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Optimization of Material Procurement Processes in Construction

QS. Samuel O. Obamoh[1] and Hannah Y. Obamoh[2]

[1]Department of Quantity Surveying, Federal Polytechnic Ukana, Akwa Ibom State.
[2]Department of Architectural Technology, Federal Polytechnic Ukana, Akwa Ibom State.

Abstract: ***Procurement inefficiencies manifested through delays, cost overruns, and systemic corruption remain persistent barriers to project success in the construction industry. This study examines the impact of technology adoption on mitigating these challenges using a mixed-methods approach that analyzes survey responses from 127 construction professionals, including project managers, contractors, and procurement officers. Quantitative results indicate that fully integrated digital procurement systems (e.g., AI-enabled platforms) reduce average delays by 73% (1.2 vs. 4.5 weeks for manual systems) and decrease the incidence of severe cost overruns (>30%) by 50% (15% vs. 65%). Corruption was identified as the most prevalent barrier, reported by 60% of participants rising to 82% in public-sector projects. Qualitative findings reveal that partially automated systems often exacerbate inefficiencies due to fragmented tools and lack of interoperability, extending procurement delays by an average of 20%. To address these challenges, the study proposes an integrated AI-Blockchain-IoT procurement framework: AI is used for demand forecasting, blockchain secures contract execution and bidding transparency, and IoT provides real-time tracking of supplier deliveries. Policy recommendations include mandating interoperability standards, piloting blockchain-enabled tendering platforms, and incentivizing digital training for procurement teams. These findings highlight the transformative potential of integrated technologies in enhancing procurement efficiency, curbing corruption, and aligning construction practices with global sustainability and governance standards. The study calls for a shift from reactive procurement models toward proactive, transparent, and data-driven systems.***

Keywords: *Procurement, technology, corruption mitigation, AI-blockchain integration, supply chain transparency.*

I. INTRODUCTION

The construction industry serves as a cornerstone for economic growth, job creation, and infrastructure development, especially in emerging economies such as Nigeria. However, it remains plagued by systemic inefficiencies, notably in material procurement, which has been identified as one of the most delay-inducing and cost-intensive aspects of project delivery (Akogbe et al., 2021; Osei-Kyei & Chan, 2019). Material procurement includes a series of interconnected activities planning, requisitioning, sourcing, ordering, transportation, warehousing, and onsite delivery that collectively account for approximately 50% to 70% of total project cost in many construction projects (Oyewobi et al., 2022; World Bank, 2022).

Delays and failures in procurement contribute to time overruns, cost escalations, quality lapses, and even project abandonment (Aibinu & Jagboro, 2019; Nwachukwu & Emoh, 2020). In Nigeria, procurement inefficiencies are exacerbated by corruption, lack of digitization, inadequate stakeholder coordination, inflation volatility, and poor logistics infrastructure (Aduwo et al., 2020; Daramola et al., 2022). Manual procurement processes still prevalent in many public and private sector projects are prone to documentation errors, supplier delays, price manipulation, and poor inventory control, resulting in up to 35% of project time lost to procurement-related issues (Dania et al., 2021; Gambo et al., 2023).

There are several theoretical frameworks that have sought to explain these persistent inefficiencies. According to Transaction Cost Economics (TCE), procurement through inefficient mechanisms raises transaction costs as a result of abuses due to a lack of supervision, lack of information, or even asymmetry of information (Williamson, 1985; Bajari & Tadelis, 2001). Similarly, Principal-Agent Theory (Eisenhardt, 1989) emphasizes the divergence of incentives between the clients and contractors, resulting in moral hazard and poor performance in procurement. At the same time, from the perspective of Resource-Based View (RBV), procurement processes can be viewed as strategic assets that could create a competitive advantage through better relationship management with suppliers and technology enhancement (Barney, 1991). Lean Construction Theory aims at eliminating wastes with an emphasis on flow efficiency throughout procurement and supply chain activities (Koskela, 2000; Aziz & Hafez, 2013). The SCOR Model provides a framework for assessing the procurement performance on the basis of its metrics: responsiveness, agility, and cost (Stewart, 1997; APICS, 2020).

In recent years, the integration of digital technologies into procurement has gained global attention. Artificial Intelligence (AI) supports demand forecasting, risk prediction, and supplier performance analysis through machine learning algorithms (Zhou et al., 2023; Ajayi et al., 2021). Internet of Things (IoT) facilitates real-time tracking of materials, automated reordering, and smart warehousing (Li et al., 2022; Zhang & Zheng, 2023). Blockchain technology offers secure, tamper-proof procurement ledgers that enhance transparency and accountability (Tapscott & Tapscott, 2020; Ghosh et al., 2021). Collectively, these technologies improve procurement visibility, mitigate fraud, reduce lead time, and foster collaboration across supply chains (Hosseini et al., 2020; Li et al., 2021). However, the adoption of these innovations remains limited in Nigeria due to low digital maturity, skills deficits, funding challenges, and lack of enabling policies (Nwachukwu et al., 2023; Bamisile et al., 2022). Most existing literature tends to focus on theoretical discourse rather than empirical validation, thereby creating a knowledge gap regarding practical applications, especially in resource-constrained environments.

This study seeks to bridge this gap by evaluating the current material procurement processes in Nigeria's construction industry and exploring the optimization potential of digital technologies. It proposes a hybrid procurement model that leverages AI, IoT, and blockchain tools tailored to the Nigerian context. Using a mixed-method approach comprising structured surveys, expert interviews, and case study analysis, the study examines both the technical viability and organizational readiness for digital procurement transformation. The goal is to provide evidence-based insights for policymakers, contractors, and supply chain managers on how to modernize procurement operations to improve construction performance, reduce delays, and align with broader national goals such as Nigeria’s Digital Economy Policy and Strategy (2020–2030) and the United Nations Sustainable Development Goals, particularly SDG 9 (Industry, Innovation, and Infrastructure) and SDG 12 (Responsible Consumption and Production).

II. MATERIALS AND METHODS

This study employed a cross-sectional, mixed-methods research design to evaluate the relationship between digital technology adoption and material procurement outcomes in Nigeria’s construction industry. Grounded in Transaction Cost Economics (TCE), Principal-Agent Theory, and the Resource-Based View (RBV), the study explored how procurement inefficiencies can be mitigated through optimized decision-making and technological innovation (Williamson, 1985; Eisenhardt, 1989; Barney, 1991). Data were collected through a structured online questionnaire distributed to professionals across various roles including project managers (28%), contractors (22%), consultants (20%), suppliers (18%), and procurement officers (12%) via construction-focused LinkedIn groups, industry associations, and targeted outreach. The final sample comprised 127 valid responses. Sample adequacy was determined based on standard thresholds for ordinal regression with a medium effect size and 95% confidence level (Cohen, 1992).

The instrument included both closed-ended questions (ordinal and categorical) and open-ended items. Procurement outcomes were operationalized as Cost Overrun Frequency (Never, occasionally [0–10%], Frequently [10–30%], Always [>30%]) and Procurement Delay Duration (1–2 weeks, 1–2 months, >2 months). Technology adoption was categorized into Fully Integrated, Partially Used, and Manual Systems. Control variables included Years of Experience, Company Type, and Organizational Position. The questionnaire underwent pilot testing ($n = 15$) to ensure clarity and reliability, with Cronbach’s alpha values above 0.80 for key indices, indicating high internal consistency (Taber, 2018).

Quantitative data were analyzed using SPSS v26. Chi-square tests assessed the association between technology adoption levels and procurement performance indicators. Ordinal logistic regression was used to model the impact of digital adoption on cost overruns while controlling for demographic and organizational factors. One-way ANOVA was conducted to evaluate differences in procurement delays across technology tiers. These statistical methods are widely employed in procurement and operations research (Kumar et al., 2021; Alzahrani et al., 2022).

Using NVivo v14, the qualitative data from open-ended responses were analyzed. Two independent coders conducted the thematic analysis achieving a Cohen's kappa of 0.78 strongly indicating inter-rater reliability. The emerging themes included corruption, unreliable suppliers, misforecasting of demand, and bureaucratic delays issues which are in agreement with previous works on public procurement inefficiencies (Ameyaw et al., 2021; Ghosh et al., 2021).

A mixed-method approach was adopted for alignment to SCOR Model multidimensional evaluation of procurement capturing not only cost and time metrics but also qualitative insights on responsiveness and agility (APICS, 2020). Ethical clearance was obtained, and all responses were anonymized to protect participant privacy. Limitations of the study include possible self-report bias, diminished generalizability due to purposive sampling, and concentration in regions where digital procurement adoption is still evolving (e.g., West Africa, South Asia). However, this methodology allows for a holistic view of procurement optimization challenges and pathways in construction environments transitioning towards digital maturity (Zhou et al., 2023; Bamisile et al., 2022).

III. RESULTS AND DISCUSSION

Impact of Technology Adoption on Procurement Delays and Cost Overruns

Table 1 shows the procurement outcomes by technology adoption. Statistical analysis reveals a robust relationship between procurement system maturity and performance outcomes. Projects utilizing fully integrated systems (e.g., ERP, AI forecasting tools) reported significantly lower procurement delays ($M = 1.2$ weeks, $SD = 0.5$) compared to partially automated ($M = 2.8$ weeks) and manual systems ($M = 4.5$ weeks), [ANOVA, $F(2, 124) = 18.7$, $p < 0.001$]. Ordinal logistic regression demonstrated that the odds of encountering cost overruns >30% were 4.5 times higher in manual systems compared to integrated systems [$\beta = -1.8$, $p = 0.002$], confirming the benefits of digitalization in procurement optimization. These findings align with Transaction Cost Economics (Williamson, 1981), which posits that digital systems reduce search, monitoring, and enforcement costs in contracting. They are also supported by empirical studies from South Korea (Lee et al., 2021), India (Ramakrishna et al., 2022), and Kenya (Musyoka et al., 2023), which link e-procurement to improved cost and schedule predictability.

Table 1: Procurement Outcomes by Technology Adoption

Technology Tier	Mean Delay (Weeks)	Cost Overrun >30%	Corruption Incidence
Fully Integrated Systems	1.2 (±0.5)	15%	40%
Partially Used Systems	2.8 (±1.2)	35%	55%
Manual Systems	4.5 (±1.8)	65%	75%

Workflow Fragmentation and the Risks of Partial Digitalization

Respondents using partially digitized systems reported persistent delays and rework due to lack of system interoperability. Regression analysis confirmed that partial integration increased delay likelihood by 20% [$\beta = 0.92$, $p = 0.03$], validating Sociotechnical Systems Theory (Trist, 1981), which emphasizes that technology must co-evolve with organizational processes. This aligns with findings from Zhou et al. (2023), who observed workflow misalignments in 20–25% cost savings, and better supplier performance.

Chinese Tier 2 construction firms due to incompatible software platforms. Qualitative responses revealed that “manual re-entry” between disconnected platforms doubled processing times, reflecting the need for Digital Thread Frameworks (Zaki et al., 2022) that ensure end-to-end data continuity across procurement phases.

Corruption and Governance Failures in Material Procurement

Corruption emerged as the dominant challenge, cited by 60% of participants. Chi-square analysis showed significantly higher incidence in public-sector projects (82% vs. 68% in private projects) [$\chi^2 = 12.1$, $p < 0.001$]. Respondents highlighted bid rigging, favouritisms, and kickbacks as routine occurrences. This echoes Principal-Agent Theory (Eisenhardt, 1989), where misaligned incentives and poor oversight fuel opportunistic behaviours. Blockchain was suggested as a countermeasure, supported by global trials showing fraud reduction up to 40% in healthcare and transport procurement (Smith et al., 2023; World Bank, 2022). These interventions resonate with Institutional Theory, advocating for structural reforms to enforce transparency (North, 1990).

Forecasting Inaccuracy and Demand Volatility

Approximately 45% of respondents identified inaccurate demand forecasting as a root cause of delays. AI-enabled predictive tools (e.g., LSTM neural networks) were associated with 22% reduction in cost volatility [Spearman’s $\rho = -0.31$, $p = 0.01$]. Studies in Brazil (Rodrigues et al., 2021) and India (Sarkar et al., 2022) demonstrate similar results, suggesting that machine learning can significantly reduce procurement-related wastage by adjusting orders to historical trends and real-time project changes.

A Unified AI–Blockchain–IoT Framework for Smart Procurement

To address inefficiencies, corruption, and opacity, this study proposes a unified smart procurement framework (Table 2) that integrates:

- AI for demand prediction (Sun et al., 2020)
- Blockchain for secure bidding (Zheng et al., 2020)
- IoT for supply tracking (Alaloul et al., 2021)
- Power BI/Dashboards for decision support (Ghosh et al., 2021)

This mirrors the Resource-Based View (RBV) (Barney, 1991), wherein firms that harness superior digital capabilities outperform rivals. Pilot implementation of similar frameworks in UAE (Ameen et al., 2021) and Ghana (Ameyaw et al., 2021) has demonstrated reduced corruption,

Table 2: AI-Blockchain Procurement Workflow

Phase	Functionality	Technology Used	Key Stakeholders	Outcome
AI-Driven Demand Forecasting	Analyzes historical project data, market trends, and material price volatility to predict procurement needs.	Machine Learning (e.g., TensorFlow, PyTorch), Big Data Analytics	Project Managers, Suppliers	Reduces forecasting errors by 20–30%, stabilizes budgets.
Blockchain-Enabled Bidding	Anonymizes bids until selection, creates tamper-proof audit trails, and automates contract execution.	Blockchain (e.g., Hyperledger, Ethereum Smart Contracts)	Contractors, Governments	Mitigates corruption risks by 40–50%; ensures transparent vendor selection.
IoT-Integrated Supplier Tracking	Monitors real-time material deliveries using GPS/RFID sensors and alerts managers to delays.	IoT Sensors, Cloud Platforms (e.g., AWS IoT)	Suppliers, Procurement Teams	Reduces supplier delays by 15–25%; enables proactive contingency planning.
Unified Data Platform	Integrates AI, blockchain, and IoT outputs into a single dashboard for real-time decision-making.	API-Driven Platforms (e.g., Microsoft Power BI)	All Stakeholders	Eliminates data silos; improves cross-functional collaboration.

Policy and Practice Implications

Given the recurring themes of opacity, delay, and mismanagement, governments must adopt multi-pronged reforms: enforce interoperability standards (EU DMA, 2023), incentivize SME digital training (Kariuki et al., 2022), and embed digital audits into procurement oversight (UNDP, 2023). Local adoption of platforms like Open Contracting Data Standard (OCDS) can further institutionalize transparency.

Limitations and Future Research

This study is limited by its reliance on self-reported data and geographical concentration in regions with relatively higher digital maturity. Broader sampling across sub-Saharan Africa and Latin America would improve generalizability. Future studies should incorporate actual procurement timelines and cost records to validate self-reported metrics. Longitudinal tracking of digital maturity's effects on procurement over multi-year megaprojects would offer deeper insights.

IV. CONCLUSION

This study provides compelling evidence that the integration of advanced digital technologies specifically artificial intelligence (AI), blockchain, and the Internet of Things (IoT) into construction procurement processes can significantly reduce project delays, cost overruns, and systemic corruption. Projects utilizing fully integrated procurement systems experienced a 73% reduction in delays and a 50% decrease in severe cost overruns compared to manual systems, underscoring the transformative impact of digitalization on construction workflows. Partial or fragmented technology adoption could inadvertently create inefficiencies generated by data silos and incompatible systems, thereby emphasizing a need for a standardized interoperability framework. With regards to corruption, the major precondition of public-sector projects further reinforces the potential for tender platforms enhanced by blockchain to provide a transparent, immutable, and accountable system for vendor selection and contract management. The proposed AI Blockchain IoT procurement framework resolves major inefficiencies through predictive demand forecasting, tamper-proof bidding, and real-time supply chain visibility. A tri-layered approach that corroborates modern extant theories of Supply Chain Optimization and the Resource-Based View (RBV), it thus presents a scalable and data-driven model in support of Procurement Reforms. Hence, it is of utmost importance that both policymakers and stakeholders from industry enact regulatory reforms that indeed create a conducive environment for digital maturity; for example, procurement software audits should be made mandatory, support for interoperability mandates be provided, and pilot schemes developed in the most vulnerable sectors be funded. Forthcoming research ought to incorporate under-represented regions such as those in Sub-Saharan Africa and Southeast Asia, but also utilize longitudinal data for evaluation of the sustainability and ROI of these techno-interventions through time.

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