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IMPACTS OF WAITING-TYPE NON-PHYSICAL WASTE ON SCHEDULE DEVIATION IN LEAN-MANAGED BUILDING PROJECTS IN INDONESIA

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ABSTRACT

Waiting-type non-physical waste remains a common issue in construction projects, yet prior studies have mainly focused on identifying its causes rather than measuring its impact on schedule performance. Limited research has examined how waiting relates to activity-level schedule characteristics in Lean Construction practices. This study investigates how waiting-type non-physical waste contributes to schedule deviation in Indonesian building construction projects. A descriptive–quantitative approach was applied using data from four projects implementing the Last Planner System (LPS). Waiting events were identified and classified at the activity level using operational indicators derived from Lean Construction literature and LPS documentation. Schedule deviation attributable to waiting was then analyzed using a CPM-based approach incorporating activity duration and slack. The results show that labor shortages were the most frequent cause of waiting, followed by unprepared work areas and material shortages. However, waiting frequency did not directly correspond to schedule impact. Waiting affecting activities with limited slack contributed disproportionately to deviation, while shorter-duration activities showed higher proportional delays and longer-duration activities accumulated greater absolute delays. These findings highlight that waiting impacts should be assessed not only by frequency, but also by activity characteristics and schedule structure.

KEYWORDS

Lean construction, waiting waste, non-physical waste, schedule deviation, Last Planner System, Critical Path Method.

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INTRODUCTION

Construction projects frequently experience non-value-adding activities that reduce workflow reliability and contribute to delays, inefficiency, and diminished project performance (Mudzakir et al., 2017). Among these inefficiencies, non-physical waste is particularly critical because it is associated with time and cost losses during project execution rather than visible material loss (Nagapan et al., 2012). Despite its significant effect on project performance, non-physical waste often receives less attention than physical waste in construction practice (Danureswara & Suripto, 2025). This is problematic because non-physical waste can disrupt workflows, delay progress, increase costs, and reduce contractor credibility (Igwe et al., 2022; Sanaky et al., 2021).

Among the various forms of non-physical waste, waiting is frequently identified as a dominant source of inefficiency in building construction projects. Previous studies have shown that waiting may result from delayed approvals, late material delivery, equipment breakdowns, disbursement issues, and adverse weather conditions, all of which contribute to project delays (Danureswara & Suripto, 2025; Prisillia & Prumono, 2018; Hatpito et al., 2020). These findings indicate that waiting is not merely an isolated interruption, but a recurring form of workflow instability that can undermine schedule performance.

Lean Construction has been increasingly adopted as an approach to reduce waste and improve workflow reliability in construction projects. Derived from Lean Manufacturing, Lean Construction emphasizes waste minimization, value maximization, and improved production flow through collaborative planning and constraint management (Tamallo & Nursin, 2020; Setiawan, 2023). One of the most widely applied Lean tools is the Last Planner System (LPS), which supports workflow control, resource coordination, and planning reliability through structured planning stages and constraint identification (Ballard, 2000; Hamzeh et al., 2012; Rusdiana et al., 2019). In this study, LPS is treated as the Lean management context of the selected projects and as an important source of operational data, particularly through constraint logs and planning records used to identify waiting events.

This study is situated in the context of Indonesian building construction projects, focusing on projects undertaken by Company X. As one of the companies that has adopted Lean Construction, Company X applies LPS in managing building and infrastructure projects. Its annual reports indicate that building and infrastructure works dominate its project portfolio, accounting for 74.28% of active projects in 2023 and 67.39% in 2024 (Annual Report Company X, 2023; 2024). However, despite the implementation of Lean Construction practices, internal project records still indicate recurring waiting-type waste caused by delayed material deliveries, unprepared work areas, slow approval processes, and equipment-related constraints (Nagapan et al., 2012). This suggests that waiting waste may persist even in projects that have formally adopted Lean tools.

Previous research on Lean Construction has largely focused on identifying waste types, analyzing their causes, and proposing improvement strategies through Lean tools such as LPS (Tamallo & Nursin, 2020; Aisyah et al., 2023; Setiono et al., 2024; Danureswara & Suripto, 2025). Although these studies have demonstrated that waiting is an important form of non-physical waste, limited research has examined how waiting translates into measurable schedule deviation at the activity level. In particular, the interaction between waiting occurrences and structural schedule characteristics, such as activity duration and available slack, remains insufficiently explored, especially in projects that already operate under Lean-managed environments. As noted by Formoso et al. (2021), slack plays a critical role in absorbing variability; however, its relationship with waiting waste in project schedules has not been adequately analyzed.

Accordingly, this study aims to examine the impact of waiting-type non-physical waste on schedule deviation in Lean-managed building construction projects in Indonesia. Drawing on

waiting data derived from LPS documentation (Ballard & Howell, 1998; Power et al., 2023) and schedule analysis based on the Critical Path Method (Perdana & Rahman, 2019), this study investigates how waiting-induced delays interact with activity duration and slack characteristics to influence both absolute and proportional schedule deviation. By linking waiting-type waste analysis with CPM-based schedule characteristics, this study contributes empirical insight into how non-physical waste affects schedule reliability at the activity level in Lean-managed projects, thereby extending prior Lean Construction research that has primarily emphasized constraint identification and workflow reliability (Ballard, 2000; Nguyen & Waikar, 2018).

LITERATURE REVIEW

LEAN CONSTRUCTION AS A FRAMEWORK FOR WASTE REDUCTION AND SCHEDULE RELIABILITY

Lean Construction is a project management philosophy derived from Lean Manufacturing, aiming to maximize value while minimizing waste throughout the construction process. This is achieved through effective planning, inventory control, collaboration, and the integration of technology (Bajjou et al., 2019; Tezel et al., 2022). At its core, Lean Construction is founded on six key principles: Respect for People, Optimize the Whole, Eliminate Waste, Focus on Flow, Generate Value, and Continuous Improvement. These principles collectively promote efficient workflow, enhance stakeholder coordination, and support sustainable project delivery. The Lean Construction Institute (2025) and Heier et al. (2023) emphasize that applying these principles transforms conventional project delivery systems by fostering collaboration and process reliability across all phases.

The application of Lean Construction has been increasingly observed in infrastructure projects within Indonesia's public and private sectors. Studies highlight that Lean tools have proven effective in identifying and mitigating various forms of construction waste, particularly non-physical waste such as waiting time, rework, and communication delays (Anggraini et al., 2022; Aisyah et al., 2023; Setiawan, 2023). These implementations demonstrate that Lean Construction is not only a theoretical framework but also a practical strategy for improving on-site construction efficiency. Within this framework, schedule reliability becomes a critical indicator of Lean performance, as unstable planning and unreliable workflows undermine value generation even when Lean tools are formally implemented (Tezel et al., 2022; Heier et al., 2023). Consequently, Lean Construction provides the conceptual basis for examining how waste—particularly waiting—affects project schedule performance.

WASTE IN LEAN CONSTRUCTION: EMPHASIS ON NON-PHYSICAL WASTE

Lean Construction emphasizes eliminating waste, defined as any action or process that does not add value from the customer's perspective. Reinhart & Putri (2025) indicate that material waste analysis is essential to enhancing work cycle efficiency and logistics, suggesting that a systematic approach to waste reduction can significantly improve project outcomes. Identifying waste types, including non-physical waste, is a prerequisite for effectively applying Lean principles (Aisyah et al., 2023).

Non-physical waste refers to intangible inefficiencies that disrupt workflows, extend project timelines, and strain resources without directly contributing to customer value. The Lean Construction Institute (LCI) classifies waste into eight categories under the DOWNTIME acronym: Defect, Waiting, Overproduction, Non-utilizing Talent, Transportation, Inventory, Motion, and Extra Processing. Each category reflects specific inefficiencies, such as rework, unnecessary delays, and suboptimal labor utilization (Aisyah et al., 2023).

Tamallo and Nursin (2020) provide a focused exploration of non-physical waste in Indonesian construction projects, identifying that schedule delays and equipment failures are

key contributors to lost efficiency and increased costs. Similarly, Bajjou and Chafi (2021) highlight that communication and planning play critical roles in mitigating both physical and non-physical waste, reinforcing the interaction between effective management strategies and performance outcomes. Among the various waste categories, non-physical waste is particularly critical because its impacts are often reflected directly in time loss and schedule inefficiency rather than material waste, making it less visible but highly consequential for project performance (Aisyah et al., 2023; Tamallo & Nursin, 2020).

WAITING AS A CRITICAL NON-PHYSICAL WASTE AFFECTING PROJECT SCHEDULES

Waiting is recognized as a significant form of non-physical waste in construction, directly affecting project timelines and leading to cost overruns (Babalola et al., 2019). It stems from idle labor, stalled workflows, and dependency bottlenecks that reduce productivity and compromise schedule reliability. Common triggers include delays in decision-making, limited availability of equipment or materials, late instructions, inadequate planning, and ineffective communication between vendors and subcontractors (Aisyah et al., 2023; Heier et al., 2023).

Addressing this waste is essential to improving workflow continuity and accelerating project delivery, aligning with Lean Construction objectives (Sarhan et al., 2017). Heier et al. (2023) further emphasize that waiting waste often arises from systemic process misalignments rather than isolated incidents, underscoring the need for comprehensive planning and coordination. Despite extensive discussion on the causes and frequency of waiting waste, fewer studies have examined how waiting events propagate into measurable schedule deviation, particularly through the interaction between waiting duration, activity characteristics, and available slack in project schedules.

LAST PLANNER SYSTEM AS A LEAN TOOL FOR MANAGING WAITING AND WORKFLOW RELIABILITY

Lean Construction tools encompass methodologies and practices designed to minimize waste and enhance efficiency in construction projects. The Last Planner System (LPS) is pivotal among these tools, providing a framework for collaborative planning and effective task assignment. By encouraging proactive engagement among team members, the LPS divides planning into stages characterized by “should,” “can,” “will,” and “did” (Ballard & Howell, 1998). This systematic approach ensures tasks are clearly defined, resources are allocated efficiently, and existing constraints are acknowledged.

Key techniques employed within LPS include milestone planning, pull planning, and weekly work planning, contributing to effective constraint management and the metric of percent plan complete (Power et al., 2023). Additional practices such as Increased Visualization, Daily Huddle Meetings, First-run Studies, and the 5S Process enhance on-site communication, organization, and readiness, ultimately mitigating errors (Hirano, 1996). Importantly, Lean methodologies emphasize identifying waiting waste, enabling teams to make real-time adjustments aligned with project goals (Aisyah et al., 2023). As emphasized by Gazali et al. (2025), applying these Lean Construction tools results in significant improvements in coordination, waste minimization, and overall process efficiency, effectively bridging theory and practice. However, the continued occurrence of waiting in projects implementing the LPS suggests that not all constraints are successfully identified and removed before execution, resulting in residual workflow instability and schedule deviation (Ballard & Howell, 1998; Power et al., 2023).

CRITICAL PATH METHOD AS AN ANALYTICAL LENS FOR EXAMINING SCHEDULE DEVIATION

The Critical Path Method (CPM) is a vital scheduling technique in project management that identifies the longest sequence of dependent activities, known as the critical path. This path has zero slack, meaning that any delay in these activities will directly affect the project's overall timeline (Perdana & Rahman, 2019). Understanding slack time is critical; positive slack indicates scheduling flexibility, while negative slack suggests potential delays due to constraints (Formoso et al., 2021).

CPM plays a crucial role in project planning and control, allowing project managers to prioritize tasks and allocate resources efficiently. The integration of CPM with Lean principles enhances decision-making by enabling more effective scheduling, monitoring, and workflow management (Nguyen & Waikar, 2018). This synergy between Lean Construction concepts and CPM aims to minimize waiting time and optimize resource utilization, ultimately leading to more predictable project timelines and improved outcomes (Karaz et al., 2023). From a Lean perspective, slack can be interpreted as a buffer that absorbs production variability, making CPM a suitable analytical lens for examining how waiting waste translates into schedule deviation in Lean-managed projects (Formoso et al., 2021).

METHODOLOGY

RESEARCH DESIGN

This study employs a descriptive–quantitative approach to identify waiting-type non-physical waste and quantify its impact on schedule deviation in building construction projects. This study adopts a structured research methodology consisting of data collection, processing, and analysis stages. The overall research framework is illustrated in **Figure 1**.

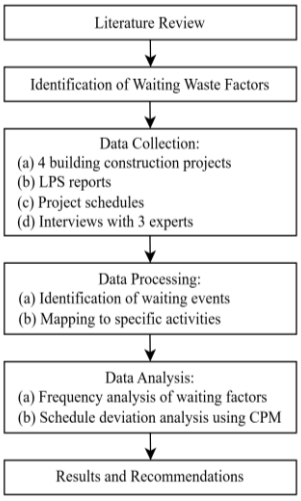

Figure 1: Research Methodology Framework

OBJECT OF STUDY AND PROJECT CHARACTERISTICS

This study investigates four building construction projects undertaken by Company X that implemented Lean Construction through LPS. The inclusion of projects implementing LPS was intended to establish a consistent Lean-managed project context and to ensure the availability of comparable planning and constraint-log documentation. Therefore, LPS implementation in this study functions as a contextual condition and data source, not as a variable to be measured comparatively across projects. The projects were selected from a population of 15 projects using

purposive sampling based on project type, construction phase, and availability of LPS documentation. The key characteristics of the selected projects are summarized in **Table 1**.

Table 1: Characteristics of selected projects

No	Project	Building Type	Project Duration	Project Scope
1	Project A	Sports Facility	370 days (+180 days maintenance)	Sports facilities, infrastructure, MEP, supporting structures
2	Project B	Hospital	600 days	Main building, powerhouse, supporting infrastructure
3	Project C	High-rise Hospital	22 months (+24 months maintenance)	Structural, architectural, MEP, infrastructure works
4	Project D	Healthcare Facility (Design–Build)	383 days (+365 days maintenance)	Service, parking, and educational facilities

UNIT OF ANALYSIS

The primary unit of analysis in this study is individual work activities recorded in the project schedules that experienced waiting events. Projects are treated as contextual units, while activity-level schedule deviations serve as the basis for quantitative analysis. This activity-based unit of analysis enables a detailed examination of how waiting events affect schedule performance through activity duration and slack characteristics within each project.

DATA SOURCES AND COLLECTION METHODS

This study utilizes secondary data obtained from document analysis of building construction projects that implemented Lean Construction through LPS. The primary data sources include LPS constraint logs, periodic Lean implementation reports, and detailed project schedules developed using Microsoft Project, which provide information on work progress, delay events, and planning reliability.

Waiting events and their underlying causes, such as labor shortages, material shortages, unprepared work areas, delayed approvals, equipment unavailability, and adverse weather, were identified from LPS constraint logs. These events were then linked to corresponding activities in the project schedules, which provide baseline and actual execution data required for schedule deviation analysis using CPM.

In addition, semi-structured interviews were conducted with three construction experts involved in project planning and execution to validate the identification and interpretation of waiting events, ensuring consistency between documented records and actual field conditions.

OPERATIONALIZATION OF WAITING AND SCHEDULE DEVIATION

Waiting-type non-physical waste is defined in this study as a condition in which scheduled work activities cannot proceed as planned due to constraints such as unavailable resources, incomplete prerequisites, or pending approvals.

Schedule deviation due to waiting is operationalized using two conditions based on activity status. For completed activities, schedule deviation is calculated as the difference between the actual finish date and the baseline finish date recorded in the project schedule. For ongoing activities, schedule deviation is determined based on the change in remaining slack before and

after the occurrence of waiting. This approach allows waiting-related impacts to be captured consistently across different activity statuses and aligns with CPM-based schedule analysis principles.

IDENTIFICATION AND CLASSIFICATION OF WAITING-TYPE NON-PHYSICAL WASTE

This study identifies and classifies waiting-type non-physical waste occurring during the execution of building construction projects implemented under Lean Construction at Company X. The identification of contributing factors was conducted through a review of Lean Construction literature and document analysis, with particular emphasis on evidence derived from the implementation of LPS as a planning and production-control tool. Operational indicators were developed to enable consistent identification, categorization, and analysis of waiting occurrences at the activity level across all projects.

Table 2: Operational Indicators of Waiting-Type Non-Physical Waste

Variable	Operational Definition	Indicators
Labor Shortage (Maulana, 2024)	A condition in which the number of available workers is insufficient when scheduled activities are due to start.	lack of manpower; workforce reduction (due to payment issues); absenteeism; waiting for operator; reallocation of workers to other tasks.
Document Approval Process (Danuswera, 2025)	Delays in activity execution caused by pending administrative approvals.	waiting for consultant or contractor letters; unresolved Change Order (CCO-1) approvals.
Design Changes (Suripto, 2021)	Work delays caused by incomplete or unapproved design revisions or drawings.	design detail changes by the planner; waiting for shop drawings.
Equipment Shortage (Maulana, 2024)	Unavailability or unpreparedness of necessary equipment for construction tasks.	excavator breakdowns; waiting for equipment; limited access to supporting tools.
Work Area Not Ready (Harpito, 2024)	Delays caused by the unavailability of the work area, which may still be in use or obstructed.	area used for material disposal; area occupied by other equipment; incomplete axial test.
Material Shortage (Maulana, 2024)	Activities are delayed due to late delivery or insufficient supply of main or supporting materials.	late material arrival; material shortages; delays in auxiliary material supply.
Adverse Weather (Maulana, 2024)	Delays in construction caused by unfavorable weather conditions.	rain disrupting on-site construction activities.

These indicators provide the operational basis for identifying, categorizing, and analyzing waiting occurrences in each project activity and for assessing their contribution to schedule deviation in Lean-managed building construction projects.

DATA ANALYSIS PROCEDURE

Data analysis is conducted in three stages. First, waiting events are identified and categorized by cause using LPS constraint logs. Second, project schedules are analyzed using the CPM to identify critical activities, slack values, and activity durations. Third, schedule deviation attributable to waiting is calculated at the activity level and aggregated to examine patterns across projects.

The results are analyzed descriptively to identify the dominant causes of waiting and assess how waiting-induced delays interact with activity duration and slack characteristics. This analytical procedure enables the examination of schedule deviation patterns in Lean-managed building projects without introducing predictive or causal modeling assumptions.

The operational indicators for waiting-type non-physical waste defined in Table 2 were consistently applied across all projects to identify and classify waiting events at the activity level. The identified waiting occurrences were subsequently processed to quantify their frequency and to calculate schedule deviation attributable to waiting, enabling systematic comparison across different waiting causes and project characteristics.

RESULTS AND DISCUSSION

DISTRIBUTION OF WAITING-TYPE NON-PHYSICAL WASTE BY CAUSE

Table 3 presents the total number of waiting-type non-physical waste occurrences identified across the observed building construction projects at Company X. Waiting events were classified using the operational indicators defined in **Table 2** and aggregated across Projects A–D to describe the distribution of waiting causes during project execution.

Table 3: Total occurrences of waiting waste in building projects at Company X

No	Cause	Project A	Project B	Project C	Project D	Total
1	Labor shortage	4	8		19	31
2	Document approval process	3		3		6
3	Design Changes	3				3
4	Equipment shortage	1			5	6
5	Work area not ready	6		2	10	18
6	Material shortage	1	1		10	12
7	Adverse weather	1			1	2

As shown in **Table 3**, a total of 78 waiting occurrences were recorded. Labor shortage was the most frequently observed cause, accounting for 31 occurrences, followed by work areas not ready (18) and material shortage (12). Other causes occurred less frequently, including the document approval process and equipment shortages, each with 6 occurrences, while design changes and adverse weather were recorded only 3 and 2 times, respectively. The persistence of waiting events across all four projects suggests that, although LPS provides a structured mechanism for identifying constraints and improving workflow reliability, not all constraints were fully removed prior to execution.

The dominance of labor-related waiting is consistent with prior Lean Construction studies that highlight workforce availability and allocation as persistent sources of non-physical waste

during construction execution (Maulana, 2024). Even in Lean-managed projects, variations in labor availability and task assignments may still result in delays when planned activities cannot proceed as scheduled. Waiting caused by the work area not being ready also accounts for a substantial portion of occurrences. This finding aligns with previous research, which emphasizes that incomplete prerequisite work and spatial conflicts often lead to delays, particularly in building projects involving multiple trades and overlapping activities (Harpito, 2024).

Material shortages, although less frequent than labor-related delays, remain a notable contributor to non-physical waste. This observation supports earlier findings that delays in material delivery and limited material availability continue to affect construction workflows, despite improvements in planning practices (Maulana, 2024). In contrast, design changes and adverse weather were observed relatively infrequently. These factors are generally more situational and episodic in nature, depending on project-specific design conditions and environmental context (Suripto, 2021).

DISTRIBUTION OF WAITING OCCURRENCES ACROSS PROJECTS

Although **Table 3** presents the aggregated occurrences of waiting-type non-physical waste by cause, the distribution of waiting events varied across the observed projects. Projects C and D had more waiting occurrences than Projects A and B, particularly for labor shortages and work areas not ready.

The variation in waiting frequency across projects indicates that waiting was not uniformly distributed, even within projects implemented under similar Lean Construction practices. Differences in project scale, activity sequencing, and execution conditions may contribute to the observed variation in waiting occurrences.

These findings suggest that the occurrence of waiting-type non-physical waste is project-specific and influenced by contextual factors beyond the type of waiting cause alone. This variation provides a basis for further examining how waiting occurrences translate into differences in schedule deviation duration, which is discussed in the following subsection.

TOTAL CONTRIBUTION OF WAITING WASTE TO THE OVERALL DEVIATION DURATION

Table 4 presents the total contribution of waiting-type non-physical waste to the overall schedule deviation duration across the observed building construction projects. The contribution is expressed in terms of total deviation duration attributable to each waiting cause and its proportion relative to the overall deviation.

Table 4: Total Contribution of Waiting Waste to the Overall Deviation Duration

Project Name	Total Duration of Schedule Deviation	Number of activities affected by waiting	Average Schedule Deviation Due to Waiting	Percentage of Deviation Duration Attributable to Waiting
Project A	32 days	19	1.68 days	21%
Project B	52 days	10	5.20 days	3%
Project C	31 days	5	6.20 days	80%
Project D	54 days	45	1.20 days	14%
Average	**42.25 days**	**19.75**	**3.57 days**	**30%**

As shown in **Table 4**, waiting events, particularly those related to labor shortages, work area readiness, and material availability, contributed substantially to the overall deviation duration.

Although some waiting causes occurred less frequently, their contribution to deviation duration remained substantial when they affected activities with limited slack or critical sequencing requirements.

These results indicate that the frequency of waiting occurrences does not necessarily correspond directly to their contribution to schedule deviation duration. Certain waiting causes with moderate occurrence frequency were associated with relatively long deviation durations, suggesting that the timing and activity context in which waiting occurs play a critical role in determining its scheduling impact.

The observed pattern is consistent with the Lean Construction literature, which emphasizes that non-physical waste should be assessed not only by how often it occurs, but also by how it interacts with activity duration and schedule structure (Formoso et al., 2021). From this perspective, waiting that affects activities with limited flexibility tends to contribute disproportionately to overall schedule deviation, even when its occurrence frequency is relatively low.

RELATIONSHIP BETWEEN ACTIVITY CHARACTERISTICS AND SCHEDULE DEVIATION

The contribution of waiting-type non-physical waste to schedule deviation varied depending on activity characteristics, particularly planned activity duration and available slack. Based on the analysis summarized in **Table 4**, waiting events affecting activities with shorter planned durations tended to result in higher proportional schedule deviation, whereas waiting events affecting longer-duration activities contributed more substantially to absolute deviation duration.

Activities with limited or no slack were more sensitive to waiting occurrences, as even short waiting periods translated directly into schedule deviation. In contrast, activities with greater slack were better able to absorb waiting without immediately increasing deviation duration. This pattern was observed consistently across the analyzed projects, indicating that the interaction between waiting and schedule structure plays a critical role in determining schedule outcomes.

These findings are consistent with prior studies emphasizing the role of slack and buffer capacity in absorbing production variability within construction schedules. Formoso et al. (2021) highlight that slack functions as a critical mechanism for mitigating the propagation of variability, while Ballard (2000) and Ballard and Howell (1998) emphasize that unreliable workflow and unaddressed constraints can rapidly erode available slack at the activity level. Similarly, Nguyen and Waikar (2018) note that schedule performance is strongly influenced by how variability interacts with activity sequencing rather than by activity duration alone. Taken together, these observations suggest that waiting-related schedule deviation in Lean-managed projects is shaped not only by the occurrence of waiting, but also by the structural characteristics of the affected activities.

CONCLUSION

This study examined the occurrence and schedule impact of waiting-type non-physical waste in Lean-managed building construction projects. The findings show that waiting arises from multiple interacting constraints, particularly labor shortages, unprepared work areas, and material shortages, which were identified as the most frequent causes. Although other factors, such as document approval delays, equipment shortages, design changes, and adverse weather, occurred less frequently, they confirm that waiting is driven by a combination of organizational, technical, and contextual conditions, even in projects implementing Lean practices.

The analysis further demonstrates that the impact of waiting on schedule deviation is not solely determined by its frequency. Waiting events affecting activities with limited slack or critical sequencing contributed disproportionately to overall schedule delays. In addition, activities with shorter planned durations exhibited higher proportional deviation, while longer-duration activities tended to accumulate greater absolute delays. These findings emphasize the importance of considering activity characteristics and schedule structure when evaluating the effects of waiting.

Overall, this study provides empirical evidence that the impact of waiting in Lean-managed projects should be assessed not only by its occurrence frequency but also by its interaction with activity-level characteristics and available slack. By integrating waiting identification with CPM-based schedule analysis, this study offers a more detailed understanding of how non-physical waste translates into schedule deviation. Future research may extend this approach by incorporating broader project contexts and exploring strategies to improve constraint management and planning reliability.

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