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# The Effect of Lean Construction Principles on Infrastructure Delivery Efficiency in Ghana

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## Abstract

Infrastructure delivery in Ghana continues to face challenges relating to project delays, cost overruns, and quality deficiencies despite increasing investments in public infrastructure. Lean construction principles have emerged globally as an effective management philosophy for improving project performance through waste reduction, value maximization, and continuous improvement. This study examined the effect of lean construction principles on infrastructure delivery efficiency in Ghana. Guided by the Unified Theory of Acceptance and Use of Technology (UTAUT), a quantitative cross-sectional survey design was adopted. Data were collected from 384 construction professionals drawn from public and private construction organizations involved in infrastructure delivery. Structural Equation Modelling (SEM) was employed to examine the relationships between lean construction adoption and infrastructure delivery outcomes. The findings reveal that the Adoption of Lean Principles (ALP) significantly improves Time Performance ($\beta = 0.45$), Cost Performance ($\beta = 0.40$), and Quality Performance ($\beta = 0.48$). Furthermore, Performance Expectancy and Facilitating Conditions emerged as the strongest predictors of lean adoption. The study concludes that lean construction principles provide an effective framework for improving infrastructure delivery efficiency in Ghana. It recommends increased investment in lean training, organizational support systems, and industry-wide awareness programmes to enhance implementation.

Keywords: Lean construction, infrastructure delivery, project performance, construction management, Ghana, UTAUT.

## 1. Introduction

The construction industry continues to face major challenges, including project delays, cost overruns, material waste, and low productivity, due to fragmented project delivery systems and

inefficient resource management (Forbes and Ahmed, 2020). These challenges are particularly severe in developing countries like Ghana, where limited resources and managerial inefficiencies constrain increasing infrastructure demands. Consequently, there is a growing need for effective project management approaches that enhance project delivery time and cost performance. Lean construction has emerged as a strategic production management philosophy for addressing these inefficiencies. Originating from the Toyota Production System, lean construction focuses on maximizing customer value while minimizing waste through continuous improvement, reliable workflow, and stakeholder collaboration (Bajjou and Chafi, 2024; Musa et al., 2023). Core lean principles such as value generation, waste minimization, flow efficiency, and respect for people are implemented through tools including the Last Planner System (LPS), Just-in-Time (JIT), 5S, and Value Stream Mapping (VSM) (Abbasi et al., 2020; Carvalho et al., 2017).

Previous studies have shown that lean construction improves project performance by reducing project duration and cost while enhancing productivity and workflow efficiency (Chen et al., 2022; Parsamehr et al., 2023). In Ghana, studies indicate growing awareness of lean construction but limited practical implementation. Research by Salifu et al. (2023), Nettey (2021), and Ankomah et al. (2020), identified positive relationships between lean practices and project coordination, schedule performance, and cost control. However, lean implementation remains fragmented, with many firms applying isolated tools rather than fully adopting lean principles. Despite increasing research on lean construction in Ghana, limited empirical evidence exists on how lean construction principles influence project delivery time and cost across construction firms.

This study, therefore, examines the effect of lean construction principles on project delivery efficiency in Ghana's construction industry. The findings are expected to support contractors,

project managers, and policymakers in promoting sustainable lean adoption and improving infrastructure delivery performance.

## 2. Literature Review

### 2.1 Lean Construction: Concept, Principles, and Project Performance

Lean construction has emerged as a contemporary project delivery philosophy aimed at improving efficiency, minimizing waste, and maximizing value throughout the construction lifecycle. Originating from the Toyota Production System (TPS), lean construction was adapted from manufacturing to address persistent construction challenges such as project delays, cost overruns, rework, and inefficient resource utilization (Forbes and Ahmed 2020; Koskela 2000, 1992). Unlike traditional construction management approaches, lean construction adopts a systems perspective that integrates workflow reliability, production efficiency, and customer value. The theoretical foundation of lean construction is rooted in Koskela's Transformation–Flow–Value (TFV) theory, which conceptualizes construction as a combination of transformation activities, continuous workflow, and value generation for clients (Koskela 2000). This framework shifted construction management beyond simple productivity optimization toward waste reduction, process improvement, and stakeholder value enhancement (Salifu et al. 202; 3Benachio et al. 2021).

Lean construction emphasizes principles such as value generation, waste minimization, continuous improvement, standardization, and respect for people, while tools such as the Last Planner System (LPS), Just-in-Time (JIT), Value Stream Mapping (VSM), Kanban, and 5S are used to operationalize these principles (Babalola et. al., 2018). However, studies indicate that organizations implementing isolated lean tools without adopting the broader lean philosophy achieve only limited improvements in project performance (Musa et al. 2023; Babalola et al. 2019).

Previous studies demonstrate that lean construction improves project duration, cost efficiency, productivity, workflow reliability, and project quality (Bajjou and Chafi 2024; Benachio et al. 2021). Waste minimization and continuous improvement have been identified as central drivers of improved project performance (Mohammadi et al. 2022; Hamzeh et al. 2019). Furthermore, organizations that combine technical lean practices with supportive organizational cultures, leadership commitment, and stakeholder collaboration consistently achieve better outcomes than firms relying solely on technical interventions (Musa et al. 2023; Enshassi et al. 2021).

Despite its growing global adoption, lean construction implementation in developing countries remains fragmented due to inadequate training, organizational resistance, financial constraints, and limited management commitment (Moyo and Emuze 2023; Ankomah et al. 2020). In Ghana, studies report increasing awareness of lean construction but relatively low levels of comprehensive implementation. Nettey (2021) and Ankomah et al. (2020) identified improvements in workflow coordination and project performance among firms applying selected lean practices. However, many firms continue to implement isolated lean tools without embedding lean philosophy into organizational systems and culture (Salifu et al. 2023; Ankomah et al. 2020). Although lean construction has received increasing scholarly attention, important research gaps remain. Existing studies largely focus on lean awareness, implementation barriers, and individual lean tools, with limited empirical evidence on how lean construction principles influence infrastructure delivery performance within developing countries (Babalola et al. 2019; Salifu et al. 2015).

In Ghana, few studies have systematically examined the relationship between principle-based lean adoption and infrastructure project delivery outcomes. This study, therefore, addresses this gap by empirically examining the influence of lean construction principles on infrastructure delivery

efficiency in Ghana. The study contributes context-specific evidence that supports improved project delivery performance and advances understanding of lean construction implementation within developing economies.

## 3. Research Methodology

### 3.1 Research Philosophy and Design

This study adopts a positivist research philosophy, which holds that reality exists independently of the researcher and can be measured through objective methods. Within this ontological stance, a deductive quantitative approach is employed, whereby hypotheses derived from existing theory on lean construction are tested empirically against data collected from construction practitioners in Ghana (Saunders et al., 2019). A cross-sectional survey design is employed to collect data from construction professionals involved in infrastructure projects under the Ministry of Works and Housing (MoWH).

The target population comprises engineers, architects, quantity surveyors, project managers, inspectors, and procurement specialists from both public and private construction organizations. Using Cochran's (1977) formula, a sample size of 384 respondents is determined and selected through systematic random sampling.

Primary data are collected using structured questionnaires based on a five-point Likert scale. The questionnaire measures lean construction adoption and project delivery outcomes, including time, cost, and quality performance. Reliability is assessed using Cronbach's alpha, while validity is established through expert review and Confirmatory Factor Analysis (CFA) (Hair et al. 2019).

Data analysis involves descriptive statistics, Relative Importance Index (RII), Confirmatory Factor Analysis (CFA), and Structural Equation Modelling (SEM) to examine relationships between lean construction principles and infrastructure delivery outcomes. Ethical principles including informed consent, confidentiality, and voluntary participation are strictly observed throughout the study (Resnik 2020).

## 4. Results

### 4.1 Structural Model Results

The structural model was estimated to examine the effects of UTAUT constructs on the Adoption of Lean Principles (ALP) and subsequent infrastructure delivery performance in Ghana. The model includes four exogenous variables: Performance Expectancy (PE), Effort Expectancy (EE), Social Influence (SI), and Facilitating Conditions (FC), a mediating construct (ALP), and three endogenous constructs: Time Performance (TP), Cost Performance (CP), and Quality Performance (QP).

#### 4.1.1 Direct Effects

Table 1. presents the standardized path coefficients, t-values, and significance levels for the direct relationships in the structural model. ALP exhibits statistically significant positive effects on all three performance constructs. In contrast, most direct effects of PE, EE, SI, and FC on performance outcomes are weak or not statistically significant.

#### 4.1.2 Indirect Effects (Mediation Analysis)

Table 2 presents the analysis of indirect effects on the outcome variables (i.e., through ALP). The indirect effect is obtained by multiplying the direct effects along the path in question.

All four exogenous constructs demonstrate statistically significant indirect effects on performance outcomes through ALP, except the SI → CP pathway, which is marginal ($p = 0.060$).

#### 4.1.3 Total Effects

Table 3 presents the total standardized effects obtained by summing direct and indirect effects. ALP exhibits the largest total effects on all performance dimensions. Among the exogenous constructs, PE and FC show relatively higher total effects compared to EE and SI.

## 4. Discussion of Structural Model Results

The structural model results provide empirical evidence on the relationships between UTAUT-based determinants, Adoption of Lean Principles, and infrastructure delivery performance in Ghana (Addy et al., 2018; Blut et al., 2022). The findings indicate that ALP plays a central mediating role in translating behavioral and organizational determinants into measurable performance outcomes (Kuebutornye et al., 2025; Addy et al., 2018).

The results show that ALP has a statistically significant positive effect on Time Performance, Cost Performance, and Quality Performance (Kuebutornye et al., 2025; Berawi et al., 2023). This confirms that the adoption of lean construction practices contributes to improved infrastructure delivery efficiency across all performance dimensions (Kuebutornye et al., 2025; Ayarkwa et al., 2012). The magnitude of the effects suggests that lean implementation is a key driver of project performance enhancement within the Ghanaian construction context (Kuebutornye et al., 2025; Dk et al., 2024). Among the performance outcomes, the strongest effect is observed for Quality Performance, followed by Time Performance and Cost Performance (Kuebutornye et al., 2025). This indicates that lean practices may have a comparatively greater influence on improving process

reliability and construction quality, while also contributing substantially to schedule adherence and cost efficiency (Kuebutornye et al., 2025; Berawi et al., 2023).

The results further indicate that Performance Expectancy and Facilitating Conditions are the most significant predictors of ALP (Addy et al., 2018, 2022). This suggests that adoption decisions are primarily influenced by perceived performance benefits and the availability of organizational, technical, and institutional support (Blut et al., 2022; Addy et al., 2018). In practical terms, stakeholders are more likely to implement lean principles when they perceive clear productivity gains and when adequate resources, tools, and support systems are in place (Dk et al., 2024; Ayarkwa et al., 2012).

In contrast, Effort Expectancy and Social Influence exhibit weaker effects on ALP (Addy et al., 2018, 2022). This indicates that perceived ease of use and external social pressure play a secondary role in adoption decisions (Blut et al., 2022; Addy et al., 2018). The relatively lower influence of these constructs suggests that lean construction adoption in Ghana is driven more by perceived value and enabling conditions than by peer influence or implementation simplicity (Kuebutornye et al., 2026; Addy et al., 2022).

The mediation analysis shows that ALP significantly transmits the effects of PE, EE, SI, and FC onto infrastructure performance outcomes (Kuebutornye et al., 2026, 2025). The significance of indirect effects, combined with relatively weak direct effects of the exogenous constructs on performance variables, indicates that ALP functions as a key mediating mechanism in the model (Kuebutornye et al., 2025; Chen et al., 2020). This implies that improvements in infrastructure delivery efficiency are achieved primarily through successful lean implementation rather than through direct behavioral or organizational influences (Kuebutornye et al., 2025; Salifu-Asubay

and Mensah, 2015). PE and FC exhibit the strongest indirect effects across all performance dimensions, highlighting their importance as upstream determinants of performance improvement (Addy et al., 2022, 2018). EE and SI demonstrate comparatively weaker mediation effects, reinforcing their secondary role in the adoption process (Blut et al., 2022; Addy et al., 2018).

The total effects results confirm that ALP is the dominant determinant of infrastructure delivery performance within the model (Kuebutornye et al., 2025; Dk et al., 2024). Its total effects exceed those of all exogenous variables across Time, Cost, and Quality Performance, confirming its central role in enhancing project delivery efficiency (Kuebutornye et al., 2025; Berawi et al., 2023). Among the antecedent variables, PE and FC again emerge as the most influential overall predictors of performance outcomes (Blut et al., 2022; Addy et al., 2018).

The findings indicate that infrastructure delivery efficiency in Ghana is largely influenced by the adoption of lean construction practices, which are mainly driven by perceived performance advantages and supportive organizational conditions (Addy et al., 2022; Salifu-Asubay and Mensah, 2015; Ayarkwa et al., 2012).

## 5.1 Conclusions

The study examined the effect of lean construction principles on infrastructure delivery efficiency in Ghana using a structural equation modelling approach based on the Unified Theory of Acceptance and Use of Technology (UTAUT). The results demonstrate that the Adoption of Lean Principles (ALP) plays a central role in improving infrastructure delivery performance.

The findings show that ALP has a significant positive effect on Time Performance, Cost Performance, and Quality Performance, indicating that lean construction practices enhance overall project delivery efficiency. Among the performance outcomes, quality improvement shows the strongest effect, followed by time and cost performance.

The results further reveal that Performance Expectancy (PE) and Facilitating Conditions (FC) are the strongest predictors of ALP. This indicates that the decision to adopt lean construction practices is mainly driven by perceived performance benefits and the availability of organizational and technical support systems. In contrast, Effort Expectancy (EE) and Social Influence (SI) exhibit weaker effects on adoption, suggesting that ease of use and external pressure play a secondary role in influencing lean implementation within the Ghanaian construction context.

Overall, the study concludes that infrastructure delivery efficiency is primarily achieved through effective lean adoption, which is strongly influenced by performance-oriented perceptions and enabling institutional conditions.

## 5.2 Theoretical Implications

### a. UTAUT Contribution

This study extends the Unified Theory of Acceptance and Use of Technology (UTAUT) to the construction management domain by demonstrating its applicability in explaining the adoption of lean construction practices. The results confirm that Performance Expectancy (PE) and Facilitating Conditions (FC) are the strongest predictors of Adoption of Lean Principles (ALP), while Effort Expectancy (EE) and Social Influence (SI) exhibit comparatively weaker effects. This suggests that in construction project environments, adoption decisions are driven more by perceived performance benefits and enabling organizational structures than by ease of use or social pressure.

Furthermore, the study empirically validates the mediating role of behavioral adoption (ALP), showing that UTAUT constructs influence infrastructure delivery performance primarily through adoption rather than direct effects.

b. Lean Construction Contribution

The study reinforces lean construction theory by empirically confirming that Adoption of Lean Principles significantly improves Time Performance, Cost Performance, and Quality Performance. ALP emerged as the most influential determinant of infrastructure delivery efficiency, indicating that lean implementation is a critical operational mechanism for reducing waste, improving workflow reliability, and enhancing project outcomes. The findings further contribute to lean theory by demonstrating that its effectiveness is maximized when supported by organizational readiness and performance-oriented perceptions, rather than being treated solely as a technical improvement approach.

5.3 Practical Implications

a. Contractors

For construction contractors, the findings highlight that successful project delivery depends heavily on the effective implementation of lean principles. Contractors should prioritize embedding lean practices such as continuous improvement, waste reduction, and workflow optimization into daily site operations. Investment in training and capacity development is essential, as perceived performance benefits and organizational support were identified as key drivers of adoption.

b. Policy Makers

Policy makers and regulatory bodies should focus on creating enabling environments that support lean construction adoption. This includes developing industry guidelines, promoting standardization of lean practices, and integrating lean principles into public procurement frameworks. Strengthening institutional support systems and providing incentives for lean adoption can significantly enhance infrastructure delivery efficiency at the national level.

c. Project Managers

Project managers play a critical role in translating lean principles into operational practice. The findings suggest that management should focus on strengthening facilitating conditions such as access to tools, digital systems, and training resources. Additionally, project managers should emphasize performance-oriented communication to reinforce the benefits of lean adoption, thereby improving implementation consistency across project teams.

## 5.4 Limitations of the Study

a. Sample Size

The study is limited by the sample size used for the structural equation modelling analysis. Although the sample was adequate for SEM estimation, a larger dataset could improve the generalizability and robustness of the findings.

b. Geographic Limitation

The study is geographically confined to Ghana. As a result, the findings may not fully represent construction industry dynamics in other developing or developed countries with different regulatory, cultural, and institutional environments.

c. Self-Reported Data

The study relies on self-reported survey data, which may introduce bias due to respondent perception, recall errors, or subjective evaluation of project performance outcomes. This may affect the precision of measured relationships within the model.

### 5.5 Future Research Directions

#### a. Other Countries

Future research should replicate this study in other countries to validate the generalizability of the model. Comparative studies between developing and developed economies would provide deeper insights into contextual differences in lean construction adoption.

#### b. Other Models (TAM, DOI, BIM Integration)

Future studies could extend the theoretical framework by incorporating alternative or complementary models such as the Technology Acceptance Model (TAM) and Diffusion of Innovation (DOI) theory. Additionally, integrating Building Information Modeling (BIM) with lean construction could provide a more comprehensive understanding of digital transformation and process efficiency in construction project delivery.

### 5.6 Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request. The datasets are not publicly available because they contain information that could compromise the privacy and confidentiality of the research participants. All data were collected and analysed in accordance with applicable ethical guidelines, and any shared data will be appropriately anonymised

### 5.6.1 Acknowledgements

The author acknowledges all respondents and supporting institutions.

### 5.6.2 Funding Declaration

There was no funding.

### 5.6.3 Declaration of Competing Interest

There was no conflict of interest.

### 5.6.4 Ethics Approval and Accordance

The Ethical Review Committee of Takoradi Technical University, Ghana, approved this study under approval/reference number Ref. No. TTU/UREC/26/096. The study was conducted in accordance with the ethical guidelines and regulations of the approving institution. All procedures involving human participants followed the approved ethical requirements.

### 5.6.5 Consent to Participate

Informed consent was obtained from all the individual participants for participation in this study.

### 5.6.6 Consent to Publish

Not applicable as no identifiable data or images are present within the manuscript.

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408 **Table 1. Standardized Direct Effects**

| Structural path | Standardized β | t | *p* | Interpretation |
|---|---|---|---|---|
| PE → ALP | **0.32** | 5.12 | 0.001 | PE positively predicts ALP |
| EE → ALP | 0.18 | 2.88 | 0.004 | EE positively predicts ALP |
| SI → ALP | 0.15 | 2.45 | 0.014 | SI positively predicts ALP |
| FC → ALP | **0.28** | 4.60 | 0.001 | FC strongly predicts ALP |
| ALP → TP | **0.45** | 8.90 | 0.001 | ALP strongly increases timely delivery |
| PE → TP | 0.12 | 2.10 | 0.036 | Small direct |
| EE → TP | 0.04 | 0.75 | 0.450 | Not significant |
| SI → TP | 0.03 | 0.60 | 0.550 | Not significant |
| FC → TP | 0.08 | 1.70 | 0.089 | Marginal |

| | | | | |
|---|---|---|---|---|
| ALP → CP | **0.40** | 7.65 | 0.001 | ALP improves cost performance |
| PE → CP | 0.10 | 1.95 | 0.051 | Borderline (≈ .05) |
| EE → CP | 0.02 | 0.35 | 0.73 | Not significant |
| SI → CP | 0.01 | 0.21 | 0.83 | Not significant |
| FC → CP | 0.08 | 1.55 | 0.12 | Not significant |
| ALP → QP | **0.48** | 9.45 | 0.001 | ALP strongly improves quality |
| PE → QP | 0.11 | 1.95 | 0.052 | Borderline |
| EE → QP | 0.03 | 0.52 | 0.6 | Not significant |
| SI → QP | 0.02 | 0.41 | 0.68 | Not significant |
| FC → QP | 0.07 | 1.35 | 0.18 | Not significant |

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411 **Table 2. Indirect Effects on Outcomes**

| **Indirect path** | **Indirect effect (β)** | **z** | ***p*** | **Interpretation** |
|---|---|---|---|---|
| PE → ALP → TP | **0.144** | 3.98 | 0.001 | Significant mediation: PE increases timely delivery via ALP |
| EE → ALP → TP | **0.081** | 2.35 | 0.019 | Small but significant |
| SI → ALP → TP | **0.068** | 2.1 | 0.036 | Small significant |
| FC → ALP → TP | **0.126** | 3.85 | 0.001 | Significant mediation |
| PE → ALP → CP | **0.128** | 3.4 | 0.001 | Significant |

| | | | | |
|---|---|---|---|---|
| EE → ALP → CP | 0.072 | 2.05 | 0.04 | Significant |
| SI → ALP → CP | 0.060 | 1.88 | 0.06 | Borderline |
| FC → ALP → CP | 0.112 | 3.2 | 0.001 | Significant |
| PE → ALP → QP | **0.154** | 4.12 | 0.001 | Significant |
| EE → ALP → QP | 0.086 | 2.5 | 0.012 | Significant |
| SI → ALP → QP | 0.072 | 2.2 | 0.028 | Significant |
| FC → ALP → QP | 0.134 | 3.95 | 0.001 | Significant |

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413 **Table 3. Total Effects on Infrastructure Delivery Performance**

| **Predictor Variable** | **Total Effect on Time Performance (TP)** | **Total Effect on Cost Performance (CP)** | **Total Effect on Quality Performance (QP)** |
|---|---|---|---|
| Performance Expectancy (PE) | 0.26 | 0.23 | 0.27 |
| Facilitating Conditions (FC) | 0.21 | 0.20 | 0.22 |
| Effort Expectancy (EE) | 0.12 | 0.11 | 0.13 |

| | | | |
|---|---|---|---|
| Social Influence (SI) | 0.10 | 0.09 | 0.11 |
| Adoption of Lean Principles (ALP) | 0.45 | 0.40 | 0.48 |

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