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APPLICATION OF LEAN CONSTRUCTION PRINCIPLES TO IMPROVE PROJECT EFFICIENCY AND REDUCE COSTS: A CASE STUDY OF AN INDONESIAN CONSTRUCTION CONTRACTOR

PENERAPAN PRINSIP-PRINSIP *LEAN CONSTRUCTION* UNTUK MENINGKATKAN EFISIENSI PROYEK DAN MENGURANGI BIAYA: STUDI KASUS PADA KONTRAKTOR KONSTRUKSI DI INDONESIA

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ABSTRACT
This study demonstrates that the integrated application of Lean Construction principles-specifically the Last Planner System (LPS), Value Stream Mapping (VSM), and 5S-can effectively address systemic inefficiencies in project delivery processes at PT AKN, a large Indonesian construction contractor. The action research intervention across four priority projects yielded measurable improvements: plan reliability increased from 60.9% to 74.5% through LPS implementation, end-to-end lead times reduced by 16.1% (4.0 days average) through VSM process redesign, and material waste decreased from 5.64% to 2.63% through 5S workplace organization. These operational improvements translated into quantified cost savings of IDR 1,237,700,000 across the evaluation window, distributed across preliminaries, material waste reduction, rework reduction, and overtime savings. Stakeholder perceptions strongly validated these findings, with 82-84% agreement on improvements in schedule reliability, reduced waiting time, and enhanced cost control. The results confirm that disciplined application of collaborative planning, flow management, and workplace organization principles can mitigate chronic schedule delays, cost overruns, and site-level waste in Indonesian construction contexts, providing actionable insights for contractors facing similar challenges.
Keywords: *Lean Construction; Last Planner System; Value Stream Mapping*

ABSTRAK
Penelitian ini menunjukkan bahwa penerapan terintegrasi prinsip-prinsip *Lean Construction*—khususnya *Last Planner System* (LPS), *Value Stream Mapping* (VSM), dan 5S—dapat secara efektif mengatasi inefisiensi sistemik dalam proses pelaksanaan proyek di PT AKN, sebuah perusahaan kontraktor konstruksi besar di Indonesia. Intervensi penelitian tindakan pada empat proyek prioritas menghasilkan peningkatan yang terukur: keandalan rencana meningkat dari 60,9% menjadi 74,5% melalui penerapan LPS, waktu siklus (*lead time*) keseluruhan berkurang sebesar 16,1% (rata-rata 4,0 hari) melalui perancangan ulang proses menggunakan VSM, dan limbah material menurun dari 5,64% menjadi 2,63% melalui penataan tempat kerja berbasis 5S. Peningkatan operasional ini menghasilkan penghematan biaya terukur sebesar Rp1.237.700.000 selama periode evaluasi, yang mencakup penghematan pada biaya persiapan (*preliminaries*), pengurangan limbah material, pengurangan pengerjaan ulang (*rework*), dan penghematan biaya lembur. Persepsi pemangku kepentingan sangat mendukung temuan ini, dengan tingkat kesepakatan 82–84% mengenai peningkatan keandalan jadwal, pengurangan waktu tunggu, dan pengendalian biaya yang lebih baik. Hasil penelitian ini mengonfirmasi bahwa penerapan prinsip perencanaan kolaboratif, manajemen aliran kerja, dan penataan tempat kerja secara disiplin dapat memitigasi keterlambatan jadwal yang kronis, pembengkakan biaya, dan pemborosan di lokasi proyek dalam konteks konstruksi Indonesia, serta memberikan wawasan praktis bagi kontraktor yang menghadapi tantangan serupa.
Kata kunci: *Lean Construction*; *Last Planner System*; *Value Stream Mapping*

INTRODUCTION

The construction sector represents a cornerstone of the global economy, with annual spending on construction-related goods and services estimated at approximately USD 10 trillion, accounting for roughly 13% of global GDP and employing about 7% of the world's workforce (McKinsey Global Institute, 2017; McKinsey & Company, 2020). Despite this strategic importance, the industry has been persistently characterized by significant productivity gaps, frequent schedule and cost overruns, and elevated levels of rework and material waste when compared to other sectors. These global patterns indicate that conventional project planning and control practices often fail to translate planned performance into reliable execution, creating a structural gap between intended and actual outcomes at the project level. In Indonesia, the construction sector serves as a key pillar of national development, supporting infrastructure programmers, industrial expansion, and the growth of residential and commercial facilities. The sector consistently ranks among the largest contributors to national gross domestic product, accounting for around 9.8-9.9% of GDP in recent years and employing more than 8.7 million people, or close to 6% of the workforce (BPS-Statistics Indonesia, 2024; Widyasanti, 2025). Despite continuous public investment and its strategic role, Indonesian construction projects still frequently encounter schedule slippages, budget deviations, and high levels of material and process waste, mirroring global evidence on underperforming construction portfolios (McKinsey Global Institute, 2017; Ministry of Public Works, 2022).

Within this broader industrial context, PT Anugerah Konstruksi Nusantara (PT AKN), a large Indonesian construction contractor anonymized for confidentiality, exhibits performance patterns broadly consistent with these systemic challenges. Established in 2003, PT AKN has positioned itself as a leading general contractor specializing in toll roads and bridges, dams and water-resources structures, high-rise buildings and apartments, industrial facilities, and additional civil and structural projects. A comprehensive review of a representative sample of 12 completed projects in PT AKN’s 2020-2023 portfolio reveals persistent inefficiencies that threaten the company's competitive position and profitability. The analysis shows that six projects experienced schedule delays ranging from two to four months, with an average delay of approximately three months. Concurrently, four projects recorded cost overruns between 8% and 15%, averaging around 11% on affected contracts and incurring approximately IDR 50 billion of additional cost per project. The most serious deviations were concentrated in high-value, complex projects such as toll roads, bridges, and high-rise residential buildings, which combine large contract values with long durations and intensive coordination requirements. These projects were associated with recurring issues including land acquisition delays, frequent design changes, material waste, rework, and poor-quality control. Although these figures are lower than extreme overruns cited in global benchmarks, they remain material in the context of PT AKN’s competitive domestic market and suggest that recurring delays, cost overruns, and waste are systemic rather than incidental, posing tangible risks to profitability and reputation.

To address such chronic inefficiencies, Lean Construction proposes a production-oriented view of projects that emphasizes value for the client, reliable and continuous flow, and systematic elimination of waste (Koskela et al., 2002; Womack & Jones, 1996). Within this paradigm, three practices are particularly relevant to addressing PT AKN’s documented performance gaps. The Last Planner System (LPS) seeks to stabilize near-term planning and improve commitment reliability through collaborative planning, systematic constraint removal, and enhanced coordination among project stakeholders (Ballard, 2000). This approach directly addresses the schedule unreliability stemming from unprepared work fronts, delayed approvals, and information gaps observed in PT AKN's portfolio. Value Stream Mapping (VSM) is employed to visualize end-to-end process flows, quantify value-adding and non-value-adding time, identify bottlenecks and waste in current processes, and redesign future-state processes with shorter lead times and improved flow (Rother & Shook, 1999). VSM can systematically address the procurement delays, equipment downtime, and coordination issues that contribute to both schedule slippages and cost overruns. The 5S method provides a structured approach to workplace organization and housekeeping through the systematic application of Sort, Set in Order, Shine, Standardize, and Sustain principles to support safe, efficient, and repeatable site execution (Hirano, 1995). This method directly targets the site-level waste, material losses, poorly organized laydown areas, and inadequate housekeeping documented across PT AKN's delayed and over-budget projects.

The integration of LPS, VSM, and 5S offers a comprehensive approach to addressing PT AKN's interrelated performance challenges. Schedule delays, cost overruns, and site-level waste are not isolated phenomena but interconnected manifestations of systemic weaknesses in planning reliability, process flow, and workplace organization. For instance, unreliable planning leads to unprepared work fronts, which in turn generate waiting time and idle resources that increase costs and create conditions for material waste and rework. Similarly, poorly organized construction sites impede efficient material handling and increase the likelihood of defects, which further disrupt schedules and escalate costs through rework and extended durations. This study therefore examines how the integrated application of these three Lean Construction tools can help PT AKN improve project time performance, reduce cost overruns, and minimize site-level waste. Specifically, the research seeks to answer three primary questions: What are the root causes of schedule unreliability, cost overruns, and production waste in PT AKN's projects? How can LPS, VSM, and 5S interventions be designed and aligned to mitigate these identified root causes? What is the observed impact of implementing these interventions on time and cost performance based on pre- and post-implementation project records? By addressing these questions through an Action Research approach, this study aims to collaboratively develop and test process improvements within PT AKN's project delivery environment, providing empirical evidence on the effectiveness of integrated Lean Construction interventions in Indonesian construction context.

This research contributes to both academic knowledge and industry practice by providing empirical evidence on the application of integrated Lean Construction principles in a large Indonesian construction contractor operating in infrastructure and building sectors. While existing literature has documented the individual benefits of LPS, VSM, and 5S in various construction contexts, limited research has systematically examined their integrated implementation within the specific challenges faced by Indonesian contractors, including coordination complexity across multiple subcontractors and suppliers, regulatory constraints, and tight contractual commitments. The study adopts an Action Research methodology because the research objective extends beyond explaining performance problems to collaboratively developing and testing process improvements with practitioners. This approach enables the researcher to work directly with PT AKN's project teams to diagnose issues through triangulated evidence from project records, stakeholder interviews, and on-site observations; co-design Lean interventions aligned to diagnosed root causes using the 5 Whys technique; implement the intervention package in selected high-impact projects; evaluate changes in time and cost performance using pre- and post-implementation comparisons; and reflect with stakeholders to capture lessons learned for wider replication. The research focuses specifically on PT AKN's internal project delivery processes-short-term planning, material and logistics management, and site organization-using performance data from the 2020-2023 baseline period and post-improvement records. By demonstrating how Lean Construction tools can be tailored to mitigate persistent time, cost, and waste issues in PT AKN's operations, this study provides actionable insights for construction practitioners facing similar challenges while contributing to the growing body of knowledge on Lean Construction implementation in emerging market contexts.

RESEARCH METHODS

Research Design

This study employs a single-cycle action research design with an embedded mixed-methods evaluation conducted within PT AKN's project delivery environment. Action research was selected as the most appropriate methodology because the research objectives extend beyond merely explaining performance problems to collaboratively developing and testing process improvements with practitioners in a live project setting. The action research cycle follows five distinct phases: diagnose, plan, act, observe/evaluate, and reflect, enabling the researcher to work directly with project personnel to identify root causes, design interventions, implement Lean Construction practices, and evaluate outcomes using both quantitative project records and qualitative stakeholder feedback.

The Diagnose phase establishes baseline conditions using internal project records including project reports, cost records, and planning/procurement documentation, supported by semi-structured interviews and site observations to clarify operational constraints and identify cost inefficiency drivers such as unstable planning, late constraint removal, disrupted procurement flow, and weak site discipline. Root causes are systematically examined using the 5 Whys analysis technique to address the first research question. In the Plan phase, the researcher and stakeholders co-design an integrated Lean intervention package comprising the Last Planner System (LPS), Value Stream Mapping (VSM), and 5S, while defining a consistent before-after evaluation window. The Act phase involves implementing the selected Lean tools in the project environment according to agreed procedures and timelines. During the Observe/Evaluate phase, quantitative evidence is derived from project records in two layers: operational output indicators capture the effects of each Lean tool (Percent Plan

Complete for LPS, lead-time reduction for VSM, and material waste rate changes for 5S), while cost-account records quantify monetary benefits including overhead/preliminaries, rework, overtime, and material waste savings. Qualitative evidence from interviews and site observations documents adoption patterns, implementation barriers, and contextual explanations for measured changes. Finally, the Reflect phase integrates quantitative project-record results with qualitative field evidence to derive lessons learned, identify enablers and barriers, and formulate recommendations for sustaining and scaling the intervention. The unit of analysis is the project implementation cycle within the defined evaluation window, with the study emphasizing transparent documentation of intervention activities, data sources, and assumptions used in before-after comparisons.

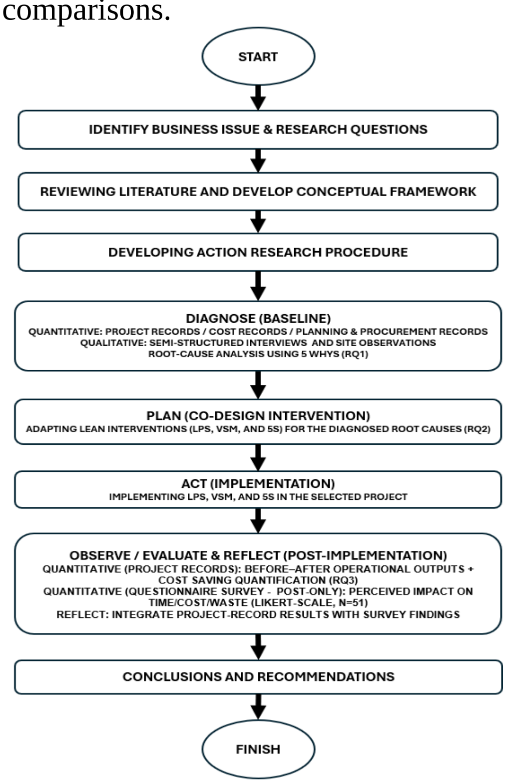


Figure 1. Research Methodology Flowchart

Data Collection

Quantitative Data Sources

The quantitative analysis employs four primary categories of project records collected within a consistent eight-week observation window (W1-W8) for each focus project, comparing baseline performance (W1-W4) versus post-implementation performance (W5-W8) following the integrated LPS-VSM-5S intervention. The data sources include: (1) Planning and progress records, comprising weekly work plans, task completion status, and constraint logs used to calculate Percent Plan Complete (PPC) and identify reasons for non-completion; (2) Quality control documentation, including QA/QC punch lists, non-conformance reports (NCR), and rework records that quantify defects and rework hours; (3) Material control records, tracking material issuance, returns to stock, and scrap/waste quantities in consistent units to measure material waste rates; and (4) Cost reports, providing budget-versus-actual comparisons by Work Breakdown Structure (WBS) to quantify monetary impacts of rework, waste, and delays. Additional supporting data include baseline and look-ahead schedules to diagnose approval and hand-off bottlenecks, daily site logs documenting events and disruptions, and 5S observation notes from spot checks during the study period. All quantitative sources were actively collected and used in the analysis, with data processing conducted immediately after each reporting cycle to ensure completeness and accuracy of the W1-W8 dataset prior to baseline-post comparative analysis.

Table 1 Summary of Data Sources, Time Window, and Use in Analysis

Data Source	Type & Unit	Time Window	Purpose
Weekly plans & PPC logs	PPC (%) and categorized reasons for non-completion	Weekly, W1–W8 (baseline W1–W4, post-implementation W5–W8)	Measure plan reliability and identify constraints (RQ1), quantify reliability improvement after LPS (RQ2)
Baseline & look-ahead schedules	Activities, dates, and constraint log entries	Baseline schedule + 3–6-week look-ahead, W1–W8	Diagnose approval/hand-off bottlenecks and delay mechanisms (RQ1), validate improvement mechanism under LPS (RQ2)
QA/QC punch lists & NCR/rework records	Defect/NCR counts and rework events, rework hours	Weekly aggregation, W1–W8	Quantify quality-related waste and rework drivers (RQ1), measure change in rework rate post-implementation (RQ2)
Material control records (issuance/returns/scrap)	Issued and returned quantities, scrap/waste quantities (consistent unit)	Weekly aggregation, W1–W8	Identify and quantify material waste and material-driven delays (RQ1), evaluate waste reduction impact (RQ2)
Cost reports	Cost line items in IDR and %, budget vs actual by WBS	Monthly reports covering W1–W8 (allocated to baseline/post windows)	Quantify monetary impacts of rework, waste, and delays, provide basis for benefit calculation (RQ2)
Daily site logs	Events, delays, disruptions, and rework notes (text)	Daily logs W1–W8	Triangulate PPC trends with observed issues (waiting, approvals, disruptions) and support root-cause analysis (RQ1)
5S observation notes	S1–S5 observations and issues log	Spot checks during W1–W8	Document workplace organization and validate 5S pathway to reduced searching/motion/waiting supporting quantified savings (RQ1/RQ2)
Semi-structured interviews	Interview transcripts/notes	Conducted within W1–W8	Validate root causes and practicality of LPS–VSM–5S (RQ1); explain and triangulate quantified impacts (RQ2)

Qualitative Data Sources

Qualitative data were collected through semi-structured interviews and direct site observations to identify and validate operational root causes of plan unreliability, delays, and waste observed in project records, while providing contextual explanations for quantified performance changes and confirming the feasibility of the LPS-VSM-5S interventions. Purposive sampling was employed to ensure comprehensive coverage of key roles directly involved in weekly planning commitments, constraint removal, quality control, and procurement/material readiness across the focus projects. The interview roster comprises five respondents representing critical project functions: Project Managers, Site Engineer, QA/QC specialist, and Procurement officer, Interviews were conducted in person or online during the W1-W8 study window, with questions structured around planning reliability, waiting and approvals, hand-offs, defect and rework drivers, material control, and 5S sustainment. With participant permission, sessions were recorded or documented with detailed notes. Participation was voluntary and based on informed consent, with company and individual identities anonymized and data stored securely for research use only.

Table 2. Interviewee Roster & Relevance

Role	Experience (yrs)	Linked RQ	Rationale for selection
Project Manager (n=2)	10	RQ1, RQ2	Leads weekly planning and PPC reviews; approves resource decisions and coordinates cross-functional constraints.
Site Engineer (n=1)	5	RQ1, RQ2	Coordinates day-to-day field execution and interfaces with planning, approvals, and subcontractors; observes flow disruptions and constraint impacts.
QA/QC (n=1)	8	RQ1, RQ2	Maintains punch lists and non-conformance records; provides evidence on defects and rework drivers linked to waste and cost.
Procurement (n=1)	7	RQ1, RQ2	Controls submittal – PO – delivery lead times and supplier readiness; provides insight into material availability and delivery accuracy.

Survey-Based Validation

To complement the record-based before-after evaluation, a post-implementation questionnaire survey (Likert scale 1-5; N=51) was administered to personnel involved in the four focus projects (A2, A4, A7, and A12). The survey captured perceived impacts of the integrated Lean package on schedule reliability, waiting time, rework frequency, material waste, and cost control. This survey evidence is used to support (post-only) validation during the Observe/Evaluate and Reflect phases, rather than as a causal baseline-to-post measurement.

Data Analysis

Performance Indicators and Operational Definitions

Performance indicators are computed using consistent definitions and formulas across all projects and observation periods to ensure comparability. Percent Plan Complete (PPC) measures the share of weekly tasks completed exactly as promised in the weekly plan, calculated as:

$$\text{PPC (\%)} = \frac{\text{Tasks completed as planned}}{\text{Tasks planned}} \times 100 \quad (3.1)$$

where tasks added mid-week are excluded and task granularity remains constant. Rework Rate quantifies the portion of direct work hours spent on corrections or repeated work:

$$\text{Rework Rate (\%)} = \frac{\text{Rework hours}}{\text{Total direct work hours}} \times 100 \quad (3.2)$$

Material Waste represents the percentage of issued material that becomes scrap or loss:

$$\text{Material Waste (\%)} = \frac{\text{Waste quantity}}{\text{Total quantity issued}} \times 100 \quad (3.3)$$

Lead Time (VSM Lead Time) measures the elapsed time required for a work package to flow from start to finish along the mapped value stream:

$$\text{Lead Time} = T_{\text{finish}} - T_{\text{start}} \quad (3.4)$$

$For\ baseline - post\ comparison, change\ in\ lead\ time\ is\ calculated\ as:$

$$\Delta LT = LT_{\text{Post}} - LT_{\text{Baseline}} \quad (3.5)$$

$$\%\Delta LT = \frac{LT_{\text{Post}} - LT_{\text{Baseline}}}{LT_{\text{Baseline}}} \times 100 \quad (3.6)$$

Cost Variance measures cost overrun or underrun relative to the approved budget:

$$\text{Cost Variance (\%)} = \frac{\text{Actual} - \text{Budget}}{\text{Budget}} \times 100 \quad (3.7)$$

where positive values indicate cost overrun and negative values indicate cost underrun. Actual costs are taken from realized cost records for the same scope and period, while Lean savings are estimated separately as avoided costs attributable to improvements.

Quantitative Analysis Procedures

The quantitative analysis employs a structured before-after comparison using two four-week evaluation windows: baseline (W1-W4) representing the Observe/Diagnose phase to map initial conditions and sources of inefficiency, and post-implementation (W5-W8) representing the Act-Observe phase after implementing the LPS-VSM-5S intervention package. To ensure consistency with data characteristics, rate and percentage-based indicators (PPC, Rework Rate, Material Waste %) are summarized using the weekly average within each window, while quantity, hour, and cost-based indicators are summarized using the four-week total within each window to align with labor-hour and cost reporting practices. Change (Δ) and percentage change (%Δ) are calculated for each performance indicator to quantify the magnitude of improvement. For cross-project portfolio reporting, weighted aggregation is applied using contract value as the weighting factor to ensure the portfolio result represents project value exposure:

$$X_{\text{Portfolio}} = \frac{\sum(w_i \cdot X_i)}{\sum w_i} \quad (3.11)$$

Weights $w_i$use Contract Value to ensure the portfolio result represents project value exposure.

Qualitative Analysis Procedures

Interview data, site observations, and project documents are analyzed using thematic coding focused on evaluating the effectiveness of the LPS, VSM, and 5S interventions. Key analytical themes include planning reliability and constraint removal mechanisms (LPS), process flow analysis and bottleneck identification (VSM), and workplace organization and material control effectiveness (5S). The coding process identifies patterns in how practitioners experienced and explained performance changes, barriers encountered during implementation, and contextual factors affecting intervention outcomes. Interpretation validity is strengthened through triangulation across multiple data sources (interviews, observations, and project documents) and member checking during periodic review sessions with the project team, where preliminary findings are presented and discussed to confirm accuracy and capture additional insights.

Mixed-Methods Integration

Integration of quantitative and qualitative findings is conducted through a convergent parallel design in which both data streams are analyzed independently and then brought together for interpretation. A joint display framework links the LPS-VSM-5S interventions with quantitative metric changes (baseline versus post-implementation), qualitative evidence explaining the change mechanisms, and implications for corrective actions and standardization. When quantitative and qualitative results converge, conclusions are strengthened through mutual confirmation. When divergences occur, differences are systematically explained based on project-specific context, implementation constraints, and the temporal dynamics of change adoption. This integrated approach enables the research to not only measure the magnitude of performance improvement but also understand why and how the improvements occurred, providing actionable insights for sustaining and scaling the Lean Construction interventions within PT AKN's broader project portfolio.

RESULTS AND DISCUSSION

Root Cause Analysis

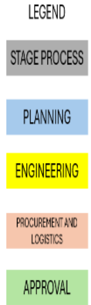
To address the first research question, a systematic root cause analysis was conducted on four priority projects (A2, A4, A7, and A12) selected based on their material performance deviations and recurring operational issues. The 5 Whys technique was employed to trace surface-level problems to their underlying systemic causes, with findings triangulated through project records and semi-structured interviews with key stakeholders. The diagnosis revealed four dominant systemic gaps driving schedule unreliability, cost overruns, and waste across the priority projects: (1) weak collaborative planning and make-ready discipline, (2) unstable design-procurement handoffs and delayed approvals, (3) external interface risks (land and permits) not embedded into short-interval planning, and (4) weak weekly monitoring and control discipline. These validated gaps formed the empirical basis for designing the integrated Lean Construction intervention package.

Table 3. Summary of Validated Systemic Root Causes and Lean Methods Applied

No.	Root Cause	Observed Symptoms	Primary Impact	Lean Methods Applied
1	The planning system lacks collaborative pull planning and make-ready discipline	Constraints are discovered late and submissions tend to be batched, which delays approvals	Schedule unreliability and increased waiting waste	**LPS**
2	The design and procurement interface is unstable, with weak standardisation in information flow	Procurement inputs change late, purchase orders are issued late, and deliveries become variable	Cost increase, rework, and material-related delays	**VSM**
3	Land and permitting readiness is not integrated into short-interval planning and readiness control	Work is released before readiness, work fronts become blocked, and re-sequencing occurs	Waiting time increases and productivity declines	**LPS + VSM**

No.	Root Cause	Observed Symptoms	Primary Impact	Lean Methods Applied
4	Monitoring and control routines are not institutionalised, with low visibility of plan versus actual	Deviations are detected late and corrective actions are delayed	Variance to plan increases and corrective costs rise	**LPS + 5S**

Table 4.5 demonstrates the direct mapping between identifie causes and the selected Lean me (LPS, VSM, and 5S). For instanc absence of collaborative pull pla governance, which manifested i constraint discovery and de approvals, was addressed througl implementation (Ballard, 2 Similarly, unstable design-procurement interfaces with weak information flow standardization were tackled through VSM to visualize and redesign process flows (Rother & Shook, 1999). The fourth root cause: weak monitoring and control routines with low visibility was addressed through the combined application of LPS for commitment tracking and 5S for visual workplace organization (Hirano, 1995).



Implementation of Lean Construction Interventions

Last Planner System (LPS) Implementation

The Last Planner System was implemented to address unreliable short-term planning, late constraint detection, and weak weekly monitoring. The intervention transformed PT AKN's weekly planning from an ad-hoc work list to a make-ready and commitment-based system, ensuring work release only when prerequisites were confirmed. Implementation followed a standard rhythm: 6-week lookahead with readiness checks and constraint logs, weekly work planning with PPC/RNC reviews committing only "ready" tasks, and daily coordination huddles for blockers and interfaces.

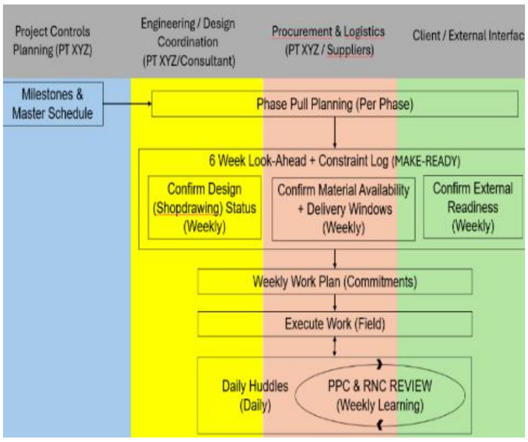


Figure 2. Proposed LPS Flow Tailored for PT AKN

Weekly planning performance was captured through Percent Plan Complete (PPC) metrics comparing pre-LPS baseline with post-LPS implementation. Across the four priority projects, PPC improved substantially: Project A2 increased from 61.1% to 77.8%, Project A4 from 58.3% to 75.0%, Project A7 from 65.0% to 72.5%, and Project A12 from 59.1% to 72.7%. The portfolio-weighted average PPC rose from 60.9% to 74.5%, representing a 13.6 percentage point improvement in plan reliability (Ballard, 2000).

Value Stream Mapping (VSM) Implementation

VSM was applied to address long approval and procurement lead times and queue-driven waiting. The pre VSM mapping revealed that baseline lead times across the four projects ranged from 21 to 28 days (average 24.8 days), with Process Cycle Efficiency (PCE) remaining low at 28-35%, indicating that most elapsed time was consumed by waiting rather than value-adding work. After VSM process designs introduced specific interface controls including fixed permit windows, QC scheduling protocols, dispatch slot locks, and work-in-process (WIP) limits to stabilize flow (Rother & Shook, 1999).

Table 4. Portfolio-Level VSM Lead-Time Results (Before vs After)

Project Code	Pre-VSM Lead Time (days)	After-VSM Lead Time (days)	Lead Time Reduction (days)	Lead Time Reduction (%)
A2	28.0	23.0	5.0	17.9%
A4	21.0	18.0	3.0	14.3%
A7	26.0	22.0	4.0	15.4%
A12	24.0	20.0	4.0	16.7%
Total	–	–	16.0	–
Average	24.8	20.8	4.0	16.1%

The first post-intervention cycle demonstrated measurable lead-time reductions across all projects: A2 reduced from 28.0 to 23.0 days (-17.9%), A4 from 21.0 to 18.0 days (-14.3%), A7 from 26.0 to 22.0 days (-15.4%), and A12 from 24.0 to 20.0 days (-16.7%). The portfolio average lead time decreased from 24.8 to 20.8 days, representing an average reduction of 4.0 days or 16.1%. These improvements were achieved through tighter release discipline, reduced queue variability at permit and dispatch interfaces, and enhanced coordination between design, procurement, and site execution teams.

5S Implementation

The 5S intervention addressed poor site organization, inefficient material handling, and avoidable waste. Implementation focused on material storage areas across the four projects, applying the five pillars of Sort, Set in Order, Shine, Standardize, and Sustain to create controlled and predictable workplace conditions (Hirano, 1995).

Table 5. 5S Audit Scores in Material Storage Areas - Before and After

Project	BEFORE					
	Sort	Set in Order	Shine	Standardise	Sustain	Overall
A2 – Toll Road (laydown yard)	2.2	2.0	2.3	1.8	1.7	2.0
A4 – Bridge (steel storage area)	2.4	2.1	2.5	2.0	1.9	2.2
A7 – Residential (blockwork yard)	2.1	1.9	2.2	1.7	1.6	1.9
A12 – Apartment (finishing store)	2.3	2.0	2.4	1.9	1.8	2.1

Project	AFTER					
	Sort	Set in Order	Shine	Standardise	Sustain	Overall
A2 – Toll Road (laydown yard)	3.6	3.8	3.7	3.5	3.4	3.6
A4 – Bridge (steel storage area)	3.7	3.9	3.8	3.6	3.5	3.7
A7 – Residential (blockwork yard)	3.8	4.0	3.9	3.7	3.6	3.8
A12 – Apartment (finishing store)	3.9	4.1	4.0	3.8	3.6	3.9

5S audit scores improved substantially across all projects, rising from an average of 2.05 (before) to 3.75 (after) on a 5-point scale. This improvement reflected a shift from mixed and inconsistent storage practices to standardized conditions with clearer locations, reduced clutter, and controlled handling routines. Importantly, these workplace improvements translated into measurable reductions in material waste rates: A2 decreased from 5.60% to 2.88% (-2.72 percentage points), A4 from 5.26% to 2.71% (-2.55 pp), A7 from 5.77% to 2.54% (-3.23 pp), and A12 from 5.94% to 2.37% (-3.57 pp), with a portfolio average reduction from 5.64% to 2.63%.

Discussion

Interpretation of Root Cause Findings

The 5 Whys analysis revealed that the recurring performance problems at PT AKN were not caused by isolated technical failures but by systemic gaps in project delivery governance. The first root cause—absence of collaborative pull planning—explains why constraints were discovered late and approvals were delayed, consistent with Ballard and Howell's (2003) observation that traditional push planning fails to ensure work readiness before release. The second root cause—unstable design-procurement handoffs—demonstrates how missing stage-gates and change control create variability in material flow, aligning with the value stream perspective that non-value-adding time accumulates at poorly managed interfaces (Rother & Shook, 1999). The third root cause—land and permitting risks not integrated into short-interval planning—illustrates a common failure mode in construction where external dependencies are treated as administrative activities rather than as make-ready prerequisites that must be cleared before work release. The fourth root cause—weak monitoring and control discipline—reflects the absence of visual management and weekly review routines necessary to detect and correct deviations early, a fundamental principle of production control in Lean Construction (Koskela et al., 2002).

Importantly, these four root causes are interrelated rather than independent. Weak planning discipline creates unprepared work fronts, which in turn generate waiting and material-related disruptions that require overtime recovery efforts. Similarly, poor site organization (addressable through 5S) compounds planning unreliability by increasing searching time, material damage, and minor execution defects, all of which reduce the likelihood of completing committed weekly tasks. This interconnectedness supports the decision to apply an integrated Lean intervention package rather than isolated tools, as the synergistic effects across LPS, VSM, and 5S address the systemic nature of the performance gaps.

Effectiveness of the Integrated Lean Intervention

The quantitative results demonstrate that the integrated application of LPS, VSM, and 5S produced measurable improvements in planning reliability, process flow, workplace organization, and cost performance within the defined evaluation window. The 13.6 percentage-point improvement in portfolio-weighted PPC (from 60.9% to 74.5%) is particularly significant, as research has established PPC as a leading indicator of project performance, with higher PPC correlating with reduced schedule variance and improved workflow stability (Ballard, 2000). The observed PPC improvements are consistent with findings from other LPS implementation studies in construction, where collaborative planning and make-ready discipline have been shown to improve commitment reliability by 10-20 percentage points during the initial stabilization period.

The 16.1% average reduction in lead time achieved through VSM is notable because it was accomplished without changing the value-adding work content, but rather by reducing non-value-adding waiting time through better interface management and WIP controls. This finding validates the core VSM principle that substantial performance gains can be realized by eliminating waste in process flow rather than by accelerating individual work activities (Rother & Shook, 1999). The specific mechanisms—fixed permit windows, QC scheduling protocols, dispatch slot locks, and WIP caps—represent practical applications of pull-based flow control adapted to the constraints of construction project environments where complete flow cannot always be achieved but queue variability can be systematically reduced.

The 5S results demonstrate both process improvement (audit score increases from 2.05 to 3.75) and outcome improvement (material waste reduction from 5.64% to 2.63%). This dual improvement confirms that workplace organization is not merely a housekeeping practice but a production enabler that directly impacts material handling efficiency, damage prevention, and execution quality (Hirano, 1995). The observed waste reductions are consistent with the expected 5S improvement mechanisms: clearer segregation and protection reducing material damage, reduced congestion and repeated movement decreasing handling losses, and improved workplace order supporting quality workmanship.

Cost and Schedule Impact Interpretation

Table 6 and Table 7 summarize the quantified Lean savings and the corresponding pre- and post-implementation cost overrun comparison for the four priority projects.

Table 6. Quantified Lean Savings Summary for the Four Priority Projects

Project	Preliminaries Saving (IDR)	Material Waste Saving (IDR)	Rework Saving (IDR)	Overtime Saving (IDR)	Total (IDR)
A2 – Toll Road	100,000,000	140,000,000	55,000,000	70,000,000	365,000,000
A4 – Bridge	75,000,000	91,450,000	53,900,000	40,500,000	260,850,000
A7 – Residential Apt.	64,000,000	125,500,000	78,650,000	74,400,000	342,550,000
A12 – Apartment Tower	56,000,000	92,100,000	68,300,000	52,900,000	269,300,000
		Total			**1,237,700,000**

Table 7 Final Pre- and Post-Lean Cost Overrun Comparison (A2, A4, A7, A12)

Project	Pre-Lean Cost Overrun		Lean Impacts Savings		Post-Lean Cost Overrun	
	(%)	**(IDR)**	**(%)**	**(IDR)**	**(%)**	**(IDR)**
A2 – Toll Road	12%	102,000,000,000	0.043%	365,000,000	11.957%	101,635,000,000
A4 – Bridge	8%	28,800,000,000	0.072%	260,850,000	7.928%	28,539,150,000
A7 – Residential Apt.	15%	45,000,000,000	0.114%	342,550,000	14.886%	44,657,450,000
A12 – Apartment Tower	10%	25,000,000,000	0.108%	269,300,000	9.892%	24,730,700,000

The quantified cost savings of IDR 1,237,700,000 across the four-week evaluation window, while representing only 0.043% to 0.114% reductions in project-level cost overruns, must be interpreted within the study's defined scope and timeframe. First, these are short-cycle benefits measured over an eight-week window (four weeks baseline, four weeks post-implementation) during the initial stabilization period of Lean adoption. Sustained implementation over full project lifecycles would likely yield cumulative savings substantially larger than the initial-period results reported here. Second, the savings calculations were deliberately conservative, including only direct, measurable cost reductions (preliminaries, material waste, rework, and overtime) and excluding potential benefits such as reduced liquidated damages exposure, improved cash flow from faster completion, and reduced warranty claims from better quality control.

The distribution of savings across the four categories provides insight into the mechanisms through which the Lean package generates value. Material waste savings (36.3% of total) and rework savings (20.7%) together account for 57% of quantified benefits, confirming that quality-related losses: damage, defects, and reprocessing, represent substantial avoidable costs addressable through better workplace organization (5S) and improved process stability (LPS and VSM). Preliminaries savings (23.8%) capture the overhead cost reduction enabled by schedule compression, demonstrating the financial value of reducing project duration even by modest amounts (3-5 days per cycle). Overtime savings (19.2%) reflect reduced reliance on premium-cost labor to recover from disruptions, a direct consequence of improved planning reliability that reduces last-minute workflow adjustments.

CONCLUSION AND SUGGESTION

This study demonstrates that the integrated application of Lean Construction principles, specifically the Last Planner System (LPS), Value Stream Mapping (VSM), and 5S can effectively address systemic inefficiencies in project delivery processes at PT AKN, a large Indonesian construction contractor. The action research intervention across four priority projects yielded measurable improvements: plan reliability increased from 60.9% to 74.5% through LPS implementation, end-to-end lead times reduced by 16.1% (4.0 days average) through VSM process redesign, and material waste decreased from 5.64% to 2.63% through 5S workplace organization. These operational improvements translated into quantified cost savings of IDR 1,237,700,000 across the evaluation window, distributed across preliminaries, material waste reduction, rework reduction, and overtime savings. Stakeholder perceptions strongly validated these findings, with 82-84% agreement on improvements in schedule reliability, reduced waiting time, and enhanced cost control. The results confirm that disciplined application of collaborative planning, flow management, and workplace organization principles can mitigate chronic schedule delays, cost overruns, and site-level waste in Indonesian construction contexts, providing actionable insights for contractors facing similar challenges.

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