



## Selection of the Best Lean Construction Techniques for the Execution Stage

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### Abstract

*This study aims to identify and prioritize critical success factors and lean construction techniques that influence lean implementation during the execution stage of construction projects in Indonesia. A quantitative research approach was employed using expert judgment collected through a structured questionnaire. The Relative Importance Index was applied to rank critical success factors and assess the importance of selected lean construction techniques, while the Analytic Hierarchy Process was used to determine priority weights through pairwise comparisons. The results indicate that top management, financial management, task execution based on scope of work, and improvement tools are the most influential factors supporting successful lean execution. The analysis also shows that Just In Time, Last Planner System, Daily Huddle Meeting, and Building Information Modeling are all considered very important techniques during the execution stage. Further prioritization reveals that Daily Huddle Meeting has the highest priority, followed by Just In Time, while Building Information Modeling and Last Planner System function as supporting techniques. The findings highlight that effective lean execution is driven primarily by managerial commitment and daily coordination practices rather than technical tools alone. This study provides practical guidance for construction practitioners in selecting appropriate lean strategies to improve execution performance and reduce waste on site.*

## Introduction

The construction industry in Indonesia continues to face persistent challenges related to inefficiency, excessive waste, and low productivity, particularly during the construction execution stage. This stage represents the core of project delivery, where execution outputs are transformed into physical construction activities on site (Alizadehsalehi & Hadavi, 2023; Cooke & Williams, 2025; Jang et al., 2022; Garcés & Peña, 2023). Due to high uncertainty, fragmented workflows, and intensive coordination requirements, execution-stage activities are highly susceptible to schedule delays, cost overruns, quality issues, and safety risks. As highlighted by (Koskela, 1997) and (Ballard & Howell, 1995), poor production flow and ineffective coordination during execution are major sources of non-value-adding activities and material waste in construction projects.

## Urgency and Regulatory Context

The urgency to improve construction execution performance in Indonesia is reinforced by the issuance of the Minister of Public Works and Housing Regulation No. 9 of 2021, which promotes the implementation of lean construction principles and Building Information Modeling (BIM) to enhance efficiency and sustainability (Uvarova et al., 2023; Moradi & Sormunen, 2024; Patel et al., 2023; AL-Zubaidi et al., 2025; Akter et al., 2025; Saleh et al.,

2024). Despite this regulatory support, industry performance indicators show that execution-stage inefficiencies remain prevalent. Material waste is estimated to reach approximately 25% of total project costs, while project delays commonly range between 30–40%, indicating substantial losses occurring during construction execution. These conditions demonstrate that regulatory encouragement alone is insufficient without a structured and practical approach to lean implementation at the execution stage.

### **Literature Review on Lean Construction in the Execution Stage**

Lean construction provides a systematic framework to improve execution-stage performance by focusing on waste reduction, workflow reliability, and continuous improvement (Tezel et al., 2018; Womack & Jones 1997). Execution-oriented lean techniques such as Just-in-Time (JIT), Last Planner System (LPS), Daily Huddle Meetings (DHM), and Building Information Modeling (BIM) have been widely reported to improve material flow, enhance communication, and stabilize production processes on construction sites (Ballard & Tommelein 2021; Noorzai, 2023, Abkar et al., 2024; Nounou et al., 2022; Dyczko, 2023; Zhang et al., 2023). However, studies in the Indonesian context indicate that these techniques are often implemented partially or without clear prioritization, resulting in limited performance improvement.

### **Critical Success Factors and Research Gap**

Previous studies emphasize that successful lean construction implementation depends on several critical success factors (CSFs), including top management commitment, financial management reliability, workforce capability, effectiveness of improvement tools, quality improvement, waste reduction, and health, safety, and environmental management (Moradi & Sormunen 2023; Negi et al., 2024; Pedrosa et al., 2023; Romo et al., 2024). While these CSFs have been extensively identified, most existing research focuses on general lean adoption or early project stages such as execution and design. Empirical studies that explicitly examine how CSFs influence the selection of lean construction techniques during the execution stage remain limited, particularly in the Indonesian construction industry (Firdaus & Zagloel, 2025; Hendrianto et al., 2024; Bigwanto et al., 2024; Pangestu & Yudoko, 2026)).

### **Problem-Solving Approach**

One of the key challenges in execution-stage lean implementation is the absence of a structured decision-making framework to prioritize lean construction techniques under real project constraints. Without systematic prioritization, contractors often apply lean tools in an ad hoc manner, reducing their effectiveness. Quantitative multi-criteria decision-making methods such as the Relative Importance Index (RII) and the Analytic Hierarchy Process (AHP) offer a structured approach to evaluate expert judgment and prioritize alternatives based on multiple influencing factors (Saaty, 2008; Belay et al., 2022; Kouskoura et al., 2025; Vahedi Nikbakht et al., 2024; Sharma et al., 2024).

### **Research Objectives and Hypothesis Development**

Based on the identified research gap, this study focuses exclusively on the construction execution stage and aims to determine the most suitable lean construction technique based on dominant critical success factors. The study integrates RII to rank execution-stage CSFs and AHP to prioritize criteria, sub-criteria, and lean construction techniques, including JIT, LPS, DHM, and BIM.

It is hypothesized that lean construction techniques with higher alignment to dominant critical success factors will demonstrate greater priority for execution-stage implementation, thereby contributing to reduced waste, improved coordination, and enhanced construction performance in Indonesian projects

## Methods

### Research Design

This study adopts a quantitative research design to identify and prioritize critical success factors (CSFs) and lean construction techniques relevant to the construction execution stage in Indonesian construction projects. A two-stage analytical framework is employed, consisting of the Relative Importance Index (RII) and the Analytic Hierarchy Process (AHP). This integrated approach enables structured evaluation of expert judgment and supports multi-criteria decision-making in complex construction environments (Saaty, 2008).

### Data Collection

Primary data were collected through a structured questionnaire distributed to ten expert respondents selected using purposive sampling. Experts were required to have at least five years of experience in construction project execution or site management, direct involvement in implementing lean construction techniques, and experience in large-scale or complex construction projects. The use of expert-based surveys is widely adopted in construction management research to capture professional judgment in decision-oriented studies (Negi et al. 2024).

The questionnaire comprised two main components: (1) assessment of CSFs using a five-point Likert scale to support RII analysis, and (2) pairwise comparison matrices for AHP analysis covering criteria, sub-criteria, and execution-stage lean construction techniques, including Just-in-Time (JIT), Last Planner System (LPS), Daily Huddle Meetings (DHM), and Building Information Modeling (BIM).

### Relative Importance Index (RII)

The Relative Importance Index (RII) was applied to rank CSFs based on expert ratings. The index was calculated using the equation:

$$RII = \frac{\sum W}{A \times N}$$

where:

W: weight assigned by respondents (1–5),

A: highest weight (5),

N: total number of respondents.

RII values range between 0 and 1, with higher values indicating greater perceived importance. RII is commonly used in construction management research to prioritize influencing factors based on expert judgment (Liu 2023).

### Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP) was employed to prioritize criteria, sub-criteria, and lean construction techniques relevant to the execution stage. AHP is a structured multi-criteria decision-making method developed by Saaty (Saaty, 2008), which evaluates complex decision problems through systematic pairwise comparisons and numerical weighting. Due to its ability to integrate qualitative and quantitative considerations, AHP has been widely applied in construction management studies for technique selection and performance evaluation (Moradi & Sormunen 2023; Saaty et al., 2022).

### Pairwise Comparison and Weighting

Pairwise comparisons were conducted using Saaty's fundamental 1–9 scale, where a value of 1 indicates equal importance and a value of 9 indicates extreme importance of one element

over another (Saaty, 2008). Experts assessed the relative importance of criteria, sub-criteria, and execution-stage lean construction techniques.

Priority weights were derived using eigenvector normalization, which computes the principal eigenvector of each comparison matrix to obtain local and global priority weights. These weights represent the relative importance of lean construction techniques with respect to the study objective and form the basis for ranking alternatives (Saaty et al., 2022).

## Results and Discussion

### Relative Importance Index (RII) of Critical Success Factors

The Relative Importance Index (RII) analysis was conducted to identify the relative importance of critical success factors (CSFs) influencing lean construction implementation during the execution stage. The RII results for all CSFs are presented in Table 1.

Table 1. RII Results for Execution Stage Critical Success Factors

Code	Influencing Factor	$\Sigma W$ (Total Score)	RII	Interpretation
P1	Top Management	45	0.9	Very Important
P2	Financial Management	45	0.9	Very Important
P3	Task Execution Based on Scope of Work	45	0.9	Very Important
P4	Workforce Capability	38	0.76	Important
P5	Quality Improvement	36	0.72	Important
P6	Waste Reduction	36	0.72	Important
P7	Improvement Tools	45	0.9	Very Important
P8	Health, Safety, and Environment (HSE)	36	0.72	Important

Source: Author's calculation, 2026

The findings indicate that Top Management (P1), Financial Management (P2), Task Execution Based on Scope of Work (P3), and Improvement Tools (P7) achieved the highest RII value of 0.90, categorizing them as very important. This result reflects a strong consensus among respondents that managerial commitment, financial readiness, clear task definition, and the availability of improvement tools are the most influential drivers of successful lean execution. These factors form the foundation for reliable decision-making and coordination during the early project stage.

In contrast, Workforce Capability (P4), Quality Improvement (P5), Waste Reduction (P6), and Health, Safety, and Environment (HSE) (P8) recorded RII values between 0.72 and 0.76, which fall under the important category. Although ranked slightly lower, these factors remain essential supporting elements for lean implementation. This suggests that operational and workforce-related aspects become more effective when supported by strong managerial and organizational readiness during the execution phase.

### RII Analysis of Lean Construction Techniques at the Execution Stage

The Relative Importance Index (RII) analysis was conducted to assess the importance of selected lean construction techniques applied during the construction execution stage. This study focuses on four techniques: Just In Time (JIT), Last Planner System (LPS), Daily Huddle Meeting (DHM), and Building Information Modeling (BIM) that presented in Table 2.

Table 2. RII Results for Execution Stage Lean Construction Technique Implementation

Code	Influencing Factor	ΣW (Total Score)	RII	Interpretation
P1	Last Planner System (LPS)	45	0.9	Very Important
P2	Just In Time (JIT)	45	0.9	Very Important
P3	Building Information Modeling (BIM)	45	0.9	Very Important
P4	Daily Huddle Meeting (DHM)	45	0.9	Very Important

Source: Author’s calculation, 2026

The results show that all four techniques obtained an identical RII value of 0.90, placing them in the very important category. This indicates a strong consensus among respondents that LPS, JIT, BIM, and DHM are essential for effective lean implementation during construction execution.

### Pairwise Comparison and Priority Ranking at the Criteria Level

The pairwise comparison at the criteria level further clarifies respondent preferences when selecting lean construction techniques. The results indicate that managerial-related criteria are prioritized over purely technical or operational factors. This finding reinforces the RII results, confirming that leadership commitment and financial readiness are perceived as critical prerequisites for effective lean execution.

This prioritization reflects the practical reality of construction projects, where strategic decisions made during the execution stage significantly influence resource allocation, coordination effectiveness, and downstream project performance. The detailed weights and rankings for each criterion are presented in Table 3 and Table 4 and serve as key inputs for subsequent AHP analysis.

Table 3. Pairwise Comparison for Criteria Level

CSF	Top Management	Financial Management	Task Execution Based on Scope of Work	Workforce Capability	Quality Improvement	Waste Reduction	Improvement Tools	Health, Safety, and Environment (HSE)
Top Management	1.00	1.29	2.10	2.52	3.74	2.78	1.35	2.66
Financial Management	0.78	1.00	3.01	2.36	3.35	1.97	1.89	2.00
Task Execution Based on Scope of Work	0.48	0.33	1.00	0.63	0.45	0.89	0.80	0.62
Workforce Capability	0.40	0.42	1.58	1.00	3.52	1.18	0.32	0.51
Quality Improvement	0.27	0.30	2.21	0.28	1.00	1.18	0.44	1.05
Waste Reduction	0.36	0.51	1.12	0.84	0.85	1.00	0.58	1.58
Improvement Tools	0.74	0.53	1.25	3.12	2.28	1.72	1.00	2.59
Health, Safety, and Environment (HSE)	0.38	0.50	1.60	1.96	0.95	0.63	0.39	1.00
SUM	4.39	4.88	13.87	12.72	16.14	11.36	6.77	12.01

Source: Author’s calculation, 2026

Table 4. Priority Weights for Criteria Level

CSF	Top Management	Financial Management	Task Execution Based on Scope of Work	Workforce Capability	Quality Improvement	Waste Reduction	Improvement Tools	Health, Safety, and Environment (HSE)	Total	Priority
Top Management	0.23	0.26	0.15	0.20	0.23	0.25	0.20	0.22	1.74	0.22
Financial Management	0.18	0.20	0.22	0.19	0.21	0.17	0.28	0.17	1.61	0.20
Task Execution Based on Scope of Work	0.11	0.07	0.07	0.05	0.03	0.08	0.12	0.05	0.58	0.07
Workforce Capability	0.09	0.09	0.11	0.08	0.22	0.10	0.05	0.04	0.78	0.10
Quality Improvement	0.06	0.06	0.16	0.02	0.06	0.10	0.06	0.09	0.62	0.08
Waste Reduction	0.08	0.10	0.08	0.07	0.05	0.09	0.09	0.13	0.69	0.09
Improvement Tools	0.17	0.11	0.09	0.25	0.14	0.15	0.15	0.22	1.27	0.16
Health, Safety, and Environment (HSE)	0.09	0.10	0.12	0.15	0.06	0.06	0.06	0.08	0.71	0.09
SUM	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	8.00	1.00

Source: Author’s calculation, 2026

**Pairwise Comparison and Priority Ranking at the Sub-Criteria Level**

At the sub-criteria level, pairwise comparison was used to determine the relative importance of each sub-factor within its respective criterion. After consistency verification and normalization, priority weights were calculated to reflect expert judgment. The results, presented in the corresponding tables, show variations in importance among sub-criteria, indicating that not all supporting factors contribute equally to lean execution effectiveness.

Table 5. Pairwise Comparison of Top Management Sub-Criteria

Sub-Criteria	Top Management Commitment	Project Leadership	Resource Allocation
Top Management Commitment	1.00	6.04	3.81
Project Leadership	0.17	1.00	0.30
Resource Allocation	0.26	3.28	1.00
Sum	1.43	10.33	5.12

Source: Author’s calculation, 2026

Table 6. Priority Weights of Top Management Sub-Criteria

Sub-Criteria	Top Management Commitment	Project Leadership	Resource Allocation	Total	Priority
Top Management Commitment	0.70	0.59	0.75	2.03	0.68
Project Leadership	0.12	0.10	0.06	0.27	0.09
Resource Allocation	0.18	0.32	0.20	0.70	0.23
Sum	1.00	1.00	1.00	3.00	1.00

Source: Author's calculation, 2026

Table 7. Pairwise Comparison of Financial Management Sub-Criteria

Sub-Criteria	Project Cost Control	Fund Allocation	Financial Reporting
Project Cost Control	1.00	1.75	0.36
Fund Allocation	0.57	1.00	0.30
Financial Reporting	2.76	3.36	1.00
Sum	4.34	6.11	1.66

Source: Author's calculation, 2026

Table 8. Priority Weights of Financial Management Sub-Criteria

Sub-Criteria	Project Cost Control	Fund Allocation	Financial Reporting	Total	Priority
Project Cost Control	0.23	0.29	0.22	0.73	0.24
Fund Allocation	0.13	0.16	0.18	0.48	0.16
Financial Reporting	0.64	0.55	0.60	1.79	0.60
Sum	1.00	1.00	1.00	3.00	1.00

Source: Author's calculation, 2026

Table 9. Pairwise Comparison of Task Execution Based on Scope of Work Sub-Criteria

Sub-Criteria	Work Schedule	Activity Sequence	Responsibility Assignment
Work Schedule	1.00	1.02	0.27
Activity Sequence	0.98	1.00	0.23
Responsibility Assignment	3.73	4.30	1.00
Sum	5.71	6.31	1.50

Source: Author's calculation, 2026

Table 10. Priority Weights of Task Execution Based on Scope of Work Sub-Criteria

Sub-Criteria	Work Schedule	Activity Sequence	Responsibility Assignment	Total	Priority
Work Schedule	0.18	0.16	0.18	0.52	0.17
Activity Sequence	0.17	0.16	0.16	0.49	0.16
Responsibility Assignment	0.65	0.68	0.67	2.00	0.67
Sum	1.00	1.00	1.00	3.00	1.00

Source: Author's calculation, 2026

Table 11. Pairwise Comparison of Workforce Capability Sub-Criteria

Sub-Criteria	Worker Skill Level	Job Training	Worker Productivity
Worker Skill Level	1.00	0.87	0.58
Job Training	1.15	1.00	0.71
Worker Productivity	1.71	1.41	1.00
Sum	3.86	3.28	2.29

Source: Author's calculation, 2026

Table 12. Priority Weights of Workforce Capability Sub-Criteria

Sub-Criteria	Worker Skill Level	Job Training	Worker Productivity	Total	Priority
Worker Skill Level	0.26	0.27	0.25	0.78	0.26
Job Training	0.30	0.31	0.31	0.91	0.30
Worker Productivity	0.44	0.43	0.44	1.31	0.44
Sum	1.00	1.00	1.00	3.00	1.00

Source: Author's calculation, 2026

Table 13. Pairwise Comparison of Quality Improvement Sub-Criteria

Sub-Criteria	Quality Inspection	Quality Assurance System	Corrective Actions
Quality Inspection	1.00	0.29	1.21
Quality Assurance System	3.40	1.00	2.47
Corrective Actions	0.82	0.40	1.00
Sum	5.23	1.70	4.68

Source: Author's calculation, 2026

Table 14. Priority Weights of Quality Improvement Sub-Criteria

Sub-Criteria	Quality Inspection	Quality Assurance System	Corrective Actions	Total	Priority
Quality Inspection	0.19	0.17	0.26	0.62	0.21
Quality Assurance System	0.65	0.59	0.53	1.77	0.59
Corrective Actions	0.16	0.24	0.21	0.61	0.20
Sum	1.00	1.00	1.00	3.00	1.00

Source: Author's calculation, 2026

Table 15. Pairwise Comparison of Waste Reduction Sub-Criteria

Sub-Criteria	Waste Identification	Waste Elimination Actions	Lean Tool Effectiveness
Waste Identification	1.00	1.15	0.88
Waste Elimination Actions	0.87	1.00	1.16
Lean Tool Effectiveness	1.14	0.86	1.00
Sum	3.01	3.01	3.04

Source: Author's calculation, 2026

Table 16. Priority Weights of Waste Reduction Sub-Criteria

Sub-Criteria	Waste Identification	Waste Elimination Actions	Lean Tool Effectiveness	Total	Priority
Waste Identification	0.33	0.38	0.29	1.00	0.33
Waste Elimination Actions	0.29	0.33	0.38	1.00	0.33
Lean Tool Effectiveness	0.38	0.29	0.33	0.99	0.33
Sum	1.00	1.00	1.00	3.00	1.00

Source: Author's calculation, 2026

Table 17. Pairwise Comparison of Improvement Tools Sub-Criteria

Sub-Criteria	Utilization of Lean Construction Tools	Usage Effectiveness	System Integration
Utilization of Lean Construction Tools	1.00	0.89	1.58
Usage Effectiveness	1.12	1.00	1.87
System Integration	0.63	0.53	1.00
Sum	2.75	2.42	4.46

Source: Author's calculation, 2026

Table 18. Priority Weights of Improvement Tools Sub-Criteria

Sub-Criteria	Utilization of Lean Construction Tools	Usage Effectiveness	System Integration	Total	Priority
Utilization of Lean Construction Tools	0.36	0.37	0.36	1.09	0.36
Usage Effectiveness	0.41	0.41	0.42	1.24	0.41
System Integration	0.23	0.22	0.22	0.67	0.22
Sum	1.00	1.00	1.00	3.00	1.00

Source: Author's calculation, 2026

Table 19. Pairwise Comparison of Health, Safety, and Environment (HSE) Sub-Criteria

Sub-Criteria	Regulatory Compliance	Regulatory Implementation	Safety Culture
Regulatory Compliance	1.00	0.87	0.67
Regulatory Implementation	1.15	1.00	0.66
Safety Culture	1.50	1.52	1.00
Sum	3.65	3.39	2.33

Source: Author's calculation, 2026

Table 20. Priority Weights of Health, Safety, and Environment (HSE) Sub-Criteria

Sub-Criteria	Regulatory Compliance	Regulatory Implementation	Safety Culture	Total	Priority
Regulatory Compliance	0.27	0.26	0.29	0.82	0.27
Regulatory Implementation	0.31	0.30	0.28	0.89	0.30
Safety Culture	0.41	0.45	0.43	1.29	0.43
Sum	1.00	1.00	1.00	3.00	1.00

Source: Author's calculation, 2026

### Pairwise Comparison and Priority Ranking of Execution Stage Lean Techniques

Pairwise comparison was also conducted at the alternative level to determine the relative priority of lean construction techniques during the execution stage. Experts evaluated each technique based on its contribution to lean implementation. After confirming matrix consistency, normalization was performed to obtain priority weights, as shown in table below.

Table 21. Pairwise Comparison of Alternatives at the Execution Stage

Alternative	Just In Time	Last Planner System	Daily Huddle Meeting
Just In Time	1.00	3.80	0.82
Last Planner System	0.26	1.00	0.29
Daily Huddle Meeting	1.23	3.45	1.00
Building Information Modeling	0.35	0.85	0.27
Sum	2.84	9.10	2.37

Source: Author's calculation, 2026

Table 22. Priority Weights of Alternatives at the Execution Stage

Alternative	Just In Time	Last Planner System	Daily Huddle Meeting	Building Information Modeling	Total	Priority
Just In Time	0.35	0.42	0.34	0.33	1.44	0.36
Last Planner System	0.09	0.11	0.12	0.13	0.46	0.11
Daily Huddle Meeting	0.43	0.38	0.42	0.43	1.66	0.41
Building Information Modeling	0.12	0.09	0.11	0.11	0.44	0.11
Sum	1.00	1.00	1.00	1.00	4.00	1.00

Source: Author's calculation, 2026

## Conclusion

This study investigated critical success factors and lean construction techniques influencing lean implementation during the execution stage of construction projects in Indonesia using the Relative Importance Index (RII) and Analytic Hierarchy Process (AHP). The results indicate that top management, financial management, task execution based on scope of work, and improvement tools are the most critical success factors, highlighting the dominant role of managerial and organizational readiness in supporting lean execution. Furthermore, RII analysis confirms that Just In Time, Last Planner System, Daily Huddle Meeting, and Building Information Modeling are all considered very important techniques at the execution stage. The hierarchy structure and the synthesized priority weights in the execution stage are presented in Figure 1.

AHP results further reveal that Daily Huddle Meeting has the highest priority, followed by Just In Time, while Building Information Modeling and Last Planner System serve as supporting techniques. These findings demonstrate that effective lean execution relies not only on advanced technical tools but also on strong leadership, structured coordination, and continuous on-site communication.

## Suggestion

Based on these findings, construction practitioners are encouraged to prioritize daily coordination mechanisms, such as Daily Huddle Meetings, supported by material flow control through Just In Time and integrated information management using Building Information Modeling. Organizations should strengthen managerial commitment and financial planning to ensure effective lean execution on site. For future research, it is recommended to expand

the number of respondents, include different project types, and integrate performance indicators such as cost, time, and productivity to further validate and refine the prioritization of lean construction techniques across different project stages

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