

Training and Infrastructure Readiness for Blockchain-Based Construction Material in Lagos State, Nigeria

¹Okuntade, T.F and ¹Augustine, I.E.

¹Department of Building Technology, Federal University of Technology, Akure, Nigeria
Corresponding author: Tope Femi Okuntade | Email: okuntadetopsy@gmail.com

Email: Ijigah Edoke Augustine: eaijigah@futa.edu.ng

Abstract

Blockchain technology offers potential to improve transparency, traceability, verification and accountability in construction material management, yet implementation requires human competencies and infrastructure. This study assesses training requirements and infrastructure readiness for blockchain-based construction material management among construction professionals in Lagos State, Nigeria. A quantitative cross-sectional survey collected data from 370 professionals involved in material procurement, management, tracking and verification. Questionnaire items measured professional characteristics, current digital-tool use, training requirements and infrastructure conditions. Data were analysed using descriptive statistics, the Friedman test, Wilcoxon signed-rank tests and Kruskal–Wallis tests. Results indicate strong demand for foundational digital and blockchain competencies. Basic smartphone and computer skills recorded the highest foundational requirement (mean score, $M = 3.938$), while smart-contract development and interpretation was the highest-rated technical competency ($M = 3.924$). Data privacy regulation ($M = 3.905$), ethical use of blockchain data ($M = 3.900$) and cybersecurity ($M = 3.884$) were highly rated governance requirements. A significant difference existed among training domains ($\chi^2(2) = 63.269$, $p < 0.001$), with technical requirements rated lower than foundational and governance requirements. Simulation-based training ($M = 3.946$) and practical workshops ($M = 3.938$) were the most preferred delivery modes. Infrastructure findings indicate high smartphone penetration ($M = 4.519$), but less favourable conditions for reliable electricity ($M = 3.673$) and internet connectivity ($M = 3.749$). Poor or unreliable internet ($M = 3.800$) was the strongest implementation constraint. No significant professional-group differences were found. The study proposes a Training-Infrastructure Readiness Framework comprising foundational competency, technical capability, governance literacy and infrastructure enablement as sequential requirements for blockchain implementation.

Keywords: blockchain technology, construction material management, digital transformation, infrastructure readiness, training readiness

Introduction

Construction material management is an important factor in determining project costs, productivity, programme performance and quality. Construction materials comprise a significant percentage of construction costs, which means it is important to handle procurement, delivery checking, storage and inventory management properly to achieve project milestones. Unfortunately, in Nigeria, construction material management still relies heavily on manual record-keeping and disconnected communication systems. Previous research in Lagos and Abuja found that material management suffers from heavy dependence on paper delivery records, oral confirmation and physical documents without digital tracing or cross-verification of the parties involved (Oseghale and Adetooto, 2021).

Weak material management leads to problems beyond administrative inefficiency. Construction projects may experience shortages, over-ordering of materials, theft, replacement of materials with substandard ones and fraudulent transactions. According to Albert *et al.* (2021), poor material management contributes

to delays in project completion, while Farinloye *et al.* (2013) reported theft and vandalism on construction sites in Lagos. These findings indicate persistent weaknesses in transaction verification, inventory visibility and accountability within construction material management. Blockchain technology offers a potential digital infrastructure for addressing some of these weaknesses. A blockchain is a distributed ledger used for sequentially documenting transactions and encrypting them (Zhenget *al.*, 2018). Smart contracts allow automated execution of specified operations when supplied with relevant information, while permissioned blockchains can restrict access to authorised persons or organisations (Christidis and Devetsikiotis, 2016; Androulaki *et al.*, 2018). These properties have been proposed for construction supply chains to support material tracking, transaction verification, auditing and automated payment processes (Hamledari and Fischer, 2020; Kshetri, 2018). Nevertheless, the technological potential of blockchain does not guarantee implementation success. Successful implementation requires construction companies to have personnel with knowledge and skills in digital technologies, blockchain transactions and smart contracts, digital information protection and relevant legal requirements. Okanlawon *et al.* (2023) reported limited blockchain knowledge among construction professionals in Nigeria. Similarly, Idowue *et al.* (2023) identified inadequate training and infrastructural shortcomings as barriers to digitalisation in the Nigerian construction industry.

Infrastructure is also critical because blockchain-based material management depends on the ability of parties and systems to synchronise and validate transactions; unstable electricity or internet connectivity may disrupt these operations. Although previous studies have examined blockchain adoption and barriers, implementation-readiness requirements have received less empirical attention. Specifically, there is limited empirical evidence on the competencies of construction specialists required for blockchain implementation and the institutional conditions necessary for blockchain-based construction material management in Lagos. Individual digital competence does not necessarily imply the ability to operate a blockchain platform, just as an organisation may have digitally literate personnel while its operating sites lack stable electricity and internet connectivity. Accordingly, this study shifts the focus from intention to implement blockchain to the conditions required for implementation. The research is based on a survey involving 370 construction specialists from Lagos State and aims to identify the competencies required for blockchain-based material management training, compare foundational, technical and governance/compliance training needs, assess infrastructure readiness and identify priority conditions for implementation.

Four research questions are addressed: (1) Which competencies are most required for blockchain-based material management among construction specialists in Lagos State? (2) Do foundational, technical and governance/compliance training needs differ? (3) What is the level of infrastructure readiness for blockchain-based construction material management in Lagos State? (4) Which training and infrastructure conditions should be prioritised for blockchain implementation? From a conceptual perspective, the study treats training demands and infrastructure conditions as complementary implementation domains. Human-capacity readiness comprises at least three groups of capacities: basic digital capacities, blockchain-related technical capacities, and governance/compliance competencies. Infrastructure readiness comprises reliable electricity, internet connectivity and access to relevant digital devices. Neither domain is sufficient alone: inadequate infrastructure can constrain otherwise capable users, while adequate infrastructure cannot compensate for a lack of user competence. Implementation readiness can therefore be understood as the intersection of human and infrastructure capacity.

Materials and Methods

Research design and sample

The study used a quantitative survey approach, which is recognised as a valid social research method for assessing perceptions at a specific point in time (Saunders *et al.*, 2019). The population comprised construction-sector professionals engaged in the procurement, management, monitoring and verification of construction materials in Lagos State. The sampling frame was estimated at approximately 5,000 practising professionals and, using the Yamane formula, a sample of 370 was drawn at a 95% confidence level and

5% margin of error. Data were collected through structured questionnaires administered between March and June 2024. A total of 420 questionnaires were distributed; 370 valid responses were returned, representing a response rate of 88.1%. The study obtained ethical approval from the Research Ethics Committee of the Federal University of Technology, Akure (FUTA), Nigeria.

Measurement instrument

There were five parts to the questionnaire. Part A focused on demographic and professional aspects while Part B discussed materials management techniques and the use of digital tools. Part C contained questions related to blockchain attitude and readiness; part D dealt with both prospective forces and obstacles to blockchain implementation and part E dealt with the training needs and choice of training mode. All the important variables were measured using a five-point Likert type scale where 1 meant not important and 5 meant very important. In this paper, we were concerned only with the aspects related to education and readiness of infrastructure. The training aspects were divided into basic educational competencies (basics of digital learning, fundamentals of blockchain, info security), technical competencies (understanding smart contracts, monitoring supply chain, using a platform, using ERP and data analysis), and operational and corporate governance aspects (privacy, ethical usages, cybersecurity, and professional ethical standards).

Data analysis

For each training and infrastructure element, descriptive statistics, including mean values and standard deviations, were calculated. Training specifications were classified into foundational, technical and governance/compliance domains. Because the domain scores were derived from ordinal Likert-scale items, the Friedman test was used to assess differences among the three training domains. Where significant differences were identified, Wilcoxon signed-rank tests were used for pairwise comparisons. Kruskal–Wallis tests were used to examine differences in training-domain scores across the five professional groups.

Results and Discussion

Training competency requirements

Table 1 presents the foundational training requirements. All items exceeded the neutral mean of 3.00. Basic smartphone and computer skills recorded the highest mean ($M = 3.938$), followed by training in basic digital tools ($M = 3.916$), indicating that respondents regarded general digital competence as an important prerequisite for blockchain implementation. The standard deviations ranged from 0.242 to 0.579. The relatively low SD for basic smartphone and computer skills indicates strong agreement among respondents, whereas the higher SD for short verified blockchain certifications indicates greater variation in respondents' views about the value of formal certification. The domain mean of 3.864 also indicates a generally high perceived need for foundational training.

Table 1: Foundational training requirements

Requirement	Mean	SD	Rank
Basic smartphone and computer skills	3.938	0.242	1
Training in basic digital tools	3.916	0.277	2
Introductory blockchain concepts	3.865	0.342	3
Short verified blockchain	3.816	0.579	4

Requirement	Mean	SD	Rank
certifications			
Understanding data security	3.784	0.412	5
Domain mean	3.864	0.176	

Table 2 presents the technical blockchain training requirements. Smart-contract development and interpretation recorded the highest mean ($M = 3.924$), followed by supply-chain tracking using blockchain ($M = 3.841$). Blockchain data analytics recorded the lowest mean ($M = 3.511$), suggesting that respondents placed greater emphasis on technical competencies directly connected with construction material processes. The standard deviations ranged from 0.265 to 0.501. The relatively low SD for smart-contract development and interpretation indicates stronger agreement, whereas the higher SD for blockchain data analytics suggests greater variation in perceived training need. The domain mean of 3.782 confirms that technical competencies were also regarded as important, although less strongly than the other training domains.

Table 2: Technical blockchain training requirements

Requirement	Mean	SD	Rank
Smart-contract development and interpretation	3.924	0.265	1
Supply-chain tracking using blockchain	3.841	0.367	2
Blockchain platform usage	3.824	0.381	3
ERP-system integration	3.811	0.392	4
Blockchain data analytics	3.511	0.501	5
Domain mean	3.782	0.173	

Table 3 presents the governance and compliance training requirements. Data privacy regulations and NDPR compliance recorded the highest mean ($M = 3.905$), followed by ethical use of blockchain data ($M = 3.900$) and cybersecurity best practices ($M = 3.884$). The findings demonstrate that respondents did not perceive blockchain training as purely technical; legal, ethical and information-security competencies were also regarded as important. The standard deviations ranged from 0.293 to 0.562. The relatively low SDs for data privacy regulations and ethical use of blockchain data indicate substantial agreement, while the higher SD for compliance with construction standards indicates more diverse views about that requirement. The domain mean of 3.859 shows that governance and compliance training was highly rated overall.

Table 3: Governance and compliance training requirements

Requirement	Mean	SD	Rank
Data privacy regulations/NDPR	3.905	0.293	1
Ethical use of blockchain data	3.900	0.300	2
Cybersecurity best practices	3.884	0.321	3
Blockchain-specific compliance	3.824	0.381	4
Compliance with construction standards	3.784	0.562	5

Requirement	Mean	SD	Rank
Domain mean	3.859	0.178	

Differences among training domains

The three training domains differed significantly ($\chi^2(2) = 63.269$, $p < 0.001$), as shown in Table 4. Pairwise Wilcoxon signed-rank tests showed that foundational requirements were rated significantly higher than technical requirements ($p < 0.001$), while governance/compliance requirements were also rated significantly higher than technical requirements ($p < 0.001$). No significant difference was found between foundational and governance/compliance requirements ($p = 0.922$). Thus, foundational and governance/compliance competencies were prioritised over specialised technical skills. This finding challenges a technology-first approach to implementation and suggests that training should begin with general digital competence and governance knowledge before advanced blockchain functions are introduced. The result is consistent with Singh *et al.*(2023), who identified inadequate knowledge and employee training as pivotal barriers to blockchain adoption in construction supply chains internationally. It also agrees with Akinradewo *et al.*(2022), who identified lack of skills or knowledge among the leading barriers to blockchain implementation in the South African built environment. The present study extends these findings by showing how construction professionals in Lagos prioritise foundational and governance/compliance competencies relative to technical skills.

Table 4: Statistical comparison of training domains

Comparison	Test	p-value	Interpretation
Overall training domains	Friedman test, $\chi^2(2) = 63.269$	< 0.001	Significant difference among domains
Foundational vs technical	Wilcoxon signed-rank test	< 0.001	Foundational rated higher
Governance/compliance vs technical	Wilcoxon signed-rank test	< 0.001	Governance/compliance rated higher
Foundational vs governance/compliance	Wilcoxon signed-rank test	0.922	No significant difference

Preferred training delivery

Preferred training delivery modes are summarised in Table 5. Simulation-based training recorded the highest mean ($M = 3.946$), followed closely by practical hands-on workshops ($M = 3.938$). Short focused online modules had the lowest mean ($M = 3.711$), although the score remained above the neutral point. The standard deviations ranged from 0.226 to 0.454, indicating relatively consistent preferences for the two highest-ranked modes and greater variation in views about short online modules. The result suggests that blockchain training should emphasise workflow simulation and practical activities rather than rely solely on theoretical or short online instruction. This emphasis on applied capacity development is consistent with the wider blockchain-adoption literature, where skills and knowledge deficits are repeatedly identified as implementation barriers (Akinradewo *et al.*, 2022; Singhet *et al.*, 2023).

Table 5: Preferred blockchain training delivery modes

Training mode	Mean	SD	Rank
Simulation-based training	3.946	0.226	1
Practical hands-on workshops	3.938	0.242	2
Regular refresher courses	3.765	0.425	3
NIOB/COREN-certified programmes	3.738	0.440	4
Short focused	3.711	0.454	5

Training mode	Mean	SD	Rank
online modules			

Infrastructure readiness and constraints

Table 6 presents the infrastructure readiness conditions. Smartphone penetration was the strongest condition ($M = 4.519$), whereas internet connectivity ($M = 3.749$) and reliable electricity ($M = 3.673$) received lower scores. The standard deviations were 0.625 for smartphone penetration, 1.379 for internet connectivity and 1.387 for reliable electricity. The substantially larger SDs for connectivity and electricity indicate marked variation in respondents' experiences across operating environments, unlike the relatively consistent assessment of smartphone access. The mixed readiness pattern is consistent with Akinradewo *et al.* (2022), who identified technological barriers, including infrastructure limitations, in the South African built environment. It also complements findings from Nigeria showing that inadequate power supply and digital facilities constrain construction-sector digitalisation (Idowuet *al.*, 2023). The present study refines these observations by showing that device access is comparatively strong while the reliability of the infrastructure supporting digital transactions remains weaker.

Table 6: Infrastructure readiness conditions

Infrastructure condition	Mean	SD	Interpretation
High smartphone penetration	4.519	0.625	Strongest condition
Internet connectivity sufficient	3.749	1.379	Moderate
Reliable electricity available	3.673	1.387	Moderate

Table 7 presents the infrastructure-related implementation constraints. Poor or unreliable internet was the strongest constraint ($M = 3.800$), followed by unstable power supply ($M = 3.643$). Lack of affordable devices recorded a substantially lower mean ($M = 3.035$). The standard deviations were 0.401, 0.480 and 0.997, respectively. The relatively low SDs for internet and power constraints indicate comparatively consistent recognition of these problems, while the larger SD for affordable devices suggests more varied experiences of device affordability. The result is consistent with the high smartphone-penetration score and indicates that access to devices is less problematic than the reliability of the infrastructure supporting digital transactions.

Table 7: Infrastructure-related implementation constraints

Constraint	Mean	SD	Rank
Poor/unreliable internet	3.800	0.401	1
Unstable power supply	3.643	0.480	2
Lack of affordable devices	3.035	0.997	3

The infrastructure findings reveal a mixed readiness environment. Smartphones provide a potentially accessible user interface for blockchain-enabled material-management applications, but connectivity and power remain less dependable enabling conditions. This distinction is particularly important for blockchain systems because transaction verification and synchronization require dependable connectivity. Previous research has similarly identified electricity and internet limitations as important challenges for digital technology implementation in Nigerian construction (Idowu *et al.*, 2023).

Professional-group differences

Table 8 summarises the Kruskal–Wallis results for the five professional groups. No statistically significant differences were found among contractors, material suppliers, quantity surveyors, site engineers and project managers for foundational training ($H = 4.693$, $p = 0.320$), technical training ($H = 7.286$, $p = 0.122$) or governance/compliance training ($H = 1.929$, $p = 0.749$). Because all p-values exceeded 0.05, the evidence suggests broadly shared training priorities across the professional groups. This finding supports a common capacity-development programme with role-specific technical modules rather than completely separate training systems. Similar use of non-parametric group comparison has been reported in blockchain adoption research among built-environment professionals (Akinradewo *et al.*, 2022), although the present analysis focuses specifically on training readiness rather than general adoption barriers.

Table 8: Kruskal–Wallis tests of training-domain scores by professional group

Training domain	H statistic	p-value	Interpretation
Foundational training	4.693	0.320	Not significant
Technical training	7.286	0.122	Not significant
Governance/compliance training	1.929	0.749	Not significant

The absence of significant differences suggests that the identified training requirements are broadly shared across the professional groups represented in the sample. Capacity development therefore need not be restricted to one professional category; instead, training can be designed as a common implementation programme with role-specific technical modules. For example, a common foundational curriculum covering blockchain concepts, digital records, cybersecurity, data privacy and ethics could be developed for all professionals, followed by specialised modules for contractors (delivery verification and inventory updates), quantity surveyors (smart-contract interpretation, procurement verification and payment triggers), and managers (system governance and organisational integration). This provides a more economical pathway for professional capacity development.

Training-infrastructure readiness framework

The empirical findings support a five-step implementation pathway. First, organisations should establish fundamental digital capacity, including smartphone and computer skills, use of digital tools, data security and basic blockchain knowledge. Second, they should develop blockchain workflow competency covering platform operations, supply-chain tracing, smart contracts and ERP integration. Third, governance and compliance capabilities should be established, including NDPR requirements, cybersecurity and professional standards. Fourth, the enabling infrastructure should be strengthened through reliable electricity, internet connectivity and appropriate digital devices. Fifth, organisations can progress to operational utilisation involving procurement verification, logistics validation, inventory tracing, materials-quality documentation, and transaction and payment records. The framework therefore shifts the implementation question from whether professionals should adopt blockchain to what conditions are required for blockchain to be used effectively in construction material processes. Implementation readiness is consequently defined as the intersection of human capacity and infrastructure capacity.

Practical implications

Before implementing blockchain, construction organisations should audit their existing capacity in digital skills, blockchain knowledge, smart-contract understanding, cybersecurity, data governance, site connectivity and electricity reliability. Blockchain implementation should therefore be treated as a socio-technical change programme rather than simply a software purchase. Professional bodies such as the Nigerian Institute of Building (NIOB) and the Council for the Regulation of Engineering in Nigeria (COREN) should develop continuing-professional-development programmes around the identified training domains, with practical application and simulation. Educational institutions should strengthen curricula in

digital literacy, blockchain fundamentals, construction applications, smart contracts, governance, cybersecurity and applied simulation. Technology developers should also design mobile-compatible interfaces capable of operating under low-bandwidth conditions, including transaction queuing and later synchronisation when connectivity is restored.

Conclusion

This study evaluated training requirements and infrastructure readiness for blockchain-based construction material management in Lagos State using responses from 370 construction professionals. The findings show that implementation readiness depends on more than access to technology: foundational digital competence, technical blockchain capability and governance/compliance knowledge are all required. Basic smartphone and computer skills were the highest-rated foundational requirement, smart-contract development and interpretation was the highest-rated technical requirement, and data privacy, ethical use of blockchain data and cybersecurity were highly rated governance requirements. The training-domain analysis showed that foundational and governance/compliance requirements were rated significantly higher than technical requirements. Infrastructure readiness was mixed: smartphone penetration was high, whereas electricity reliability and internet connectivity were less favourable, with poor or unreliable internet identified as the strongest implementation constraint. The study therefore proposes a Training-Infrastructure Readiness Framework linking foundational competence, technical capability, governance literacy, infrastructure enablement and operational deployment. The study has limitations. It uses cross-sectional perception data and therefore assesses perceived readiness rather than actual implementation outcomes. Training items measured perceived competency requirements and did not directly test respondents' blockchain skills. Infrastructure measures were perception-based and did not include actual electricity uptime or internet speed. In addition, professional groups were unevenly represented, with material suppliers forming the largest group. Future studies should combine survey evidence with practical skills assessments, on-site infrastructure measurements and experimental blockchain implementation.

References

- Akinradewo, O. I., Aigbavboa, C. O., Edwards, D. J., & Oke, A. E. (2022). A principal component analysis of barriers to the implementation of blockchain technology in the South African built environment. *Journal of Engineering, Design and Technology*, 20(4), 914–934. <https://doi.org/10.1108/JEDT-05-2021-0292>
- Albert, I., Shakantu, W., & Ibrahim, S. (2021). The effect of poor materials management in the construction industry: A case study of Abuja, Nigeria. *Acta Structilia*, 28(1), 142–167. <https://doi.org/10.18820/24150487/as28i1.6>
- Androulaki, E., Barger, A., Bortnikov, V., Cachin, C., Christidis, K., De Caro, A., Enyeart, D., Ferris, C., Laventman, G., Manevich, Y., Muralidharan, S., Murthy, C., Nguyen, B., Sethi, M., Singh, G., Smith, K., Sorniotti, A., Stathakopoulou, C., Vukolic, M., Cocco, S. W., & Yellick, J. (2018). Hyperledger Fabric: A distributed operating system for permissioned blockchains. *Proceedings of the Thirteenth EuroSys Conference*, 1–15. <https://doi.org/10.1145/3190508.3190538>
- Christidis, K., & Devetsikiotis, M. (2016). Blockchains and smart contracts for the Internet of Things. *IEEE Access*, 4, 2292–2303. <https://doi.org/10.1109/ACCESS.2016.2566339>
- Farinloye, O. O., Odusami, K., & Adewunmi, Y. (2013). Theft and vandalism control measures on building sites in Lagos, Nigeria. *Journal of Engineering, Project, and Production Management*, 3(1), 9–21. <https://doi.org/10.32738/JEPPM.201301.0003>
- Hamledari, H., & Fischer, M. (2020). The application of blockchain-based crypto assets for integrating the physical and financial supply chains in the construction and engineering industry. *arXiv:2001.09940*. <https://arxiv.org/abs/2001.09940>
- Idowu, A. O., Aigbavboa, C., & Oke, A. E. (2023). Barriers to digitalization in the Nigerian construction industry. *Proceedings of the 2023 European Conference on Computing in Construction and the 40th International CIB W78 Conference*. <https://doi.org/10.35490/EC3.2023.196>

- Kshetri, N. (2018). Blockchain's roles in meeting key supply chain management objectives. *International Journal of Information Management*, 39, 80–89.
- Okanlawon, T. T., Oyewobi, L. O., & Jimoh, R. A. (2023). Evaluation of the drivers to the implementation of blockchain technology in the construction supply chain management in Nigeria. *Journal of Financial Management of Property and Construction*, 28(3), 459–476. <https://doi.org/10.1108/JFMPC-11-2022-0058>
- Oseghale, G. E., & Adetooto, J. D. (2021). Evaluation of material management methods in selected building construction sites in Abuja and Lagos State, Nigeria. *American Journal of Mechanical and Materials Engineering*, 5(1), 11–17. <https://doi.org/10.11648/j.ajmme.20210501.13>
- Saunders, M., Lewis, P., & Thornhill, A. (2019). Research methods for business students (8th ed.). *Pearson*.
- Singh, A. K., Kumar, V. R. P., Dehdasht, G., Mohandes, S. R., Manu, P., & Pour Rahimian, F. (2023). Investigating barriers to blockchain adoption in construction supply chain management: A fuzzy-based MCDM approach. *Technological Forecasting and Social Change*, 196, 122849. <https://doi.org/10.1016/j.techfore.2023.122849>
- Zheng, Z., Xie, S., Dai, H., Chen, X., & Wang, H. (2018). Blockchain technology: Architecture and applications. *IEEE International Congress on Big Data*, 557–564.