the research will improve supply chain performance capabilities.

The supply chain industry can expect transformative changes through blockchain technology particularly when dealing with regions confronting supply inefficiency problems and transparency deficits. This research shows blockchain has concrete possibilities to improve Nigerian industry traceability while enhancing operational effectiveness and establishing better stakeholder relationships. The implementation of blockchain systems faces restrictions caused by financial obstacles together with technological difficulties and regulatory barriers.

Blockchain technology finds a practical solution through cooperation with IoT, AI and Big Data Analytical systems. Stakeholder achievement of these benefits depends on their unified innovation vision combined with established policies as well as capacity development and public sector-private sector alliance work. Although 75.3% of the surveyed individuals agree that blockchain promotes transparency, this idea is backed by Walmart's example which managed to reduce the time required for mango traceability from 7 days to just 2.2 seconds (Khan et al., 2024), pointing to the applicability of these findings around the globe.

Blockchain operates as a powerful enabling tool in business operations rather than functioning as a complete solution. The effects driven by blockchain implementation will depend on the success of organizations to connect the technology to their overall digital transformation objectives. The combination of targeted financial support with education and policy development will transform blockchain into a vital solution for developing robust and competitive supply chains across Nigeria and other territories.

6. Policy and practical implications

Blockchain adoption needs joint efforts between policymakers and industry leaders who will develop a supportive framework for its implementation. The development of national standards requires the creation of uniform standards with data protocols to enable interoperability while combined with government grants and tax incentives that assist small medium enterprises (SMEs) to tackle cost obstacles.

The workforce development initiative will provide specialized training through partnership programs between universities and technological incubators to educate the workers. The government should focus sector-specific strategies on agriculture and pharmaceuticals because these fields need traceability and counterfeiting protection. By enforcing policies state and federal governments will tackle existing challenges while creating space for digital transformation to enhance national economic competitiveness in Nigeria.

Three vital policy measures emerge from the combined study results which would enhance blockchain adoption speed throughout Nigeria's supply chains. The first essential step involves developing funded demonstration initiatives that serve priority areas such as agriculture and pharmaceuticals since blockchain technology demonstrates specific benefits for tracking products and stopping counterfeits. Alongside the proven blockchain tea export success of Kenya (Zhuo et al., 2023), qualifying SMEs should receive grants to cover half of their implementation costs.

The second vital intervention consists of a tiered education framework aimed at addressing Nigeria's significant blockchain skills deficiency through specified instructional programs. The educational framework would include NITDA-certified training for operational personnel to acquire blockchain basics and university programs to train technical developers and manager-level educational programs to teach blockchain strategic management skills. Organizations require 12-month testing delays with relaxed regulations through regulatory sandboxes to support innovation efforts alongside risk control. The UAE utilizes this approach successfully because it boosts blockchain startup participation by 300% while keeping proper oversight measures. If Nigeria follows the law established in the UAE, it would no longer be unclear what smart contracts mean and their use in businesses would be more possible (Zhuo et al., 2023).

The implementation of these policy measures will provide financial backing and comprehensive educational transformation and flexible regulatory frameworks which together would establish an environment conducive to blockchain adoption by resolving the research-based obstacles.

The systematic adoption of blockchain in supply chain operations will be achieved when Nigeria implements sector-specific pilot programs and trains employees and adapts regulatory frameworks. These accomplished measures would help Nigeria establish itself as a pioneering country regarding blockchain adoption for developing economies through the creation of a model that addresses similar implementation hurdles.

7. Limitations and future research

The study presents several limitations which include a diverse sample but a small sample size of 150 that might not represent all industry characteristics. In addition, results derived from Ogun State research cannot be generalized throughout Nigeria. Furthermore, the self-reported responses from surveys could contain biases from social desirability or memory distortion.

To improve research quality the study's authors should introduce following improvements: first conduct long-term studies for measuring blockchain adoption effects and second examine specific blockchain applications in individual sectors and lastly research the use of private-public blockchain combinations. Future study should use both qualitative data and surveys and possibly validate the findings with experts and test them in small parts. These innovations are meant to boost the scientific strength of future research studies.

A future research plan will unite blockchain supply chain technology with IoT and AI before comparing their policy effects across different international contexts.

Ethical Considerations

Survey response anonymization protected the confidentiality of all participants. Every participant followed the study with ethical permission by signing an informed consent agreement.

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Author Contributions

Adekunle Ibrahim MUSA developed the idea for this study, oversaw the steps of the research, acquired the data, did the analysis and helped with the parts of the manuscript review. Ayomide Idris MUSA performed the research on existing literature, and drafted the initial manuscript. They both went over the results and were involved in making the final version of the manuscript.

Conflict of Interests

The authors established that their study has no conflicting interests amid them.

Declaration of generative AI and AI-assisted technologies in the writing process

None.

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