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Optimization of Quality Performance in Building Projects Through Lean Construction Practices

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Abstract

Construction quality is affected not only by inspection and material compliance but also by the reliability of planning, coordination, information flow, material delivery, and execution processes. This paper examines the relationship between Lean Construction practices and quality performance in selected RERA-registered residential building projects. The study reported questionnaire responses from 100 construction professionals and used site-based checklists to support interpretation of reported practices. Descriptive statistics were used to assess implementation and quality indicators; internal consistency was assessed using Cronbach's alpha; and Pearson correlation and multiple regression were reported to examine the relationship between Lean practices and quality performance. The questionnaire contained 40 items and achieved a reported Cronbach's alpha of 0.976. Lean Construction and quality performance were strongly positively correlated ($r = 0.852$, $p < 0.01$). The report further gives a regression R^2 of 0.785 and identifies the Last Planner System ($\beta = 0.641$) and Just-In-Time practices ($\beta = 0.261$) as influential predictors, while Value Management was not statistically significant as a direct predictor. The lowest mean among selected implementation indicators was 3.65 for value engineering during planning/design, highlighting an improvement opportunity. These findings support stronger collaborative planning, readiness checks, material-flow coordination, and final-stage compliance management. Because the design is observational and cross-sectional, the results establish association rather than causal effect.

Keywords—Lean Construction, construction quality, Last Planner System, Just-In-Time, rework, residential building projects, Pearson correlation, multiple regression.

I. Introduction

Building projects bring together designers, contractors, suppliers, supervisors, and clients across interdependent tasks. Defects, rework, non-conformance, and inconsistent workmanship can arise when work starts with incomplete information, resources are unavailable, trade interfaces are poorly coordinated, or accepted procedures are applied inconsistently. Inspection remains essential, but inspection alone may identify a deviation after labour, material, and time have already been consumed. Lean Construction addresses these process conditions through value-focused planning, waste reduction, reliable workflow, standardization, visual control, and continuous improvement [1]–[5].

The report underpinning this paper focuses on selected RERA-registered residential building projects and evaluates Value Management (VM), Industrialized Building System (IBS), Just-In-Time (JIT), and the Last Planner System (LPS), alongside quality planning, inspection, KPI monitoring, defect control, rework, and final compliance. Its stated research gap is the need to relate Lean implementation to quality outcomes and translate findings into practical priorities. Recent work similarly discusses Lean–BIM integration, automated planning, takt planning, and the causes of construction defects [21]–[25].

The paper has three objectives: (1) describe reported Lean implementation and quality-performance indicators; (2) examine the reported association between Lean practices and quality performance; and (3) identify actionable barriers and improvement priorities. The evidence is interpreted conservatively: the study's reported statistics are reproduced, but no unreported coefficients, confidence intervals, model diagnostics, or causal claims are added.

II. Related Work

Lean Construction extends production-system thinking to project delivery by treating workflow reliability and waste as central management concerns. The Last Planner System emphasizes collaborative planning, constraint removal, and commitments made only when activities are ready [1], [2]. Value Stream Mapping supports identification of non-value-adding activities and opportunities to improve flow [3]. The literature also indicates that Lean tools can be integrated with formal quality management rather than treated as a substitute for inspection and QA/QC systems [4].

Studies of Lean and BIM report that digital coordination can help identify design clashes, omissions, and information gaps before these propagate to site execution [5], [6]. Quantitative studies have assessed Lean and BIM effects on process flow and project performance [7], while more recent studies examine prefabricated building performance, Lean implementation barriers, and integrated delivery [8]–[12]. Research on Lean Six Sigma provides a complementary quality-improvement perspective by linking defect analysis to process improvement [13].

Recent literature also extends the discussion to one-piece flow in mass housing, takt planning combined with LPS, and automation of planning and control [14]–[17]. A systematic review of building quality identifies poor workmanship, planning and scheduling problems, and design changes as recurring defect-related themes [18]. Other reviews highlight implementation enablers such as leadership, training, collaboration, and organizational culture [10], [19], [20].

The present study is positioned as an applied, project-context analysis rather than a new universal Lean theory. Its contribution is the combined interpretation of reported survey statistics and site-based checklist observations, with particular attention to LPS, JIT, final-stage compliance, and barriers in residential projects.

III. Research Methodology

A. Research Design and Study Context

The source report describes a questionnaire survey of 100 respondents connected with selected RERA-registered residential building projects and complementary site-based checklist observations. Respondent roles included project managers, site engineers, planning engineers, quality engineers, contractors, supervisors, and other construction professionals. The analytical methods reported are frequency and percentage summaries, mean and standard-deviation analysis, Cronbach's alpha, Pearson correlation, multiple regression, and qualitative comparison with site observations.

B. Measurement and Constructs

Lean practices are represented in the source report through VM, IBS, JIT, and LPS. Quality performance is represented by quality planning, KPI monitoring, ISO/inspection adherence, defect identification, rework management, corrective action, workmanship, and final client/statutory compliance. The questionnaire contained 40 items. The report does not provide a complete item-level codebook or the raw response matrix in the material used to prepare this paper; therefore, item-level recomputation and independent reproduction of the statistical models were not possible.

C. Analysis Procedure

The analysis sequence is: survey and checklist collection; descriptive analysis; internal-consistency assessment; correlation between total Lean and total Quality scores; multiple regression for selected Lean predictors; and interpretation against observed implementation barriers. The source reports a Cronbach's alpha of 0.976 for the 40-item questionnaire and a separate alpha of 0.901 for eight barrier-related variables. Statistical significance is reported for the overall correlation, while the regression discussion identifies LPS and JIT as influential predictors and VM as non-significant.

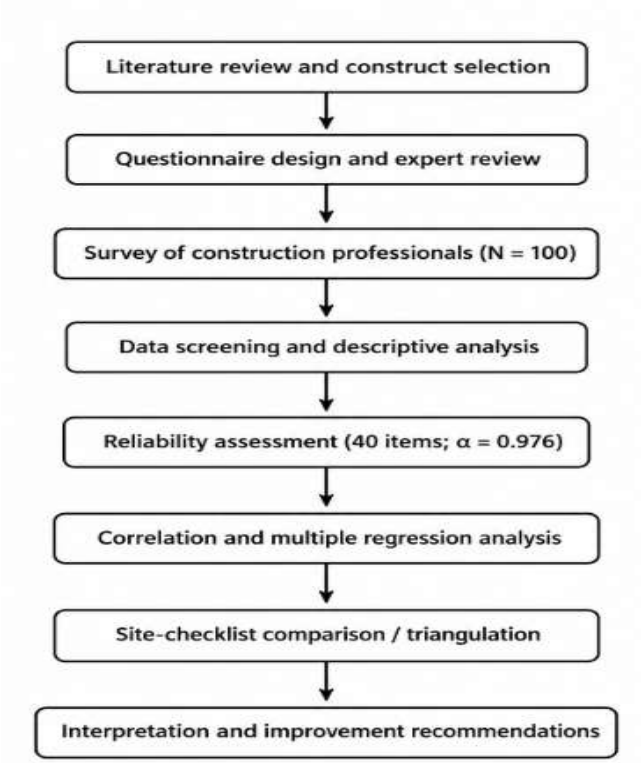


Fig. 1. Analysis workflow reconstructed from the study procedure.

The workflow makes explicit that the survey and site-checklist evidence are summarized before inferential analysis. Reliability assessment is placed before interpretation of the relationship between Lean practices and quality performance. The final step translates the statistical and descriptive findings into operational recommendations. This sequence is consistent with the report's use of questionnaire data, descriptive summaries, correlation, regression, and site-based observations. It is a process representation rather than evidence of a newly executed analysis. The reported data remain observational; therefore, the workflow supports structured association analysis but does not by itself establish causal effects. A future replication should preserve the raw dataset, variable dictionary, missing-data rules, model specification, and software output so that every coefficient and significance value can be independently verified.



Fig. 2. Construction work in progress

The fig illustrates the physical setting in which construction quality is planned, executed, and inspected. Although the image is illustrative rather than a measured result, it helps locate the study's quality-management problem in everyday

site operations: materials, work fronts, access, sequencing, and inspection activities must be coordinated while construction proceeds. A photograph cannot demonstrate that defects have decreased or that Lean practices caused an improvement; those claims must come from systematic measurements. In this paper, the image is therefore used only as contextual evidence and not as a data point. The study's empirical claims are based on the reported questionnaire and checklist analyses. For a stronger case-study presentation, future versions could pair such photographs with a documented observation protocol, date, project identifier, and coded evidence of planning boards, storage practices, inspection status, and corrective actions.



Fig. 3. Visual planning board used as an example of collaborative planning

The planning-board photograph illustrates a visual mechanism for communicating task status, sequencing, and near-term commitments to site teams. In Lean Construction, such boards can make constraints and work readiness more visible and can support coordination between trades. Their potential quality value lies in preventing work from starting before prerequisites are met, reducing ambiguity about instructions, and exposing schedule conflicts early enough for corrective action. However, the presence of a board alone does not prove that the Last Planner System is being implemented consistently. Effective use requires regular updates, ownership of commitments, constraint removal, and feedback on incomplete tasks. The source report's checklist narrative notes that weekly planning was common but constraint identification and readiness-based release were not consistently observed. The photograph should therefore be read as an illustration of a tool, while the survey and checklist narrative provide the reported evidence about implementation.

IV. Results and Discussion

A. Questionnaire Reliability

Table I. Reported Questionnaire Reliability

Measure	Reported value	Interpretation in source report
Cronbach's alpha	0.976	Excellent internal consistency
Number of questionnaire items	40	Lean practices and quality-performance indicators
Barrier-scale Cronbach's alpha	0.901	Eight barrier-related variables

Interpretation: The report records an overall Cronbach's alpha of 0.976 across 40 questionnaire items, indicating very high internal consistency under the study's chosen reliability measure. It also reports alpha = 0.901 for a separate set of eight barrier-related variables. These values support consistency among the items as scored, but they do not

alone establish construct validity, unidimensionality, or absence of redundant items. For a journal-ready version, reliability should be accompanied by item-total statistics and evidence that each construct is measured coherently. Because the raw data and full item mapping were not supplied separately, this paper reproduces the reported reliability figures without recalculating them. The results should be interpreted as questionnaire reliability evidence rather than proof that every item is valid or that the model is free from measurement error.

B. Respondent Profile

Table II. Designation-Wise Distribution Of Respondents

Designation	Frequency	Percent
Project Manager	15	15%
Site Engineer	12	12%
Planning Engineer	10	10%
Quality Engineer	15	15%
Contractor	21	21%
Supervisor	13	13%
Other	14	14%
Total	100	100%

Interpretation: The designation distribution totals 100 respondents. Contractors form the largest single group at 21%, while project managers and quality engineers each account for 15%. Supervisors contribute 13%, site engineers 12%, planning engineers 10%, and other roles 14%. This spread includes both management and site-level perspectives, which is useful because quality outcomes depend on decisions made during planning, procurement, supervision, execution, and inspection. However, designation diversity does not automatically guarantee representativeness of the wider construction sector. The paper therefore limits generalization to the selected residential-project context described in the report. A stronger external-validity assessment would document geographic coverage, project count, respondent experience, selection criteria, response rate, and the number of respondents associated with each project.

C. Descriptive Quality Indicators

Table III. Selected Reported Quality-Performance Means

Indicator	Mean	SD
Defects identified early during execution	4.17	Not reported in available table extract
Quality issues resolved within defined timelines	4.17	0.965
Final output meets client and statutory requirements	3.68	1.230
Rework/defect outcomes (reported range)	4.15–4.17	Varies by item

Interpretation: The source report gives high mean scores for early defect identification and timely resolution of quality issues, with values around 4.17. These values suggest that respondents generally perceived the studied projects as having established mechanisms for detecting and correcting deviations. In contrast, the final-output compliance indicator has a lower mean of 3.68 and a reported standard deviation of 1.23, indicating a comparatively weaker and more variable perception of compliance with client and statutory requirements. This contrast is operationally important: internal inspections and corrective action may be functioning while documentation, coordination, approvals, or final acceptance still need attention. The reported scale anchors and item-level distributions should accompany these means in a final journal version. The difference is descriptive and should not be treated as statistically significant without an appropriate comparison test.

D. Relationship Between Lean Practices and Quality Performance

Table IV. Reported Lean–Quality Association and Regression Summary

Analysis	Reported result	Meaning
Pearson correlation	$r = 0.852$; $p < 0.01$; $N = 100$	Very strong positive association
Multiple regression	$R^2 = 0.785$	78.5% of observed variation explained by model as reported
Last Planner System	$\beta = 0.641$	Largest reported predictor coefficient
Just-In-Time	$\beta = 0.261$	Positive reported predictor coefficient
Value Management	Direct effect not statistically significant	No statistically significant direct effect reported

The reported Pearson coefficient ($r = 0.852$, $N = 100$) indicates a strong positive association between the composite Lean Construction score and the composite Quality score. The report states $p = 0.000$; this should conventionally be written as $p < 0.001$ because statistical software rounds very small p-values rather than demonstrating a probability of exactly zero. The regression summary reports $R^2 = 0.785$, indicating that the fitted model accounts for 78.5% of sample variation in the quality outcome under the model as specified. LPS has the largest reported coefficient ($\beta = 0.641$), followed by JIT ($\beta = 0.261$), while VM is reported as non-significant. Coefficients should not be compared as standardized effects unless the source output confirms their scaling. Without the complete regression table and diagnostics, the reported model cannot be independently audited.

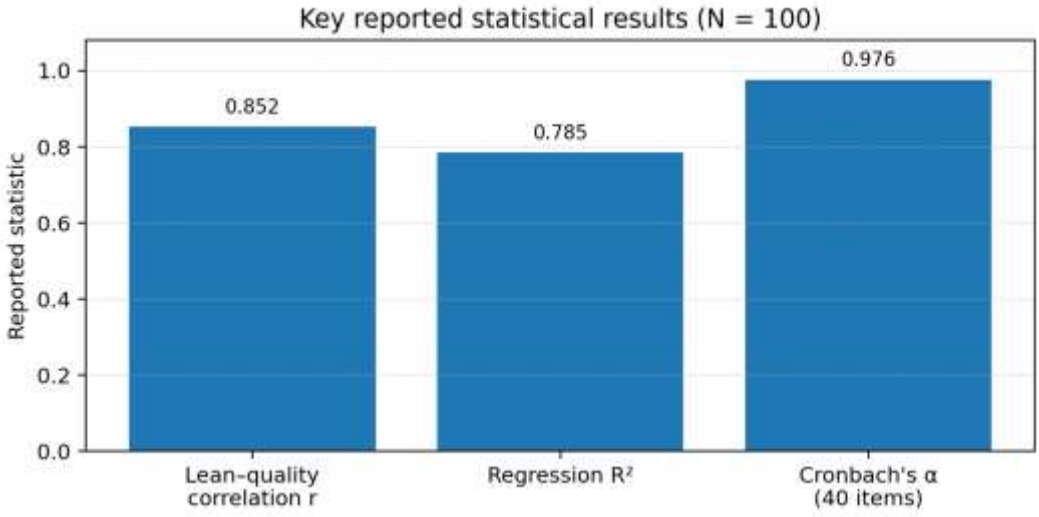


Fig. 4. Selected reported reliability and relationship statistics.

The chart places three reported statistics side by side: questionnaire reliability ($\alpha = 0.976$), the Lean–Quality correlation ($r = 0.852$), and the regression coefficient of determination ($R^2 = 0.785$). These values describe different properties and should not be interpreted as interchangeable measures. Cronbach's alpha concerns internal consistency among questionnaire items; Pearson's r summarizes the direction and strength of a bivariate linear association; and R^2 describes the proportion of sample outcome variance accounted for by the fitted regression model. The visualization is intended to make the reported numerical results easier to compare, not to imply that one statistic is inherently superior to another. The high correlation and R^2 are encouraging, but model stability, predictor overlap, residual assumptions, and external validation remain important before predictive or causal claims can be made.

E. Implementation Barriers and Improvement Priorities

Table V. Selected Implementation and Barrier Indicators

Indicator	Mean	Reported interpretation
Value engineering during planning/design	3.65	Lowest selected mean; improvement opportunity
Activities begin only when prerequisites are ready	3.90	Readiness/workflow constraint
Materials delivered only when required on site	3.93	JIT/material coordination opportunity
Workers trained on quality standards and procedures	3.94	Training opportunity
Corrective actions based on KPI results	4.22	Relatively stronger reported practice

The lowest selected mean is 3.65 for carrying out value engineering during the planning/design stage. This points to an opportunity to strengthen early-stage evaluation of alternatives before design and execution decisions become costly to change. Readiness-based task execution (3.90), just-in-time material delivery (3.93), and worker training (3.94) also score below the strongest item in this subset. Corrective actions based on KPI results score 4.22, suggesting a comparatively stronger reported monitoring practice. The practical implication is not to abandon existing quality control but to connect monitoring more consistently to upstream prevention. Suggested actions include value-engineering workshops, look-ahead constraint registers, make-ready checklists, procurement coordination with weekly plans, and role-specific Lean training. These priorities are derived from descriptive means; formal ranking uncertainty or significance was not reported.

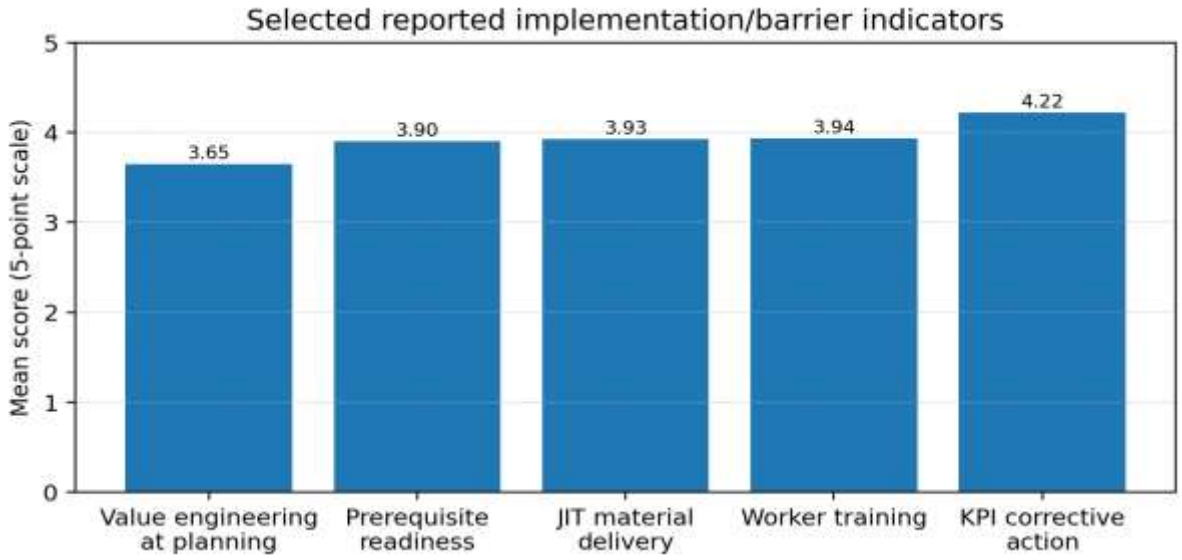


Fig. 5. Means for selected implementation indicators.

The figure visualizes the relative scores of five selected indicators on the report's five-point response scale. Value engineering at planning/design is lowest (3.65), while KPI-based corrective action is highest among the selected indicators (4.22). The difference reinforces the interpretation that monitoring and correction may be more established than early value engineering and work-readiness controls. The other values—3.90 for prerequisite readiness, 3.93 for just-in-time material delivery, and 3.94 for worker training—suggest that improvements in planning discipline, procurement timing, and workforce capability remain relevant. These are descriptive comparisons, not hypothesis tests; no confidence intervals or standard errors are shown because they were not provided in the relevant source extract. The figure is best used to guide discussion and improvement planning rather than to assert statistically significant differences between items.

F. Site-Based Checklist Triangulation

The source report states that checklist observations broadly aligned with questionnaire responses. Projects reporting stronger visual management were described as having visible quality checklists, progress boards, material-identification tags, and work-instruction charts. Better JIT scores were associated in the observations with reduced stockpiling and more coordinated delivery, whereas lower JIT scores coincided with excess storage and occasional material damage. LPS implementation was described as partial: weekly meetings were common, but constraint identification and readiness-based task release were not consistently observed. These observations provide contextual support for the survey interpretation, but the report extract does not provide a coded checklist dataset, inter-rater reliability, or a project-by-project comparison matrix. The triangulation should therefore be understood as qualitative corroboration rather than an independent quantitative validation of the correlation or regression model.

G. Proposed Lean–Quality Conceptual Model

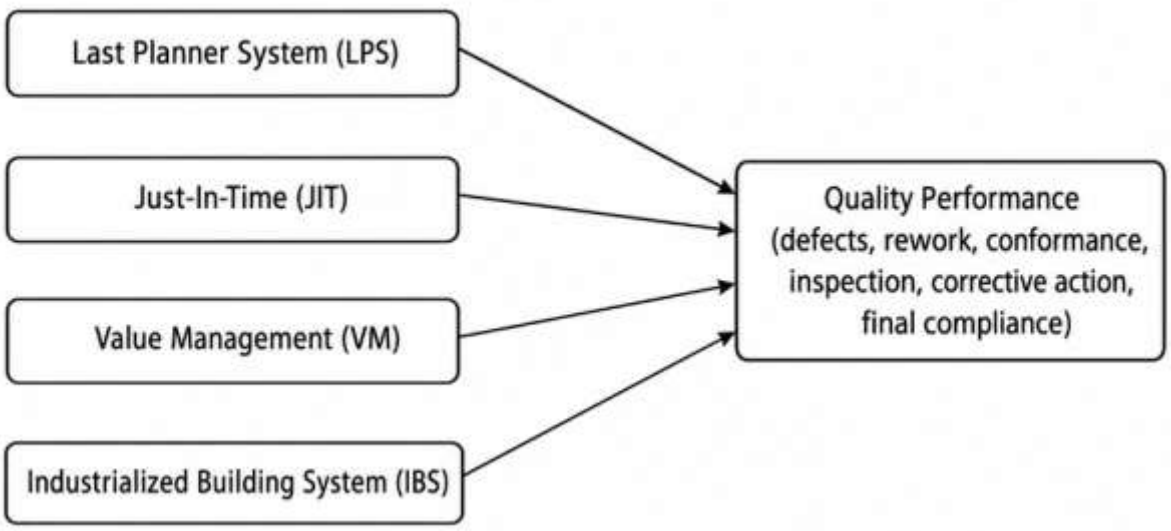


Fig. 6. Lean-practice dimensions and quality-performance outcome represented in the paper.

The model summarizes the relationships evaluated in the report by linking LPS, JIT, VM, and IBS with a broad quality-performance outcome. The outcome covers prevention and control indicators, including defects, rework, conformance, inspection, corrective action, and final compliance. The model is a conceptual representation of the report's analytical framing and is not a newly estimated structural equation model. The empirical results supplied by the report support a strong overall Lean–Quality association and identify LPS and JIT as the stronger reported regression predictors. VM's non-significant direct effect should not be interpreted as proof that value management is useless; its effect may depend on timing, implementation maturity, measurement, or other project conditions. The raw model specification should be aligned with the final regression output before publication.

H. Practical Implications

The findings support five practical actions. First, strengthen LPS through weekly collaborative planning, look-ahead schedules, constraint logs, and task-readiness checks. Second, coordinate procurement and work plans so that materials arrive when required and are protected from damage. Third, conduct value-engineering reviews early, documenting functional requirements, constructability, cost, and quality trade-offs. Fourth, standardize visual management and quality information at the point of work. Fifth, monitor defect rates, rework, non-conformance, plan reliability, and corrective-action closure, with root-cause analysis for repeated deviations. Final-stage compliance should receive specific attention because its reported mean (3.68) is lower than the selected early-defect and corrective-action indicators. These recommendations are consistent with the source report and with broader Lean Construction literature [1]–[20].

V. Limitations

The analysis is based on the statistics and narrative reported in the uploaded document; the raw respondent-level dataset and complete SPSS output were not supplied separately. The paper therefore does not independently recompute alpha, correlation, regression, or descriptive statistics. The source report does not provide all predictor coefficients, standard errors, confidence intervals, regression diagnostics, missing-data rules, or a complete project sampling frame in the extracts used here. A cross-sectional questionnaire can establish association but cannot by itself demonstrate causation. The reported R^2 should not be interpreted as out-of-sample predictive performance. The findings are most directly applicable to the selected residential building projects and should not automatically be generalized to all building types or regions.

VI. Conclusion

This paper examined reported evidence on Lean Construction practices and quality performance in selected residential building projects. The source report describes 100 respondents and a 40-item questionnaire with Cronbach's alpha of 0.976. It reports a strong positive Lean–Quality correlation ($r = 0.852$, $p < 0.01$) and a regression R^2 of 0.785. LPS ($\beta = 0.641$) and JIT ($\beta = 0.261$) are identified as the more influential reported predictors, while VM was not statistically significant as a direct predictor. Descriptive findings show comparatively high ratings for early defect identification and timely corrective action, but a lower score for final client/statutory compliance (mean = 3.68). Value engineering at planning/design has the lowest selected implementation mean (3.65), making it a practical area for improvement. Overall, stronger planning reliability, work-readiness controls, material-flow coordination, early value engineering, workforce training, and final-stage documentation are recommended. Further publication should include the complete regression output, raw-data reproducibility details, and formal diagnostics. The study supports a strong association between Lean practices and quality outcomes, while causal claims require longitudinal or experimental evidence.

References

[1] H. Erol, I. Dikmen, and M. T. Birgonul, "Measuring the impact of lean construction practices on project duration and variability: A simulation-based study on residential buildings," Journal of Civil Engineering and Management, vol. 23, no. 2, pp. 241–251, 2017, doi: 10.3846/13923730.2015.1068846.

[2] L. Diaz, M. de Oliveira, P. Pucharelli, and J. Pinzon, "Integration between the Last Planner System and the Quality Management System applied in the civil construction industry," Revista Ingeniería de Construcción, vol. 34, no. 2, pp. 146–158, 2019, doi: 10.4067/S0718-50732019000200146.

[3] P. V. Ramani and L. K. Lingan, "Application of lean in construction using value stream mapping," Engineering, Construction and Architectural Management, vol. 28, no. 1, pp. 216–228, 2021, doi: 10.1108/ECAM-12-2018-0572.

[4] E. N. Shaqour, "The impact of adopting lean construction in Egypt: Level of knowledge, application, and benefits," Ain Shams Engineering Journal, vol. 13, no. 2, Art. no. 101551, 2022, doi: 10.1016/j.asej.2021.07.005.

[5] A. M. Eldeep, M. A. M. Farag, and L. M. Abd El-hafez, "Using BIM as a lean management tool in construction processes—A case study," Ain Shams Engineering Journal, vol. 13, no. 2, Art. no. 101556, 2022, doi: 10.1016/j.asej.2021.07.009.

[6] K. El Mounla, D. Beladjine, K. Beddiar, and B. Mazari, "Lean-BIM approach for improving the performance of a construction project in the design phase," Buildings, vol. 13, no. 3, Art. no. 654, 2023, doi: 10.3390/buildings13030654.

[7] M. J. Maraqa, R. Sacks, and S. Spatari, "Quantitative assessment of the impacts of BIM and lean on process and operations flow in construction projects," Engineering, Construction and Architectural Management, vol. 28, no. 8, pp. 2176–2198, 2021, doi: 10.1108/ECAM-12-2020-1068.

[8] C. Z. Li, V. W. Y. Tam, M. Hu, and Y. Zhou, "Lean construction management: A catalyst for evaluating and enhancing prefabricated building project performance in China," Journal of Building Engineering, vol. 94, Art. no. 109930, 2024, doi: 10.1016/j.jobe.2024.109930.

[9] M. Aslam, E. Baffoe-Twum, M. Ahmed, and A. Ulhaq, "Unveiling effectiveness of lean construction practices: A comprehensive study through surveys and case studies," Civil Engineering Journal, vol. 10, no. 4, pp. 1145–1158, 2024, doi: 10.28991/CEJ-2024-010-04-09.

[10] S. Moradi and P. Sormunen, "Implementing lean construction: A literature study of barriers, enablers, and implications," Buildings, vol. 13, no. 2, Art. no. 556, 2023, doi: 10.3390/buildings13020556.

[11] P. T. Ramesh and E. N. Swaminathan, "A synergetic effect of the integration of lean, sustainable construction practices and alliance contract on operation performance in the Indian construction industry," Sustainability, vol. 16, no. 5, Art. no. 1857, 2024, doi: 10.3390/su16051857.

[12] A. Maru, W. Jekale, and B. Asteray, "Investigating the impact of lean construction principles on contractors' project performance in Ethiopia using PLS-SEM," Journal of Project Management, vol. 9, no. 3, pp. 227–238, 2024, doi: 10.5267/j.jpm.2024.4.004.

[13] K. Idrissi Gartoumi, M. Aboussaleh, and S. Zaki, "Implementing lean construction to improve quality and megaproject construction: A case study," Journal of Financial Management of Property and Construction, vol. 29, no. 1, pp. 1–22, 2024, doi: 10.1108/JFMPC-12-2022-0063.

[14] D. A. Saad, M. Habib, and A. Abou-Zeid, "Investigating the application of one-piece flow from lean manufacturing in the construction delivery of mass housing projects," Scientific Reports, vol. 15, Art. no. 34110, 2025, doi: 10.1038/s41598-025-19779-w.

[15] W. Power, D. Sinnott, and P. Lynch, "Takt complementing Last Planner® System on residential construction projects," Construction Economics and Building, vol. 24, no. 4/5, pp. 58–80, 2024, doi: 10.5130/AJCEB.v24i4/5.8846.

[16] A. K. Agrawal, Y. Zou, L. Chen, M. A. Abdelmegid, and V. González, "Moving toward lean construction through automation of planning and control in Last Planner System: A systematic literature review," Developments in the Built Environment, vol. 17, Art. no. 100419, 2024, doi: 10.1016/j.dibe.2024.100419.

[17] Y. Pérez, J. Ávila, and O. Sánchez, "Influence of BIM and Lean on mitigating delay factors in building projects," Results in Engineering, vol. 22, Art. no. 102236, 2024, doi: 10.1016/j.rineng.2024.102236.

[18] A. T. Gurmu and M. N. Mahmood, "Critical factors affecting quality in building construction projects: Systematic review and meta-analysis," Journal of Construction Engineering and Management, vol. 150, no. 3, 2024, doi: 10.1061/JCEMD4.COENG-13794.

[19] G. Garcés, E. Forcael, C. Osorio, K. Castañeda, and O. Sánchez, "Systematic review of Lean Construction: An approach to sustainability and efficiency in construction management," Journal of Infrastructure Preservation and Resilience, vol. 6, Art. no. 6, 2025, doi: 10.1186/s43065-025-00119-1.

[20] G. Karunasena, A. Gurmu, S. Shooshtarian, N. Udawatta, C. S. R. Perera, and T. Maqsood, "Effect of construction defects on construction and demolition waste management in building construction: A systematic literature review," Integrated Environmental Assessment and Management, vol. 21, no. 2, pp. 233–244, 2025, doi: 10.1093/inteam/vjae026.

[21] L. Koskela, Application of the New Production Philosophy to Construction. Stanford, CA, USA: Center for Integrated Facility Engineering, Stanford University, 1992.

[22] G. Ballard, The Last Planner System of Production Control. Birmingham, U.K.: University of Birmingham, 2000.

[23] G. A. Howell, "What is lean construction—1999," in Proc. 7th Annual Conf. Int. Group for Lean Construction, Berkeley, CA, USA, 1999.

[24] R. Sacks, L. Koskela, B. A. Dave, and R. Owen, "Interaction of lean and building information modeling in construction," Journal of Construction Engineering and Management, vol. 136, no. 9, pp. 968–980, 2010.

[25] L. Koskela, G. Ballard, G. Howell, and I. Tommelein, "The foundations of lean construction," in Design and Construction: Building in Value, R. Best and G. de Valence, Eds. Oxford, U.K.: Butterworth-Heinemann, 2002, pp. 211–226.

[26] H. Yu, T. Tweed, M. Al-Hussein, and R. Nasseri, "Development of lean model for house construction using value stream mapping," Journal of Construction Engineering and Management, vol. 135, no. 8, pp. 782–790, 2009, doi: 10.1061/(ASCE)0733-9364(2009)135:8(782).

[27] P. Nguyen and R. Akhavian, "Synergistic effect of integrated project delivery, lean construction, and building information modeling on project performance measures: A quantitative and qualitative analysis," Advances in Civil Engineering, 2019, Art. no. 1267048, doi: 10.1155/2019/1267048.

[28] W. Xing, J. L. Hao, L. Qian, V. W. Y. Tam, and K. S. Sikora, "Implementing lean construction techniques and management methods in Chinese projects: A case study in Suzhou, China," Journal of Cleaner Production, vol. 286, Art. no. 124944, 2021, doi: 10.1016/j.jclepro.2020.124944.

[29] L. Amusan, C. Aigbavboa, S. Essien, M. Emetere, and B. Obaju, "Construction 4.0 application: Industry 4.0, Internet of Things and lean construction tools' application in quality management system of residential building projects," Buildings, vol. 12, no. 10, Art. no. 1557, 2022, doi: 10.3390/buildings12101557.

[30] K. K. K. Mohan, D. Tomy, A. Vasukuttan, P. V. Ramani, and B. B. Akomah, "Improving construction efficiency through lean techniques and digital tools: Case of a real-time implementation in an institutional building construction," Frontiers in Built Environment, vol. 12, 2026, Art. no. 1761692, doi: 10.3389/fbuil.2026.1761692.