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ARTICLES (PEER REVIEWED)

Distributed Ledger Technology Applications for Advancing Construction Practices in Nigeria

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Abstract

The purpose of the study was to evaluate the application areas of distributed ledger technologies (DLTs) in the construction industry, aiming to enhance construction practices in Nigeria. The study examined how DLTs could transform various facets of construction through their unique attributes and capabilities. This objective was achieved through a quantitative research approach, utilizing a structured questionnaire to systematically gather data from various stakeholders in the Nigerian construction sector. Data obtained were analyzed using percentages, frequencies, mean scores, the Kruskal–Wallis H-test, the Shapiro–Wilk test, exploratory factor analysis, and unifactorial analysis. The most highly ranked application areas of DLT in the construction industry are payment

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management, asset management, property management, supply chain management, and smart contracts. Further analysis revealed four distinct clusters of application areas, namely, construction lifecycle management, project lifecycle enhancement, resource and financial management, and project oversight and optimization. The practical implications of this study pave the way for improved construction practices, regulatory support, technological innovation, and investment opportunities in the construction sector. These findings provide valuable insights for stakeholders seeking to leverage the transformative potential of DLTs in construction. While the impact of DLTs has been explored in various sectors globally, this research uniquely focuses on opportunities specific to Nigeria's construction sector. The findings of this study offer insights into the unique ways that DLT can address industry-specific challenges, enhancing project management, financial processes, quality assurance, sustainability efforts, and more.

Keywords

Asset Lifecycle; Distributed Ledger Technology; Blockchain Technology; Construction Industry; Supply Chain Management

Introduction

As a result of their numerous advantages, distributed ledger technologies (DLTs) have made significant inroads in several sectors, including finance, supply chain management, health care, real estate, intellectual property, energy, agriculture, education, transportation, manufacturing, and even construction ([Aliu et al., 2023](#); [Ebekozi et al., 2023](#)). Specifically in the construction industry, DLTs have the potential to revolutionize how projects are planned, executed, and managed ([Darabseh & Joo, 2021](#); [Aliu et al., 2023](#); [Li et al., 2023](#)). In the aspect of construction project management, DLTs offer a game-changing solution by allowing the creation of a shared ledger where all relevant project data, from architectural plans to progress reports, can be securely recorded and accessed in real time ([Akinradewo et al., 2022](#)). This transparency enhances collaboration among stakeholders, including architects, engineers, contractors, and project owners, ensuring that everyone works with the most up-to-date information. Smart contracts, a fundamental component of DLTs, have the potential to revolutionize financial processes in the construction industry ([Ameyaw et al., 2023](#)). These self-executing contracts can automate payment procedures based on predefined conditions and milestones. By doing so, they minimize the administrative burden associated with managing payments and ensure that contractors and subcontractors receive timely compensation ([Bera et al., 2020](#)). Another groundbreaking potential of DLTs in construction is the tokenization of projects ([Tian et al., 2022](#)). This innovation allows for fractional ownership and investment opportunities, simplifying the funding of large-scale construction projects by introducing new financing options, potentially reducing dependence on traditional banking and lending institutions.

Despite the widespread benefits of DLTs in the construction sector, awareness and adoption remain generally low, especially among professionals in developing countries. This is due to several key factors that hinder their uptake. One of the primary obstacles to DLT adoption in developing countries such as Nigeria is limited technological infrastructure ([Okanlawon et al., 2023](#)). Access to stable Internet connectivity and the necessary hardware can be inconsistent, posing a significant barrier to the widespread use of DLTs, which rely heavily on a reliable Internet connection. Moreover, there is often a shortage of technical expertise in these regions, considering that DLTs are complex technologies that require specialized knowledge to understand and implement effectively ([Akinradewo et al., 2022](#)). In Nigeria, the lack of professionals with the necessary skills to work with DLTs in the construction sector can further impede their adoption. Resistance to change in the construction industry is a common issue worldwide, as professionals may be stuck in traditional methods and may hesitate to adopt new technologies, including DLTs, without clear evidence of their benefits ([Singh et al., 2023](#)). This resistance can slow down the

adoption process and limit the potential advantages of DLTs. Limited awareness is also a critical challenge, as many professionals in the construction sector in developing countries may not be fully informed about how DLTs can streamline processes, improve transparency, and enhance project management ([Olawumi et al., 2022](#)). This lack of awareness can result in missed opportunities for efficiency and productivity gains.

Although these challenges exist, there is potential for DLT adoption in the construction industry in countries such as Nigeria. Consequently, this study is exclusively dedicated to exploring and examining the application areas of DLTs in the construction sector. By focusing on DLT's application in the construction sector, this study aims to provide a comprehensive understanding of how this transformative technology can address specific industry challenges and contribute to its growth and improvement. Unlike broader studies on DLT, this research uniquely focuses on the construction sector. This targeted approach allows for a closer examination of the industry's distinct challenges, opportunities, and requirements for successful DLT integration. The outcomes of this study are of significant importance to construction professionals, policymakers and regulators, technology providers, investors and financiers, and the academic community, as it provides valuable insights and knowledge essential for advancing the construction industry's understanding and utilization of DLTs. This study is also significant because it addresses a critical gap in the understanding and utilization of DLTs in the construction industry, particularly in countries such as Nigeria. While the potential benefits of DLT adoption are evident, the specific application of this transformative technology in the context of construction is not yet well-explored, a gap that this study fills. The article is structured as follows: the second section examines existing studies, the third section discusses the research methodology process, the fourth section presents the results, the fifth section is dedicated to the discussion, the sixth section explores the implications of the findings, and the seventh section concludes and outlines areas for future research.

Literature review

UNIQUENESS OF DISTRIBUTED LEDGER TECHNOLOGY

As previously mentioned, DLT, often referred to as blockchain, has emerged as a transformative and disruptive force that transcends industry boundaries, revolutionizes conventional processes, and fundamentally alters how data are managed and shared ([Ameyaw et al., 2023](#)). Its impact has been felt across various sectors, ranging from finance to health care, and its applications continue to grow and diversify. DLT's unique attributes and capabilities have positioned it as a key driver of innovation and efficiency in today's increasingly digital world ([Darabseh & Joo, 2021](#)). In the financial sector, the introduction of DLT marked a watershed moment. According to [Kayal and Rohilla \(2021\)](#), Bitcoin, the pioneering cryptocurrency built on blockchain technology, challenged traditional financial systems by enabling secure and transparent peer-to-peer transactions without the need for intermediaries such as banks. This innovation has paved the way for a plethora of other cryptocurrencies and decentralized financial platforms, creating new avenues for financial inclusion and innovation. In health care, DLT has answered the call for secure and interoperable data management, as electronic health records can be securely stored on DLT platforms, ensuring data integrity while affording patients greater control over their health data ([Thakur, 2022](#)). Additionally, DLT supports drug traceability, addressing a pressing issue of pharmaceutical authenticity and provenance ([Kuo et al., 2017](#)). With DLT, pharmaceutical companies can now provide a clear record of a drug's journey from production to distribution, bolstering safety and patient trust. Real estate transactions have seen a transformation as well, with DLT providing a secure and efficient way to manage property records ([Yadav et al., 2022](#); [Kissi et al., 2023](#)). Property titles and ownership records can now be securely stored on a blockchain, reducing fraudulent land grabs and simplifying property transfers.

Tokenization of real estate assets has also become possible, enabling fractional ownership and making real estate investment more accessible to a broader range of investors ([Tian et al., 2022](#)).

APPLICATION OF DISTRIBUTED LEDGER TECHNOLOGY IN THE CONSTRUCTION INDUSTRY

The construction industry is undergoing a significant transformation through the application of DLT. This revolutionary technology has found its place in various aspects of construction, offering solutions to long-standing challenges and bringing transparency and efficiency to the forefront ([Ebekozi et al., 2023](#)). One of the ways through which DLT is profoundly impacting the construction industry is by revolutionizing supply chain management ([Ameyaw et al., 2023](#)). Construction projects often involve complex and multi-tiered supply chains, with numerous suppliers, contractors, and subcontractors involved. Traditionally, managing these supply chains has been a challenging task, fraught with inefficiencies, delays, and disputes. However, DLT has emerged as a game-changer in this regard, providing a transparent and immutable ledger that can track the flow of materials and equipment from their source to the construction site ([Singh et al., 2023](#)). For instance, if a critical building material is delayed or if there are issues with the quality of materials delivered, DLT can quickly pinpoint the source of the problem. This reduces disputes and allows for timely resolutions, ultimately preventing costly project delays ([Akinradewo et al., 2022](#)). DLT is also reshaping how construction projects are planned, executed, and managed by providing a shared ledger where all pertinent project data, from intricate architectural plans to real-time progress reports, can be securely recorded and accessed ([Di Giuda et al., 2020](#)). This transparency promotes collaboration among stakeholders, contributing to improved project efficiency and a reduction in costly delays, which have plagued the construction industry for years.

DLT has also introduced an innovative concept to the construction industry—the tokenization of projects ([Tian et al., 2022](#)). This groundbreaking approach allows large-scale construction endeavors to be divided into tokens, thereby enabling fractional ownership and investment opportunities. This innovation simplifies the funding process, potentially reducing the industry's reliance on traditional banking and lending institutions ([Ameyaw et al., 2023](#)). DLTs also have the potential to streamline document management by securely storing all project-related documents on a blockchain ([Olugbemi, 2022](#)). This ensures document integrity and authenticity while minimizing the risk of document loss. DLT's capabilities extend to improving quality assurance and inspection processes in construction. According to [Ebekozi et al. \(2023\)](#), inspection reports, compliance checks, and quality control data can be recorded on a blockchain, creating an immutable record of project quality. This transparency significantly reduces disputes and preserves high construction standards, ultimately leading to safer and more reliable structures ([Akinradewo et al., 2022](#)). Moreover, DLT can also facilitate proactive risk management by providing stakeholders with a comprehensive view of project data through integrated predictive analytics and risk assessment tools, enabling stakeholders to identify and mitigate risks proactively ([Babich & Hilary, 2019](#)). This data-driven approach contributes to smoother project execution, minimizing costly disruptions and delays.

DISTRIBUTED LEDGER TECHNOLOGY IN NIGERIA'S CONSTRUCTION SECTOR

Among the primary challenges that the Nigerian construction sector is facing are the prevalence of corruption and a lack of transparency ([Ebekozi, 2020](#)). Mismanagement of funds, bribery, and fraud are common occurrences, leading to project delays, cost overruns, and substandard infrastructure ([Badiora & Ojewale, 2022](#)). DLT, with its inherent transparency and immutability, can revolutionize the way transactions and contracts are recorded and managed within the nation's sector. By leveraging blockchain technology, DLT ensures that all transactions are securely recorded on a decentralized ledger that is accessible to all stakeholders, thus reducing the risk of fraud and enhancing transparency. Another

significant challenge in the Nigerian construction sector is the lack of trust and collaboration among stakeholders ([Ishaq et al., 2019](#)). Disputes over project specifications, payments, and timelines often arise due to the absence of a reliable and transparent system for tracking project progress and transactions ([Ebekozen, 2020](#)). DLT can facilitate trust and collaboration by providing a single source of truth that is accessible to all parties involved in a construction project. According to [Ameyaw et al. \(2023\)](#), smart contracts, a key feature of DLT, can automate and enforce contractual agreements, ensuring that all stakeholders adhere to the terms and conditions agreed upon. Moreover, the Nigerian construction sector grapples with issues related to project management and documentation ([Osuizugbo & Ojelabi, 2020](#)). Manual record-keeping processes are prone to errors, inconsistencies, and data loss, leading to inefficiencies and delays in project delivery. Therefore, DLT can streamline project management processes by digitizing and automating the documentation process ([Akinradewo et al., 2022](#)). Project milestones, approvals, and payments can be recorded in real-time on a blockchain, providing stakeholders with instant access to accurate and up-to-date information ([Ebekozen et al., 2023](#)). Additionally, DLT has the potential to address issues of land tenure and property rights in Nigeria, which have long been a significant impediment to the construction sector ([Oladehinde et al., 2024](#)). According to their study, land disputes, unclear property rights, and the absence of reliable land registries often hinder construction projects and deter investment in the sector. Therefore, by utilizing blockchain technology, DLT can create a secure and immutable record of land ownership, transactions, and titles ([Okanlawon et al., 2023](#)). This transparent and tamper-proof system can help clarify property rights, reduce land disputes, and streamline the process of acquiring land for construction purposes.

[Table 1](#) shows a summary of some of these application areas identified in the reviewed studies. The authors believe that this list is not exhaustive but serves as a starting point upon which to build further research and exploration into the transformative potential of DLT in construction.

Table 1. Summary of selected distributed ledger technology types used in the construction industry.

S/N	Distributed ledger technology areas	Literature sources
1	Asset management	Akinradewo et al. (2022) and Ameyaw et al. (2023)
2	Communication	Akinradewo et al. (2022) , Ebekozen et al. (2023) , and Ameyaw et al. (2023)
3	Construction management	Di Giuda et al. (2020) and Sadeghi et al. (2022)
4	Construction stage	Kayal and Rohilla (2021) , Olugbemi (2022) , and Ebekozen et al. (2023)
5	Contract awarding	Di Giuda et al. (2020) , Kayal and Rohilla (2021) , and Griffin et al. (2022)
6	Cost control	Thakur (2022) and Ebekozen et al. (2023)
7	Data storage	Di Giuda et al. (2020) and Ameyaw et al. (2023)
8	Design stage	Akinradewo et al. (2022) and Sadeghi et al. (2022)
9	Detail designing	Kayal and Rohilla (2021) and Ameyaw et al. (2023)
10	Dispute resolution	Olugbemi (2022) , Thakur (2022) , and Ebekozen et al. (2023)

Table 1. continued

S/N	Distributed ledger technology areas	Literature sources
11	Document management	Di Giuda et al. (2020) , Akinradewo et al. (2022) , and Olugbemi (2022)
12	Environmental engineering	Griffin et al. (2022) , Thakur (2022) , and Ebekoziem et al. (2023)
13	Feasibility study	Kayal and Rohilla (2021) , Sadeghi et al. (2022) , and Thakur (2022)
14	Maintenance	Kayal and Rohilla (2021) , Akinradewo et al. (2022) , and Olugbemi (2022)
15	Payment management	Kayal and Rohilla (2021) , Griffin et al. (2022) , and Thakur (2022)
16	Procurement management	Di Giuda et al. (2020) and Ebekoziem et al. (2023)
17	Project control	Di Giuda et al. (2020) and Ebekoziem et al. (2023)
18	Project monitoring	Ameyaw et al. (2023) and Ebekoziem et al. (2023)
19	Project planning	Kayal and Rohilla (2021) , Sadeghi et al. (2022) , and Ebekoziem et al. (2023)
20	Property management	Akinradewo et al. (2022) , Griffin et al. (2022) , and Thakur (2022)
21	Scheme designing	Di Giuda et al. (2020) and Ameyaw et al. (2023)
22	Site operations	Akinradewo et al. (2022) and Thakur (2022)
23	Smart contract	Kayal and Rohilla (2021) , Ameyaw et al. (2023) , and Ebekoziem et al. (2023)
24	Supply chain management	Di Giuda et al. (2020) , Akinradewo et al. (2022) , and Olugbemi (2022)
25	Tender action	Kayal and Rohilla (2021) , Griffin et al. (2022) , and Ebekoziem et al. (2023)
26	Transportation control	Di Giuda et al. (2020) and Akinradewo et al. (2022)
27	Value management	Sadeghi et al. (2022) , Thakur (2022) , and Ebekoziem et al. (2023)

Research methodology

This study aims to evaluate the application of DLTs in the construction industry for the purpose of enhancing construction practices in Nigeria. To achieve this goal, a quantitative research approach was adopted through a survey distributed to various stakeholders in the construction industry. This approach was selected for its structured and data-driven methodology, which facilitates data collection, analysis of DLT adoption, and the derivation of actionable insights ([Ogunsanya et al., 2022](#)). Lagos State was chosen as the study area for several compelling reasons. This decision was motivated by the fact that Lagos State offers a rich context for investigating specific factors and dynamics relevant to our research objectives. As one of

Nigeria's largest and most economically significant states, Lagos serves as a microcosm of the challenges and opportunities in the broader construction industry in Nigeria. Its diverse urban and infrastructure development projects make it an ideal location for assessing the practical application of DLTs and their potential impact on construction practices ([Adekunle et al., 2021](#)).

For this study, data collection involved a combination of purposive and snowball sampling techniques to obtain responses from construction professionals. Both purposive and snowball sampling methods were chosen to ensure a diverse and representative group of respondents. The purposive sampling approach involved the intentional selection of specific individuals and organizations in the construction industry with pertinent knowledge and experience concerning DLTs and construction practices in Nigeria. Subsequently, the snowball sampling technique was introduced to expand the scope of data collection in the construction community. Once responses were obtained from initially selected participants, they were encouraged to refer us to other professionals and contacts in the industry who might offer valuable insights. This iterative process facilitated the expansion of our network of respondents, creating a more comprehensive and diverse pool of participants ([Etikan et al., 2016](#)). To determine the appropriate sample size for the study, the Yamane equation was used. This equation is particularly useful for estimating sample sizes in large populations while maintaining a desirable level of accuracy and confidence. An examination of accessible annual reports from professional bodies representing construction professionals revealed a total population of 5,330 members, including 1,700 architects, 700 builders, 1,850 engineers, and 1,080 quantity surveyors. By applying the Yamane equation with the precision level set at 10%, the resulting calculated sample size was 98 respondents. A 5-point Likert scale was used to measure the level of application of DLTs, with 5 = very high, 4 = high, 3 = moderate, 2 = low, and 1 = very low.

Before distributing the questionnaires, a pilot study was conducted to verify the effectiveness and clarity of the survey instrument ([Quiles et al., 2019](#)). This pilot study served as a critical preparatory step in the research process. During the pilot study, a small subset of individuals who were not part of the main study group were invited to participate in a trial run of the questionnaire. This select group of participants provided feedback on various aspects of the survey, including the clarity of the questions, the relevance of the response options, and the overall flow of the instrument. The feedback obtained from the pilot study participants played a pivotal role in refining the questionnaire. The final version of the questionnaire was structured into two distinct sections. The first section aimed to gather demographic information, providing insights into the diverse backgrounds of the participants. The second section focused on gauging the level of DLT application among construction professionals. Google Forms was selected as the platform for survey distribution due to its user-friendly interface and robust data collection capabilities. A total of 98 questionnaires were distributed to the participants, and 86 of them were successfully retrieved, resulting in a response rate of 88%, which was deemed satisfactory, as response rates above 20% are considered appropriate for most questionnaire-based studies ([Moser & Kalton, 1999](#)).

The Statistical Package for the Social Sciences, a commonly used software tool for quantitative data analysis, was used to analyze the collected data. To assess the internal consistency and reliability of the survey instrument, this study utilized Cronbach's alpha coefficient. A high Cronbach's alpha value indicates strong internal consistency among the items in the measurement scale ([Christmann & Van Aelst, 2006](#)). The 27 application areas considered in this study displayed a Cronbach's alpha coefficient of 0.889, indicating a high level of internal consistency among the variables under investigation. Frequency and percentage distributions were used to effectively illustrate the demographic characteristics of the participants. The normality of the data was evaluated through the use of statistical tests such as the Shapiro-Wilk test, which enabled the determination of whether the data exhibited a normal distribution, a critical consideration for various types of quantitative analyses. The study used the Kruskal-Wallis H-test to assess if there were statistically significant differences in the responses provided by participants from various groups ([Pallant, 2013](#)). Mean values and standard deviations were utilized as statistical tools to facilitate the ranking and

comparison of the collected data. These measures allowed for a clear understanding of the central tendencies and variations within the dataset, aiding in the interpretation of research findings and providing a basis for making informed comparisons and conclusions. Lastly, exploratory factor analysis was used to uncover underlying patterns and relationships within the dataset. This statistical technique helped identify latent factors or constructs that may not have been apparent through other analyses. Furthermore, the unifactorial determination method was used to confirm the construct validity of the different clusters of application areas. This method was utilized to ensure that the questionnaire effectively measured the intended variables within each cluster.

Results

BACKGROUND DETAILS OF RESPONDENTS

The demographic profile of the respondents encompassed a range of characteristics, including their academic qualifications, professions, years of experience, and membership status. In terms of academic qualifications, the majority of respondents had bachelor's degrees (B.Tech/B.Sc.), comprising 51.2% of the sample, followed by master's degrees (M.Tech/M.Sc.) at 32.6%. A smaller proportion had higher national diplomas, accounting for 12.8%, while the smallest proportion had achieved Ph.D. qualifications (3.4%). Regarding the professions of the respondents, engineers (including mechanical, civil, and electrical engineers) represented the largest group, comprising 38.3% of the participants. Architects accounted for 24.4% of the respondents, followed by quantity surveyors at 23.3% and builders at 14% of the sample. Years of experience in the construction sector varied, with the majority in the 6–10-year range (48.9%). Participants with 11–15 years of experience comprised 36% of the sample, while those with 1–5 and 16–20 years of experience comprised 10.5% and 2.3%, respectively. Respondents with more than 21 years of experience also made up 2.3% of the sample. In terms of membership status, the largest group consisted of fellows (47.7%), followed by corporate members (25.6%), graduates (18.6%), and probationers (8.1%). Based on the profile of the respondents, it is evident that the survey captured a diverse range of professionals in the construction industry.

MEAN RANKINGS OF VARIOUS APPLICATION AREAS OF DISTRIBUTED LEDGER TECHNOLOGY

The normality test, conducted using the Shapiro–Wilk normality test, aimed to assess the distribution of responses across various application areas of DLT in the construction industry. This statistical examination is crucial for evaluating whether the data adhere to a normal distribution, a prerequisite for certain statistical analyses (Yazici & Yolacan, 2007). The results of this test yielded significant findings, as values for all application areas of DLT fell well below the 0.05 threshold. This indicates that the data for each application area did not conform to a normal distribution, signifying varying degrees of deviation from the expected normal distribution curve. Subsequently, the Kruskal–Wallis H-test was likely used to investigate potential disparities among the application areas concerning their perceived importance or significance. This non-parametric test is particularly suitable for situations involving non-normally distributed data and can offer valuable insights into any statistically significant variations among the application areas. From Table 2, it is evident that all 27 application areas possess p -values significantly below the 0.05 threshold at a 95% confidence level. This suggests substantial disparities in how respondents assessed the importance of these various DLT application areas in the construction industry. In essence, the respondents did not uniformly agree on the significance of these applications, indicating notable differences in their opinions.

Based on the mean rankings, *payment management* emerged as the most highly ranked application area of DLT in the construction industry, boasting a mean ranking of 2.52. This suggests that, on average, respondents deemed *payment management* as the most vital and potentially transformative area for

Table 2. Mean rankings of various application areas of distributed ledger technology in construction.

Application areas	Mean ($\bar{X}$)	Standard deviation (SD)	Rank	Normality (Shapiro-Wilk)			Kruskal-Wallis H-test	
				Statistic	df	Sig.	χ^2	Sig.
Payment management	2.52	1.244	1	0.628	86	0.000	35.381	0.811
Asset management	2.50	1.176	2	0.802	86	0.000	14.607	0.624
Property management	2.47	1.145	3	0.523	86	0.000	3.781	0.672
Supply chain management	2.44	1.261	4	0.787	86	0.000	17.454	0.395
Smart contract	2.42	1.278	5	0.920	86	0.000	1.587	0.801
Design stage	2.41	1.202	6	0.698	86	0.000	15.587	0.670
Procurement management	2.41	1.259	7	0.831	86	0.000	2.918	0.812
Data storage	2.37	1.311	8	0.754	86	0.000	17.498	0.623
Feasibility study	2.37	1.329	9	1.954	86	0.000	5.922	0.671
Construction stage	2.34	1.289	10	0.935	86	0.000	2.958	0.396
Construction management	2.29	1.362	11	1.010	86	0.000	11.586	0.800
Value management	2.28	1.025	12	0.302	86	0.000	7.442	0.668
Document management	2.28	1.307	13	0.898	86	0.000	1.722	0.813
Project monitoring	2.27	1.231	14	0.896	86	0.000	3.322	0.622
Contract awarding	2.27	1.287	15	0.391	86	0.000	1.949	0.670
Site operations	2.21	1.228	16	0.669	86	0.000	35.380	0.397
Cost control	2.16	1.362	17	0.726	86	0.000	14.596	0.799
Communication	2.14	1.339	18	0.820	86	0.000	3.771	0.667
Detail designing	2.13	1.291	19	0.667	86	0.000	17.446	0.814
Environmental engineering	2.12	1.231	20	1.830	86	0.000	1.578	0.621
Project planning	2.12	1.358	21	0.972	86	0.000	15.576	0.669
Project control	2.10	1.198	22	0.799	86	0.000	2.929	0.398
Transportation control	2.09	1.233	23	0.908	86	0.000	17.490	0.798
Scheme designing	2.06	1.192	24	0.647	86	0.000	5.913	0.666
Maintenance	2.06	1.323	25	1.987	86	0.000	2.950	0.815
Dispute resolution	2.05	1.016	26	0.838	86	0.000	11.580	0.620
Tender action	1.99	1.269	27	0.417	86	0.000	7.432	0.668

χ^2 = chi-square.

**Significant at $p < 0.05$.

implementing DLT in construction. Following closely, *asset management* secured the second-highest mean ranking at 2.50, indicating that respondents also held *asset management* in high regard as a significant application area of DLT in the construction sector. In the third position, *property management* obtained a mean ranking of 2.47, underscoring its pivotal role as another domain ready for DLT adoption, as it garnered substantial recognition from survey participants. In the fourth position, *supply chain management* received a mean ranking of 2.44, emphasizing respondents' acknowledgment of the potential benefits of integrating DLT into *supply chain management* in the construction industry, a critical factor for project timeliness and cost control. In the fifth position, *smart contracts* received a mean ranking of 2.42. Although slightly below the top four, *smart contracts* still received significant consideration, highlighting their capacity to revolutionize contract execution and management in construction projects, promoting transparency and reducing disputes ([Ameyaw et al., 2023](#)). Conversely, *tender action*, *dispute resolution*, and *maintenance* received the lowest mean rankings in the study. Tender action had the lowest mean ranking at 1.99, followed by dispute resolution at 2.05 and maintenance at 2.06. These rankings suggest that respondents considered these areas to be of lower importance when it comes to implementing DLT in construction. It is important to note that these lower rankings do not necessarily imply that DLT has no role to play in these areas. Rather, they may reflect a lower level of awareness or perceived impact than other application areas. Further research and exploration of how DLT can benefit these aspects of the construction industry could provide valuable insights for future adoption and implementation strategies.

RESULTS OF EXPLORATORY FACTOR ANALYSIS

Exploratory factor analysis was used as a crucial step in organizing and structuring the diverse application areas of DLT into more coherent and manageable subcategories. Before conducting exploratory factor analysis, it was imperative to evaluate the suitability of the data through the application of two fundamental statistical tests: the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity (BTS). The KMO measure assesses whether the dataset is suitable for factor analysis by examining the intercorrelations between variables. A KMO value approaching 1.0 indicates that the data are well-suited for factor analysis. Typically, a KMO value exceeding 0.70 is deemed acceptable, while values surpassing 0.80 are considered excellent. For this study, a KMO value of 0.855 was achieved, which was considered excellent. Simultaneously, the BTS scrutinizes whether the correlation matrix is an identity matrix, which would indicate that variables are uncorrelated. Instead, a low p -value (typically below 0.05) from this test signifies significant relationships between variables, confirming the appropriateness of the data for factor analysis. [Table 3](#) shows that the BTS reached statistical significance, yielding a high chi-squared value of 4,326.14 with 351 degrees of freedom. Thus, factor analysis was deemed appropriate for the dataset, and a varimax rotation with Kaiser normalization was adopted to simplify the interpretation of factors by maximizing the variance of factor loadings. This rotation method helped ensure that each factor is characterized by a distinct set of variables, making it easier to interpret the underlying structure of the data. The findings in [Table 3](#) reveal that Component 1 (72.271%), Component 2 (5.952%), Component 3 (4.463%), and Component 4 (3.815%) collectively account for 86.501% of the total cumulative variance.

Furthermore, the unifactorial determination method was used to ascertain the construct validity of the clusters of application areas. This method serves as a crucial step in the analysis, as it assesses the internal consistency and coherence of the identified clusters. The unifactorial determination method entails evaluating the extent to which the variables grouped within each cluster contribute to a single overarching construct. Essentially, it helps confirm that the clusters truly represent distinct and meaningful facets of the broader concept, which, in this context, pertains to the application areas of DLT ([Aliu et al., 2022](#)). Unifactoriality is attained when the variables within each cluster demonstrate a substantial degree of interrelatedness and consistently contribute to a unified, coherent construct. Additionally, this condition

is met when the average variance explained exceeds the established threshold of 0.5. [Table 4](#) shows four distinct clusters, namely, “construction lifecycle management,” “project lifecycle enhancement,” “resource and financial management,” and “project oversight and optimization,” each demonstrating good internal consistency, variance explanation, and suitability for unifactorial interpretation. These clusters provide valuable insights into the diverse facets of DLT application areas, offering a solid foundation for further analysis and discussions regarding their implications in the construction sector.

Table 3. Total variance explained for application areas.

Component	Initial eigenvalues			Rotation sums of squared loadings		
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	19.513	72.271	72.271	6.209	22.995	22.995
2	1.607	5.952	78.223	6.033	22.345	45.345
3	1.205	4.463	82.686	5.667	20.99	66.339
4	1.030	3.815	86.501	5.446	20.171	86.501
Kaiser–Meyer–Olkin measure of sampling adequacy						0.855
Bartlett’s test of sphericity		Approx. χ^2		4,326.14		
		df		351		
		Sig.		0.000		

(Source: authors’ description.)

Table 4. Results of varimax rotation.

Application areas	Component			
	1	2	3	4
<i>Construction lifecycle management</i>				
Property management	0.861			
Document management	0.763			
Dispute resolution	0.758			
Design stage	0.754			
Construction stage	0.750			
Feasibility study	0.734			
Contract awarding	0.723			
Project monitoring	0.712			
Site operations	0.693			
Environmental engineering	0.682			

Table 4. continued

Application areas	Component			
	1	2	3	4
<i>Project lifecycle enhancement</i>				
Project planning		0.774		
Scheme designing		0.735		
Data storage		0.722		
Value management		0.719		
Construction management		0.681		
Transportation control		0.648		
<i>Resource and financial management</i>				
Asset management			0.721	
Payment management			0.707	
Procurement management			0.692	
Smart contract			0.686	
Maintenance			0.648	
<i>Project oversight and optimization</i>				
Project control				0.708
Tender action				0.701
Communication				0.681
Detail designing				0.677
Cost control				0.656
Cluster	Cluster interpretation	Cronbach's α (reliability)	Variance explained (%) (unifactorial)	KMO (unifactorial)
1	Construction lifecycle management	0.816	39.264	0.813
2	Project lifecycle enhancement	0.784	16.775	0.766
3	Resource and financial management	0.762	11.097	0.783
4	Project oversight and optimization	0.733	25.631	0.809

KMO, Kaiser–Meyer–Olkin.

Discussion of extracted factors

CONSTRUCTION LIFECYCLE MANAGEMENT

This cluster comprises 10 variables that collectively explain a substantial 72.271% of the total variance. Among these, property management holds a pivotal position, reinforcing the findings of [Darabseh and Joo \(2021\)](#). Through the integration of DLTs, particularly blockchain, property management practices can undergo a transformative enhancement. DLTs enable the creation of transparent and immutable records for property transactions, ownership changes, and rental agreements, effectively countering issues related to fraud and simplifying intricate property transfer processes ([Olugbemi, 2022](#)). In addition, by embracing DLTs, the construction sector can significantly fortify the security and accessibility of critical documents such as titles, permits, architectural plans, and contracts. [Okanlawon et al. \(2023\)](#) emphasized that storing these documents on a blockchain guarantees their integrity over time, thereby diminishing the risk of tampering and legal disputes. Moreover, DLTs, particularly the transparent and tamper-proof ledger of blockchain, can act as an impartial and dependable source of information during dispute resolution processes. This capability expedites dispute resolution and ensures equitable outcomes for all parties involved ([Darabseh & Joo, 2021](#)).

The potential of DLTs extends to the design stage of construction projects ([Singh & Ashuri, 2019](#)). Smart contracts can be used to automate payments, and the distributed ledger can serve as a repository for design revisions and decisions. This streamlined approach contributes to more efficient project management, reducing misunderstandings and enhancing collaboration ([Dogo et al., 2019](#)). Similarly, real-time tracking of project progress, material deliveries, and automated payments based on predefined milestones significantly reduce delays, minimize conflicts, and foster a heightened level of transparency across the entire project ([Akinradewo et al., 2022](#)). Feasibility study emerges as another vital variable within this cluster, and DLTs offer a secure and transparent platform for data storage and sharing. This expedites decision-making processes by ensuring data integrity and accessibility concerning project feasibility. Additionally, DLTs are a game-changer in contract awarding processes. The utilization of blockchain-based smart contracts automates various facets of contract execution, such as payments and milestone achievements, resulting in a reduced likelihood of disputes and project delays ([Di Giuda et al., 2020](#)). Moreover, the real-time data accessibility offered by DLTs provides stakeholders with valuable insights into construction progress, expenditures, and resource management ([Akinradewo et al., 2022](#)). This drives informed decision-making and enhances overall project efficiency.

PROJECT LIFECYCLE ENHANCEMENT

This cluster comprises six variables that collectively account for 5.952% of the total variance explained. These variables are instrumental in shaping the landscape of project management, construction, and transportation control and have been collectively labeled as “project lifecycle enhancement.” The application of DLTs in these areas has shown significant promise, as highlighted in various studies. Effective project planning is recognized as a cornerstone of project success, and DLTs offer substantial enhancements in this field. As noted by [Di Giuda et al. \(2020\)](#), DLTs enable real-time collaboration among stakeholders, optimizing resource allocation and automating task scheduling. These capabilities improve efficiency and reduce delays in project planning, ultimately contributing to the smoother execution of projects ([Akinradewo et al., 2022](#)). Scheme designing is another pivotal phase in construction projects, and DLTs provide a robust solution by securely managing design data ([Bera et al., 2020](#)). Blockchain technology, as described by [Lansiaux et al. \(2022\)](#), ensures an immutable record of design revisions and decisions, fostering design consistency

throughout the project. This not only upholds design integrity but also streamlines communication and decision-making among project stakeholders.

Data storage is another fundamental requirement in modern project management, particularly in data-intensive fields such as construction and transportation control. [Aliu et al. \(2023\)](#) underscored the significance of DLTs in offering secure and transparent data storage solutions. DLTs safeguard the integrity and accessibility of project-related information, which is vital for informed decision-making ([Singh & Ashuri, 2019](#)). Value management assumes a vital role within this cluster, focusing on the optimization of project costs and resources. According to [Dogo et al. \(2019\)](#), DLTs provide real-time insights into project expenditures, resource utilization, and potential cost-saving opportunities. This empowers project managers to make data-driven decisions, thereby maximizing the value derived from projects. Furthermore, the integration of blockchain technology in construction management enhances transparency and accountability. As highlighted by [Akinradewo et al. \(2022\)](#), smart contracts automate payments, and real-time tracking of progress and resource allocation minimizes delays and disputes. This, in turn, results in more efficient and streamlined construction processes. Lastly, DLTs can be harnessed for transportation control ([Olawumi et al., 2022](#)). They can be used to monitor and optimize transportation routes, track cargo deliveries, and ensure compliance with transportation regulations. This heightened transparency and control contribute significantly to the efficiency and reliability of transportation management, a crucial element in the successful execution of projects.

RESOURCE AND FINANCIAL MANAGEMENT

This cluster encompasses five variables that collectively elucidate 4.463% of the total variance. Renamed as “resource and financial management,” the findings within this cluster align with the research conducted by [Li et al. \(2023\)](#). Within this cluster, asset management plays a crucial role, as it is indispensable for optimizing resource utilization and ensuring the longevity of valuable assets. [Lansiaux et al. \(2022\)](#) asserted that DLTs can substantially enhance asset management in the construction sector. By providing a secure and transparent platform, DLTs enable the tracking and management of assets throughout their lifecycle. This comprehensive approach includes recording asset acquisitions, maintenance activities, and disposals, ultimately contributing to improved asset efficiency and cost-effectiveness. Efficient payment management holds equal importance in construction organizations, given that timely and accurate financial transactions are fundamental for seamless project execution. [Akinradewo et al. \(2022\)](#) emphasized that DLTs, through the utilization of cryptocurrencies and smart contracts, can streamline payment processes in the construction industry. These technologies offer advantages such as reduced transaction costs and enhanced payment security. This streamlined approach enhances financial operations in construction projects, leading to cost savings and more effective financial control.

Additionally, procurement management plays a significant role in the construction industry by ensuring the timely acquisition of materials and services. [Bera et al. \(2020\)](#) pointed out that DLTs can enhance procurement processes by providing transparent and tamper-proof records of supplier contracts, orders, and deliveries. This transparency not only mitigates the risk of fraud but also fosters improved supplier relationships, ultimately resulting in cost savings and operational efficiency in construction projects. The use of smart contracts stands out for its transformative potential in the construction industry. [Ameyaw et al. \(2023\)](#) highlighted that smart contracts, powered by DLTs, automate and self-execute predefined contract terms and conditions. In construction projects, this automation reduces reliance on intermediaries, minimizes the risk of contractual disputes, and ensures the automatic fulfillment of contractual obligations. This transformative capability has the potential to revolutionize the construction industry by streamlining contract execution and payment processes, thereby enhancing overall project efficiency and reducing delays. Moreover, DLTs can be effectively utilized to create a transparent and auditable maintenance history for construction assets ([Olawumi et al., 2022](#)). This ensures that maintenance tasks are performed according to

schedule and maintenance records are accurate. This, in turn, contributes to the overall efficiency and cost-effectiveness of construction projects.

PROJECT OVERSIGHT AND OPTIMIZATION

This cluster comprises five variables that collectively explain 3.815% of the total variance. Based on the latent variables contained within this cluster, it has been aptly renamed “project oversight and optimization.” According to [Darabseh and Joo \(2021\)](#), DLTs have the potential to revolutionize project control by offering real-time access to project data. This capability facilitates the tracking of project progress, the identification of issues, and data-driven decision-making. The transparency and immediacy afforded by DLTs significantly contribute to more efficient project oversight, a critical component for achieving successful project outcomes ([Singh & Ashuri, 2019](#)). In addition to enhancing project control, DLTs offer a robust solution for tender action. By ensuring the transparency and immutability of tender documents, bids, and contract awards ([Bera et al., 2020](#)), DLTs mitigate the risk of fraud and corruption. Furthermore, they foster a competitive and trustworthy environment among contractors and suppliers, which is essential for cost-effective and reliable project execution. Effective communication is also fundamental to project success, and DLTs, particularly blockchain technology, provide a secure and transparent communication framework ([Di Giuda et al., 2020](#)). This ensures that project-related discussions and decisions remain unchanged over time, promoting trust and accountability among stakeholders. Clear and secure communication channels are pivotal for coordinated efforts in complex projects ([Akinradewo et al., 2022](#)).

Detail designing represents another critical phase, especially in construction and engineering projects, as accurate and up-to-date design plans are indispensable to prevent errors and misunderstandings during project execution ([Olugbemi, 2022](#)). DLTs offer a secure platform for storing and sharing detailed design plans and revisions among project teams. This ensures that all stakeholders have access to the latest design information, ultimately contributing to better project outcomes ([Darabseh & Joo, 2021](#)). Lastly, effective cost control is paramount to stay within budget constraints and meet financial objectives. DLTs offer real-time cost data and automate cost-tracking processes. Smart contracts, as discussed by [Ameyaw et al. \(2023\)](#), can enforce cost control measures, such as predefined spending limits or approval workflows. This level of automation facilitates the monitoring of expenses and the prevention of cost overruns, ultimately bolstering financial control in project management.

Implications of the preceding findings

The findings presented in the discussion section carry significant theoretical implications for the field of construction management. They advance existing theories by highlighting the transformative potential of DLTs, particularly blockchain, in the construction sector. These findings expand the theoretical understanding of how emerging technologies can shape and optimize construction practices, emphasizing the need to consider DLTs as a pivotal tool for improving project planning, execution, and oversight. In addition, these results contribute to the broader theoretical discourse on the integration of emerging technologies in construction and project management. They underscore the importance of recognizing DLTs as a disruptive force that can revolutionize traditional construction management practices. This theoretical perspective acknowledges the evolving nature of construction management theory and the necessity of embracing innovative technologies to stay at the forefront of the industry. Furthermore, the findings have implications for theories related to resource optimization in construction projects. By demonstrating how DLTs can optimize asset management, payment processes, procurement, and cost control, they provide theoretical support for the concept that technology-driven resource management can lead to more cost-effective and efficient project execution. This contributes to the ongoing discussion about the role of technology in reshaping resource optimization strategies in construction management theory.

From a practical perspective, the findings of this study offer valuable guidance for construction industry stakeholders. They present opportunities for improved construction practices by advocating for the adoption of DLTs. Construction companies can practically implement DLT solutions to streamline property management, design processes, procurement, and financial management. These practical applications can lead to tangible improvements in project efficiency and transparency. One of the immediate practical benefits highlighted by these findings is the potential reduction of fraud and disputes in the construction industry. By implementing DLTs to create transparent and immutable records, organizations can enhance trust among stakeholders, reduce the risk of fraudulent activities, and minimize the occurrence of disputes. These practical implications directly impact the bottom line and reputation of construction firms. Furthermore, the findings emphasize the enhancement of project oversight as a practical outcome. Project managers and stakeholders can leverage real-time access to project data and transparent communication channels provided by DLTs to make more informed decisions and exercise better control over project execution. This translates into more successful and efficiently managed projects. Resource optimization in construction organizations can also be practically achieved through the insights gained from this research. By using DLTs to track and manage assets efficiently, optimize procurement processes, and enforce cost control measures, organizations can ensure the optimal use of resources, leading to practical improvements in resource management. Moreover, the practical applications of DLT extend beyond individual construction firms to the broader ecosystem of stakeholders involved in construction projects. For instance, government agencies responsible for regulatory oversight can utilize DLT to monitor project progress, ensure compliance with building codes and regulations, and enhance transparency in public infrastructure projects. This can lead to more accountable governance and improved delivery of infrastructure services to the public.

Conclusions and areas for future research

The advent of DLT has the potential to revolutionize the construction industry in ways that were previously unimaginable. DLTs offer the promise of not only enhancing operational efficiency but also reducing costs and minimizing disputes, ultimately resulting in more sustainable and economically viable construction projects. While the concept of DLT has garnered global recognition for its potential to reshape the construction sector, its adoption in developing countries is gradually gaining prominence. As such, the main aim of this study was to evaluate the application of DLTs in the construction industry for the purpose of enhancing construction practices in Nigeria. This objective was achieved through a quantitative research approach, utilizing a structured questionnaire to systematically gather data from various stakeholders in the Nigerian construction sector. The findings revealed that the most highly ranked application areas of DLT in the construction industry are payment management, asset management, property management, supply chain management, and smart contracts. Further analysis revealed four distinct clusters of application areas, namely, construction lifecycle management, project lifecycle enhancement, resource and financial management, and project oversight and optimization.

The primary contribution of this study is its comprehensive assessment of the potential and practical applications of DLT in the construction industry, particularly in the Nigerian context. By systematically analyzing the preferences and priorities of key stakeholders, this research offers valuable insights into the specific areas where DLT can have the most significant impact. In addition, the identification of four distinct clusters of application areas provides a structured framework for understanding how DLT can be integrated into various phases and processes in the construction sector. This study serves as a foundational resource for policymakers, industry professionals, and researchers interested in leveraging DLT to enhance construction practices. Additionally, this research underscores the need for continued exploration and adaptation of DLT solutions to address the unique challenges and opportunities present in emerging economies, further advancing the evolution of the construction industry on a global scale.

While this study has made significant contributions to understanding the potential applications of DLT in the construction industry, it is essential to recognize and address certain limitations. These limitations underscore the need for cautious interpretation of the findings and suggest areas for future research and improvement. The study's geographic scope within Lagos State may not fully capture the diversity of construction practices and challenges that exist across different states or regions in Nigeria. To gain a more comprehensive understanding of DLT adoption and its implications on a national or global scale, further research efforts should consider broader geographic representation and engagement with diverse construction contexts. Another limitation pertains to the rapidly evolving nature of technology, including DLT. The findings of this study are based on a specific point in time and may not fully capture the dynamic nature of DLT applications in the construction industry. As technology advances and innovations emerge, the relevance and impact of DLT may evolve, necessitating further research and monitoring. Additionally, this study adopted a purposive and snowballing sampling approach, which may introduce biases and limit the generalizability of the findings. While this method allowed for targeted selection of participants with relevant expertise, it may have overlooked perspectives from underrepresented or marginalized groups in the construction industry. Future research might want to explore alternative sampling methods to ensure broader representation and inclusivity. Lastly, this study adopted a quantitative research approach through a well-structured questionnaire, which may not fully capture the contextual factors or in-depth insights that qualitative methods can provide. To address this limitation and gain a more holistic understanding of DLT adoption in construction, future research endeavors could consider complementing quantitative data with qualitative methods such as interviews, focus groups, or case studies. This mixed-methods approach would allow for a deeper exploration of stakeholders' experiences, motivations, and challenges associated with DLT adoption.

Data availability statement

All data or codes generated or used during the study are available from the corresponding author.

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