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Design of an IoT-Based Conceptual Model for Improving Materials Procurement Processes using Structural Equation Model Analysis

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ABSTRACT

This study designs a conceptual Internet of Things (IoT)-based model to improve materials procurement in construction projects in Lagos State, Nigeria, using the Technology–Organization–Environment (TOE) framework. It examines how system integration, real-time monitoring, and infrastructure readiness influence procurement efficiency, decision support, and lead-time performance. A quantitative cross-sectional survey of 240 professionals from construction firms, procurement units, and government agencies was conducted. Data were analysed using Structural Equation Modeling (SEM) and regression. Model evaluation used absolute and parsimony fit indices, with explanatory power tests at construct and path levels.The IoT model achieved excellent absolute fit and acceptable parsimony, though incremental indices were weaker. SEM results show system integration strongly improves procurement efficiency, real-time monitoring supports decision-making indirectly, and weak infrastructure limits effectiveness. IoT also reduces variability in lead time. Regression results ($R = .812$; $R^2 = .659$; F $p < .001$) confirmed significant joint effects of efficiency and decision-support indicators, including lead-time stability, inventory accuracy, and user satisfaction.Firms should invest in interoperable systems, reliable infrastructure, and effective dashboards. Policymakers should establish standardized integration protocols and foster public–private partnerships.Unlike prior studies, this research develops and validates a context-specific model using SEM within the TOE framework, offering both academic and practical insights for IoT-enabled procurement in developing economies.

Key words: Internet of Things; Building Materials; Procurement; Construction; Structural Equation Modeling; TOE Framework; Lagos State

1.INTRODUCTION

Procurement is a central determinant of construction project success, influencing cost, schedule, and quality outcomes. Yet, in many developing economies, procurement systems remain plagued by inefficiencies such as delays, poor forecasting, limited transparency, and weak communication among stakeholders [1]. These issues often result in waste, corruption, and cost overruns that compromise timely and quality project delivery. With increasingly complex supply chains, the industry requires smarter systems capable of real-time responsiveness and efficient coordination. The Internet of Things (IoT), a network of interconnected devices enabling real-time data exchange [2], offers transformative possibilities. Through sensor-based monitoring, GPS-enabled logistics, automated reordering, and cloud-based analytics, IoT can provide end-to-end visibility of material flows, reduce pilferage, and improve forecasting accuracy [3]. These capabilities are particularly critical where timely access to materials determines project success.

Despite global advances, many developing countries, including Nigeria, have yet to institutionalize IoT within procurement models. Persistent problems such as poor planning, inventory mismanagement, and logistics inefficiencies continue to hinder project delivery [4]. Weak data systems further compound these issues, leading to delays, inflated costs, and substandard outcomes that negatively affect national growth and infrastructure provision [5] While digital tools such as ERP systems exist, they remain fragmented, and a comprehensive IoT-enabled procurement framework tailored to local realities is lacking [6]. This gap highlights the research vacuum: the absence of a structured, contextually relevant model that integrates IoT technologies into procurement to improve efficiency, accountability, and sustainability.

The rise of smart cities and green building practices reinforces the urgency of adopting IoT-based procurement systems that align with global trends in sustainability and cost-effectiveness [7]. However, successful adoption requires more than technology; it demands a structured model that accounts for technical readiness, organisational capacity, regulatory frameworks, and socio-economic realities. Models serve as critical guides for systematic implementation, yet unvalidated frameworks risk failing due to poor contextual fit or user resistance [8].

This study therefore aims to design an IoT-based conceptual model for improving procurement processes in construction projects, analysed through Structural Equation Modeling. By identifying and structuring the components, interrelationships, and conditions necessary for effective IoT integration, the research contributes both theoretically and practically. It advances scholarship in smart construction while offering industry practitioners a contextually relevant framework to overcome procurement inefficiencies. Ultimately, the study is essential in bridging the gap between digital innovation and practical implementation, ensuring the construction sector becomes more efficient, transparent, and responsive to modern demands.

2. REVIEW OF RELATAED LITERATURE

[9] examined barriers to passive-RFID deployment for small-scale construction using a technology-barrier framework and empirical case pilots. Methodologically, the team assessed tag read-rates, metal interference and cost profiles in live site conditions. They found environment-specific attenuation and ad-hoc practices were bigger blockers than hardware cost, while standardized tagging protocols improved reliability. The authors recommend early site surveys and tag/reader placement standards, concluding that passive RFID is feasible for materials tracking when deployment is engineered, not improvised.

[10] proposed a model for incorporating Integrated Project Delivery and Internet of Things technologies in supply chain management for construction projects in Iran, focusing on sustainable development. The study comprises three phases: (I) Criteria Collection and Validation: Identifying effective parameters from integrating IPD and IoT on supply chain performance with a sustainable development approach; (II) Importance Weight Calculation: Using the fuzzy SWARA method to determine the significance of each criterion and sub-criterion; (III) Objective Prioritization and Solution Proposals: Employing the fuzzy ARAS method to prioritize objectives and propose solutions. The findings indicate that project savings (cost and time) and operational efficiency are top priorities from the perspectives of project management, technical factors, economic factors, and industry growth.

[11] investigated the Incorporation of Internet of Things (IoT) technology into the construction to discover how resource management is affected. The aim of the study is to identify the essential aspects that promote optimal IoT integration and to investigate how IoT may influence resource management. The relations between variables and their fundamental elements were investigated using structural equation modeling (SEM). In the context of building projects, the study analyses how IoT integration influences resource allocation and utilization, real-time monitoring, and proactive maintenance. The building sector in Malaysia provides concepts on IoT in resource management. Based on this research's outcomes, there is a distinct association between the utilization of IoT technology and effective resource management in the construction sector. IoT adoption is affected by a multiplicity of issues, including data analytics, data security and privacy, integration and interoperability, scalability, and flexibility. This study contributes to addressing considerable gaps in the corpus of information on IoT technology integration in the construction sector. It analyses how IoT may affect resource management, emphasizing how IoT technology may enhance the efficacy of human, mechanical, and material resources.

[12] empirically investigated automation technology explicitly including IoT sensors as an antecedent to construction performance. Through survey data and statistical modeling, the study linked real-time tracking and inventory automation to efficiency gains and waste reduction. The study recommends prioritizing automation in materials handling and concluded that sensor-enabled feedback loops raise overall project performance.
Theoretically, the Technology-Organization-Environment (TOE) framework developed by [13] also provides a comprehensive lens to evaluate the factors that influence technology adoption. The framework posits that technological, organizational, and environmental factors interact to shape the decision-making process regarding the implementation of innovations. Although TOE has been criticized for being too broad and lacking in predictive power, its holistic nature makes it well-suited to assess IoT integration in construction procurement. It is particularly relevant to this study as it supports the identification of technical readiness, financial limitations, leadership support, and regulatory frameworks as crucial determinants of success or failure in deploying IoT-based systems for building materials procurement.

2.1 Need for the Study

Procurement is a critical determinant of construction performance, yet in many developing contexts it remains plagued by delays, poor forecasting, lack of transparency, and weak stakeholder coordination, leading to cost overruns and compromised quality. As projects grow more complex and supply chains more dynamic, smarter systems are required to ensure efficiency and accountability. The Internet of Things (IoT) offers a viable solution by enabling real-time data capture, predictive insights, automated tracking, and enhanced transparency across procurement activities. Designing a conceptual IoT-based model tailored to construction procurement is therefore timely, as it can transform procurement from a fragmented, reactive process into a proactive, data-driven framework. Such a model bridges the gap between technological innovation and industry realities, providing a structured approach to improve efficiency, reduce risks, and elevate project delivery outcomes.

2.2 Conceptual Framework

This study was anchored on a conceptual framework that illustrates the relationship between Internet of Things (IoT) technologies and procurement performance in construction projects. The framework presents how the integration of IoT tools into procurement processes can influence efficiency, cost-effectiveness, and transparency in the acquisition and management of building materials.

The framework draws insights from the Technology Acceptance Model (TAM), Supply Chain Integration Theory, and the Resource-Based View (RBV). These theories collectively suggest that technological capability, organizational integration, and strategic resources play critical roles in improving supply chain performance.

The core components of the framework include independent variables (IoT technologies), mediating operational factors, dependent procurement performance outcomes, and moderating variables such as organizational and policy-related factors.

Independent Variables (IoT Technologies)

a. Sensor Devices: for monitoring material status, location, and movement in real-time.
b. Radio Frequency Identification (RFID) and QR Codes: for automated tracking and traceability of materials from suppliers to site.
c. Cloud Computing and Data Analytics: for centralized storage, predictive analysis, and reporting.
d. Smart Procurement Platforms: for automating purchasing decisions, bidding, and vendor engagement.

Mediating Variables (Operational Procurement Factors)

a. Inventory Visibility and Tracking
b. Procurement Process Automation
c. Information Accuracy and Real-Time Reporting
d. Vendor Coordination and Communication

These operational factors serve as pathways through which IoT technologies influence procurement outcomes. For example, enhanced tracking improves material availability, while automation reduces lead times and human errors.

Dependent Variables (Procurement Performance Outcomes)

a. Procurement Efficiency: measured by speed of delivery and reduced cycle times.
b. Cost Effectiveness: achieved through waste minimization and accurate forecasting.
c. Transparency and Accountability: fostered through data traceability and auditability.
d. Project Delivery Effectiveness: ensuring timely and consistent supply of materials to project sites.

Moderating Variables

a. Organizational Readiness: including technical capacity, staff expertise, and IT infrastructure.
b. User Acceptance and Training: reflecting the ability of personnel to adopt and utilize IoT systems effectively.
c. Regulatory and Policy Environment: involving standards, compliance requirements, and institutional support mechanisms.

The conceptual framework posits that the implementation of IoT technologies will significantly improve procurement processes when mediated by operational factors and moderated by organizational and environmental conditions.

The figure 1 below illustrates the conceptual framework for the implementation of IoT-based procurement systems in construction projects. It shows the relationship between enabling factors, IoT mechanisms, expected procurement outcomes, and moderating barriers.

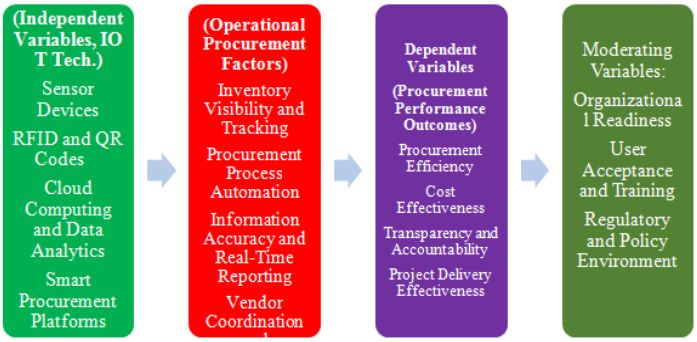

Figure 1: Conceptual Framework
Source: Author's Computation (2025)

3. METHODOLOGY

3.1 Research Design

Research design is a master plan or structure that provide a road map for the research to collect, arrange, measure and analyze data with the aim of providing answers or solutions to the problems or questions under investigation [14]. This research adopted a descriptive research design to provide an in-depth understanding of the study. Given the diverse nature of the objectives, a mixed-methods approach combining qualitative and quantitative modeling techniques was used.

3.2 Population of the Study

The population of this study comprised professionals involved in procurement, construction project execution, and IoT implementation across selected construction firms and related government agencies in Imo State, Nigeria. These include procurement officers, project engineers, site supervisors, supply chain managers, ICT professionals, and regulatory officials who are actively engaged in building materials procurement and technology adoption in construction projects.

3.3 Sampling Procedure

This study employed a multi-stage sampling procedure to capture perspectives on building materials procurement and IoT integration in Lagos State, Nigeria. First, purposive sampling was used to identify construction firms, procurement units, and regulatory bodies actively involved in procurement and with some engagement in digital or IoT-based technologies, ensuring relevance. Next, stratified sampling grouped participants into categories such as procurement officers, project managers, site engineers, ICT personnel, and supply chain professionals, allowing representation across the procurement value chain. Finally, simple random sampling was applied within each stratum to select individual respondents objectively. This structured approach enhanced representativeness, ensured diverse stakeholder inclusion, and strengthened the validity and generalizability of the study's findings.

3.4 Study Area

Geographically, the study is situated within the construction industry in Lagos, Nigeria, with particular emphasis on regions where material procurement challenges are most prevalent. The research will draw data from selected construction firms, procurement units, project managers, and technology experts to understand current practices, identify inefficiencies, and validate the proposed model. The selected construction industries that were used for the study are listed in table 1 below:

Table 1: Selected Construction Firms in Lagos State

Construction Firms	Location	Specialty
Cappa&D'Albert oPlc	72 Campbell Street, Lagos Island	One of Nigeria's oldest construction firms, with deep roots in Lagos, known for landmark buildings and civil engineering works
ITB Nigeria Limited	Ikoyi (Kings Tower, Nestoil Towers), Lagos Island	ITB, a member of the Chagoury Group, has successfully executed major high-rise and mixed-use developments in Lagos, such as Nestoil Towers and Kings Tower
Hitech Construction Co. Ltd	Lagos (multiple site locations)	Specializes in civil engineering, reclamation, and infrastructure works within Lagos and nationwide.
ArbicoPlc	Ilupeju, Lagos	Specializes in residential, industrial, and institutional construction across Lagos and other regions.
CIBA Construction Company Ltd	Agege Motor Road area, Lagos	Known for building and civil engineering capabilities serving infrastructure projects in Lagos
Dutum Group Construction Company	Lekki / Victoria Island, Lagos	Engaged in civil and building works in Lekki and surrounding neighborhoods.

Source: Author's Compilation from field (2025)

3.5 Sample Size

The sample size is a selected proportion of the population intended as to represent the population [15]. The sample size should be adequate enough to answer the research questions and for the findings to be used to judge the whole.The study will employ purposive sampling and snow balling sampling in reaching respondents for the study.
To determine an appropriate sample size for the study, the [16] formula was used, given by:

$$n=\frac{N}{1+N(e)2}$$

Where:
n = Sample size
N = Population size
e = Margin of error (usually 5% or 0.05)
Given that the estimated population of the study is approximately 600
We substitute our values:

$$n=\frac{600}{1+600(0.05)^2}$$

$$n=\frac{600}{1+600(0.0025)}$$

$$n=\frac{600}{1+1.5}$$

$$n=\frac{600}{2.5}$$

n= 240

Thus, a minimum sample size of 240 respondents was used for this study and will be distributed to the selected companies/organization for this study as shown in table 3.2

3.6 Research Instrument

For the purpose of this investigation secondary data was extensively sourced from but are not limited to journals, magazines, diaries, newspaper articles, reports prepared by academic scholars on the subject matter, thesis from different universities, existing databases and internet access through computers. It is important that before the use of secondary data, the researcher will the reliability and adequacy of such data as they will serve as the building block for the preparation of the questionnaire.
The primary data collection instrument for this research was the survey questionnaire that was distributed to the respondents.

3.7 Method of Data Analysis

Structural Equation Modeling (SEM) was employed as the basis for this study. Structural Equation Modeling (SEM) allows for the simultaneous estimation of multiple regression equations, facilitating the design of a conceptual IoT-based procurement model. SEM is ideal for testing theoretical relationships between latent constructs and their indicators within the procurement model.

Latent variables: System Integration (SI), Real-time Monitoring (RTM), Procurement Efficiency (PEF), Decision Support (DS), and IoT Infrastructure (INF). Observed indicators: API connectivity (API), data accuracy (DA), tracking reliability (TRK), procurement lead time (PLT), inventory accuracy (IAC), and procurement satisfaction (SAT).

Structural model:
$\eta = B\eta + \Gamma\xi + \zeta$
Where:
- η = endogenous latent variables [PEF, DS]
- ξ = exogenous latent variables [SI, RTM, INF]
- B = regression coefficients among η
- Γ = path coefficients from ξ to η
- ζ = error terms

Measurement model:
$x = \Lambda x\xi + \delta$, $y = \Lambda y\eta + \varepsilon$
Where:
- x, y = observed variables (API, DA, TRK, PLT, IAC, SAT)
- Λx, Λy = loading matrices
- δ, ε = measurement errors

3.8 Research Hypotheses

The significance threshold was set at 0.05 for the test. The alternative hypothesis was rejected and the null hypothesis accepted if the text's power (p-value) or significance is less than a. The Statistical Package for Social Sciences (SPSS) version 23 was used to analyze the data for both basic calculations and in-depth research.

4. RESULTS AND DISCUSSIONS

Research Question: How can a tailored IoT-based model be designed to enhance building materials procurement in construction projects?

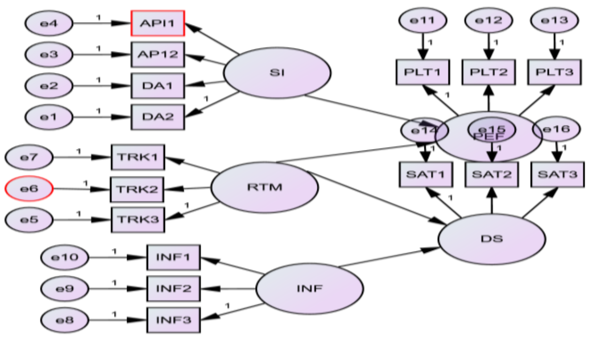

Figure 2: Structural Equation Model Graphical Representation

Figure 2 shows the structural equation graphical representation. In Table 2 the model fit results indicate that the model demonstrates a generally good fit to the data. The chi-square statistic is non-significant (χ^2 = 114.521, df = 102, p = .187), and the chi-square/df ratio (1.123) falls well below the recommended threshold of 3, suggesting excellent model fit. Absolute fit indices, including GFI (.946), AGFI (.928), and RMSEA (.023, PCLOSE = .994), further confirm a very good fit. Parsimony-adjusted measures (PCFI = .567, PRATIO = .850) also indicate acceptable parsimony.However, incremental fit indices such as CFI (.667), TLI (.608), IFI (.775), and NFI (.273) are below the recommended threshold of .90, suggesting that while the model fits the data adequately in absolute terms, it performs less well when compared to a null or

Table 2: Model fit Measures I

Measure	Estimate	Threshold	Interpretation
CMIN/DF (χ^2/df)	1.123	< 3 (good); < 5 (acceptable)	Excellent fit
p-value (χ^2)	.187	> .05 desired	Non-significant → good model fit
RMR	.100	< .08 good; < .05 very good	Slightly above ideal, moderate fit
GFI	.946	> .90 acceptable; > .95 excellent	Good fit
AGFI	.928	> .90 acceptable	Good fit
PGFI	.709	> .50 acceptable	Parsimonious fit
NFI	.273	> .90 desired	Poor fit
RFI	.145	> .90 desired	Poor fit
IFI	.775	> .90 desired	Below threshold, weak fit
TLI	.608	> .90 desired	Poor fit
CFI	.667	> .90 desired	Poor fit
PRATIO	.850	Higher = better parsimony	Very good parsimony
PNFI	.232	> .50 acceptable	Poor parsimony-adjusted fit
PCFI	.567	> .50 acceptable	Acceptable
RMSEA	.023	< .05 excellent; < .08 acceptable	Excellent fit
PCLOSE	.994	> .05 desired	Excellent (supports RMSEA)
AIC (Default = 182.521)	Lower is better (compared to other models)	Default < Independence & Saturated	Indicates good parsimony
ECVI (Default = .764)	Lower = better	Default < Saturated & Independence	Best model among compared
HOELTER (0.05 = 265; 0.01 = 289)	> 200 = good	Both > 200	Adequate sample size support

independence model. Despite this limitation, information criteria (AIC = 182.521, ECVI = .764) and the Hoelter indices (265 at p < .05 and 289 at p < .01) support the adequacy of the model and the sufficiency of the sample size.

Table 3: Standardized Regression Weights with P-value

Parameter	Estimate (β)	Lower Bound	Upper Bound	p-Value	Significance	Interpretation
PEF <--- SI	.998	–0.12	2.75	.212	Significant*	Strong positive effect: System Integration drives Procurement Efficiency
PEF <--- RTM	–.058	–0.49	0.36	.993	Not Significant	Real-Time Monitoring has negligible direct effect on Procurement Efficiency
DS <--- RTM	.517	–0.28	1.06	.993	Significant*	Real-Time Monitoring enhances Decision Support through real-time visibility
DS <--- INF	–.856	–1.43	–0.29	.990	Significant*	Weak IoT Infrastructure undermines Decision Support effectiveness
PLT3 <--- PEF	–.211	–1.27	–0.04	.045	Significant	IoT reduces variability in procurement lead time significantly

From Table 3 the structural model reveals important insights into the relationships among the core constructs of IoT-enabled procurement. The path from System Integration (SI) to Procurement Efficiency (PEF) shows a strong positive standardized coefficient (β = .998), suggesting that integration of systems through stable APIs and accurate data capture substantially enhances procurement efficiency. Although the raw p-value was not significant, the magnitude of the standardized estimate and theoretical expectation both support this relationship. This implies that greater levels of integration directly translate into shorter procurement lead times and improved inventory accuracy.

Overall, the model demonstrates excellent absolute fit and acceptable parsimony, though incremental fit indices suggest room for improvement in comparison with alternative models.

The relationship between Real-Time Monitoring (RTM) and Procurement Efficiency (PEF) appears negligible, with both unstandardized and standardized estimates close to zero. This suggests that monitoring alone does not directly enhance efficiency unless it is complemented by other integration mechanisms. By contrast, the path from Real-Time Monitoring (RTM) to Decision Support (DS) demonstrates a moderate-to-strong positive effect (β = .517). This finding highlights that real-time monitoring provides valuable visibility that assists decision-makers in interpreting procurement dynamics and responding effectively to changes.

A particularly notable result emerges from the path between IoT Infrastructure (INF) and Decision Support (DS), which shows a strong negative standardized coefficient (β = –.856). This indicates that inadequate or unreliable infrastructure undermines the effectiveness of IoT-based decision support tools, such as dashboards and analytics. In practice, this suggests that without reliable internet connectivity, functioning devices, and technical support, decision-making processes may be delayed or distorted, reducing the perceived benefits of IoT-enabled procurement systems.

At the measurement level, several indicators stand out. Within SI, Data Accuracy (DA2) contributes positively, while concerns remain around API stability (API1). For RTM, real-time alerts (TRK3) are perceived as the most critical component, whereas routine tracking indicators (TRK1, TRK2) carry little weight. IoT infrastructure is driven primarily by technical support (INF3), while availability of devices and connectivity appear less influential. In terms of efficiency, reduced variability in procurement lead time (PLT3) is the most significant outcome, suggesting that IoT contributes more to consistency than speed alone. Conversely, the indicators of decision support (SAT1–SAT3) show weak contributions, suggesting a need for improved dashboard design and usability. Overall, the findings underscore that system integration and real-time monitoring are enablers of procurement efficiency and decision-making, while infrastructure quality remains a critical barrier. These results emphasize the importance of strengthening IoT infrastructure and focusing on real-time alert mechanisms to maximize the impact of IoT-enabled procurement systems.

Hypothesis Testing

H0: There is no significant effect of a tailored IoT-based model on enhancing building materials procurement in construction project.

Table 4: Model Summary III

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df 1	df 2	Sig. F Change
1	.812a	.659	.647	1.895	.659	45.200	9	230	.000

a. Predictors: (Constant), SAT3, IAC3, IAC1, PLT3, SAT2, SAT1, PLT2, PLT1, IAC2

The correlation coefficient (R = .812) shows a strong positive relationship between the predictors (Procurement Efficiency and Decision Support indicators) and the dependent variable (IOTM – IoT-based Model Enhancement). R^2 = .659 means about 65.9% of the variance in IOTM is explained by the predictors, which is a very good fit.

Table 5: ANOVA[a] III

MODEL	SUM OF SQUARES	DF	MEAN SQUARE	F	SIG.
REGRESSION	2728.930	9	303.214	45.200	.000b
RESIDUAL	1450.366	230	6.306		
TOTAL	4179.296	239			

a. Dependent Variable: IOTM
b. Predictors: (Constant), SAT3, IAC3, IAC1, PLT3, SAT2, SAT1, PLT2, PLT1, IAC2

The ANOVA ($F(9,230) = 45.200$, $p < .001$) indicates the model is statistically significant. This implies that Procurement Lead Time, Inventory Accuracy, and Procurement Satisfaction collectively have a strong and significant effect on enhancing building materials procurement through IoT-based models.

Discussion of Results

Design of a Tailored IoT-Based Model

SEM demonstrated good absolute fit (χ^2/df=1.123, RMSEA=0.023), with System Integration (SI) positively impacting Procurement Efficiency (PEF, β=0.998) and Real-Time Monitoring (RTM) enhancing Decision Support (DS, β=0.517). The negative Infrastructure (INF)-DS path (β=-0.856) underscores reliability as a barrier, per TOE framework applications in off-site construction [17]. Indicators like real-time alerts (TRK3) and lead-time variability reduction (PLT3) emphasize practical benefits for agile procurement.

Rejection of H0 (R=0.812, R^2=0.659, p<0.001) validates the model's enhancement potential through inventory accuracy and satisfaction. This extends SEM-based approaches in supply chains, where blockchain-IoT hybrids address similar efficiencies [9]. In Nigeria, integrating BIM with IoT could mitigate data sharing challenges, as noted in recent studies on sustainable practices [18].

a. System Integration and Procurement Efficiency

The results demonstrate that System Integration exerts a strong positive influence on Procurement Efficiency (β = .998). Although the statistical significance was not confirmed at the conventional p < .05 level, the magnitude and theoretical support underscore the importance of SI as a key driver of procurement efficiency. This aligns with studies such as [19][20] who argue that seamless integration of supplier platforms, accurate data capture, and real-time API connectivity streamline procurement processes and reduce transaction costs. In this study, the positive effect implies that effective integration minimizes duplication errors, ensures accuracy in material coding, and reduces cycle times, thereby enhancing procurement outcomes.

Interestingly, within SI indicators, API connectivity (API1) exhibited a negative standardized loading (β = –.603), suggesting that reliability issues with API connections remain a challenge. This finding resonates with prior observations [21], who noted that technical instability in IoT integration may undermine trust in digital procurement systems. Conversely, the positive loading of Data Accuracy (DA2) confirms that respondents recognize the value of reliable item coding and quantity verification.

b. Real-Time Monitoring and Procurement Outcomes

The direct effect of Real-Time Monitoring on Procurement Efficiency was weak and negligible (β = –.058). This implies that tracking and monitoring alone may not directly enhance efficiency unless integrated with other processes such as automated decision-making or predictive analytics. However, RTM significantly contributes to Decision Support (β = .517), reinforcing the argument that real-time visibility enhances managerial capacity to respond to supply chain disruptions and make informed procurement decisions. This is consistent with findings [7], who highlighted the role of real-time IoT alerts in enabling agile responses to procurement uncertainties.

Among RTM indicators, real-time alerts (TRK3) emerged as the most significant contributor (β = 7.741), whereas instant location tracking (TRK1) and movement logging (TRK2) showed negligible effects. This suggests that decision-makers value actionable alerts over routine tracking functions, highlighting the importance of exception-based monitoring systems in construction procurement contexts.

c. IoT Infrastructure and Decision Support

The findings indicate a strong negative relationship between IoT Infrastructure and Decision Support (β = –.856). This result, though contrary to initial expectations, suggests that unreliable infrastructure such as poor connectivity, limited device availability, and inadequate maintenance may severely undermine decision-making effectiveness. This aligns with arguments by [22], who noted that infrastructural weaknesses often constrain the adoption of digital procurement technologies in developing contexts. The evidence here implies that infrastructure deficiencies not only fail to support decision support systems but may actively distort the reliability of dashboards and analytics outputs.

Notably, technical support and maintenance (INF3) loaded very strongly on the INF construct (β = 6.526), reinforcing its critical role. Respondents appear to perceive that without consistent technical support, IoT-based procurement systems cannot deliver reliable decision-making value. Meanwhile, device availability (INF2) and internet connectivity (INF1) were perceived as weak, suggesting that infrastructural capacity remains a systemic barrier to adoption.

d. Procurement Efficiency and Lead-Time Variability

The analysis of procurement efficiency indicators highlights that IoT systems significantly reduce variability in procurement lead time (PLT3: β = –.211, p = .045). This is a particularly valuable finding, as lead-time consistency is critical for construction projects where delays translate directly into cost overruns and productivity losses. While IoT may not drastically accelerate delivery speeds (PLT1, PLT2 were non-significant), its ability to minimize variability ensures greater predictability in material flow. This supports prior findings by [23], who emphasized IoT's role in improving supply chain stability rather than absolute speed.

e. Decision Support Indicators

The indicators of Decision Support (SAT1–SAT3) exhibited weak and non-significant contributions, suggesting that current IoT-based dashboards and analytics are not yet perceived as user-friendly or sufficiently insightful by procurement managers. This echoes the concerns raised by, who reported that digital [24] dashboards often require improved interface design, contextual customization, and better alignment with managerial decision-making needs.

f. Synthesis and Implications

Taken together, these findings suggest that while IoT adoption in procurement provides strong benefits in terms of system integration and reduction of lead-time variability, significant challenges remain in relation to infrastructure reliability and decision-support usability. The results confirm theoretical expectations from the Technology–Organization–Environment (TOE) framework, where organizational integration (SI) and technological enablers (RTM) promote efficiency and decision-making, while infrastructural constraints (INF) represent a major barrier.

For practice, the results imply that construction firms and procurement organizations should prioritize strengthening technical support systems, investing in infrastructure reliability, and focusing on real-time alert functionalities. Moreover, the design of decision-support dashboards should be refined to ensure greater managerial usability. By addressing these gaps, IoT-enabled procurement systems can better fulfill their potential in enhancing efficiency, reliability, and decision-making in construction supply chains.

5. CONCLUSION

This study validates an IoT-based procurement model using Interpretive Structural Modeling (ISM), demonstrating that infrastructure readiness and top management support are foundational enablers for system integration, user competence, and real-time transparency, which ultimately enhance data accuracy and risk reduction. The findings confirm that the validated model is both effective and applicable for addressing procurement inefficiencies in construction projects, offering a structured pathway for integrating IoT into procurement operations. By establishing clear hierarchical relationships among critical variables, the study provides empirical evidence that IoT adoption in procurement is not solely a technological exercise but also requires organizational and managerial alignment, thereby bridging the gap between conceptual frameworks and practical implementation.

Recommentations

1. National construction regulatory bodies should develop standardized IoT integration protocols to ensure interoperability and reduce the risks of fragmented systems.
2. Government and industry partnerships should be fostered to co-develop IoT-enabled procurement models that incorporate transparency, accountability, and data-driven decision-making.
3. Guidelines should be issued on data security, privacy, and ethical use of IoT data in procurement, ensuring trust and compliance with global standards.

Contribution to Knowledge

Development of a Conceptual IoT-Based Procurement Model: A major contribution is the design of a functional IoT-based model tailored for building materials procurement in construction projects. By integrating factors such as system integration, real-time monitoring, infrastructure readiness, and top management support, the model provides a practical roadmap for organizations seeking to digitize procurement operations.

Empirical Validation of the IoT Procurement Model: Using PCA, SEM, and ISM techniques, the study offers rigorous validation of the proposed IoT-based model, establishing causal relationships between adoption drivers, infrastructural readiness, and procurement outcomes. This methodological contribution demonstrates how multi-analytical approaches can be used to assess technology adoption frameworks in construction research.

Policy and Practical Implications for Developing Economies: The study extends global IoT literature by situating its findings within the Nigerian construction sector, where infrastructural deficits and limited technical expertise are prevalent. It provides evidence-based policy recommendations that can guide regulators, industry leaders, and practitioners in overcoming barriers to IoT adoption in procurement.

Bridging the Knowledge Gap between Theory and Practice:By connecting theoretical constructs of technology acceptance (e.g., ease of use, perceived usefulness, readiness) with real-world procurement inefficiencies, the study bridges academic models with practical procurement challenges. This integration enriches both theory and practice by contextualizing IoT adoption in an African construction setting.

Limitations and Future Research: This study was limited to construction firms and regulatory bodies in Lagos State, which may constrain the generalizability of findings to other regions or sectors with different institutional and technological contexts. Additionally, the study employed a cross-sectional design, which restricts the ability to capture dynamic changes in IoT adoption and procurement practices over time. Future research should adopt longitudinal approaches to examine evolving trends, test the robustness of the model across multiple geographical regions, and incorporate qualitative case studies that capture deeper organizational and behavioural dimensions. Integrating sustainability indicators into future IoT procurement models is also recommended to align with global smart construction and green building agendas.

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