WWW.IJRPR.COM

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

BLOCKCHAIN-ENABLED TRANSPARENCY IN CONSTRUCTION MATERIAL SUPPLY CHAINS: A FRAMEWORK FOR FRAUD PREVENTION

Umarov Akylbek Galymbetovich

Aktobe State University, Aktobe, Kazakhstan.

ABSTRACT

The construction industry faces ongoing challenges because of fraud together with inefficiency and insufficient transparency in material supply. The industry faces three major problems which result in higher prices and inferior work quality and delayed project completion thus damaging both public trust and industry standards. The problems in material tracking have led blockchain technology to transform the process of collecting and verifying construction materials throughout project duration. The article presents a systematic approach to implement blockchain solutions within construction material supply chains for fraud prevention purposes. The framework protects transactions by implementing decentralized ledgers together with smart contracts and immediate supply tracking capabilities. Digital procurement and blockchain technology advancements demonstrate how tamper-proof records combined with automated compliance systems reduce opportunities for fraudulent activities. The research identifies key supply chain procedure weaknesses through a complete blockchain model to create better ethical and efficient technology-based construction ecosystems. The research findings provide direction to officials and contractors and construction technology makers for establishing enduring secure supply networks across the world.

Keywords: Blockchain Technology, Construction Supply Chain, Transparency and Accountability, Fraud Prevention, Smart Contracts in Construction

1. Introduction

The construction industry acts as a cornerstone for national development despite ongoing problems with fraud, corruption and wasteful practices that mostly occur in supply chain operations. Various entities including suppliers and contractors and regulators and logistics providers exist in construction material supply chains that span across multiple geographical regions. The intricate nature of this system combined with weak control mechanisms creates an environment where fraud and misreporting alongside procurement fraud can easily occur. A project suffers from substantial financial losses along with damaged corporate reputation due to three main forms of deception: false documentation and modified invoices and incorrect materials. Construction procurement now requires real-time verification and greater accountability measures. The stakeholders involved with project work seek systems that authenticate the source and quality of raw materials throughout the supply chain. Traditional supply chain management tools serve their purpose yet they fail to deliver secure decentralized records that are reliable. Experts from the industry along with researchers have started exploring digital solutions to address the trust and visibility issues in construction workflow management.

The construction supply chain transparency problem can be addressed through blockchain technology according to many industry stakeholders. Blockchain started as a secure digital currency system that maintains an immutable shared record to perform instant transaction verification. Supply chain management implemented with blockchain technology brought positive results to agriculture and pharmaceuticals and automotive manufacturing by enabling better operational tracking and fraud prevention. Through blockchain technology construction can track material origins while automatically enforcing compliance standards to build trust among various project participants. The main objective of this research investigates blockchain technology's potential to enhance supply chain transparency while preventing fraudulent activities in construction materials. The system presents a structured approach that links blockchain to the entire process from purchasing through delivery and product inspection. The paper investigates existing problems with current methods while showing how blockchain enhances these processes through specific examples of effective policy development. The paper contributes to existing construction technology knowledge through its analysis of supply chain structures that resist fraud and offer transparency while focusing on these specific topics.

2. Challenges in Traditional Construction Supply Chains

2.1 Overview of Procurement and Material Tracking in Construction

The outcome of every construction project depends on obtaining appropriate building materials through efficient and accurate delivery because these materials sustain the entire process. The supply chain system determines construction quality and cost and project timelines because it includes material

sourcing and transportation and storage and application processes. The traditional construction material supply chain operates through separate and unconnected stakeholders who work independently.

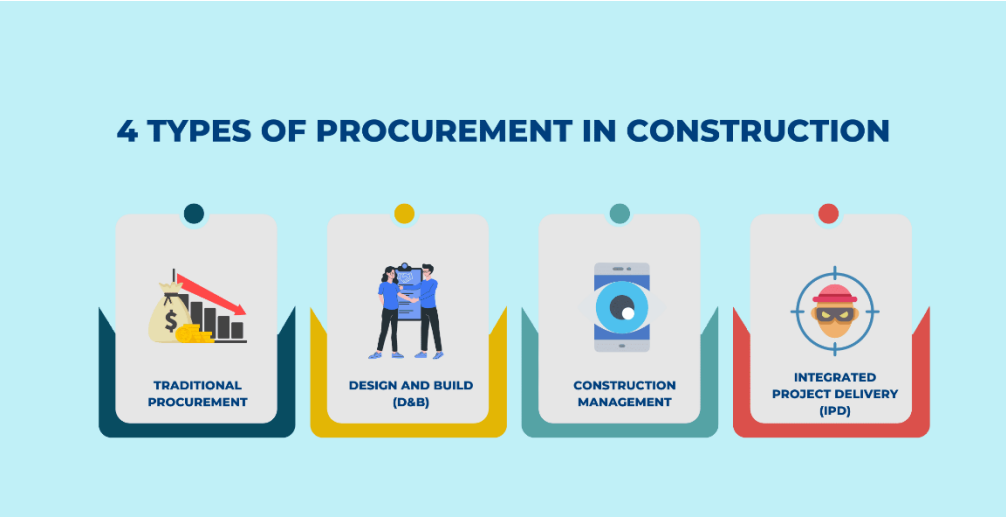

Fig 1: Right procurement methods in construction

The management of procurement activities during these situations relies on paper forms together with manual record keeping and spreadsheets. The traditional methods of tracking material movement lead to errors while also slowing down operations and decreasing productivity. The procurement center fails to communicate effectively with site managers about information and actions which results in regular mismatches between planned schedules and available resources. The manual processing system makes it challenging for procurement teams to handle their extensive workload which includes manual invoice reviews and delivery comparisons and product inspections. The supply chain becomes less responsive because of limited automation which creates difficulties for decision-making processes. Project managers face better supply chain visibility through digital systems which enables them to make incorrect assessments about required necessities. The process of material requirement estimation and supply chain bottleneck detection becomes challenging which leads to project delays. These inefficiencies increase construction material supply chain costs and risks which demonstrates the immediate need for system improvement and unification.

2.2 Common Areas Vulnerable to Fraud, Corruption, and Misreporting

The construction industry has faced widespread fraud and corruption problems through its material procurement and handling processes for many years. Standard supply chains contain multiple vulnerabilities that create numerous opportunities for exploitation. The delivery of substandard materials to clients occurs frequently but payment documents show that the delivered products were of high quality. The replacements weaken structural integrity while creating safety risks and requiring complex ongoing maintenance work. A company that lacks proper documentation and manual payment approval processes makes it simple for fraudsters to use duplicate charges and fake invoices for their schemes. The lack of verification methods allows contractors and suppliers to submit multiple invoices for one material batch while falsely claiming they delivered more products than they actually did. The absence of real-time tracking and reconciliation systems makes it harder to detect and investigate these activities.

The purchasing officials frequently collaborate with their vendor partners which creates problems in their business relationships. The practice of bribery leads to non-transparent award selection and no project savings which results in higher project costs. The practice of favoritism results in selecting unqualified suppliers which produces substandard project outcomes while extending project delivery times. Traditional systems create difficulties in identifying responsible parties and recovering losses after project completion because they remain challenging to understand. The situation becomes worse because of organizational challenges which include weak monitoring systems and poor management and insufficient regulatory frameworks. The combination of large financial investments and complex government involvement in political projects makes them highly vulnerable to corruption. Construction companies experience reduced stakeholder trust along with decreased credibility because of these problems.

2.3 Lack of Real-Time Visibility and Verification

The main drawback of traditional construction supply chains is their inability to provide real-time monitoring or reliable verification of information. The collection of procurement, shipping, storage and site usage data happens infrequently through invoicing and goods arrival events which leads to extensive delays. The system's data capture prevents project managers from taking immediate action regarding supply chain issues and quality problems and logistics challenges. Data storage and management practices follow separate systems which prevent suppliers from freely sharing information with logistics providers and contractors. The accuracy of information remains difficult to verify because integration does not exist. The difference between shipping reports from transporters and material receipts creates disputes which remain unresolved until project closure.

Manual data entry introduces additional risks because human errors can occur through forgetfulness or intentional manipulation of information. The process of data entry contains major errors which lead to substantial mistakes in inventory records and required purchases and payment amounts. The

inability to track material flow easily leads to delayed issue detection which increases the likelihood of budget overruns and missed deadlines and quality mistakes. The absence of an authoritative leader to organize verification results in decreased openness and reduced accountability. The auditing process for supply chain activities remains challenging for both financiers and regulators who need to verify agreement compliance and investigate misconduct claims. The current situation leads to distrust which blocks the adoption of innovative procurement and construction processes.

Table 1: Major Pain Points in Traditional Construction Supply Chains

Pain Point	Description
Lack of Traceability	**Difficulty in verifying the origin and quality of construction materials**
Manual Documentation	**Increases errors, delays, and opportunities for data manipulation**
Fragmented Systems	**Poor communication between stakeholders across the supply chain**
Procurement Fraud	**Material substitution, over-invoicing, and duplicate payments**
Corruption in Tender Processes	**Collusion and bribery affecting procurement decisions**
Delayed Detection of Anomalies	**Limited ability to identify fraud or inefficiencies in real-time**
Lack of Real-Time Visibility	**Inability to monitor supply chain flow dynamically and respond quickly to issues**

2.4 Implications for Industry Performance

The typical construction supply chain weaknesses and shortcomings result in significant performance and sustainability problems for the industry. The delivery of important materials to teams and equipment becomes delayed because of procurement problems which causes them to stop working. The stoppage of construction work results in increased labor expenses and disrupted schedules which extend the project duration. The financial and safety consequences of material fraud are severe when it occurs. The use of inferior materials results in unsafe structures with reduced durability which shortens their expected lifespan. The completion of a project leads to substantial financial strain on clients and damages the businesses involved when major repairs become necessary.

The project will suffer financial losses because of wastage and theft and higher costs from incomplete services when material purchase management fails to be effective and proper audits cannot take place. Supply chain opacity creates funding uncertainty among investors and lenders which reduces the available funds for future development projects.

The deterioration of trust between supply chain members and contractors makes it harder to coordinate the demanding tasks that construction projects need. Public corruption in government projects leads to decreased public trust which requires changes to purchasing procedures. The existing problems demonstrate that construction supply chains need innovative solutions to achieve transparency and accountability alongside productivity improvements. Digital tools integrated with project management practices show promise to resolve ongoing construction challenges which enable companies to deliver safe projects of high quality within budget and on schedule.

3. Blockchain as a Disruptive Solution

3.1 Understanding Blockchain Technology in the Construction Context

The technology of blockchain enables secure transaction recording across multiple linked computers that are distributed across the network. The technology began as a tool for Bitcoin cryptocurrency but blockchain now supports various industries including construction. The main blockchain applications for supply chain transformation include transparency alongside immutability and decentralization. The blockchain system creates a protected space to store every transaction from material requirements through to final delivery of materials while recording each step with its corresponding timestamp. The blockchain system maintains a record of each block through its previous block hash and timestamp and transaction details which prevents any modifications to the stored data. The stable data record functions as a verification tool for transactions while protecting traditional systems from frequent fraud attempts.

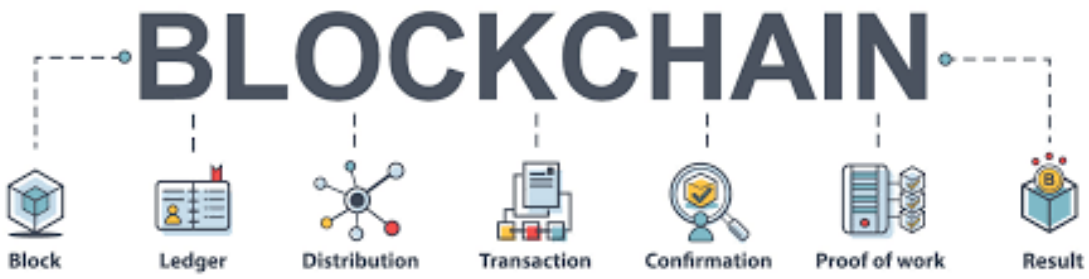

Fig 2: Blockchain Technology in Construction

The blockchain system allows network members who have committed to access the same ledger information as centralized options do. All material suppliers and contractors and project managers and regulatory bodies receive real-time data simultaneously. The system becomes trustworthy for supply chain members because multiple parties verify each record which prevents anyone from deceiving the system.

3.2 Enhancing Transparency and Traceability

The blockchain technology enables authorized users to view supply chain data in real-time as transactions occur. The system now enables faster detection of dishonest business partners who attempt to exploit information asymmetry through fake specifications or fabricated invoices. The concrete business demonstrates this concept by recording supplier information along with grade specifications and batch numbers and delivery times and status updates on the blockchain. The supply chain records each stage from loading to moving to delivery to verification at the location which maintains an accurate item tracking system. The need for traceability becomes critical when tracking high-value or safety-focused materials such as steel and electrical cables and fire-resistant panels. Blockchain technology enables post-construction issue tracking which identifies both the source of problems and their exact location and responsible parties. Auditors monitor standards while using unmodified records to verify that the company follows approved sourcing and installation procedures.

3.3 Fraud Prevention through Smart Contracts

The construction industry heavily relies on blockchain technology through smart contracts. The blockchain-based smart contract executes its terms automatically through self-activation because it contains coded instructions. Smart contracts can be programmed to deliver payments and fulfill contracts only when specific shipments reach the construction site. The implementation of this technology reduces the opportunities for system manipulation. Traditional procurement requires multiple authorizations which creates numerous opportunities for fraudulent activities. Smart contracts resolve these issues because they establish all payment and order conditions in advance which receive continuous monitoring until they automatically trigger when fulfilled. Smart contracts enable payment authorization only after each project phase reaches completion. The reduced financial risk for contractors during cash management leads them to complete their work according to specifications. The blockchain storage combined with its conditional processes makes it difficult to perform unauthorized actions or send poorly made goods or overcharge.

3.4 Integration with IoT and Real-Time Verification

The combination of blockchain technology with IoT systems enhances the ability to combat fraud through their joint operation. The Internet of Things (IoT) relies on GPS devices and RFID tags and sensors and scanners to monitor construction materials. The devices enable real-time blockchain data transmission of temperature and vibration and location and usage information which creates tamper-proof instant records. The GPS technology installed in cement trucks enables them to send their present location data to show their movement toward the construction site. The delivery process ends when sensors automatically note both the time of arrival and the amount of goods received. The blockchain system automatically verifies and records all details so the shipment remains error-free. Site engineers can verify correct orders by scanning delivered goods with QR codes which allows them to check blockchain records. The system provides continuous access to precise data through automated processes which enables better data-driven decision making. Project managers gain complete supply chain visibility through blockchain and IoT integration which enables them to detect issues promptly and respond swiftly while maintaining accountability across all stakeholders.

3.5 Cost Reduction and Process Optimization

The initial monetary investment for blockchain technology implementation leads to substantial long-term advantages. Companies achieve reduced core administrative costs through automation of procurement functions and payment processing and documentation systems. The elimination of document sorting and invoice verification and follow-up tasks occurred because of blockchain implementation. The use of blockchain technology reduces disputes because it delivers accurate information which all parties can access. All parties access the identical unalterable record which eliminates confusion about delivery requirements and material specifications and payment procedures. The reduction of disagreements leads to shorter delays and decreased expenses related to dispute resolution. The combination of blockchain transparency and operational efficiency leads stakeholders to trust both the project and its reputation more strongly. Secure supply chain integrity management projects receive support from investors and regulators and customers who prefer them. Companies that maintain a positive reputation will receive additional opportunities which enhances their market competitiveness.

4. Framework for Blockchain-Enabled Transparency

4.1 Conceptual Design of the Framework

The blockchain system for construction material supply chains includes multiple interconnected layers that align with current digital infrastructure to combat fraud and track materials and improve operational processes. The blockchain framework consists of four fundamental layers which include the Identity Layer and the Contractual Layer and the Provenance Layer and the Auditing and Analytics Layer. The different functions of each layer exist within a protected blockchain network which enables them to work together. Every participant on the blockchain receives a digital identity which enables authentication of suppliers together with contractors and regulatory agencies and logistics providers and clients. The implementation of digital identities eliminates anonymous transactions which enables the tracing of every action back to a specific member of society.

The Contractual Layer implements smart contracts which automatically execute procurement processes and payment distribution and compliance verification and penalty enforcement for non-compliance. The automatic activation of these contracts upon receiving data minimizes the potential for human interference. The tracking system of this Layer monitors construction materials throughout their entire journey from production to delivery. The tracking system monitors each material through its origin information and batch ID and quality certificates and transportation details and site confirmation records. The Auditing and Analytics Layer collects transaction data for project monitoring during execution and post-project evaluation. Authorized users can use this system to detect trends and identify inconsistencies while measuring supply chain entity compliance with requirements.

Table 2: Core Components of the Proposed Blockchain Framework

Component	Function	Benefit
Digital Identity	**Assigns a unique, verifiable identity to every supply chain actor**	**Prevents impersonation and unauthorized access**
Smart Contracts	**Automates procurement, payments, and compliance tasks**	**Reduces fraud and ensures rule-based execution**
Material Provenance	**Tracks materials from source to site, including certification and handling**	**Enables traceability and quality assurance**
Auditing Nodes	**Monitors and verifies data integrity across the blockchain network**	**Supports transparency, reporting, and audits**
API Integration Layer	**Connects blockchain to ERP, BIM, and other legacy systems**	**Ensures operational continuity and scalability**

4.2 Integration with Existing Supply Chain Systems

The proposed framework for construction supply chains must integrate with current ERP systems and BIM and logistics tracking software. The proposed framework includes an API-based Integration Layer to enable communication between blockchain network and standard digital services. The blockchain ledger accepts procurement orders and invoices and logistics updates and warehouse management information through standardized APIs. The existing system infrastructure remains unchanged while the connection enables companies to enhance system safety and certainty and transparency.

The procurement manager using SAP ERP can initiate material orders which get recorded directly on the blockchain system. The blockchain platform and ERP system receive updates whenever the order moves through its stages including sendoff and arrival and proof of receipt. Users benefit from two-way synchronization because it reduces data update time while maintaining copy-free consistent data.

4.3 Hypothetical Scenario Illustrating Framework Application

A major infrastructure project serves as an example to demonstrate how precast concrete panels need to be acquired and transported to multiple build stages for installation. The construction company team works with numerous suppliers and logistics companies during their operations. The procurement team approves a deal which allows a certificated supplier to create a smart contract that they upload to the blockchain system. Payment approval occurs after scanning the delivery's QR-code and receiving confirmation from IoT sensors. Each supplier gains access to the blockchain through digital identities to post their batch numbers and test reports and shipment details. The combination of GPS IoT devices enables real-time shipment tracking which automatically logs details on the blockchain. The procurement order automatically checks for a match after engineers scan the QR codes at the site.

The smart contract releases payment portions to suppliers when all standards match including unit numbers and batch codes and delivery addresses. The auditing node allows both regulatory officers and project managers to access data in real time after delivery logging. The supply chain model gains increased security and responsibility through blockchain records which enable both quality grievance listening and detailed inspection using blockchain ledgers for resolution. The supply chain model gains enhanced security and responsibility and fraud-proof capabilities through this system.

5. Fraud Prevention through Blockchain: Mechanisms and Impact

5.1 Blockchain's Role in Detecting and Preventing Construction Fraud

The construction material supply chain fraud detection relies on identifying forged invoices and incorrect material certifications and substandard materials and duplicate job submissions. The combination of poor procurement clarity and weak communication between witnesses and no centralized verification system enables this type of fraud to occur. Blockchain technology provides an immutable decentralized platform for plain-to-see information which makes unauthorized data modification and unauthorized access virtually impossible. The main fraud prevention system blockchain uses is the immutable ledger. The blockchain stores data which cannot be altered or deleted unless all network nodes give their approval. Every transaction along with item movements and contract terms exists in an unalterable permanent record. The permanent nature of blockchain records makes it difficult to modify invoice figures and delivered goods and certifications which reduces construction fraud opportunities.

Moreover, decentralization prevents single-point control. The traditional system enables a corrupt system member to modify information without detection. The verification process for new transactions requires agreement from multiple independent network components thus making unauthorized changes extremely difficult. The data integrity of blockchain is enhanced by its cryptographic security protocols. The transactions in the chain are

connected through cryptographic hashes which makes any attempt to break or modify the chain detectable. The entire material supply process remains protected and traceable because of this system.

5.2 Enhanced Traceability and Real-Time Validation

The ability to track products throughout the construction supply chain plays a crucial role for project planning as well as for preventing fraud. The blockchain system documents each step of a product's journey from its original material source to processing and shipping and finally to its use in construction. The system assigns tokens or IDs to each unit of construction material which gets stored on the blockchain. Each token includes details about its origin as well as its composition and test results and certificates and a timestamp for ownership transfers. The system maintains an unalterable record of asset ownership by adding new information to the blockchain at each point in time. The batch number on a steel bar at a building site can be checked against both the logbook and shipping route records at the foundry.

The combination of Internet of Things (IoT) devices with QR codes enables instant verification and blockchain storage of products and shipping information. The blockchain receives automatic updates whenever shipments move between warehouses and customs and delivery sites through scanning operations. Real-time synchronization enables immediate detection of supply amount errors and product delivery discrepancies and route deviations which allows for immediate corrective actions. The ability to monitor all actions through the system makes it challenging for anyone to perform fraudulent activities including product substitution or delivery falsification or certification forgery.

5.3 Smart Contracts as Anti-Fraud Mechanisms

Smart contracts operate as digital contracts which execute predefined rules and conditions that developers have embedded within their code. The system uses these contracts to perform vital operations that include order addition and payment processing for milestones and compliance verification and penalty enforcement for unfulfilled responsibilities. A smart contract would trigger payment after three conditions are met: the certified materials reach their destination, the engineer verifies the delivered amount and quality and there exists documentation of timely delivery when payment execution occurs. The payment system will not activate when any of these conditions fail to meet their requirements because an alarm will trigger an examination process.

The automation of compliance eliminates opportunities for middlemen to receive bribes or experience pressure or errors that humans can make. The system operates based on verified data which prevents any influence of biases on its decisions. Smart contracts enable suppliers and buyers and regulators to verify that their responsibilities will receive transparent and fair assessment. The use of blockchain-based manual validation reduces the occurrence of duplicate invoices and false acceptances and intentional dishonest behavior to a significant extent. The blockchain allows smart contracts to connect with reputation systems which enable buyers to evaluate supplier trustworthiness through examination of their past compliance records.

5.4 Real-World Applications and Pilot Studies

Different starting projects and pilots have proven that blockchain helps keep fraud to a minimum on construction and infrastructure projects. ProBuild Australia tested a material provenance system for big commercial projects by working with a blockchain company. The system monitored concrete origin while verifying certifications and tracking delivery routes. The system resulted in a 35% decrease of material-related conflicts while achieving an 18% improvement in procurement clarity which led to faster and cheaper project completion. The Smart City project in Dubai uses blockchain technology to handle public construction operations. The implementation of blockchain technology allows Dubai municipal projects to track every building material that receives certification through easy monitoring. The first blockchain implementation results in better steel factory contractor approval processes and reduced counterfeit steel occurrences.

The State Construction Engineering Corporation (CSCEC) of China used blockchain technology alongside logistics firms to track valuable assets throughout infrastructure projects. The combination of GPS and RFID tags on the blockchain network provided real-time tracking of assets which helped prevent theft and incorrect deliveries. These examples demonstrate that blockchain technology gains worldwide acceptance for supply chain integrity improvement at every project stage. The shift in regulatory and client perspectives toward reliable record keeping and data control leads to better long-term fraud prevention efforts.

6. Limitations and Barriers to Adoption

6.1 Technical Constraints

The implementation of blockchain technology in construction material supply faces technical challenges that slow down its potential benefits. The advanced nature of blockchain technology creates challenges for construction firms to implement it because they lack sufficient IT capabilities. The establishment and operation and maintenance of blockchain networks require personnel who possess cryptographic and development competencies. The scalability of blockchain networks becomes a frequent challenge especially when they operate as public or permissioned systems. Construction projects require daily tracking of numerous material arrivals and inspections and paperwork. The current blockchain systems face limitations in handling only specific transaction volumes at a time which reduces their operational effectiveness. The bottleneck in the system causes responsive actions to slow down which threatens to damage the essential benefits of transparency and traceability. The solution to enable transparent interoperability between blockchain and legacy supply chain software remains unsolved. Most construction companies use ERP systems and digital buying tools which do not integrate well with blockchain technology. The lack of connection between different technologies forces companies to implement customized solutions and middleware which increases complexity and costs.

6.2 Organizational and Cultural Resistance

Organizations must transform their operational approaches and mental frameworks when adopting blockchain technology yet this transition often encounters significant resistance. The fear of others discovering their weaknesses leads construction firms and their subcontractors and suppliers to resist sharing confidential business data through a shared platform. The lack of trust between stakeholders could prevent blockchain from achieving its necessary level of adoption and support. The implementation of blockchain technology establishes new organizational structures which challenge the traditional hierarchical systems found across different industries. The standard hierarchies in procurement and compliance and middle management roles tend to resist systems that reduce their decision-making power and reveal their errors. Organizations must overcome two major challenges related to training and upskilling their employees. Companies need to spend substantial resources on educational and informative and change management programs to prepare their employees for blockchain readiness.

6.3 Regulatory and Legal Challenges

The implementation of blockchain to enhance supply chain transparency in construction operates within an existing complex legal framework. Blockchain operations face challenges because they need to adapt to varying national laws regarding data privacy and intellectual property and electronic contracts. The permanent nature of blockchain ledgers conflicts with the European Union's GDPR rules which grant individuals the right to request data deletion. The unclear legal status of personal data storage on distributed ledgers exists because of this situation. The legal status of smart contracts remains unclear regarding their enforceability under the law. Smart contracts operate autonomously yet lack universal legal frameworks which creates potential risks for all parties involved. The regulatory community remains uncertain about how blockchain operations should be interpreted under construction and procurement legal frameworks.

6.4 Financial Cost and Investment Barriers

Construction companies including SMEs need to address financial obstacles before they can implement blockchain technology. The development of a customized blockchain system together with IoT hardware implementation and continuous system maintenance expenses a significant amount of money and continues over time. The investment in blockchain technology will not produce immediate results because its main advantages emerge in the future through enhanced transparency and reduced fraud and increased efficiency. The combination of delayed return expectations and regulatory and technological risks leads companies to delay their smart contract development decisions. The implementation of blockchain technology requires modifications to existing contracts and payment procedures which creates additional financial and legal obstacles.

6.5 Scalability and Interoperability Issues

Construction projects that grow in scale and complexity require proportional growth in blockchain data storage. The growth of transactions in large supply chains exceeds the performance capabilities of most blockchain architectures which results in slower system performance. The inability to establish common procedures between blockchain platforms prevents them from being connected. The system's total efficiency decreases when supply chain participants operate on different blockchain networks because they face challenges when sharing information and confirming actions. The development of cross-chain communication and industry-wide standards requires additional research and collaboration between industry participants to establish interoperable systems in the construction sector.

Table 3: Barriers to Blockchain Adoption in Construction

Barrier Category	**Description**	**Impact**
Technical	Complexity, scalability limits, lack of interoperability with existing software	Delays in implementation, reduced system efficiency
Organizational	Resistance to change, data sharing reluctance, lack of technical skills	Low adoption rates, incomplete blockchain networks
Regulatory	Data privacy conflicts, uncertain smart contract enforceability	Legal risks, compliance challenges
Financial	High initial costs, uncertain ROI, contractual adjustments	Budget constraints, slower technology uptake
Scalability & Interoperability	Limited transaction throughput, absence of standardized protocols	System bottlenecks, fragmented supply chain data

7. Policy and Industry Recommendations

7.1 Guidelines for using Blockchain in both public and private construction contracting

The successful implementation of blockchain technology in construction material supply chains requires guidelines that apply to both public agencies and private sector businesses. Experts recommend policymakers to create regulations which specify blockchain applications for documentation and confirmation and distribution of procurement information. The system should maintain transparency but protect all business secrets from disclosure.
Public procurement groups should promote blockchain adoption in megaprojects by making blockchain guidelines mandatory for contractors. The approach enables suppliers and contractors to work with blockchain systems which verify product origins while minimizing fraudulent activities. The implementation of these policies requires predefined standards together with established evaluation procedures for blockchain success. Organizations should begin their blockchain implementation by launching small projects in procurement to determine their effectiveness and cost structure and user acceptance. The system requires early establishment of blockchain rules for participant participation and data management and dispute resolution processes to achieve participant and organizational trust.

7.2 Stakeholder Collaboration and Standards Development

The decentralized nature of blockchain requires complete cooperation from all stakeholders in the construction supply chain. Owners and contractors and suppliers and regulators and technology providers must work together to create common blockchain solutions which require industry standard agreements for data transfer and approval. These organizations can work together to create blockchain protocols that match the requirements of construction supply chains. The organizations should maintain transparency while safeguarding both confidential and creative information. Multi-stakeholder teams must reach consensus on optimal methods to integrate blockchain technology with current procurement and quality control systems to enhance blockchain value. The organizations should provide health organizations with opportunities to share pilot testing insights and explore fresh approaches for improvement.

7.3 Training and Capacity Building

The building industry needs to expand blockchain adoption so it requires developing training programs for its workforce. The training program should demonstrate blockchain functionality to IT professionals and procurement officers and project managers and auditors so they can understand its value. The training program should include workshops and certifications and digital platforms which provide staff members with practical experience using blockchain tools and smart contract management. The program will help address problems caused by staff members who lack understanding of the system while motivating employees to start implementing changes at work. Legal and compliance experts require training to understand how blockchain-based contracts and audits function while following regulatory guidelines. All parties involved must gain thorough blockchain knowledge to achieve successful and impactful adoption.

7.4 Cybersecurity and Legal Frameworks

The security of supply chain data becomes more critical when more businesses adopt blockchain technology. Policy leaders and industry chiefs should prioritize the development of blockchain-specific cybersecurity measures for construction that include encryption and ID controls and fraudulent activity detection methods. The treatment of blockchain resources and smart contracts as valid entities must begin for dispute resolution and audit platforms. The authorities need to work with legal experts to establish precise guidelines regarding blockchain evidence usage and smart contract liability and unchanging blockchain ledger privacy concerns. The implementation of supportive legal and cybersecurity frameworks will provide assurance to blockchain system users about safe and secure operation.

Conclusion

The research into standard construction materials supply problems proved that blockchain technology offers substantial benefits for transparency enhancement and fraud prevention throughout these processes. The complex nature of construction supply chains together with their multi-layered structure creates an environment where different materials substitution combined with false documentation and rule-breaking corruption can easily occur thus damaging project quality while increasing total costs and decreasing stakeholder trust. Traditional tracking systems with poor visibility along with fixed records create difficulties in both detecting and addressing fraud and identifying those accountable for it. According to the research team, the framework will achieve productivity by using distributed ledger technology features including decentralization and immutability and transparency. The solution uses a layered system that includes digital identities together with smart contracts and provenance tracking and decentralized nodes to establish safety and automatic supply chain management. Smart contracts with compliance requirements enable automatic operation of most processes and reduce the potential for manipulation. The system provides instant data verification together with complete transparency so stakeholders can trust that construction site materials are genuine and meet ethical sourcing standards and quality requirements.
The study identifies major obstacles which prevent blockchain from becoming a standard construction tool despite its potential to transform the industry. The main barriers facing blockchain software implementation consist of its inherent scalability limitations together with difficulties in integrating it with existing systems. Organizations face two main challenges in blockchain adoption speed because of their unfamiliarity with blockchain technology alongside concerns about initial investment costs. The current update of regulations acknowledges blockchain documents but also addresses privacy-related issues and security concerns as well as liability problems that arise during automated contract execution. The solution

requires joint policy actions together with industry collaborations and extensive stakeholder training to overcome these problems. The research indicates blockchain functions best when used as a strategy to enhance supply chain governance rather than as a standalone solution. The success of implementation depends on solutions that adapt to project requirements and promote stakeholder partnerships while conducting on-site monitoring and evaluation throughout pilot programs.

Researchers should perform case studies about blockchain applications to fight construction site fraud as well as evaluate blockchain's economic value and combine blockchain with IoT sensors and AI in supply chain experiments. Studies that track blockchain adoption patterns over time will provide researchers with essential data about its ongoing impact on supply chain openness as well as business operations and regulatory changes. Blockchain technology used for construction material supply chain transparency enhances awareness while increasing accountability and effectiveness in the process. The system maintains audit trails and automated compliance regulations alongside trusted data for all stakeholders which together create an effective fraud-fighting mechanism. The construction industry needs blockchain technology to maintain both reliability and sustainability of infrastructure as it moves toward digitalization. The adoption of blockchain for fighting fraud and building a strong trustworthy building sector requires active industry support combined with research investments and collaborative partnerships.

REFERENCES:

[1] Azhar, S. M. F. J., Ghani, E. K., Muhammad, K., & Sukmadilaga, C. (2023). Factors Influencing Academic Fraud Prevention among Accounting Students. Review of Economics and Finance, 21, 43–54. https://doi.org/10.55365/1923.x2023.21.5

[2] Chen, Z., Hammad, A. W. A., & Alyami, M. (2024). Building construction supply chain resilience under supply and demand uncertainties. Automation in Construction, 158. https://doi.org/10.1016/j.autcon.2023.105190

[3] Fan, Z. P., Wu, X. Y., & Cao, B. B. (2022). Considering the traceability awareness of consumers: should the supply chain adopt the blockchain technology? Annals of Operations Research, 309(2), 837–860. https://doi.org/10.1007/s10479-020-03729-y

[4] Fox, J. (2007). The uncertain relationship between transparency and accountability. Development in Practice, 17(4–5), 663–671. https://doi.org/10.1080/09614520701469955

[5] Gaventa, J., & Mcgee, R. (2013). The impact of transparency and accountability initiatives. Development Policy Review, 31(S1). https://doi.org/10.1111/dpr.12017

[6] Gharaibeh, L., Eriksson, K. M., Lantz, B., Matarneh, S., & Elghaish, F. (2024). Toward digital construction supply chain-based Industry 4.0 solutions: scientometric-thematic analysis. Smart and Sustainable Built Environment, 13(1), 42–62. https://doi.org/10.1108/SASBE-12-2021-0224

[7] Khan, S. A., Mubarik, M. S., Kusi-Sarpong, S., Gupta, H., Zaman, S. I., & Mubarik, M. (2022). Blockchain technologies as enablers of supply chain mapping for sustainable supply chains. Business Strategy and the Environment, 31(8), 3742–3756. https://doi.org/10.1002/bse.3029

[8] Lukman, R. P., & Chariri, A. (2023). THE ROLE OF INTERNAL AUDITORS IN FRAUD PREVENTION AND DETECTION: EMPIRICAL FINDINGS FROM GENERAL BANKING. DIPONEGORO JOURNAL OF ACCOUNTING, 12(1), 1–11. Retrieved from http://ejournal-s1.undip.ac.id/index.php/accounting

[9] Moldalieva, J. (2021). Localizing transparency and accountability in extractives. Extractive Industries and Society, 8(4). https://doi.org/10.1016/j.exis.2021.100991

[10] Morkunas, V. J., Paschen, J., & Boon, E. (2019). How blockchain technologies impact your business model. Business Horizons, 62(3), 295–306. https://doi.org/10.1016/j.bushor.2019.01.009

[11] Rifai, M. H., & Mardijuwono, A. W. (2020). Relationship between auditor integrity and organizational commitment to fraud prevention. Asian Journal of Accounting Research, 5(2), 315–325. https://doi.org/10.1108/AJAR-02-2020-0011

[12] Rifai, M. H., & Mardijuwono, A. W. (2020). Relationship between auditor integrity and organizational commitment to fraud prevention. Asian Journal of Accounting Research, 5(2), 315–325. https://doi.org/10.1108/AJAR-02-2020-0011

[13] Rompoti, K., Madas, M., & Kitsios, F. (2020). A conceptual framework for effective contracting in construction supply chains. International Journal of Construction Supply Chain Management, 10(3), 92–114. https://doi.org/10.14424/ijcscm100320-92-114

[14] Saberi, S., Kouhizadeh, M., Sarkis, J., & Shen, L. (2019). Blockchain technology and its relationships to sustainable supply chain management. International Journal of Production Research, 57(7), 2117–2135. https://doi.org/10.1080/00207543.2018.1533261

[15] Tariq, E., Akour, I., Al-Shanableh, N., Alquqa, E. K., Alzboun, N., Al-Hawary, S. I. S., & Alshurideh, M. T. (2024). How cybersecurity influences fraud prevention: An empirical study on Jordanian commercial banks. International Journal of Data and Network Science, 8(1), 69–76. https://doi.org/10.5267/j.ijdns.2023.10.016