



Identification of Critical Factors Influencing Lean Construction Performance in Construction Projects

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Abstract

The Indonesian construction sector continues to face persistent problems related to inefficiency, material waste, schedule delays, and cost overruns, despite increasing interest in adopting Lean Construction principles. These challenges indicate that lean implementation has not been fully supported by well-defined organizational and managerial foundations. This study aims to identify and validate the indicators that form the Critical Success Factors influencing Lean Construction Performance in high-rise building projects in Indonesia. This research uses quantitative methods. The research population consists of construction professionals involved in high-rise building projects, including contractors, consultants, and project management teams. A total of 360 questionnaires were distributed, of which 155 responses were returned. After data screening, 125 valid responses were used for further analysis. Data analysis was conducted using Structural Equation Modeling with the Partial Least Squares method through SmartPLS 3.0, focusing on the evaluation of the measurement model. The results indicate that the proposed constructs are formed by valid and reliable indicators after eliminating indicators with outer loadings below 0.70. The validated indicators represent management commitment and involvement, human resource development, communication and collaboration, internal client focus, and planning techniques and continuous improvement. These findings provide empirical evidence on the key indicator structure of Critical Success Factors relevant to Lean Construction Performance.

Introduction

In the era of globalization and digital transformation, Indonesia has intensified efforts to promote technological adoption and sustainability as key drivers of national economic growth. Nevertheless, the construction and infrastructure sector, which plays a strategic role in development, remains one of the largest contributors to carbon emissions, material waste, and excessive energy consumption (Yao et al., 2023; Liu et al., 2025; Min et al., 2022; Labaran et al., 2022; Almusaed et al., 2024; Wang et al., 2024). These environmental and operational challenges are closely associated with persistent inefficiencies in construction project delivery, including resource waste, schedule delays, and cost overruns. Empirical evidence from construction projects in Aceh Province indicates that project delays can reach up to 80 percent of the planned duration, highlighting the severity of inefficiency in construction practices in Indonesia (Rauzana & Dharma, 2022; Fitriani et al., 2025; Kaming et al., 1997).

To address these challenges, Lean Construction (LC) has been introduced as an alternative project management approach adapted from Lean Production principles originally developed in the manufacturing industry (Zhang & Chen, 2016; Garcés & Peña, 2023; Bayhan et al., 2023; Zheng et al., 2024; Zheng et al., 2024). Lean Construction focuses on maximizing value for clients while minimizing waste across the construction process through enhanced collaboration, stable and reliable planning systems, effective workflow control, and continuous improvement initiatives (Aslam et al., 2020; Li et al., 2024; Alnajjar et al., 2025; Allouzi & Al Jaafreh, 2023; Garcés et al., 2025; Likita et al., 2025). As a result, LC has gained increasing attention as a systematic approach for improving efficiency and effectiveness in construction project execution.

Extensive international studies have attempted to identify Critical Success Factors (CSFs) that influence the successful implementation of lean practices. Prior research consistently identifies management commitment, communication and collaboration, human resource capability, organizational culture, and technological support as key determinants of lean success (Grace Tetteh et al., 2024; Sahoo, 2022; Fayyaz et al., 2025; Kaur Paposia et al., 2023). However, most of these studies have been conducted in countries such as Saudi Arabia, Brazil, China, Ghana, and the United Kingdom, where institutional settings, organizational structures, and cultural characteristics differ significantly from those in Indonesia (Aslam et al., 2020; Badran & Abdallah, 2025; Grace Tetteh et al., 2024; C. Z. Li et al., 2024; Zhang & Chen, 2016).

At the national level, several studies have examined lean implementation within the Indonesian context. Irfandi et al. (2022) found that the success of lean practices in Indonesian megaprojects is strongly influenced by top management commitment, effective communication and coordination, workforce readiness, and alignment between organizational culture and lean principles. Similarly, Tanudiharjo et al. (2021) emphasized the importance of training, leadership, and employee involvement in supporting lean implementation. These findings indicate that human and organizational factors play a more dominant role in lean adoption than the mere application of lean tools (Bouranta et al., 2022; Januszek et al., 2024; Rumman & Alqudah, 2024; Limon, 2023).

Despite these contributions, there remains a lack of systematic and quantitative research that identifies specific indicators forming the CSF variables relevant to high-rise building projects in Indonesia. Given the complexity and scale of such projects, it is essential to establish context-specific indicators that accurately represent the critical factors influencing lean performance. Therefore, this study focuses on identifying and validating the indicators that constitute key CSF variables associated with Lean Construction Performance in Indonesian high-rise building projects.

Literature Review

Management Commitment and Involvement

Management commitment and involvement are widely recognized as fundamental determinants of successful Lean Construction implementation. Strong support from top management provides not only sufficient resources but also clear strategic direction and consistent supervision of lean practices at the project level. Bayhan et al. (2019) emphasize that management commitment is closely linked to lean leadership, which plays a critical role in embedding efficiency, waste reduction, and continuous improvement values throughout the organization. When management actively demonstrates commitment, lean principles are more likely to be accepted and practiced by employees across different organizational levels. Further empirical evidence supports the direct influence of management involvement on Lean Construction Performance. Demirkesen (2020) highlights that management participation in strategic decision making significantly affects operational efficiency, waste minimization,

and quality improvement in construction projects. These findings indicate that management commitment and involvement has a significant effect to improved lean performance by shaping organizational culture, decision making processes, and performance control mechanisms.

H1: Management Commitment and Involvement has a significant effect on Lean Construction Performance.

Human Resource Development (HRD)

Human resource development plays a central role in determining the effectiveness of lean implementation in construction projects. Lean principles require workers who possess not only technical competence but also a clear understanding of lean concepts and tools. Bayhan et al. (2019) state that selecting skilled and competent employees ensures that lean practices can be implemented accurately and consistently. Training and development programs further strengthen workers' understanding of lean techniques, thereby increasing productivity and improving work quality. In addition to training, incentive and compensation systems serve as important motivational factors that encourage employees to adhere to lean standards and continuously improve their performance (Bayhan et al., 2019). Knowledge management within organizations also supports human resource development by facilitating the sharing of experiences and lessons learned across projects (Bigwanto et al., 2024). Empirical findings by Zhang and Chen (2016) demonstrate that continuous training in lean tools, particularly the Last Planner System, enhances productivity and significantly reduces waste. These studies collectively confirm that human resource development has a significant effect on Lean Construction Performance.

H2: Human Resource Development has a significant effect on Lean Construction Performance.

Communication and Collaboration

Effective communication and collaboration are essential elements in achieving successful Lean Construction implementation. Lean projects involve multiple stakeholders whose activities must be closely coordinated to avoid delays and rework. Meshref et al. (2022) explain that clear and open communication among contractors, consultants, and project owners reduces misunderstandings and accelerates decision making processes. Effective communication also ensures that project information is shared accurately and timely, supporting smooth workflow execution. Beyond communication, collaboration and teamwork foster a collective commitment to lean objectives. Bigwanto et al. (2024) emphasize that a strong teamwork culture enhances process efficiency and problem solving capability. Role clarity among team members further supports consistent execution of lean responsibilities (Bayhan et al., 2019). Supporting this view, Badran and Abdallah (2025) report that transparent communication improves coordination, reduces errors, and strengthens integration across project teams. These findings underline the importance of communication and collaboration as direct contributors to Lean Construction Performance.

H3: Communication and Collaboration has a significant effect on Lean Construction Performance.

Internal Client Focus

Internal client focus is a strategic aspect of lean implementation that emphasizes value creation throughout the project lifecycle. A clear understanding of internal client needs and expectations allows project teams to prioritize activities that deliver value while eliminating non value adding processes. Bigwanto et al. (2024) state that clearly defined client requirements help teams establish accurate priorities and improve process alignment with

project objectives. Active involvement of internal clients through continuous feedback further supports ongoing process improvement. Feedback mechanisms enable project teams to identify performance gaps and implement corrective actions that align with client expectations (Bigwanto et al., 2024). Bajjou and Chafi (2025) explain that a deep understanding of client value strengthens feedback cycles and enhances efficiency in terms of time, quality, and productivity. These findings demonstrate that internal client focus directly influences Lean Construction Performance by guiding value oriented decision making and continuous improvement efforts.

H4: Internal Client Focus has a significant effect on Lean Construction Performance

Planning Techniques and Continuous Improvement

Planning techniques and continuous improvement represent the operational core of Lean Construction implementation. Organizations with strong technical capabilities are better equipped to integrate lean tools such as 5S, Kaizen, and Value Stream Mapping into their project workflows (Demirkesen & Bayhan, 2022). Effective planning supported by reliable data enables project teams to identify potential sources of waste and take corrective action at an early stage. Regular performance evaluation is also essential for sustaining continuous improvement. Badran and Abdallah (2025) emphasize that data based planning and routine performance assessment enhance decision making speed and accuracy. The application of lean methods such as Just in Time, visual management, mechanization, and standardized construction processes further contributes to improved efficiency and work quality (S. Li et al., 2017). Zhang and Chen (2016) confirm that structured planning combined with continuous improvement practices significantly increases productivity, while Demirkesen (2020) notes that organizations committed to continuous improvement consistently achieve higher lean performance levels.

H5: Technical Planning & Continuous Improvement has a significant effect on Lean Construction Performance

Lean Construction Performance

Lean Construction Performance represents the extent to which lean principles are translated into measurable project outcomes. Rather than being assessed solely through general project success indicators, several studies have explicitly formulated Key Performance Indicators to evaluate performance in lean based construction projects. These KPIs provide a structured and operational approach to assessing whether lean implementation delivers its intended benefits. Bigwanto et al. (2024) directly identify a comprehensive set of KPIs for lean construction projects, including the creation of a strong project organizational culture, achievement of overall project performance, waste reduction, workforce competence, on time project delivery, fast decision making processes, effective knowledge management, stable work processes with minimal variability, and financial performance. These indicators highlight that lean performance extends beyond cost and schedule control, incorporating organizational, behavioral, and process stability aspects that are critical for sustained improvement. Therefore, the use of clearly defined KPIs enables project stakeholders to objectively evaluate lean implementation effectiveness and provides a robust basis for empirical analysis in lean construction research.

Development Hypothesis

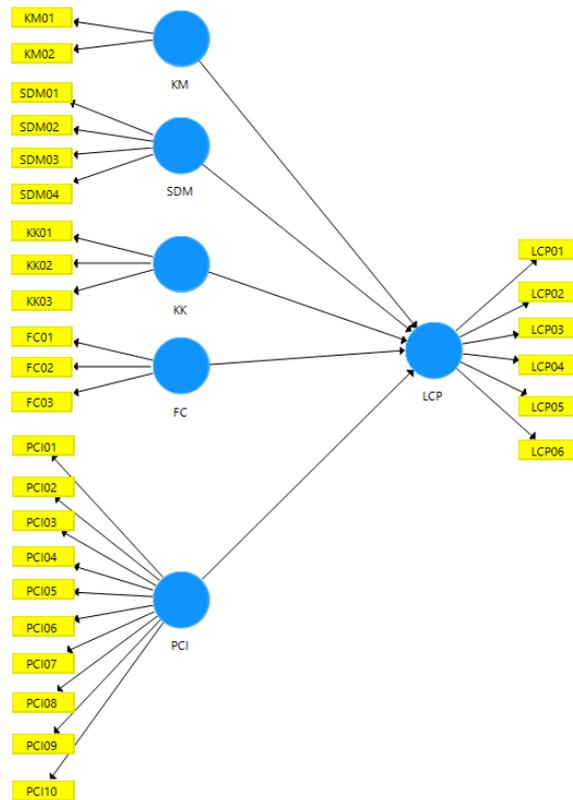


Figure 1. Research Framework

Methods

Data analysis in this study was conducted systematically using Structural Equation Modelling-Partial Least Squares (SEM-PLS) with the assistance of SmartPLS 3.0 software. For SEM-PLS testing, the sample size was determined based on practical guidelines in the SEM literature, namely the rule of thumb of 5-10 times the largest number of structural paths pointing to a construct or 5-10 times the largest number of indicators within a single variable (Hair et al., 2017). The maximum number of indicators in one variable is 10, by applying the upper bound of 10 times the number of indicators, the calculation is as follows:

$$n = 10 \times k = 10 \times 10 = 100$$

Information:

n = the minimum number of respondents

k = the number of indicators or hypothesized paths in the study

Therefore, to ensure data adequacy and the validity of the analysis results, this study employed a minimum of 100 respondents. The respondents comprised professionals directly involved in the execution and control of high-rise building projects implementing Lean Construction, including project managers, site managers, engineering teams, QC/QA personnel, HSE personnel, supervising consultants, and other relevant experts or practitioners during the research period.

The questionnaire was developed based on a literature review to assess the relevance of the variables and indicators used in the study. Responses were measured using a five-point Likert scale, where a score of 1 indicates that the indicator is very irrelevant and a score of 5 indicates that it is very relevant as a research indicator.

The data analysis technique applied in this research is Structural Equation Modeling-Partial Least Squares (SEM-PLS). In this study, the analysis focuses on testing the outer model to evaluate the validity and reliability of the measurement model.

Table 1. Factors & Sub-factors under Study

Variables	Code	Indicators	References
Management Commitment and Involvement	KM01	Top Management Support and Commitment	(Bayhan et al., 2019; Watfa & Sawalha, 2021)
	KM02	Lean Leadership	(Bayhan et al., 2019; Watfa & Sawalha, 2021)
Human Resource Development	SDM01	Select Skilled / Competent Employee	(Bayhan et al., 2019; Bigwanto et al., 2024)
	SDM02	Training and Skill Development	(Bayhan et al., 2019; Bigwanto et al., 2024; Zhang & Chen, 2016)
	SDM03	Incentives and Compensation	(Bayhan et al., 2019; Demirkesen, 2020; Kokkaew et al., 2022)
	SDM04	Knowledge Management within Organization	(Bigwanto et al., 2024; Kokkaew et al., 2022)
Communication and Collaboration	KK01	Communication between Project Stakeholders	(Bayhan et al., 2019; Bigwanto et al., 2024; Meshref et al., 2022)
	KK02	Promoting a Culture of Teamwork	(Badran & Abdallah, 2025; Bigwanto et al., 2024)
	KK03	Existence of Clear Roles in Lean	(Bayhan et al., 2019)
Internal Client Focus	FC01	Clear Definition of Client's Requirements	(Bigwanto et al., 2024)
	FC02	Value Identification and Optimization	(Bajjou & Chafi, 2025)
	FC03	Client Engagement in Providing Feedback	(Bajjou & Chafi, 2025; Bigwanto et al., 2024)
Planning Techniques & Continuous Improvement	PCI01	Adopting a Lean Culture	(Demirkesen, 2020; Demirkesen & Bayhan, 2022)
	PCI02	Technical Capacity for Implementing Lean Tools	(Bayhan et al., 2019; Demirkesen & Bayhan, 2022)
	PCI03	Availability of Lean Tools and Technique	(Bayhan et al., 2019; Demirkesen & Bayhan, 2022)
	PCI04	Monitoring and Reducing Cost Overruns	(Badran & Abdallah, 2025; Zhang & Chen, 2016)
	PCI05	Last Planner System	(Bajjou & Chafi, 2025; S. Li et al., 2017; Zhang & Chen, 2016)
Planning Techniques & Continuous Improvement	PCI06	Plan-Do-Check-Action (PDCA)	(Bajjou & Chafi, 2025; S. Li et al., 2017; Zhang & Chen, 2016)
	PCI07	Process Documentation & Standardization	(Badran & Abdallah, 2025; Bajjou & Chafi, 2025)

	PCI08	Mechanization and Standardization of Construction and Assembly	(Badran & Abdallah, 2025)
	PCI09	Visual Management and Control in Projects	(Bajjou & Chafi, 2025; S. Li et al., 2017; Meshref et al., 2022)
	PCI10	Just-In-Time	(Badran & Abdallah, 2025; S. Li et al., 2017; Meshref et al., 2022; Zhang & Chen, 2016)
Lean Construction Performance	LCP01	Achievement of Project Performance	(Bigwanto et al., 2024)
	LCP02	Waste Reduced	(Bigwanto et al., 2024)
	LCP03	Project Schedule on Time	(Bigwanto et al., 2024)
	LCP04	There Was No Variability in Work	(Bigwanto et al., 2024)
	LCP05	Financial Performance	(Bigwanto et al., 2024)
	LCP06	Fast Decision-Making Process	(Bigwanto et al., 2024)

Source: Processed Data (2026)

Results and Discussion

Respondent Characteristics

A total of 360 questionnaires were distributed in this study, of which 155 responses were returned. All collected data were subsequently subjected to a data screening process using Google Forms to ensure completeness, consistency, and suitability for further analysis. After removing incomplete and invalid responses, a total of 125 questionnaires were deemed valid and were included in the subsequent statistical analysis. This sample size as seen in Table 2 is considered adequate to represent professionals involved in high rise building construction projects.

Table 2. Characteristics of Research Respondents

No.	Characteristics		Frequency	Percentage
1	Gender	Male	111	89%
		Female	14	11%
Amount			125	100%
2	Job Positions	Project Managers	16	13%
		Site Managers	25	20%
		Engineering Team	47	38%
		QC / QA	8	6%
		HSE	8	6%
		Supervising Consultants	12	10%
Amount			99	100%
3	Education	Master's Degree (S2)	18	14%
		Bachelor's Degree (S1)	92	74%
		Diploma (D3)	15	12%
Amount			125	100%
4	Work Experiences	1 - 3 Years	15	12%
		3 - 5 Years	6	5%
		5 - 10 Years	28	23%

		10 - 15 Years	23	18%
		> 15 Years	53	42%
Amount			125	100%

Convergent Validity

Convergent validity was evaluated to examine the extent to which the indicators consistently measure their respective latent constructs. According to Hair (2017), convergent validity is considered satisfactory when indicator loadings > 0.70 and the AVE value of each construct is > 0.50 .

Based on the results of the initial model estimation, indicators LCP03, LCP04, and PCI10 failed to meet the minimum loading requirement, indicating that these indicators were not sufficiently robust in representing their respective latent constructs. Therefore, an indicator elimination procedure was implemented by removing the indicators with inadequate loading values, followed by a second model estimation. The results of the second estimation demonstrate that all remaining indicators achieved outer loading values > 0.70 as seen in Table 3 and also AVE values > 0.50 as seen in Table 4.

Table 3. Convergent Validity Test Output

Variables	Code	Outer Loadings	Variables	Code	Outer Loadings
Management Commitment and Involvement	KM01	0.946	Planning Techniques & Continuous Improvement	PCI01	0.857
	KM02	0.932		PCI02	0.812
Human Resource Development	SDM01	0.815	Planning Techniques & Continuous Improvement	PCI03	0.866
	SDM02	0.786		PCI04	0.841
	SDM03	0.853		PCI05	0.850
	SDM04	0.833		PCI06	0.859
Communication and Collaboration	KK01	0.852		PCI07	0.879
	KK02	0.892		PCI08	0.779
	KK03	0.922		PCI09	0.814
Internal Client Focus	FC01	0.929		Lean Construction Performance	LCP01
	FC02	0.934	LCP02		0.742
	FC03	0.793	LCP05		0.834
		LCP06	0.852		

Source: Processed Data (2026)

Table 4. Average Variance Extracted (AVE) Test Output

	Average Variance Extracted (AVE)	Information
Internal Client Focus (FC)	0.788	Valid
Communication and Collaboration (KK)	0.791	Valid
Management Commitment and Involvement (KM)	0.881	Valid
Lean Construction Performance (LCP)	0.687	Valid
Planning Techniques & Continuous Improvement (PCI)	0.706	Valid
Human Resource Development (SDM)	0.676	Valid

Source: Processed Data (2026)

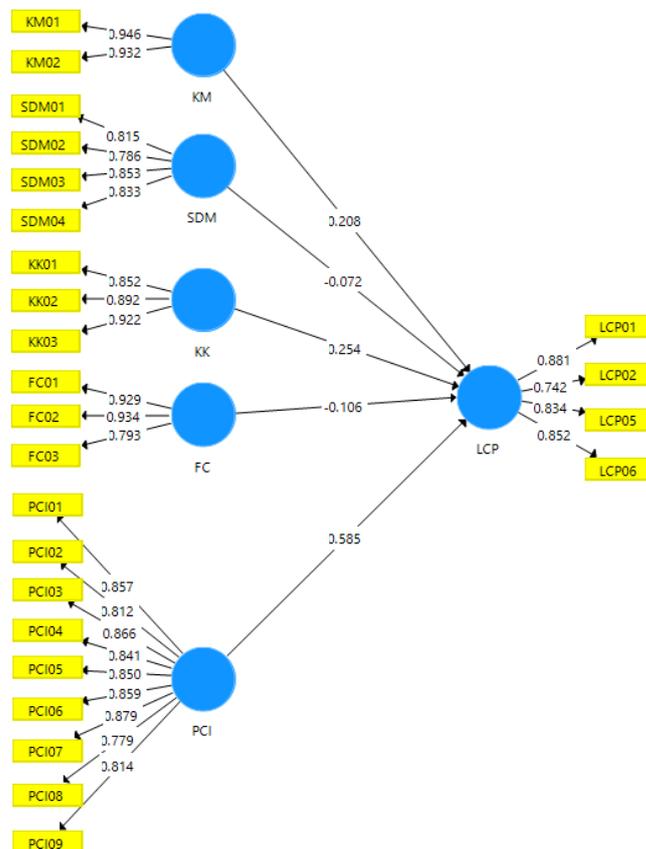


Figure 2. Outer Loadings Output After Elimination

Discriminant Validity

The Fornell-Larcker approach is used to assess whether a construct explains a greater proportion of variance in its own indicators than in the indicators of other constructs. According to this criterion, the square root of the AVE for a construct must be greater than its correlation values with other constructs (Hair et al., 2017).

Based on Table 5, the square root of the AVE for Internal Client Focus (FC) is 0.888, Communication and Collaboration (KK) is 0.889, Management Commitment and Involvement (KM) is 0.939, Lean Construction Performance (LCP) is 0.829, Planning Techniques and Continuous Improvement (PCI) is 0.840, and Human Resource Development (SDM) is 0.822. All of these values are higher than the corresponding inter-construct correlation values, indicating that each construct demonstrates adequate discriminant validity under the Fornell-Larcker criterion.

Table 5. Discriminant Validity Test Output

Internal Client Focus (FC)		Communication and Collaboration (KK)	Management Commitment and Involvement (KM)	Lean Construction Performance (LCP)	Planning Techniques & Continuous Improvement (PCI)	Human Resource Development (SDM)
FC	0.888					
KK	0.782	0.889				
KM	0.665	0.702	0.939			
LCP	0.630	0.739	0.688	0.829		
PCI	0.766	0.816	0.715	0.804	0.840	
SDM	0.694	0.769	0.646	0.639	0.777	0.822

Source: Processed Data (2026)

Reliability Test

Construct reliability testing was conducted to evaluate the level of internal consistency among indicators in measuring a latent construct (Hair et al., 2017). Two main measures were namely Cronbach's Alpha, which assumes equal indicator loadings, and Composite Reliability, which accounts for the actual weights or outer loadings of each indicator. Based on the test results presented in Table 6, all latent constructs in the research model exhibit Cronbach's Alpha values of at least 0.70 and Composite Reliability values of at least 0.70. These results indicate that the indicators within each construct demonstrate good internal consistency and are reliable in measuring their respective latent constructs.

Table 6. Reliability Test Output

	Cronbach's Alpha	Composite Reliability	Information
Internal Client Focus (FC)	0.867	0.917	Reliabel
Communication and Collaboration (KK)	0.868	0.919	Reliabel
Management Commitment and Involvement (KM)	0.865	0.937	Reliabel
Lean Construction Performance (LCP)	0.848	0.897	Reliabel
Planning Techniques & Continuous Improvement (PCI)	0.948	0.956	Reliabel
Human Resource Development (SDM)	0.841	0.893	Reliabel

Source: Processed Data (2026)

Conclusion

Based on the evaluation results of the measurement model, the variables influencing Lean Construction Performance are represented by valid and reliable indicators after the elimination of indicators with outer loading values below 0.70, as follows:

Management Commitment and Involvement (KM) is formed by indicators of top management commitment and support, as well as lean leadership. Among these, lean leadership is identified as the most influential indicator.

Human Resource Development (SDM) is represented by indicators including the selection of competent employees, training and development, incentives and compensation, and organizational knowledge management. The most influential indicator within this construct is organizational knowledge management.

Communication and Collaboration (KK) is formed by indicators of communication among project stakeholders, the promotion of a teamwork culture, and the existence of clear roles in lean implementation. The indicator with the strongest influence is the presence of clear roles in lean.

Internal Client Focus (FC) is represented by indicators of clearly defined client requirements, value identification and optimization, and client involvement in providing feedback. The most influential indicator within this construct is value identification and optimization.

Planning Techniques and Continuous Improvement (PCI) is formed by indicators including the adoption of lean culture, technical capacity to implement lean tools, availability of lean tools and techniques, monitoring and reduction of cost overruns, Last Planner System, Plan–Do–Check–Action, process documentation and standardization, mechanization and standardization of construction and assembly, as well as visual management and control at the project level. The most influential indicator in this construct is process documentation and standardization.

Lean Construction Performance (LCP) is represented by indicators of project performance achievement, waste reduction, financial performance, and fast decision-making processes. The indicator with the strongest influence is project performance achievement.

The advice that researchers can give based on the research results is construction companies are advised to focus on strengthening the key factors that have been empirically validated in this study rather than applying lean practices in a fragmented manner. Companies should also invest in systematic human resource development, particularly by strengthening organizational knowledge management systems to ensure that lessons learned and best practices are effectively transferred across projects. In addition, firms are encouraged to translate client requirements into clearly defined value and embed them into technical planning systems, supported by standardized processes, proper documentation, and continuous improvement routines.

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