



Developing A Project Control Using Lean Construction to Reduce Project Delays: A Case Study of PT Ubinkayu Indonesia

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Abstract

Background: Project delays remain a major challenge in the construction industry due to their impact on project performance, revenue recognition, and contractual risks. This issue occurred in PT Ubinkayu Indonesia's Project PRJ-155 in Surabaya, where actual progress reached only 44.24% compared with the planned 100%, resulting in a 55.76% schedule deviation.

Objective: This study aims to identify the root causes of project delays, determine improvement priorities, and develop an integrated Project Control Framework to enhance project performance.

Methods: A mixed-method case study was conducted using the Define-Measure-Analyze (DMA) approach from Lean Six Sigma, combined with Lean Construction principles. Quantitative analysis evaluated project performance indicators, including labor productivity, planning reliability, workflow stability, corrective activities, rework rate, and workforce utilization. Qualitative data were collected through observations, interviews, document reviews, and focus group discussions. A Current Reality Tree (CRT) was applied to analyze causal relationships, while the Analytic Hierarchy Process (AHP) was used to prioritize improvement alternatives.

Results: The study identified the absence of a structured project control mechanism as the main cause of delays, leading to unstable workflows, shifting priorities, excessive workforce movement, corrective activities, and rework. Three improvement initiatives were proposed: Progress-Based Productivity Management, Installation Readiness Gate with Constraint Heatmap Planning, and Progressive Installation Inspection. AHP results showed that Installation Readiness Gate with Constraint Heatmap Planning was the highest-priority initiative.

Conclusion: The proposed framework can improve planning reliability, labor productivity, workflow stability, and project completion efficiency while reducing corrective activities, rework, and financial risks associated with delays.

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INTRODUCTION

The construction industry continues to expand alongside increasing demand for residential, commercial, and infrastructure development. This growth has been accompanied by a substantial increase in demand for architectural wood products used in building interiors and exteriors. The expansion of sustainable construction practices, green building initiatives, and premium interior design has further accelerated the utilization of wood-based materials because of their durability, aesthetic value, renewability, and relatively low environmental impact

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compared with conventional construction materials. Recent studies have highlighted that wood-based construction materials play an increasingly important role in achieving sustainable building objectives while supporting environmentally responsible construction practices ([Garcés & Peña, 2023](#); [Ibrahim et al., 2025](#)). Likewise, global market reports indicate continuous growth in both the architectural wood products and interior design industries, reflecting increasing demand for customized wood products across residential and commercial construction projects ([Wresearch, 2022](#); [Insights, 2025](#); [Research, 2025](#)).

Architectural wood products, commonly referred to as architectural woodwork, comprise customized wood-based components that contribute not only to building functionality but also to interior aesthetics and overall construction quality. Unlike standardized construction materials, architectural wood products are generally delivered through a make-to-order production system, in which product specifications, manufacturing schedules, logistics, and installation activities are tailored to the requirements of individual projects. Consequently, project execution requires effective coordination among production, logistics, project planning, and on-site installation teams to ensure that work is completed according to contractual schedules despite continuously changing site conditions ([Architectural Woodwork Institute, 2024](#); [Ibrahim et al., 2025](#)).

The increasing demand for customized architectural wood products has simultaneously increased the complexity of project execution. In Indonesia, the continued growth of the property, hospitality, commercial, and interior design sectors has significantly expanded demand for customized products such as solid wood doors, flooring, wall panels, staircases, and other architectural wood components. Market analyses project sustained growth in Indonesia's interior design and wood product industries over the coming years, indicating considerable business opportunities while simultaneously increasing operational challenges for companies responsible for manufacturing and installation services ([6Wresearch, 2022](#); [Insights, 2026](#); [Intelligence, 2025](#); [Research, 2025](#)). As project complexity increases, companies are required not only to manufacture high-quality products but also to maintain effective project planning, workforce coordination, and installation control throughout project execution.

From an operations management perspective, completing projects according to schedule represents one of the most important indicators of organizational performance. Nevertheless, project delays remain one of the most persistent challenges in the construction industry because they increase operational costs, reduce labor productivity, disrupt workflow continuity, delay revenue recognition, and increase exposure to contractual penalties ([Mohamad et al., 2021](#); [Nepal et al., 2025](#); [Romzi & Doh, 2022](#)). Previous studies have shown that ineffective planning, unstable workflow, inadequate coordination, and inefficient workforce utilization frequently lead to schedule overruns and declining project performance ([Bigwanto et al., 2024](#)). Furthermore, Lean Construction research emphasizes that workflow variability and the presence of non-value-added activities significantly reduce operational efficiency by generating waiting time, unnecessary movement, repeated corrective work, and other forms of process waste ([Ibrahim et al., 2025](#); [Moradi & Sormunen, 2023](#)).

PT Ubinkayu Indonesia, a company specializing in the manufacturing and installation of customized solid wood products, experienced these operational challenges during Project PRJ-155 Surabaya. Although the company possesses adequate operational capacity, including approximately 175 employees and annual revenue of around IDR 90–100 billion, the project experienced significant schedule delays. Actual project progress reached only 44.24% of the planned completion level, representing a 55.76-percentage-point shortfall. This delay reduced the company's ability to recognize project revenue while simultaneously increasing the risk of contractual penalties. Revenue data between 2023 and 2025 further indicate that actual revenue consistently remained below planned targets, demonstrating that project delays represent not only operational inefficiencies but also strategic business issues affecting organizational profitability.

To reduce project delays, PT Ubinkayu Indonesia implemented several operational initiatives, including daily progress monitoring by the Project Planning and Control (PPC) team, routine coordination meetings with site supervisors, and periodic project evaluations. Although these initiatives improved project monitoring, overall performance remained below expectations because the existing project control system primarily emphasized monitoring work progress after execution had already begun rather than preventing operational disruptions before installation

activities commenced. Consequently, recurring problems related to work-area readiness, workflow instability, workforce productivity, corrective activities, and installation quality continued to affect project performance.

Previous studies have investigated project delays from various perspectives, including Lean Construction implementation, project scheduling optimization, productivity improvement, risk management, stakeholder management, visual management, and project performance measurement (Alarcón et al., 2024; Forcael et al., 2020; Marinopoulou et al., 2022; Pongboonchai-Empla et al., 2024; Serpell & Rubio, 2023). However, most studies focus on improving individual operational aspects, such as schedule control, workforce productivity, or quality management, separately. Empirical studies that integrate work-readiness verification, workflow stability, workforce performance monitoring, and installation quality into a comprehensive project control mechanism remain relatively limited, particularly within customized architectural wood installation projects characterized by make-to-order production systems, dependence on construction-site readiness, and intensive coordination among multiple project stakeholders.

To address these gaps, this study develops an integrated Project Control Framework based on Lean Construction principles. The framework combines the Current Reality Tree (CRT) to identify causal relationships among operational problems and the Analytic Hierarchy Process (AHP) to prioritize implementation alternatives according to organizational impact and implementation feasibility. Rather than addressing productivity, planning, and quality as separate improvement initiatives, the proposed framework integrates preventive project control mechanisms to ensure work readiness before installation activities commence, stabilize workflow execution, strengthen workforce productivity monitoring, minimize corrective activities and rework, and improve overall project performance. Accordingly, this study aims to identify the root causes of project delays experienced during Project PRJ-155 Surabaya, formulate appropriate improvement alternatives, determine their implementation priorities using AHP, and develop a comprehensive Project Control Framework that can support more systematic project monitoring and control. Beyond its practical contribution to PT Ubinkayu Indonesia, this study also contributes to the Lean Construction literature by demonstrating how Lean Construction principles can be operationalized into an integrated project control framework for labor-intensive architectural wood installation projects with similar operational characteristics.

The research gap is therefore integrative: prior approaches commonly isolate productivity, schedule reliability, or quality, whereas make-to-order installation delays emerge from interdependent readiness constraints. The study's conceptual contribution is a project control framework that links four control functions—readiness verification, workflow stabilization, workforce performance monitoring, and progressive quality assurance—within a single Lean Construction control logic. This integration is particularly important when upstream fabrication, site readiness, installation sequencing, and rework risks are tightly coupled.

METHOD

PT Ubinkayu Indonesia's PRJ-155 Surabaya project was selected as an information-rich critical case because it combined severe schedule deviation, repeated sequence changes, rework, and make-to-order installation dependencies. These characteristics make the case suitable for developing a framework intended for analytically similar projects in which installation can only proceed after multiple readiness constraints have been released.

This study employed a mixed-method case study to investigate the root causes of project delays and develop an integrated project control framework for PT Ubinkayu Indonesia. A case study approach was selected because it enables an in-depth investigation of operational problems within their real-life context while combining quantitative and qualitative evidence to produce comprehensive findings. The research focused on Project PRJ-155 Surabaya, which experienced significant schedule delays during the installation of solid wood doors. The project was selected because it represented the most critical ongoing project requiring immediate operational improvement and provided sufficient quantitative and qualitative data to evaluate project performance.

The research adopted the Define–Measure–Analyze (DMA) phases derived from the Lean Six Sigma methodology and integrated them with Lean Construction principles to identify operational problems, evaluate project performance, determine the underlying causes of project

delays, and formulate improvement alternatives. Unlike the complete DMAIC cycle, this study focused only on the Define, Measure, and Analyze phases because the objective was to develop a practical business solution and implementation framework rather than conduct full-scale implementation and long-term operational control.

During the Define phase, the research identified the primary business issue through interviews with company management, direct field observations, and reviews of project documentation. The SIPOC (Supplier–Input–Process–Output–Customer) diagram was developed to understand the overall installation process and determine the critical process requiring detailed investigation. These activities established the research scope and identified project delay as the principal operational issue.

In the Measure phase, project performance was evaluated using operational data collected from project records, installation reports, field observations, and company documents. Quantitative performance indicators included labor productivity, planning reliability, workflow stability, workforce utilization, corrective activity intensity, rework rate, and schedule performance. These indicators were selected because they directly reflected installation performance and enabled the identification of operational deviations contributing to project delays. In addition to quantitative analysis, qualitative information was obtained through site observations and semi-structured interviews to provide contextual explanations for the measured performance.

The Analyze phase aimed to determine the root causes of project delays by integrating quantitative findings with qualitative evidence. Pareto analysis was first applied to identify the most significant operational problems requiring further investigation. Subsequently, the Current Reality Tree (CRT), based on the Theory of Constraints, was developed to map the causal relationships among undesirable effects and identify the core problem responsible for recurring project delays. The CRT structure and causal logic were then validated through a Focus Group Discussion (FGD) involving six stakeholders representing project management, project planning and control, engineering, quality assurance, site supervision, and project operations. The FGD ensured that the identified root causes accurately reflected actual project conditions before improvement alternatives were formulated. The CRT was further validated by checking the causal links against project records and through structured stakeholder discussions. AHP judgments were obtained from six experts selected based on their direct responsibilities or experience in project planning and control, engineering, site supervision, quality, and project management. Pairwise-comparison consistency was evaluated using the Consistency Ratio (CR); only judgments meeting the conventional CR threshold of 0.10 or lower were retained for prioritization. Focus Group Discussion (FGD), Supplier–Input–Process–Output–Customer (SIPOC), Project Planning and Control (PPC), CRT, and AHP were introduced at first use and applied consistently thereafter.

Based on the validated root causes, three improvement alternatives were developed using Lean Construction principles: Progress-Based Productivity Management, Installation Readiness Gate with Constraint Heatmap Planning, and Progressive Installation Inspection. These alternatives were designed to address the identified operational deficiencies related to workforce productivity, work readiness, workflow stability, and installation quality. To determine the implementation priority, the alternatives were evaluated using the Analytic Hierarchy Process (AHP). Pairwise-comparison questionnaires were completed by six experts selected according to their experience and responsibilities in project execution. The evaluation considered four decision criteria: implementation feasibility, implementation cost, expected impact on project performance, and implementation sustainability. Consistency Ratio (CR) values of less than 0.10 were used to verify the reliability of the expert judgments before calculating the final priority weights.

Finally, the AHP results were used to determine the implementation sequence of the proposed improvement initiatives rather than to select a single standalone solution. The implementation roadmap begins with the Installation Readiness Gate with Constraint Heatmap Planning as the first-phase initiative to establish work readiness and stabilize the project workflow. Once this foundation is in place, Progress-Based Productivity Management is introduced to improve workforce productivity and monitor operational performance. The final phase implements Progressive Installation Inspection to strengthen installation quality control

and minimize corrective activities and rework. Together, these three complementary initiatives form an integrated Project Control Framework that strengthens planning reliability, improves project execution, and enhances overall project performance. The framework also incorporates implementation feasibility assessment, risk management, key performance indicators, and an implementation roadmap to support practical adoption at PT Ubinkayu Indonesia.

RESULTS AND DISCUSSION

Results

Analysis

The results of this study are presented according to the Define–Measure–Analyze (DMA) phases adopted in the research methodology. Following the identification of the project performance issue, an analysis was conducted to determine the critical process contributing to the overall project delay. The selected process was subsequently evaluated using operational performance indicators, followed by root cause analysis and the prioritization of improvement initiatives for developing the proposed Project Control Framework.

Define Phase

The Define phase is the initial stage of the DMAIC framework, aimed at defining the problem, establishing the research scope, and identifying the specific process targeted for improvement. This research focuses on project delays occurring in residential projects at PT Ubinkayu Indonesia. Project PRJ-155 Surabaya experienced a significant schedule delay, with actual project progress reaching only 44.24% compared with the planned completion of 100%, resulting in a schedule deviation of 55.76%. This delay reduced project revenue realization and increased the potential for contractual penalties, indicating that project performance had deviated substantially from the planned schedule. In addition, company revenue performance during the 2023–2025 period consistently remained below the planned target. In 2025, the company generated approximately IDR 80.5 billion against the planned target of IDR 82.0 billion, resulting in an unrealized revenue gap of approximately IDR 1.5 billion. These findings confirmed that project delays had become a significant operational and business issue requiring further investigation.

To determine the primary source of project delays, an analysis of the major work packages within Project PRJ-155 was conducted. The comparison showed that the door installation process contributed the largest proportion of schedule deviation and had the greatest impact on overall project completion. Unlike other work packages, door installation was highly dependent on work area readiness, coordination with preceding construction activities, and continuous workflow during field execution. Consequently, disruptions occurring during door installation frequently propagated to subsequent project activities, amplifying the overall project delay. Based on these findings, the remainder of the analysis focused specifically on the door installation process, as it represented the critical process with the greatest influence on project performance.

SIPOC Diagram

The SIPOC (Supplier, Input, Process, Output, Customer) diagram is used to map the end-to-end workflow for Teak Doors spanning from suppliers and project inputs to on-site installation and the final output received by the customer. This mapping reveals a high level of activity interdependence within the actual conditions of the site work area.

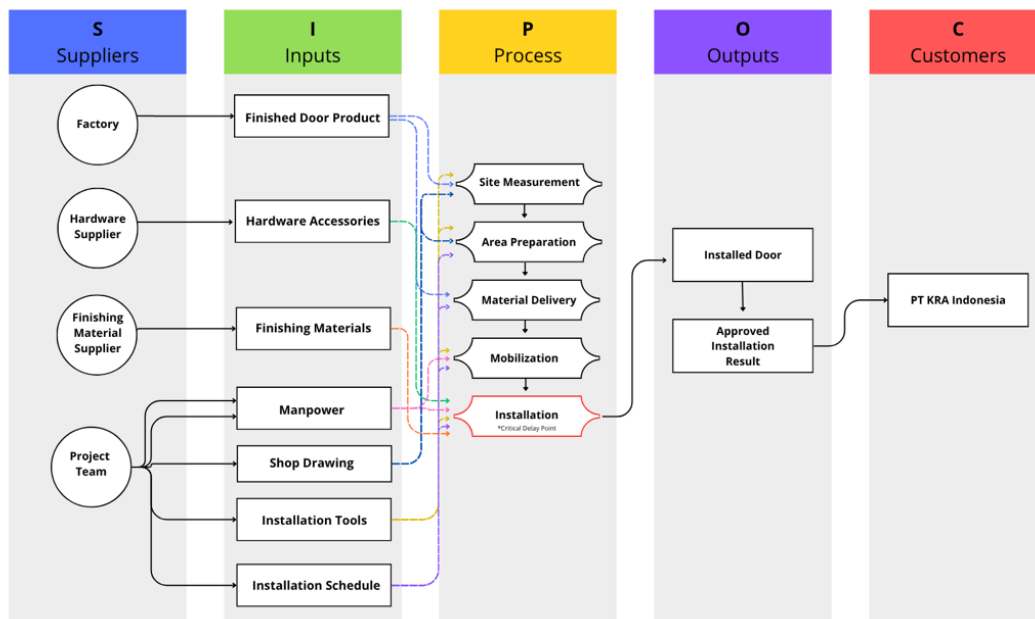


Figure 1. SIPOC Diagram

Based on the mapping results in figure 1, the installation process has been identified as a critical delay point, as it serves as the integration hub for various inputs and subsequent work activities. This indicates that the installation process has the most significant impact on project progress delays compared to other processes.

Door Installation Process Flow

To understand the process flow in greater detail, the workflow for door installation was mapped out, covering everything from the initial measurement stage to the final finishing and on-site protection of the doors. Door installation process flow will visualize by figure IV.5 below.

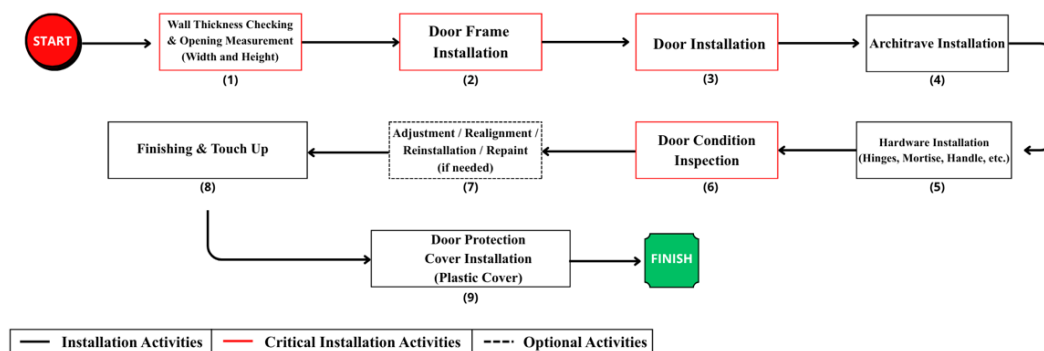


Figure 2. Door Installation Process Flow

Figure 2 illustrates the door installation process flow, spanning from the initial area measurement stage to the installation of final door protection on-site. This process map is used to visualize and fully understand the actual workflow of door installation, as well as to identify process stages where deviations from ideal conditions might occur. The process begins with checking wall thickness and opening dimensions, followed by the installation of the frame, door leaf, architrave, and hardware, as well as finishing, quality inspection, and the installation of final protection. If any non-conformities are detected during inspection, corrective actions such as adjustments, repairs, or re-installation are carried out before the work proceeds to the next stage.

Measure Phase

The Measure phase aims to quantitatively evaluate the current operational performance of the PRJ-155 project by measuring the extent of schedule deviations and the effectiveness of project execution during the door installation process.

Workforce Performance

Following the overall project performance assessment, this study evaluates workforce performance during the door installation process to determine how effectively available labor resources are converted into completed door installations.

Table 1

Workforce Capacity Calculation Based on Available Man-Hours

Period	Workers	Working Hours	Working Days	Project Duration	Available Manhours
Week 1-6	4 workers	8 hours	7 days	6 weeks	1.344 manhours
Week 7-13	8 workers	8 hours	7 days	7 weeks	3.136 manhours
Total AM					4.480 manhours

Based on Table 1, the total available man-hours during the observation period amounted to 4,480 man-hours, this figure comprises 1,344 man-hours from Week 1 through Week 6 with a workforce of four, and 3,136 man-hours from Week 7 through Week 13 following an increase in the workforce to eight personnel. This increase in workforce size resulted in a significant rise in available man-hour capacity during the second half of the project execution period. While these available man-hours represent the maximum labor capacity for installation work during the observation period, the figure alone does not indicate the effectiveness of their utilization in generating work output. Therefore, a labor productivity analysis is required to evaluate the extent to which the allocated man-hours were successfully converted into the completion of door installation work in accordance with project targets.

Project Performance

To evaluate planning reliability across the critical door installation activities, the planning instability ratio was calculated for each teak door type included in Project PRJ-155. This assessment compares the number of planned installations with the actual execution sequence to determine the extent of workflow deviations occurring during project implementation. The results are presented in Table 2.

Table 2

Workflow Planning Recapitulation of Both Teak Door

Door Type	Amount of Door	Planning Instability Ratio
Teak Door 2,85	22 Units	72.73%
Teak Door 2,59	7 Units	100%

As presented in Table 2, both teak door types experienced a high level of planning instability throughout the installation process. Teak Door 2.85, which accounted for 22 installation units, recorded a planning instability ratio of 72.73%, indicating that nearly three-quarters of the planned installation activities experienced sequence changes or reprioritization during execution. Meanwhile, Teak Door 2.59, consisting of 7 installation units, recorded a planning instability ratio of 100%, meaning that every planned installation activity deviated from the original installation sequence.

To further assess installation quality performance, the rework intensity and rework rate were analyzed for each teak door type included in Project PRJ-155. These indicators were used to measure the frequency of corrective work required during installation and the proportion of installed doors that required rework before achieving the expected installation quality. The results are summarized in Table 3.

Table 3

Workflow Planning Recapitulation of Both Teak Door

Door Type	Amount of Door	Rework Intensity	Rework Rate
Teak Door 2,85	22 Units	1,18	68.18%
Teak Door 2,59	7 Units	1,14	57.14%

As shown in Table 3, both teak door types exhibited a high level of rework throughout the installation process. Teak Door 2.85, which comprised 22 installation units, recorded a rework intensity of 1.18 and a rework rate of 68.18%, indicating that more than two-thirds of the installed units required corrective work during execution. Similarly, Teak Door 2.59, consisting of 7 installation units, recorded a rework intensity of 1.14 and a rework rate of 57.14%, showing that over half of the installed units also required rework before completion.

Analyze Phase

Stakeholder Analysis

Stakeholder identification was conducted to determine the parties involved in the PRJ-155 door installation project and to evaluate their respective roles, levels of interest, and decision-making authority. This assessment provides an understanding of each stakeholder's influence on project planning, execution, quality control, and overall project performance. The identified stakeholders and their corresponding power-interest assessment are presented in Table 4.

Table 4

Stakeholder Roles and Power-Interest Classification

No	Stakeholder	Roles	Interest	Power
1	PPC Department (Project Planning and Control)	Developing project schedules, installation work plans, monitoring progress, and coordinating workflow planning.	High	High
2	Project Engineering Team	Preparing shop drawings, technical specifications, installation details, and providing technical support to ensure constructability during installation	High	Medium
3	Site Supervisor	Supervising daily door installation activities, coordinating workforce deployment, ensuring adherence to workflow planning, monitoring installation productivity, and resolving field execution issues	High	High
4	Workforce	Executing door installation activities in accordance with project work instructions and site supervision.	Medium	Low
5	Quality Control (QC) Team	Conducting installation quality inspections, identifying non-conformities, verifying corrective actions, and ensuring compliance with project quality standards.	High	Medium
6	Project Manager	Directing overall project execution, allocating project resources, making strategic decisions, and ensuring project objectives related to cost, schedule, and quality are achieved.	High	High

Table 4 identifies the stakeholders involved in the PRJ-155 door installation project based on their roles, level of interest, and decision-making authority. The results indicate that the Project Manager, PPC Department, and Site Supervisor are the primary stakeholders with high power and high interest, while the Project Engineering Team and QC Team provide technical and quality support with moderate decision-making authority. The Workforce primarily functions as the project executor with limited influence on planning and strategic decisions. The stakeholder

assessment provides the basis for stakeholder mapping and the selection of respondents for the subsequent analysis.

Undesirable Effect Identification

The identified issues were subjected to a clustering process based on similar characteristics. The clustering results indicate that the majority of operational issues can be grouped into three primary "undesirable effects" representing the dominant problems encountered during the installation phase.

UDE 1: Low Workforce Productivity

To evaluate the extent of workforce productivity issues during the installation process, several performance indicators were measured based on project records and field observation data. The summary of the workforce performance measurement results is presented in Table 5

Table 5

Summary of Workforce Performance Measurement Results

Indicator	Current Result	Interpretation
Available Manhours	4,480 MH	Total available labor capacity during the 13-week installation period.
Target Labor Productivity	0.00647 door/MH	Target productivity required to complete all 29 doors within the available manhours.
Actual Labor Productivity	0.00268 door/MH	Actual labor productivity achieved during the observation period.
Workforce Efficiency Ratio	41.38%	Only 41.38% of the planned installation output was completed.
Workforce Productivity Index	0.414	Actual productivity reached only 41.4% of the expected productivity level.
Workforce Productivity Loss	58.60%	Approximately 58.6% of the available labor capacity was not converted into completed installation output.

As summarized in Table 5, the workforce performance indicators consistently demonstrate that available labor resources were not effectively converted into installation output. Although a total of 4,480 available man-hours were provided during the 13-week installation period, the actual labor productivity reached only 0.00268 door/MH, equivalent to 41.4% of the expected productivity level. Consequently, workforce productivity loss reached 58.6%, indicating substantial underutilization of available labor capacity. These quantitative findings are further supported by field observations, which revealed several non-value-added activities and operational inefficiencies during the installation process.

UDE 2: Low Workflow Stability

To evaluate workflow stability during the door installation process, the planned installation sequence was compared with the actual sequence implemented in the field. Workflow stability was assessed by identifying planning deviations, including sequence changes and task reprioritization, that occurred during project execution. The summary of workflow planning performance for each door type is presented in Table 6.

Table 6

Workflow Planning Recapitulation of Teak Door of PRJ-155

Door Type	Total Unit	According to plan	Planning Deviation	Planning Instability Ratio
Teak Door 2.85	22	6	16	72.73%
Teak Door 2.59	7	0	7	100.00%

From Table 6, both the teak door 2.85 and teak door 2.59 units exhibited high levels of planning deviation. In fact, every single unit of the teak door 2.59 underwent changes relative to the initial plan. This indicates that the low workflow stability stemmed from an inability to

maintain the planned work sequence during project execution, regardless of whether or not the units required corrective actions.

UDE 3: Low Installation Process Capability

Installation process capability was evaluated to determine the ability of the door installation process to consistently achieve first-time-right installation. The assessment was performed by analyzing the proportion of units requiring rework and the intensity of corrective activities performed during installation. The summary of the rework analysis for each door type is presented in Table 7.

Table 7

Rework Activities Recapitulation Teak Door of PRJ-155

Door Type	Total Unit	Units with CA	Rework Door Ratio	Total Rework Activity	Rework Activity Intensity
Teak Door 2.85	22	15	68.18%	26	1.18
Teak Door 2.59	7	4	57.14%	8	1.14

Table 7 shows the analysis results, indicate that both door types exhibit low installation process capability, evidenced by a high proportion of units requiring rework and an average rework frequency exceeding one incident per unit. However, the Teak Door 2.85 presents a more critical situation than the Teak Door 2.59, reflected in both its Rework Door Ratio (72.73%) and Rework Activity Intensity (1.18). These findings demonstrate that the installation process fails to consistently achieve "first-time-right" installations that meet specifications.

Rootcause Analysis

The results identified three dominant Undesirable Effects (UDEs): low workforce productivity, low workflow stability, and low first-time-right installation success. Together, these three issues represented the largest proportion of operational losses observed during the door installation process and therefore became the primary focus of further analysis. To determine the causal relationships among these operational issues, a Current Reality Tree (CRT) was developed based on the Theory of Constraints. The analysis revealed that the identified undesirable effects were interconnected and originated from common underlying operational causes rather than occurring independently.

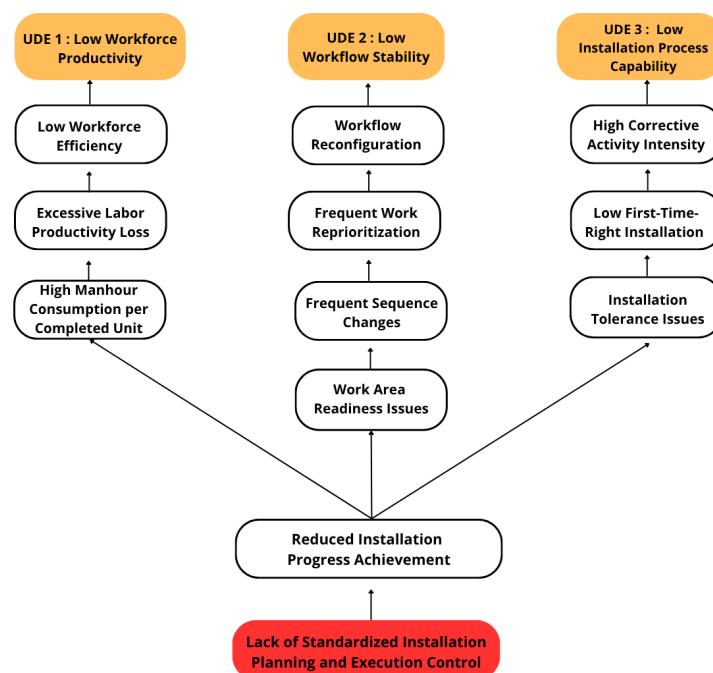


Figure 3. Current Reality Tree

Based on the figure 3, the CRT demonstrated that project delays were primarily associated with the absence of a structured project control mechanism capable of ensuring work readiness before installation activities commenced. Consequently, installation work frequently started under constrained site conditions, resulting in workflow disruptions, repeated workforce relocation, unstable installation sequences, excessive corrective activities, and declining labor productivity. The proposed causal relationships were subsequently validated through a Focus Group Discussion (FGD) involving six company stakeholders, confirming that the CRT accurately represented the operational conditions encountered during Project PRJ-155.

Discussion

The proposed framework remains a design output rather than an implemented intervention. Its three controls are analytically linked to the identified wastes and root causes, but their effects on time, cost, quality, and productivity have not yet been measured after deployment. Accordingly, all performance implications are stated as potential or expected effects that require longitudinal implementation and post-intervention evaluation.

The dominance of work readiness is theoretically consistent with Lean Construction's emphasis on reliable workflow and constraint removal. Manpower and technology affect execution capacity, but they cannot generate flow when prerequisite conditions—approved drawings, completed preceding work, accessible work areas, materials, and inspection readiness—remain unresolved. In this case, the readiness constraint therefore operates upstream of labor productivity: unstable release of executable work creates waiting, reallocations, and corrective activity even when nominal labor capacity is available.

Business Solution

This subsection presents a proposed business solution to address the primary root cause of delays in the teak door installation work for the PRJ-155 Surabaya project.

Current Condition

Before formulating alternative business solutions, it is essential to first understand the project's overall current condition to establish a basis for defining the scope of improvements. The project's current status is outlined based on measurements taken during the "Define" phase, providing a comprehensive overview of PRJ-155's performance specifically regarding schedule adherence, project productivity, and financial performance. This presentation aims to demonstrate the project's performance decline, characterized by delayed completion, low productivity, and deviations from project targets. A summary of the project's overall current condition is presented in Table 8.

Table 8

Current Condition of PRJ-155 Project Performance (Whole Project)

Performance Dimension	Indicator	Current Result	Unit	Interpretation
Project Schedule Performance	Schedule Performance Index (SPI)	0.44	Index	The project achieved only 44% of the planned work during the evaluation period, indicating that project execution was substantially behind schedule.
	Schedule Variance (SV)	-55.76	%	Actual project progress remained 55.76% below the planned completion target, indicating significant schedule deviation.
	Delay Percentage	77.11	%	The projected delay reached 91 days, equivalent to 77.11% of the contractual duration, indicating a high risk of late project completion.
	Potential delay	91	days	Penalty exposure must be calculated from contract value, not assumption.

Performance Dimension	Indicator	Current Result	Unit	Interpretation
Project Productivity	Project Productivity Loss	42.66	%	The overall project productivity was considerably lower than the productivity required to achieve the contractual completion target.
Project Financial Performance	Cost Variance (CV)	- Rp1,095,601,826	Rupiah	The realized value of completed work remained substantially below the planned contract value, indicating significant project performance deviation.
	Potential loss	Rp178,788,428	Rupiah	Penalty based on 0.1% x contract value x delay days.

Based on table 8 that detailed the project-level measurements, PRJ-155 shows performance falling below targets across nearly all key indicators. An SPI of 0.44, a Schedule Variance of -55.76%, a Delay Percentage of 77.11%, and a Project Productivity Loss of 42.66% indicate that the project is experiencing significant delays. Furthermore, the negative Cost Variance suggests that the value of completed work remains far below the planned contract value. These findings indicate an overall decline in project performance, necessitating further identification of the specific activities contributing most significantly to the delays.

Based on the current condition at the project level, it can be concluded that PRJ-155 is experiencing a decline in performance, characterized by delayed completion, low project productivity, and deviations from schedule and work value targets. However, this assessment reflects the project's aggregate performance and does not yet pinpoint the specific activities primarily responsible for the delays. Consequently, the scope of the discussion focuses on the work elements contributing most significantly to the project delay. Based on the Pareto analysis conducted in the previous stage, procurement and door installation tasks were identified as the activities contributing most significantly to the delay of PRJ-155. Accordingly, the current condition is subsequently presented with a specific focus on the door installation process, serving as the basis for formulating alternative business solutions.

Table 9

Current Condition of Door Installation Process Performance (PRJ 155)

Performance Dimension	Indicator	Current Result	Unit	Interpretation
Door Installation Performance	Teak Door 2.85m completion rate	40.91	%	Only 9 of 22 units completed, progress remains constrained.
	Teak Door 2.59m completion rate	42.86	%	Only 3 of 7 units completed, similar installation disruption occurs.
	Overall door completion rate	41.38	%	Only 12 of 29 doors completed, installation progress is still low
Workforce Performance	Available Manhours	4,480	MH	Total labor capacity allocated for the observed door installation activities during the 13-week observation period.
	Target Labor Productivity	0.00647	Door/MH	Minimum productivity required to complete all planned door installation activities within the available

Performance Dimension	Indicator	Current Result	Unit	Interpretation
				labor capacity.
	Actual Labor Productivity	0.00268	Door/MH	Actual labor productivity remained substantially below the required productivity level.
	Labor Requirement (Target)	154.6	MH/Door	Target labor consumption required to complete one installed door.
	Labor Requirement (Actual)	373.3	MH/Door	Actual labor consumption per installed door was more than twice the planned requirement.
	Workforce Efficiency Ratio	41.38	%	Only 41.38% of the planned installation output was completed during the observation period.
	Workforce Productivity Index	0.414	Index	Actual workforce productivity achieved only 41.4% of the expected productivity target.
	Workforce Productivity Loss	58.60	%	More than half of the available workforce productivity potential was not converted into completed installation output.
Workflow Performance	Planning Instability Ratio (Teak Door 2.85)	72.73	%	Most installation activities deviated from the original work sequence.
	Planning Instability Ratio (Teak Door 2.59)	100.00	%	Every observed unit experienced changes from the original installation plan.
Installation Quality Performance	Rework Activity Intensity	PJ-2,85 : 1,18 PJ,259 : 1,14 PJ2,59 : 57.14	Activity/Unit	Nearly one corrective activity was required for every installed door, indicating frequent field adjustments.
	Rework Rate	PJ-2,85 : 68.18	%	Approximately one-third of the installed door units required reinstallation before completion.

Table 9 indicates that the door installation process exhibited unsatisfactory performance across all evaluated dimensions. From the project performance perspective, the overall door completion rate reached only 41.38%, indicating that less than half of the planned installation work had been completed. From the workforce performance perspective, actual labor productivity achieved only 41.4% of the required target, resulting in a productivity loss of 58.60% and significantly higher labor consumption than planned. In addition, workflow performance was characterized by substantial planning instability, with planning instability ratios of 72.73% for Teak Door 2.85 and 100% for Teak Door 2.59, reflecting frequent deviations from the planned installation sequence. Furthermore, installation quality performance showed high rework intensity and rework rates in both door types, indicating that corrective work occurred repeatedly throughout project execution. Overall, these findings demonstrate that the project delay was associated with interconnected deficiencies in project execution, workforce utilization, workflow stability, and installation quality, providing the basis for the subsequent root cause analysis.

Lean Construction**Lean Waste Identification**

Lean Construction classifies activities that do not add value into eight categories of waste. However, not all these categories are present in the PRJ-155 door installation process. Based on field observations, productivity analysis, workflow analysis, corrective activity analysis, and the Current Reality Tree (CRT), this study identifies five types of waste that predominantly contribute to the poor operational performance of the door installation process: waiting, motion, unused talent, defects, and overprocessing. These five types of waste were selected because they directly affect labor productivity, workflow stability, installation quality, and the time required to complete the work.

Table 10*Identification of Lean Waste in the PRJ-155 Door Installation Process*

Lean Waste	Evidence in PRJ-155	Current Condition	Impact
Waiting	The workforce waits for the area to be ready, for preliminary work to be completed, or for implementation decisions.	Planning Instability Ratio by 72.73% of PJ,285 and 100% of PJ,259 sequence changes, and work reprioritization.	Idle time increases and project productivity declines.
Motion	Labor reallocation between areas due to changes in work priorities.	Both of door faced Sequence change by 17 activities and reprioritization by 6 activities during installation process	Effective working time is reduced, and the workflow is disrupted.
Unused Talent	Labor productivity is not yet optimal, despite the availability of man-hour capacity. Many workers are still observed engaging in unnecessary activities while work is in a "work available" status.	Actual Labor Productivity 0,00268 door/MH, Workforce Productivity Loss 58,60%	Labor utilization is not optimal.
Defects	Rework activities are frequently encountered.	Rework rate of 68.18% for PJ2.85 and 57.14% for PJ-2.59, with rework intensities of 1.18 and 1.14.	Extend the duration of the work
Overprocessing	Repeated inspections and adjustments were carried out due to work discrepancies.	Rework activity was identified on 34 occasions across several installation stages.	Activity increases without yielding new progress.

Source: Author's analysis results

Table 10 indicates that multiple types of Lean waste were consistently observed throughout the PRJ-155 door installation process. Waiting and motion waste were primarily caused by unstable work sequencing and frequent changes in installation priorities, resulting in workflow interruptions and reduced labor efficiency. Unused talent was reflected in the low workforce productivity despite sufficient labor capacity, indicating that available human resources were not fully utilized. In addition, high rework rates and repeated corrective activities demonstrated the presence of defects and overprocessing, which prolonged installation time without adding value. Overall, these findings confirm that non-value-added activities significantly reduced workforce performance and contributed to project delays, highlighting the need for a more structured project control system to improve workflow stability and eliminate operational waste.

Selection of Lean Construction Practices

Based on the identification of waste, this study establishes two Lean Construction practices Visual Management and Standardization as the foundation for developing a business solution. Visual Management was selected for its ability to enhance transparency regarding work area readiness, thereby reducing waste associated with waiting and motion. Meanwhile, Standardization was chosen to minimize work process variations that lead to unused talent, defects, and overprocessing through the consistent implementation of work procedures, monitoring mechanisms, and inspections.

Table 11

Mapping Lean Waste into Lean Construction Practices

Lean Waste	Lean Construction Practice	Basis of Election
Waiting	Visual Management	Provides visual information regarding area readiness, ensuring that work is released only when all prerequisites have been met
Motion	Visual Management	Reduce labor turnover by clarifying work locations that are ready for execution and avoiding excessive initial planning failures
Unused Talent	Standardization	Standardize productivity monitoring mechanisms so that working time is utilized more effectively
Defects	Standardization	Standardize execution and inspection processes to reduce rework
Overprocessing	Standardization	Standardize the inspection process so that repeated adjustments can be minimized

Based on Table 11, mapping results indicate that most of the identified waste can be addressed through two Lean Construction practices are Visual Management and Standardization. These practices complement each other. Visual Management enhances the clarity of operational information prior to the execution of work, while Standardization ensures that processes follow consistent procedures, thereby reducing execution variability. Consequently, these selected Lean Construction practices serve as the foundation for formulating improvement alternatives in this study.

Proposed Solution Development

Based on the results of mapping lean waste against Lean Construction Practices, this study develops three complementary improvement alternatives. Each alternative is designed to address a specific category of waste, aligning with the root causes identified during the "Analyze" phase. Consequently, the proposed alternatives do not function as standalone solutions but rather as components of an operational control system aimed at enhancing labor productivity, improving workflow stability, and reducing corrective activities during project execution.

Table 12

Relationship Between Lean Waste, Lean Construction Practices, and Proposed Solutions

Lean Waste	Problem Identified	Lean Construction Practice	Proposed Solution	Primary Objective
Unused Talent	There is no standardized mechanism for monitoring and evaluating labor productivity.	Standardization	Alternative 1 – Progress-Based Productivity Management System	Enhance the effectiveness of workforce utilization through periodic monitoring and evaluation of productivity.

Lean Waste	Problem Identified	Lean Construction Practice	Proposed Solution	Primary Objective
Waiting	The work area does not yet meet all requirements prior to the commencement of work.	Visual Management	Alternative 2 – Installation Readiness Gate with Constraint Heatmap Planning	Ensuring work is released only to areas that are truly ready, thereby reducing waiting times and preventing planning failures from the outset. Maintaining workflow stability by minimizing workforce reassignments resulting from changes in work priorities.
Motion	Changes in work priorities led to the movement of personnel between areas.	Visual Management	Alternative 2 – Installation Readiness Gate with Constraint Heatmap Planning	
Defects	Variations in the installation process resulted in the work failing to meet specifications during the initial installation.	Standardization	Alternative 3 – Progressive Installation Inspection	Improve work quality consistency to achieve first-time-right installation.
Overprocessing	Repeated inspections and adjustments were carried out due to discrepancies in the work results.	Standardization	Alternative 3 – Progressive Installation Inspection	Reduce non-value-added inspection and adjustment activities through phased inspections.

From Table 12 known that, each proposed improvement alternative was designed to eliminate a specific category of lean waste identified during the analysis phase. Alternative 1 (Progress-Based Productivity Review) addresses the waste of unused talent by improving labor productivity through standardized performance monitoring. Alternative 2 (Installation Readiness Gate with Constraint Heatmap Planning) targets waiting and motion waste by ensuring that only fully prepared work areas are released for installation, thereby improving workflow stability. Alternative 3 (Progressive Installation Inspection) focuses on reducing defects and overprocessing by implementing staged quality inspections that minimize rework and ensure first-time-right installation. Collectively, these alternatives form an integrated Lean Construction-based project control framework to improve planning reliability, productivity, and quality performance.

Improvement Alternatives and Prioritization

Following the development of the proposed Project Control Framework, an Analytical Hierarchy Process (AHP) evaluation was conducted to determine the logical implementation sequence of its three control mechanisms. These judgments are commonly made using Saaty's fundamental scale, which ranges from 1 to 9 to represent the relative importance between elements, although other rating scales may also be used depending on the nature of the decision problem (Kuo & Chen, 2023; Saaty, 1987). The prioritization considered the relative importance

of penalty impact, cost efficiency, and implementation feasibility, producing the composite scores and final rankings shown in Table 13.

Table 13

AHP Composite Score and Final Scenario Ranking

Scenario	C1 Penalty Impact (w=0.539)	C2 Cost Efficiency (w=0.164)	C3 Feasibility (w=0.297)	Composite Score	Rank
S1 Productivity Review	0.260	0.623	0.557	0.408	2nd
S2 Readiness Gate & Heatmap	0.633	0.239	0.123	0.417	1st
S3 Progressive Inspection	0.106	0.137	0.320	0.175	3rd

Based on Table 13, the proposed improvement initiatives were evaluated using the Analytical Hierarchy Process (AHP) to determine their implementation sequence. The evaluation identified Installation Readiness Gate with Constraint Heatmap Planning as the first implementation priority because establishing work readiness and eliminating project constraints before installation activities begin provides the necessary foundation for subsequent improvements. Progress-Based Productivity Management was ranked as the second priority to strengthen workforce performance monitoring and improve productivity control during project execution. Finally, Progressive Installation Inspection was identified as the third implementation priority to reinforce installation quality control, minimize corrective activities and rework, and sustain the improvements achieved during earlier implementation stages. Rather than representing independent or competing solutions, the AHP results establish a logical implementation sequence in which each initiative serves as a prerequisite for the effectiveness of the next. Collectively, these three complementary initiatives constitute the proposed Project Control Framework, providing a systematic and integrated approach to improving project execution, workforce performance, workflow stability, and overall project performance.

Intersection with Human Resources Management

S1 – Progress-Based Productivity Management System

Alternative 1 introduces the Progress-Based Productivity Management System to improve workforce productivity through standardized monitoring and continuous performance evaluation. Supported by Goal-Setting Theory, the system integrates clear productivity targets, regular communication, performance reviews, and coaching to strengthen workforce commitment and accountability. The proposed work programs such as Daily Productivity Briefing, Crew Skill Matrix, Weekly Productivity Review, and Weekly Coaching Review. Form a continuous improvement cycle that enhances labor productivity, workforce efficiency, and productive man-hour utilization while reducing productivity losses through consistent implementation and feedback.

S2 – Installation Readiness Gate with Constraint Heatmap Planning

Alternative 2 proposes the Installation Readiness Gate with Constraint Heatmap Planning to improve planning reliability and workflow stability by ensuring that installation activities begin only when all prerequisite conditions have been satisfied. Supported by Ability–Motivation–Opportunity (AMO) Theory, the system strengthens personnel competence, commitment, and collaboration through readiness briefings, competency assessments, weekly review meetings, and structured constraint resolution. These initiatives are expected to reduce waiting, unnecessary motion, work reprioritization, and sequence changes while improving planning reliability and ensuring consistent implementation of the readiness gate process.

S3 – Progressive Installation Inspection

Alternative 3 implements Progressive Installation Inspection to improve installation quality and minimize rework through staged inspections at critical installation milestones. Integrated with Training Transfer Theory, the approach ensures that Standard Work Instructions are not only understood but also consistently applied through pre-work briefings, on-site

coaching with inspection feedback, and weekly quality reviews. This systematic quality control process is expected to reduce rework intensity and rework rates, improve first-time-right installation, and reinforce the continuous transfer of knowledge into daily work practices through consistent implementation and evaluation.

CONCLUSION

The PRJ-155 delay was primarily associated with the absence of a structured mechanism for releasing installation work only after readiness constraints had been satisfied. The analysis linked this weakness to planning instability, waiting, labor underutilization, corrective activities, and rework. Based on DMA, Lean Construction, CRT, and AHP, the study formulated an integrated Project Control Framework comprising progress-based productivity management, an Installation Readiness Gate with constraint heatmap planning, and progressive installation inspection; the readiness-gate alternative received the highest implementation priority.

The framework should be understood as a validated analytical recommendation rather than evidence of realized performance improvement because the study did not include implementation and post-improvement measurement. Its contribution lies in integrating readiness, workflow, workforce, and quality controls for make-to-order installation projects. Future research should implement the framework longitudinally, measure changes in schedule, cost, quality, and labor productivity, and test its transferability across construction projects with different scopes and organizational conditions.

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AUTHOR CONTRIBUTION STATEMENT

Mahesa Hamisena contributed to the conceptualization, research design, data collection, data analysis, development of the Lean Construction-based Project Control Framework, and preparation of the original manuscript. Akbar Adhi Utama contributed to research supervision, methodological validation, critical review, and refinement of the manuscript. Both authors contributed to the interpretation of findings, discussion development, manuscript revision, and approved the final version of the article for publication.

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