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ANALYSIS OF KEY SUCCESS FACTORS OF LEAN CONSTRUCTION PERFORMANCE

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ABSTRACT

Inefficiency, material waste, schedule delays, and cost overruns remain major issues affecting Indonesia's construction projects, especially in high-rise projects. Lean construction gains recognition as a solution to these problems, though its application does not always lead to better project performance. By separating managerial practices from actual performance outcomes, this study aims to examine the hypothesized relationships between critical success factors and lean construction performance. A standardized questionnaire was distributed to professionals working in high-rise building projects, including project managers, site managers, engineers, consultants, and other experienced professionals. A total of 125 valid responses were analyzed using the Structural Equation Modeling-Partial Least Squares (SEM-PLS) method. The study examined direct and indirect effects of management commitment, human resource development, internal client focus, technical planning & continuous improvement, and lean construction performance. The results showed that Technical Planning & Continuous Improvement had the greatest direct influence on Lean Construction Performance at 58%. Meanwhile, when enabled through Human Resource Development, the indirect effect on Lean Construction Performance is at 28.8%. Followed by direct influence of Communication and Collaboration on Lean Construction Performance at 28.8%. These findings indicate that lean construction performance improves most effectively through planning systems and continuous improvement, then communication and collaboration.

KEYWORDS

Lean construction, collaboration, commitment, continuous improvement, waste.

INTRODUCTION

Indonesia continues to encourage technological adoption and sustainability initiatives as important drivers of national economic growth in the context of accelerating globalization and digital change. Ironically, despite its immense development, the building and infrastructure sector remains one of the largest contributors to energy consumption, carbon emissions, and material waste (Yao et al., 2023). Resource inefficiency, schedule delays, and cost overruns are among the ongoing project-level issues in Indonesia that are strongly linked to these

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environmental factors. According to empirical findings from building projects in the province of Aceh, project delays could reach up to 80% of the scheduled time, indicating significant inefficiencies in project execution (Rauzana & Dharma, 2022). Furthermore, approximately 30%-40% of construction resources, including materials, labor, and time, are wasted due to inadequate project management practices, weak planning processes, and poor coordination among project stakeholders (Fitriani et al., 2023).

In order to solve these issues, Lean Construction was developed as a strategic management strategy focusing on value creation and elimination of waste throughout the project lifecycle (Zhang & Chen, 2016). Lean Construction aims to increase project efficiency and overall performance through the integration of collaboration, efficient planning systems, workflow control, and continuous improvement (Aslam et al., 2020; Li et al., 2024). Empirical findings from prefabricated building projects in China demonstrate that Lean Construction Management can significantly improve project efficiency and performance outcomes (Li et al., 2024).

However, the implementation of Lean Construction has not always resulted in improved project performance in Indonesian high-rise construction projects. Projects still suffer rework, material waste, cost overruns, and poor team interaction even when lean principles are used (Irfandi et al., 2022). This situation implies the importance of how far the Critical Success Factors link together can influence Lean Performance outcomes.

Therefore, it is important to understand the difference between Lean Construction Management (LCM) and Lean Construction Performance (LCP). The Last Planner System, 5S, Kanban, and Visual Management are just a few of the managerial techniques, tools, and practices that LCM focuses on and which influence how lean concepts are used in project environments (Li et al., 2024). LCP, on the other hand, represents the tangible results of lean implementation, such as increased client satisfaction, innovation, time efficiency, cost reduction, and quality improvement (Li et al., 2024; Tortorella et al., 2021).

Although international studies have examined the relationship between Critical Success Factors and Lean Implementation in both the manufacturing and construction industries across the world (Aslam et al., 2020; Badran & Abdallah, 2025; Frank et al., 2025; Grace Tetteh et al., 2024; Tortorella et al., 2021), quantitative research that explicitly models the hypothesized relationships among Critical Success Factors and Lean Construction Performance in the context of Indonesian high-rise building projects remains limited. In addition, previous literature often focused on isolated success factors, it lacked a comprehensive synthesis that linked these factors to the tangible results of Lean Construction Performance.

Accordingly, to address this gap, this study introduced a specific Lean Performance model by extending the validated framework developed by Candraningtyas & Wiguna (2026) to provide empirical evidence for high-rise building projects in Indonesia. By integrating managerial, human resource, communication, client focus, continuous improvement, and technical planning factors, the research utilized a Structural Equation Modeling-Partial Least Squares (SEM-PLS) approach to analyze the hypothesized effects of each Critical Success Factor on Lean Construction Performance. Ultimately, the study established a specialized Lean Construction Performance model that offered empirical evidence to support the development of a specific Lean Performance model for high-rise building projects in Indonesia.

LITERATURE REVIEW

THE PROCESS OF DETERMINING VARIABLES, INDICATORS, AND FORMING A CONCEPTUAL MODEL

The identification of factors and development of the conceptual model were based on a literature synthesis. The initial step required collecting and reviewing 30 international and national journal articles that discuss success factors in Lean Construction implementation. Article titles, abstracts, and research findings were systematically analyzed using keywords such as “Lean Construction Performance,” “Critical Success Factors,” “Lean Construction Principles,” “Lean Key Drivers & Enablers,” and “Key Performance Indicators (KPI).”

The review results were then compiled into a synthesis table with 87 indicators, 19 variables, and 6 main performance clusters. The specific variables and indicators utilized in this study were derived from the identification of critical factors detailed in the work of Candraningtyas & Wiguna (2026). After these elements were established, a theoretical refinement process was conducted to screen and select the most relevant and significant variables influencing Lean Construction performance in high-rise projects.

RELATIONSHIP BETWEEN MANAGEMENT COMMITMENT & INVOLVEMENT AND HUMAN RESOURCE DEVELOPMENT

Management commitment and involvement are essential in strengthening human resource development in construction projects. Strong top management support creates favorable conditions for training, competency enhancement, and effective reward systems, while active involvement ensures the availability of resources and strategic guidance required for lean-oriented workforce development (Watfa & Sawalha, 2021). In addition to establishing a culture of continuous improvement and process efficiency, managerial engagement and commitment to improve individual capacity are emphasized as a critical aspect in developing human resource capability (Bayhan et al., 2019; Demirkesen, 2020).

RELATIONSHIP BETWEEN MANAGEMENT COMMITMENT & INVOLVEMENT AND COMMUNICATION & COLLABORATION

Management commitment significantly influences communication quality and Collaboration among project stakeholders. Participative leadership promotes open and two-way communication, allowing managers and project teams to share information more effectively (Watfa & Sawalha, 2021). Strong management support also promotes collaborative cultures that improve teamwork and coordination (Babalola et al., 2019). Moreover, management participation in cross-functional communication reduces inefficiencies caused by misunderstandings and speeds up problem-solving (Demirkesen, 2020), making managerial commitment a crucial facilitator of efficient communication and teamwork in lean construction projects.

RELATIONSHIP BETWEEN MANAGEMENT COMMITMENT & INVOLVEMENT AND LEAN CONSTRUCTION PERFORMANCE

Management commitment and involvement directly contribute to improved lean construction performance by ensuring consistent application of lean principles across organizational levels (Demirkesen & Bayhan, 2022). Active managerial participation in strategic decision-making enhances operational efficiency, reduces waste, and improves project quality (Demirkesen, 2020). Commitment to lean culture further supports the development of responsive and value-oriented work systems (Watfa & Sawalha, 2021), strengthening organizational alignment with lean objectives and improving overall project performance and sustainability.

RELATIONSHIP BETWEEN COMMUNICATION & COLLABORATION AND LEAN CONSTRUCTION PERFORMANCE

Effective communication and strong Collaboration provide a critical foundation for successful lean implementation. Transparent communication accelerates decision-making, reduces errors, and improves coordination across project functions (Badran & Abdallah, 2025). Interdisciplinary Collaboration further supports the identification of process improvement opportunities, leading to enhanced efficiency and productivity (Demirkesen, 2020). By aligning objectives and fostering shared understanding, communication and collaboration reduce variability and strengthen workflow reliability, directly contributing to improved lean construction performance.

RELATIONSHIP BETWEEN HUMAN RESOURCE DEVELOPMENT AND INTERNAL CLIENT FOCUS

Human resource development enhances workforce capability to understand and respond to internal client requirements. Continuous training improves employees' ability to translate client needs into value-added technical solutions (Kokkaew et al., 2022), while lean-oriented competencies strengthen internal service orientation (Watfa & Sawalha, 2021). Employees who understand value creation processes are more proactive in identifying and fulfilling internal customer needs (Badran & Abdallah, 2025). Therefore, investment in human resource development directly supports a stronger internal client focus within lean construction environments.

RELATIONSHIP BETWEEN INTERNAL CLIENT FOCUS AND LEAN CONSTRUCTION PERFORMANCE

Internal client focus acts as a key driver of lean construction performance improvement. A deep understanding of client needs and value expectations enables the design of efficient and waste-free construction processes (Bajjou & Chafi, 2025). Client-oriented practices strengthen feedback mechanisms that support continuous improvement, leading to better time performance, quality, and productivity (Villazón et al., 2020). By aligning processes with value creation, internal client focus directly contributes to sustained improvements in lean construction performance.

RELATIONSHIP BETWEEN HUMAN RESOURCE DEVELOPMENT AND TECHNICAL PLANNING & CONTINUOUS IMPROVEMENT

Competent and well-trained personnel are better equipped to apply lean technical planning and support continuous improvement. Lean-oriented knowledge enables systematic integration of efficient planning methods and process analysis (Meshref et al., 2022). Technical competence supported by structured training ensures execution quality and optimizes planning outcomes (Demirkesen & Bayhan, 2022), while enhancing understanding of the integration between technical and managerial aspects of lean implementation (Kokkaew et al., 2022). Consequently, human resource development forms a fundamental basis for effective technical planning and continuous improvement systems.

RELATIONSHIP BETWEEN INTERNAL CLIENT FOCUS, TECHNICAL PLANNING & CONTINUOUS IMPROVEMENT

Internal client focus encourages the development of planning systems that respond effectively to client value expectations. Understanding internal client needs supports adaptive planning and continuous improvement aligned with project value objectives (Meshref et al., 2022). Client orientation also promotes lean culture adoption across organizational levels, including

technical execution and decision making (Bigwanto et al., 2024). By prioritizing value creation, planning activities, and technical innovations remain focused on efficiency and waste reduction, strengthening the integration between technical planning and continuous improvement practices.

RELATIONSHIP BETWEEN TECHNICAL PLANNING & CONTINUOUS IMPROVEMENT AND LEAN CONSTRUCTION PERFORMANCE

Technical planning and continuous improvement are primary determinants of lean construction performance, particularly in waste identification and elimination. Structured planning and lean tools enhance productivity, efficiency (Meshref et al., 2022; Zhang & Chen, 2016), and quality consistency (Demirkesen, 2020). Continuous improvement supports reduced rework, improved standardization (Rosli et al., 2023), and early detection of non-value-added activities (Shaqour, 2022). Effective waste management strategies further strengthen project productivity and quality outcomes, confirming the direct contribution of planning capability and continuous improvement to improved lean construction performance (Badran & Abdallah, 2025; Bajjou & Chafi, 2025; Li et al., 2024).

RESEARCH METHODOLOGY AND OBJECTIVES

Data were analyzed using a structured approach based on Structural Equation Modeling-Partial Least Squares. The sample size followed SEM-PLS guidelines, which recommend a minimum of five to ten times for each indicator or the largest number of structural paths (Hair et al., 2017). Given that the construct with the highest number of indicators comprised ten items, the upper threshold was applied, resulting in a minimum sample requirement of 100 respondents.

Accordingly, this study involved a minimum of 100 professionals actively engaged in the planning, execution, and supervision of high-rise building projects adopting Lean Construction principles, including: (1) project managers, (2) site managers, (3) site engineers, (4) quality and safety personnel, (5) consultants, and (6) other relevant practitioners.

A standardized questionnaire was developed based on validated constructs from previous Lean Construction studies, adapted to the Indonesian project context, and reviewed by industry experts prior to distribution. Data were collected using a five-point Likert scale ranging from strongly disagree to strongly agree. The SEM-PLS analysis emphasized the evaluation of the structural model by assessing VIF, R2, Q2, f2, and direct as well as indirect path relationships.

DEVELOPMENT HYPOTHESIS

Based on the relationships formed in the literature review, the research framework and hypotheses for this study were shown in Figure 1:

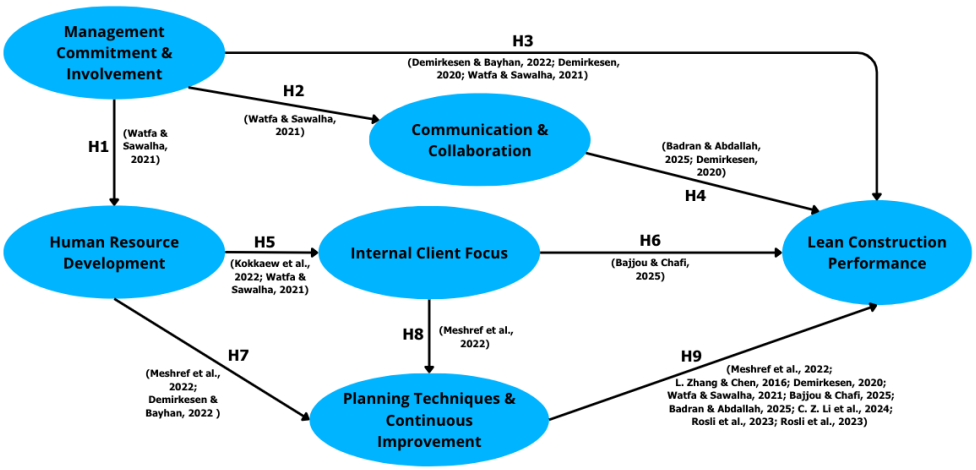


Figure 1: Research framework

ANALYSIS RESULTS

RESPONDENT CHARACTERISTICS

A total of 360 questionnaires were distributed, and 155 responses were returned. After data screening to ensure completeness and consistency, 125 valid questionnaires were retained for analysis. The respondents represented professionals involved in high-rise building construction. In terms of job roles, the sample was dominated by technical and operational personnel, including engineering teams, site managers, and project managers, as shown in Figure 2. Educationally, most respondents held a bachelor's degree, followed by master's and diploma qualifications. Regarding experience, the majority of respondents had more than 15 years of professional involvement in construction projects.

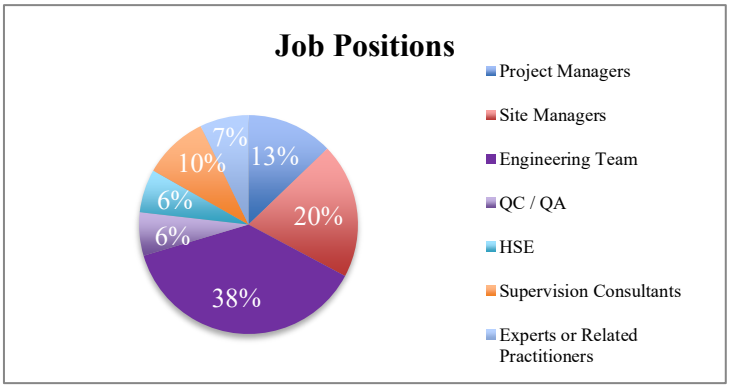


Figure 2: Respondent characteristics by job positions

CONSTRUCT VARIABILITY AND RELIABILITY (AVE AND CR)

Reliability and validity testing confirmed the robustness of the indicators adapted from the validated instrument developed by Candraningtyas & Wiguna (2026). All constructs achieved statistical validity and reliability, supported by Composite Reliability (CR) values exceeding 0.70, Average Variance Extracted (AVE) values exceeding 0.50, and discriminant validity confirmed through HTMT ratios.

MAGNITUDE OF VARIABLE INFLUENCE (INNER COLLINEARITY STATISTICS VIF)

Multicollinearity was assessed using the Variance Inflation Factor (VIF) to ensure exogenous constructs did not bias estimations (Hair et al., 2017). Based on the results analysis from Figure 1, all VIF values were below < 5.00, indicating that each construct acted as a distinct lever. This allows practitioners to improve specific lean activities without the risk of redundant or overlapping processes.

MAGNITUDE OF EXOGENOUS VARIABLE INFLUENCE (COEFFICIENT OF DETERMINATION R^2)

The coefficient of determination (R^2) measured the explanatory power of exogenous constructs on endogenous constructs. Weak, moderate, and strong explanatory power were indicated by R^2 values of 0.25, 0.50, and 0.75 (Hair et al., 2017). According to the results analysis from Figure 1, Lean Construction Performance R^2 value of 0.691 implied that 69.1% of its variance was explained by variables in the model. This means, focusing on these specific success factors provides a high degree of control over project outcomes, with the remaining 30.9% impacted by external factors.

EFFECT SIZE BETWEEN VARIABLES (F-SQUARE F^2)

The effect size test (f^2) evaluates the relative contribution of each exogenous construct to a specific endogenous construct. Values of 0.02 (small), 0.15 (moderate), and 0.35 (large) effects (Hair et al., 2017). Based on the results analysis from Figure 1, all values from the analysis ranged from 0.216 to 0.792, indicating that management commitment and human resource development are dominant drivers to improve lean construction performance. If a firm lacks to-down support or skilled labor, even the most advanced lean tools will likely to fail to achieve their full potential.

PREDICTIVE RELEVANCE TEST (Q-SQUARE Q^2)

Predictive relevance (Q^2) assesses the model's capability to predict observed values using the blindfolding procedure. A Q^2 value greater than zero indicated adequate predictive relevance (Hair et al., 2017). As shown in the results analysis from Figure 1, all endogenous constructs have Q^2 values above zero, ranged from 0.282 to 0.411, confirmed the model's predictive relevance. This suggests that if these Lean variables are implemented in the future high-rise projects, they will consistently yield the same high-performance results.

DIRECT & INDIRECT HYPOTHESIS TESTING AND VARIABLE SIGNIFICANCE

Path coefficient analysis evaluated the direction, strength, and significance of relationships among latent constructs. Statistical significance is determined by p-values below 0.05 (Hair et al., 2017).

Table 1: Direct hypothesis test output

		Loading Factors (O)	T Statistics (|O/STDEV|)	P Values	Information
H1	Management Commitment → Human Resource Development	0.652	7.038	0.000	**Accepted**
H2	Management Commitment → Communication and Collaboration	0.631	5.748	0.000	**Accepted**
H4	Communication and Collaboration → Lean	0.288	2.625	0.009	**Accepted**

	Construction Performance				
H5	Human Resource Development → Internal Client Focus	0.665	8.781	0.000	**Accepted**
H7	Human Resource Development → Technical Planning & Continuous Improvement	0.495	4.535	0.000	**Accepted**
H8	Internal Client Focus → Technical Planning & Continuous Improvement	0.376	3.455	0.001	**Accepted**
H9	Technical Planning & Continuous Improvement → Lean Construction Performance	0.580	5.940	0.000	**Accepted**

Initial results in Table 1 showed that all paths met t-statistics above 1.96 and p-values below 0.05. However, the hypotheses of Internal Client Focus → Lean Construction Performance and Management Commitment & Involvement → Lean Construction Performance exhibited weak structural coefficients.

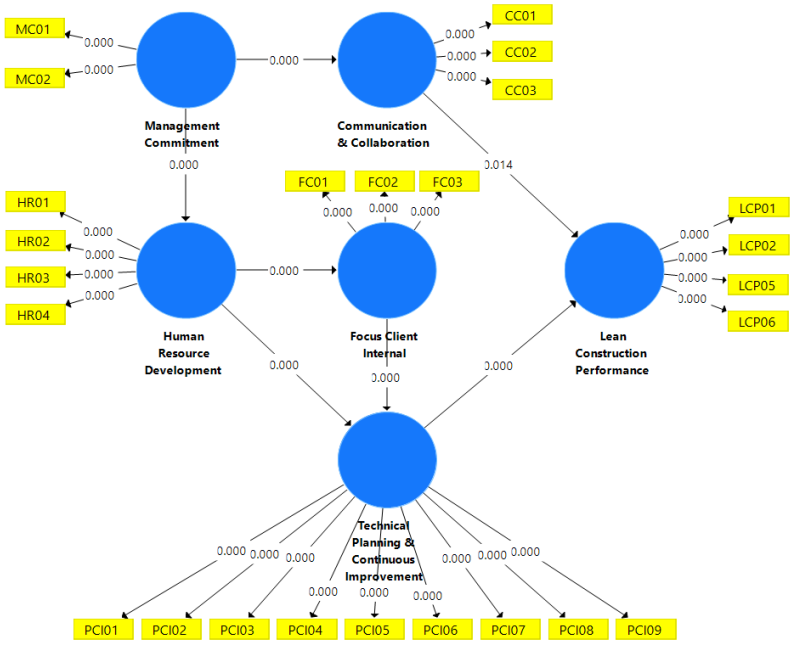


Figure 3: Hypothesis test output after elimination

As part of an exploratory model refinement process, these paths were re-evaluated based statistical results and theoretical considerations. From a conceptual perspective, Internal Client Focus and Management Commitment & Involvement are commonly understood to influence Lean performance indirectly through enabling mechanisms such as workforce capability development and structured planning processes rather than through direct performance effects. These paths were therefore eliminated to better reflect indirect influence observed in Lean implementation, and the model was recalculated, as seen in Figure 3.

As shown in Figure 3, the final results indicated that all remaining paths were significant, confirmed that 7 out of 9 hypotheses in the final structural model were accepted, and the model was stable.

Table 2: Indirect hypothesis test output

	Loading Factors (O)	T Statistics (|O/STDEV|)	P Values	Information
Management Commitment → Human Resource Development → Internal Client Focus → Technical Planning & Continuous Improvement → Lean Construction Performance	0.095	2.216	0.027	**Significant**
Human Resource Development → Internal Client Focus → Technical Planning & Continuous Improvement → Lean Construction Performance	0.145	2.493	0.013	**Significant**
Management Commitment → Communication and Collaboration → Lean Construction Performance	0.182	2.255	0.024	**Significant**
Management Commitment → Human Resource Development → Technical Planning & Continuous Improvement → Lean Construction Performance	0.187	2.818	0.005	**Significant**
Internal Client Focus → Technical Planning & Continuous Improvement → Lean Construction Performance	0.218	2.782	0.005	**Significant**
Human Resource Development → Technical Planning & Continuous Improvement → Lean Construction Performance	**0.288**	**3.577**	**0.000**	**Significant**

Based on Table 2, all mediation hypotheses show p-values below 0.05 and t-statistics above 1.96, indicating significant indirect effects. The strongest mediation path was Human Resource Development → Technical Planning & Continuous Improvement → Lean Construction Performance, showing that improved human resource capacity strengthened technical lean practices, which subsequently enhanced lean construction performance.

RESEARCH DISCUSSIONS

H1: THE EFFECT OF MANAGEMENT COMMITMENT AND INVOLVEMENT ON HUMAN RESOURCE DEVELOPMENT

The direct relationship between Management Commitment and Involvement on Human Resource Development emerged as the second-strongest direct path in the model, with a loading of 65.2%. This suggested that the most immediate impact of top management commitment on lean implementation is reflected in the development of human capabilities. For example, management can institutionalize Lean education through regular workshops on pull planning, problem-solving techniques, and workflow management, ensuring that workforce skills evolve alongside Lean adoption. This finding aligns with Gao & Low (2015), who place people at the core of the lean system, as well as Kokkaew et al. (2022) and Babalola et al. (2019), who argue that management involvement is an essential need for successful human resource development in Lean Construction.

H2: THE EFFECT OF MANAGEMENT COMMITMENT & INVOLVEMENT ON COMMUNICATION AND COLLABORATION

The direct path from Management Commitment & Involvement to Communication and Collaboration ranked third with a loading of 63.1%, but remained strong, indicating that management played a significant role in shaping a collaborative work climate through communication structures and project coordination. Managerial practices such as daily coordination meetings, weekly planning sessions, and cross-functional collaboration platforms to enhance workflow transparency. This finding is consistent with Watfa & Sawalha (2021), who emphasize the role of management in fostering cross-functional communication, and Bajjou & Chafi (2025), who suggest that a collaborative culture results from consistent managerial commitment.

H4: THE EFFECT OF COMMUNICATION AND COLLABORATION ON LEAN CONSTRUCTION PERFORMANCE

The direct effect of Communication and Collaboration on Lean Construction Performance was the weakest but still significant, with a loading of 28.8%, indicated that communication and collaboration served as supporting factors for lean performance. In complex construction projects, structured coordination routines such as role clarity, teamwork, and coordination helped reduced variability and waste, although their impact is not as strong as technical factors. This finding aligns with Bayhan et al. (2019) and Badran & Abdallah (2025), who emphasize that communication contributes to process stability.

H5: THE EFFECT OF HUMAN RESOURCE DEVELOPMENT ON INTERNAL CLIENT FOCUS

The direct path from Human Resource Development to Internal Client Focus was the strongest direct relationship in the model, with a loading of 66.5%. This indicated that competent human resources have a higher ability to understand client needs and the value to be created. Lean strategies should include training programs focused on value-based planning, customer requirement interpretation, and feedback integration mechanisms. This finding aligns with Zhang & Chen (2016), who stated that value orientation in lean relies heavily on human capabilities, as well as Kokkaew et al. (2022) and Bajjou & Chafi (2025), who emphasized that human resource development is the primary foundation for value creation in Lean Construction.

H7: THE EFFECT OF HUMAN RESOURCE DEVELOPMENT ON TECHNICAL PLANNING & CONTINUOUS IMPROVEMENT

The influence of Human Resource Development on Technical Planning & Continuous Improvement was a fairly strong direct path, with a loading of 49.5%, and is also part of the most dominant indirect path to Lean Construction Performance. This finding indicated that continuous improvement is highly dependent on the ability of human resources to identify problems and implement improvements. Practically, Lean implementation should emphasize skill development in root-cause analysis, structured problem-solving, and workflow analysis to ensure that improvement cycles are sustained. This aligns with Zhang & Chen (2016) and Demirkesen (2020), who assert that people are the primary enablers of lean practices

H8: THE EFFECT OF INTERNAL CLIENT FOCUS ON TECHNICAL PLANNING & CONTINUOUS IMPROVEMENT

The path of Internal Client Focus to Technical Planning & Continuous Improvement showed a moderate direct effect with a loading of 37.6%, indicated that understanding client values

helps teams develop more targeted plans. This highlights the importance of integrating client value criteria into planning processes through structured feedback loops and requirement tracking systems. This finding aligns with Babalola et al. (2019), who emphasize value creation as a core principle of lean, and Bajjou & Chafi (2025), who assert that client value orientation must be systematically integrated into planning to have a tangible impact on performance.

H9: THE EFFECT OF TECHNICAL PLANNING & CONTINUOUS IMPROVEMENT ON LEAN CONSTRUCTION PERFORMANCE

The effect of Technical Planning & Continuous Improvement on Lean Construction Performance was a direct path with a loading of 58%, confirmed that Lean Construction performance is largely determined by the consistent implementation of planning and continuous improvement systems in the field. Institutionalizing planning reliability mechanisms such as pull planning, weekly work planning, and performance monitoring help to stabilize workflow and reduce variability. This finding aligns with Singh & Kumar (2020) and is supported by Badran & Abdallah (2025) and Bajjou & Chafi (2025), who stated that in projects with mature lean adoption, technical aspects of planning and continuous improvement are the primary determinants of Lean Construction performance.

When Technical Planning and Continuous Improvement were enabled through Human Resource Development, their effect on Lean Construction Performance has a significant indirect relationship at 28.8%. This finding suggested that planning systems and continuous improvement practices required capable personnel to interpret data, identify waste, and implement corrective actions. Human resource development therefore, functioned as an enabling mechanism that translated planning tools into effective operational practices. This result is consistent with Zhang & Chen (2016), who emphasize that lean implementation depends on individuals' abilities to recognize and eliminate waste, and with Demirkesen (2020), who identifies human competence as the primary enabler of lean practices.

MANAGERIAL IMPLICATIONS

The managerial implications of this study showed that Technical Planning and Continuous Improvement (PCI) was the most critical driver of Lean Construction Performance (LCP), as it has the strongest direct influence on project outcomes. This finding indicates the need to prioritize the consistent and disciplined application of planning systems, standardized processes, and continuous improvement practices to achieve outstanding lean performance on site. However, Human Resource Development showed that workforce capability functions as a supporting enabler. Without competent personnel, technical planning & improvement initiatives cannot operate effectively. In addition, Communication and Collaboration emphasized the importance of clear roles, teamwork, and intensive coordination to reduce variability, minimize waste, and stabilize project execution.

CONCLUSIONS AND RECOMMENDATIONS

It is found that Technical Planning & Continuous Improvement showed the strongest direct influence on Lean Construction Performance (58%), confirming that consistent planning systems and continuous improvement practices on site are the primary determinants of lean performance. When Technical Planning & Continuous Improvement was enabled through Human Resource Development, a significant indirect relationship was identified (28.8%), while it does not directly drive outcomes, it activates technical systems by providing the analytical skills necessary for problem-solving. Communication and Collaboration emerged as the second-largest direct influence on Lean Construction Performance (28.8%), proving

that clear roles, teamwork, and coordination are essential for reducing variability, minimizing waste, and maintaining schedule & cost performance.

Based on these findings, it is recommended to prioritize strengthening Technical Planning & Continuous Improvement to enhance Lean Construction Performance by regularly using Lean planning routines, such as pull planning sessions, weekly work planning, and Percent Plan Complete (PPC) monitoring to stabilize workflows. Continuous improvement should be supported using A3 problem-solving, root-cause analysis, and performance review meetings. To ensure effectivity, additional attention should be given to Human Resource Development by enhancing employees' technical competencies, problem-solving skills, and understanding of lean principles, as workforce capability serves as a critical enabler of planning and improvement. Additionally, Communication and Collaboration should be reinforced through clear roles, transparent information flows, and stakeholders coordination to reduce process variability and waste.

This study provides insights into Lean Construction implementation within high-rise construction projects in Indonesia using perception-based survey data, and findings should be interpreted within these contextual boundaries. Therefore, the applicability of the results may be limited to similar project types and regional contexts, and caution should be exercised when generalizing the findings to other construction sectors or geographical settings.

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