

ANALYSIS OF BUILDING CONSTRUCTION PROJECT MANAGEMENT USING LEAN CONSTRUCTION APPROACH TO DETERMINE COST AND TIME WASTE IN THE CONSTRUCTION PROJECT OF PONDOK PESANTREN SYIFAUL QULUB SURABAYA

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ABSTRACT

This research investigates cost waste in detailed engineering design for the Syifaul Qulub Surabaya Islamic Boarding School construction project, aiming for on-time, on-budget completion. Utilizing a Lean Construction approach, the study analyzes waste reduction in this densely populated, limited-access urban environment. Primary data from questionnaires were processed to weigh waste in each activity, followed by value stream analysis tools, including Process Activity Mapping, to identify Value-Added (VA) and Non-Value-Added (NVA) activities. The findings revealed that waiting was the primary cause of waste, contributing to 41.8% of critical waste and a 33-day project delay. Root causes included material procurement issues, transportation challenges, and equipment problems. Waste accounted for 21% of all project jobs, categorized as Unnecessary Movement (13.7%), Transportation (12.2%), Material Defects (11%), Storage (10.9%), and Overproduction (6.8%). By addressing these wastes through targeted Lean interventions, the research suggests a potential project acceleration of approximately 16.5% (33 days) and a cost reduction of 5-10% by optimizing resource use and minimizing material waste. These results demonstrate the practical benefits of Lean Construction in mitigating inefficiencies and delays in challenging urban builds.

Keywords: critical waste; fishbone diagram; lean construction; waste; value-added

INTRODUCTION

In the implementation of construction projects, there are often work order changes, modifications, and additional work that can cause project delays. Factors such as poor planning, inefficient execution, and weak supervision are the main causes of delays, which ultimately increase project costs and reduce the chances of success (Michalski et al., 2021; Schimanski et al., 2021; Senthil & Muthukannan, 2022). In addition, construction also involves high risks due to human resources, materials, equipment, and technology used (Wu et al., 2024). In optimizing project efficiency, the concept of Lean Construction was introduced by Glenn Ballard, Greg Howell, Mike Casten, and Lauri Koskela since 1992, focusing on increasing value, reducing waste, and transparency in projects (Ibrahim et al., 2025). Implementing Lean Construction in Indonesia has received increasing attention due to its potential to improve project sustainability.

The adoption of Lean Construction in Indonesia faces significant challenges. Adhi & Muslim (2023) highlight that low contractor adoption rates stem from a lack of awareness, resistance to change, and lack of structured implementation frameworks. Irfandi & Rachmawati (2023) also identified supporting and inhibiting factors influencing Lean Construction practices in large-scale Indonesian projects. Key barriers include limited technological adaptation, workforce skill gaps, and the reluctance of stakeholders to shift from conventional construction methods. Furthermore, Anggraini et al. (2022) found that many Indonesian construction firms struggle with integrating Lean principles due to unclear regulations, fragmented supply chains, and inefficient project coordination.

The case study of the construction of Syifaul Qulub Islamic Boarding School in Surabaya revealed various challenges in the implementation of construction projects, such as difficulties in accessing materials and steel fabrication carried out outside the project site, which had the potential to cause delays and wasteful costs. In the context of the Open University Surabaya Distance Learning Program Unit phase II project, examining cost and time performance using the Earned Value method is important to evaluate project management effectiveness (Nurkaruniati et al., 2024). Lean construction has its

roots in Toyota's production system, which aims to increase project value and reduce waste by optimizing planning and resource management (Koskela et al., 2019). In addition, Lean Construction can help the construction industry face challenges such as rising material prices, skilled labor shortages, and demands for higher quality standards. The study of Allo & Bhaskara (2022) showed that applying lean construction in the project planning stage can significantly minimize waste and improve efficiency. Furthermore, the study highlights the relevance of Lean Construction methods such as virtual design and construction, prefabrication, and just-in-time systems in supporting environmental sustainability (Lalmi et al., 2021; Singh & Kumar, 2021; Xing et al., 2021).

In addition to improving project efficiency, Lean Construction also plays a role in adapting the construction industry to new trends and challenges, such as using digital technology (Building Information Modeling), improved work safety, and sustainability demands in infrastructure development. Li et al. (2024) found that the application of Lean Construction combined with long-term supply chain collaboration provides more effective results than the application of Lean concepts separately. In addition, the COVID-19 pandemic is driving the need for more flexible and adaptive construction strategies, including supply chain risk management and stricter work safety protocols. In the long run, implementing Lean Construction can help the construction industry overcome challenges such as material cost inflation, demand for high-quality buildings, and the growing trend of modular construction. With an approach that focuses on reducing waste, increasing resource efficiency, and better collaboration between stakeholders, Lean Construction has the potential to be a key solution in improving the productivity and sustainability of the construction industry in Indonesia.

Implementing lean construction practices is challenging (Sarhan et al., 2017). identified barriers to the implementation of lean construction practices in the Kingdom of Saudi Arabia, including issues related to labor productivity, coordination, and communication. Similarly, Saieg et al. (2018) reported on the underlying factors hindering the implementation of Lean construction in the Chinese construction industry, such as cultural, organizational, and procurement issues. In addition, the integration of Building Information Modeling (BIM) with Lean construction has been explored to visualize the product and process aspects of construction projects in accordance with Lean construction principles by Malvik (2025). This integration has been shown to increase the efficiency of lean construction and improve design and performance. In summary, Lean construction offers significant potential to improve the performance and sustainability of construction projects. However, in order to successfully implement lean construction methods, many obstacles must be overcome and a collaborative approach must be used.

In addition, Anggraini et al. (2022) conducted a case study of lean construction implementation on a construction project in Indonesia, focusing on eliminating waste and barriers to lean construction implementation in Indonesia. These studies collectively highlighted the relevance of lean construction in Indonesia, discussed the potential for sustainable and efficient construction practices, and identified specific challenges and success factors of the work in the Indonesian context. Overall, research on lean construction in Indonesia shows an increasing interest in applying Lean principles to improve construction practices and address sustainability issues.

While previous studies have explored Lean Construction implementation in Indonesia, a gap exists in the specific application and analysis of waste reduction on educational facility construction projects within densely populated urban environments. This research uniquely addresses this gap by focusing on constructing the Syifaul Qulub Islamic Boarding School in Surabaya, a project constrained by limited access and logistical complexities inherent to densely populated areas. By applying Lean Construction principles and the Value Stream Analysis Tool (VALSAT), this study provides a detailed, context-specific analysis of cost and time waste, offering practical solutions for optimizing construction processes in similar urban educational projects. The "so what?" factor is that this research offers tangible insights and actionable strategies for improving construction efficiency and reducing waste in a challenging, common urban construction scenario in the Indonesian context.

This research aims to analyze the reduction of cost and time wastage in the Syifaul Qulub Islamic Boarding School construction project in Surabaya, which is located in a densely populated area with limited access. By using the lean construction approach, this research seeks to provide efficient solutions in managing construction projects, especially in the face of geographical challenges and limited accessibility. This approach is expected to identify and minimize non-value-added activities, thereby increasing cost and time efficiency in project implementation.

METHOD

This study uses a quantitative approach to analyze the reduction of cost and time waste in the Syifaul Qulub Surabaya Islamic Boarding School construction project with a lean construction approach. The research subjects included all workers and project implementers, with criteria including field workers who have a minimum education of SMA / equivalent and have work experience in the construction field for at least three years (as many as 8 people), project implementers who have a minimum education of D3 in civil engineering (1 person), and project managers who have a minimum education of S1 in civil engineering or architecture (1 person). The study population was all project workers and implementers. At the same time, the sample was determined using a purposive sampling method, which ensured the representation of respondents in accordance with the research objectives.

The research was conducted at the construction project site of Syifaul Qulub Islamic Boarding School Surabaya, which is located at Jl. Kedungdoro Gang Pondok Number 29, Surabaya, during November 2024 when the construction project was running. Data was collected through a questionnaire based on the Value Stream Analysis Tool (VALSAT), interviews, field observations, and project documentation. The questionnaire covers various categories of waste, such as material defects, waiting, overproduction, inappropriate processing, excess transportation, unnecessary inventory, and unnecessary movement, with waste weighting based on a scale of 1-5, where a score of 1 indicates no waste and a score of 5 indicates very high waste.

Data analysis was carried out in several stages, starting from the identification of activities that cause waste using VALSAT, waste weighting based on the average score of respondents, to the creation of Value Stream Mapping to map value-added activities (Value Added/VA), activities that are necessary but not value-added (Necessary but Non-Value Added/NNVA), and activities that are not value-added (Non-Value Added/NVA). Furthermore, critical waste was analyzed using a fishbone diagram to identify the root causes of waste and develop solutions through an evaluation matrix. The validity and reliability of the questionnaire were tested to ensure that the measuring instrument used could accurately represent the research variables. This method is expected to identify the causes of waste and provide practical improvement recommendations to increase the efficiency of construction projects by applying lean construction principles. While offering valuable insights into waste reduction in urban educational construction using Lean Construction and VALSAT, this case study is limited by its single-project focus, small sample size, and reliance on self-reported data, potentially introducing biases. While the quantitative results may not be directly transferable, the methodology and identified waste categories provide a framework applicable to similar construction projects in densely populated areas. Future research should consider larger samples and comparative case studies to enhance the generalizability of these findings.

RESULTS AND DISCUSSION

Research Findings

Waste Identification

The first step in identifying waste is waste weighting, as described in the previous chapter. In the table, the waste weighting score value is based on VALSAT. Then through the questionnaire data distributed, the results of the analysis are obtained in the form of the weight of waste in each activity as follows:

Table 1. Recap of Waste Questionnaire for each activity

No.	Category of Waste	Respondents										Total
		1	2	3	4	5	6	7	8	9	10	
A	Defect											91
A1	Defects in Materials											71
1	Are defects found in Ø10 iron material?	1	1	1	1	1	1	1	1	2	1	11
2	Are defects found in Ø12 iron material?	1	1	1	1	1	1	1	1	1	1	10

Table 2. Recap of the Questionnaire of Waste of each activity Continued

No.	Category of Waste	Respondents										Total
		1	2	3	4	5	6	7	8	9	10	
3	Are defects found in Ø16 iron material?	1	1	1	1	1	1	1	1	1	1	10

4	Are there any defects found in Iron D22?	1	1	1	1	1	1	1	1	1	10
5	Are defects found in H Beam 250 GG steel material?	1	1	1	1	1	1	1	1	1	10
6	Are defects found in H Beam 300 GG steel material?	1	1	1	1	1	1	1	1	1	10
7	Are defects found in the 5/8 steel anchor material?	1	1	1	1	1	1	1	1	1	10
A2	Defects in Steel Structure Prefabrication										20
8	Are there any defects in the weld joints?	1	1	1	1	1	1	1	1	1	10
9	Is there a defect in the bolt nut hole?	1	1	1	1	1	1	1	1	1	10

Source: Processed by Researcher, 2024

In the same way, the weighting results for each activity that occurs, such as waste Waiting, Unnecessary Motion, Transportation (Excessive Transportation), material storage (Unnecessary Inventory), overproduction, and work that is not in accordance with procedures (Inappropriate Processing).

Table 3. Recap of the Waste of each activity according to the ranking

No.	Category of Waste	Value	Weight
1	Waiting	346	43%
2	Unnecessary Motion	113	14%
3	Excessive Transportation	101	12%
4	Defect	91	11%
5	Unnecessary Inventory	90	11%
6	Over Production	56	7%
7	Inappropriate Processing	30	4%

Source: Processed by Researcher, 2024

The table above shows the highest and lowest ranks of each type of waste. The following is an analysis of waste based on the ranking of the highest to lowest waste from the results of the seven waste analyses.

1. Waiting: This type of waiting waste falls into the category of waste that often occurs in projects. This waiting waste can occur in machines, people, or information. In this project, waste waiting is the biggest waste. It occurs because of the time the material gets to the project site, so that it disrupts the work, besides that, the length of waiting for work instructions, tools to arrive, and tool repairs is also a factor that disrupts work. Still, of all of them, the greatest value in the waste waiting analysis is waiting for the arrival of labor to the project site.
2. Unnecessary Motion: the next biggest waste is that many workers waste time, such as smoking, relaxing, not returning to work quickly when the break ends, and not working effectively (slow at work).
3. Excessive Transportation: This type of waste occurs when moving people or materials, which wastes time, energy, and cost. Given the densely populated area of this project site, the movement of project materials is done manually. It takes quite a long time and a lot of energy.
4. Defects: This type of waste can be in the form of defects in the materials ordered from suppliers and defects in the field's construction work process.
5. Unnecessary Inventory: This type of waste is in the form of excessive inventory levels and incorrect ordering of materials, causing them to go unused.
6. Overproduction: Overproduction waste in this project is the accumulation of tools and materials at the project site. Sand and rebar materials often pile up there because they have not been used for construction. This type of waste also occurs due to work done beyond the instructions given.
7. Inappropriate Processing: This type of waste can include work processes that use tools or machines that are unsuitable in capacity or capability, mismatches between standard work procedures and field applications, and significant differences in work methods between operators in the construction area.

Value Stream Analysis Tool (VALSAT)

The next step is determining the value stream mapping tool using the Value Stream Analysis Tool (VALSAT). In VALSAT, seven tools will be used to analyze these wastes. Determination of suitability is done by multiplying the average score of each waste with the Value Stream Mapping suitability matrix, and the Value Stream Mapping with the largest total score according to the VALSAT results will be used

as the selected mapping to be able to identify waste in detail. This selection is based on the fact that the Value Stream Mapping with the largest score is most suitable for identifying waste in the value stream.

Table 4. Recapitulation of VALSAT Results

Waste/Structure	Process Activity Mapping	Supply Chain Response Matrix	Product Variety Funnel	Quality Filter Mapping	Demand Amplification Mapping	Decision Point Analysis	Physical Structure
Waiting	H 311,4	H 311,4	L346		M1038	M1038	
Unnecessary Motion	H 1017	L 113					
Excessive Transportation	H 90,9						L 10,1
Defect	L 9,1			H 89,1			
Unnecessary Inventory	M27	H 81	M 27		H 81	M 27	L 9
Over Production	L7	M21		L7	M21	M21	
Inappropriate Processing	H 36		M 12	L4		L4	
Total	583.1	424.7	73.6	100	205.8	155.8	19.1

Source: Processed by Researcher, 2024

Description:

- H (High Correlation): Multiplier factor = 9
- M (Medium Correlation): Multiplier factor = 3
- L (Low Correlation): Multiplier factor = 1

The table shows that the selected tools with the highest score, 583.1, are Process Activity Mapping. The next process will be the detailed Process Activity Mapping (PAM) mapping.

Process Activity Mapping (PAM)

Process Activity Mapping maps all activities in detail to eliminate waste. Process activity mapping will provide an overview of the physical flow, information, and time required for each activity, the distance traveled, in each production stage. Then identify activities divided into five activity classifications: operations, transportation, inspection, delay, and storage. Operation and inspection are value-added activities. Meanwhile, transportation and storage are important but not value-added. The delay is an activity that is avoided because it is a non-value-added activity. The collected data is processed into the process activity mapping.

Table 5. Process Activity Mapping

No.	Activities	Tools/Machines	Distance (m)	Time (days)	TK	Activities	VA/NVA/NNVA
1	Demolition		14	2	0		VA
2	Land clearing / transporting demolition materials		550	7	2	T	NNVA
3	Bowplank measurement and installation		7	3	0		VA
4	Foundation Excavation		9	5	0		VA
5	Waiting for materials to arrive		4	1		D	NVA
6	Raw material inspection		2	2		I	NNVA
7	Strous Foundation Reinforcement		7	2	0		VA
8	Pile cap concreting		7	2	0		VA
9	Sloof Reinforcement		7	6	0		VA

10	Strous foundation and pile cap installation		2	12	0	VA
11	Backfill the soil	Stamper	3	6	0	VA
12	Sirtu backfill	Stamper	2	6	0	VA
13	Waiting for workers to arrive		2	10	D	NVA
14	30x40 cm ² sloof casting; K300	Molen	1	35	0	VA
15	Casting sloof 20x30 cm ² ; K300	Molen	1	35	0	VA

Source: Researcher, 2024

Table6. Process Activity Mapping Continued

No.	Activities	Tools/Machines	Distance (m)	Time (days)	TK	Activities	VA/NVA/NNVA
16	35x35 cm ² column casting; K300	Molen		3	35	O	VA
17	Waiting for Steel Structure Fabrication		18	3		D	NVA
18	Material Preparation on Site		800	4	5	T	NNVA
19	Managing Material Storage		2	2		S	NNVA
20	Waiting for steel structure workers to arrive		5	4		D	NVA
21	Steel Structure Installer		36	5	0		VA
22	New wall pairing		16	5	0		VA
23	Plastering + painting of old wall (1Pc:5Ps)		6	3	0		VA
24	Plastering + painting of old wall (1Pc:2Ps)		6	3	0		VA
25	Plastering + concrete mortar (1Pc:3Ps)		3	2	0		VA
26	Water installation		2	3	0		VA
27	Dirty Water Installation		2	3	0		VA
28	Install 1x36Watt TL Lamp		3	3	0		VA
29	Install Dual Switch		3	4	0		VA

Source: Researcher, 2024

Table 7. Process Activity Mapping Continued

No.	Activities	Tools/Machines	Distance (m)	Time (days)	TK	Activities	VA/NVA/NNVA
30	Plug the socket		3	4	0		VA
31	Installation Wearing		3	4	0		VA
32	Waiting for Dome Materials on Site		2	4		D	NVA
33	Waiting for workers to arrive		2	6		D	NVA
34	Dome and tower frame installer		4	6	0		VA
35	Dome and Tower Cover Installation		2	2	0		VA
Total			200	2	0		VA

Source: Researcher, 2024

Description:

The blue marks in the table are activities that occur from the production process flow.

- a. TK: Labor
 - b. O : Operation
 - c. T : Transportation
 - d. I : Inspection
 - e. S : Storage
 - f. D : Delay
- VA : Value Added
NVA : NonValue Added
NNVA : Necessary NonValue Added

The further grouped value-added activities (VA), activities that have no added value but are still needed (NNVA), and activities that have no added value (NVA).

Table 8. Total calculation of PAM activities

Activities	Total	Time (days)
Operation	25	152
Transportation	2	11
Inspection	1	2
Storage	1	2
Delay	6	33
Total	35	200

Source: Researcher, 2024

The time for the entire construction process from foundation to dome is 200 days, with a total of 35 activities, with 25 operations, two transportation, one inspection, one storage, and six delays contained in all activities.

Table 9. Total calculation of VA, NVA, NNVA

Type of Activity	Total	Time (days)	Percentage
VA	25	152	76%
NVA	6	33	17%
NNVA	4	15	8%
Total	35	200	100%

Source: Researcher, 2024

The calculation of value-added activities (VA) takes 152 days (76%), while non-value-added activities (NVA) take 33 days (17%), and activities that have no added value but are needed (NNVA) take 15 days (8%).

Analysis and Interpretation of Results

Analysis of the data that has been collected and data processing has been carried out. The three tools chosen in value stream mapping are process stream mapping, supply chain response matrix, and demand amplification mapping, which will be evaluated, and improvements will be recommended based on the root cause of each waste that occurs.

Analysis of Building Construction Project Management Using Lean Construction Approach to Determine Cost and Time Waste in the Construction Project of Pondok Pesantren Syifaul Qulub Surabaya

Waste Analysis on Whole Stream Construction Project

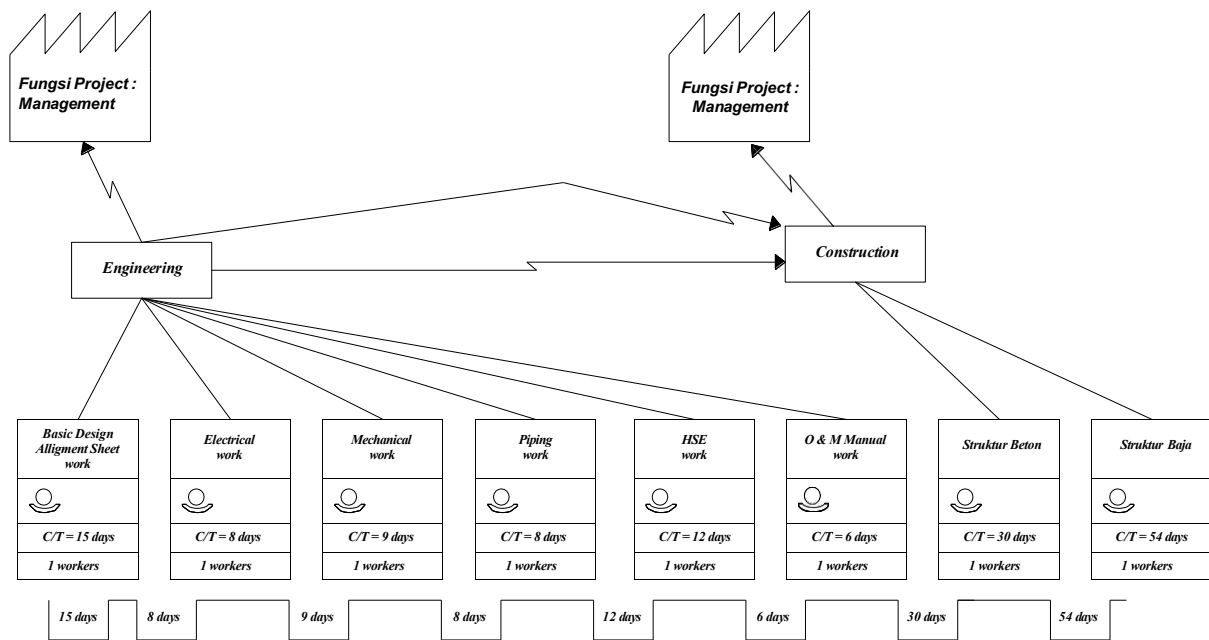


Figure 1. Big Picture Mapping
Source: Processed by Researcher, 2024

The first step in identifying waste that occurs is to do Big Picture Mapping (BPM), which represents the entire project stream. From this depiction, which areas have the potential for waste will be known. In BPM, it can be seen that engineering and construction activities have a total time of 200 (two hundred) days, which is obtained from the summation of the operating time of engineering and construction activities. Meanwhile, from the project it is known that the total construction time from the beginning of planning to execution is 200 (two hundred) days. No time is allocated for implementing other activities included in the non-value-added engineering and construction activities, so the schedule is very tight. It must be carried out in parallel, simultaneously. These activities have the potential to cause delays in this project. In the project schedule plan, it is determined that the project will be completed in the 3rd week of February 2025, but in reality, the project schedule will be delayed and re-planned to be completed in March 2025, week 4. To anticipate this in the next project work, it can be done by reviewing the manpower engineers' needs with the ideal time needed to complete the existing deliverables, and making SOPs along with clear timelines for the preparation, review of engineering documents, along with the qualifications of engineers needed.

Waste Analysis Based on Process Activity Mapping (PAM)

Process activity mapping will provide an overview of the physical flow, information, and time required for each activity and the distance traveled in each production stage. Then identify activities divided into five activity classifications: operations, transportation, inspection, delay, and storage. Operation and inspection are value-added activities. Meanwhile, transportation and storage are important but not value-added. The delay is an activity that is avoided because it is a non-value-added activity. The collected data is processed into the process activity mapping.

The calculation of value-added activities (VA) with a time of 152 days (76%), while non-value-added activities (NVA) take 33 days (17%), and activities that have no added value but are needed (NNVA) take 15 days (8%).

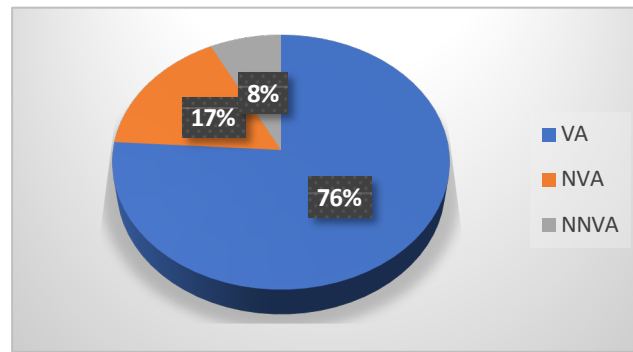


Figure 2. Comparison of Value Added, Non-Value Added Activity and Necessary Non-Value Added Activity

Source: Processed by Researcher, 2024

The figure shows that non-value-added activities (NVA) have a fairly large percentage, second only to Value-Added Activities (VA), which is 17%. Therefore, they must be reduced to shorten the cycle time and reduce workmanship delays.

Fishbone Diagram Analysis of Waste Factors

Finding the root cause of critical waste with the cause and effects diagram method (Fishbone) is done by looking at the factors that cause problems with five factors: humans, machines, work environment, materials, and work methods. Fishbone Diagram of factors causing waste waiting in the Syifaul Qulub Islamic boarding school construction project in Surabaya. Five factors are known through the Fishbone Diagram of waste waiting: humans, machines, work environment, materials, and work methods.

1. Human

Delays in workers' arrival at the project site and the number of workers working lazily (not according to work procedures) create critical waste that can affect time and costs.

2. Environment

The work location setting is not good, there are still many piles of materials at the work site, and the storage location is not in one place. It is located far from the work site, which also causes critical waste that can affect time and costs.

3. Machine

The delay in the arrival of the jackdrill tool makes the demolition work run slowly, in the casting work, there is a time delay due to waiting for the repair of the molen machine, so that it can be said to be the cause of critical waste that can affect time and cost.

4. Methods

The manual dismantling method makes the work time longer than planned, this is also a cause of critical waste that can affect time and cost.

5. Materials

Delays in material delivery due to the logistics department being less careful in bringing in material, are one of the factors causing critical waste that can affect time and costs.

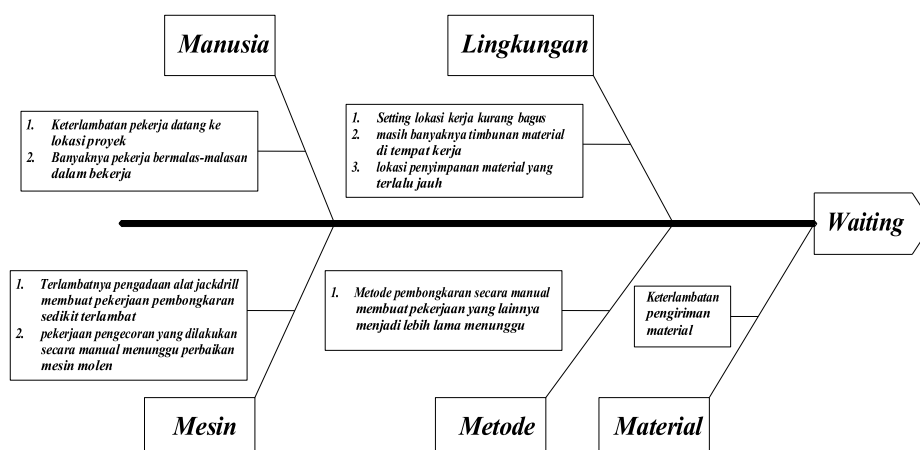


Figure 3. Comparison of Fishbone Diagram waste waiting

Source: Processed by Researcher, 2024

Solutions to Waste

In this study, several tools were used to analyze the evaluation of cost waste in the construction project of Syifaul Qulub Islamic boarding school in Surabaya. The tool used is the evaluation matrix.

Table 12. If Then Formulation

No.	If	Then	When
1	Difficulty in material transfer	Material storage is placed close to the work site	Time of Implementation
		Cleaned the work floor by removing waste materials	Time of Implementation
2	Lost Equipment	Purchasing new equipment	Time of Implementation
		provide a special place for tool storage	Time of Implementation
3	Broken Equipment	Using equipment carefully	Time of Implementation
		Maintaining equipment on a scaled basis	Time of Implementation
4	Pros of buying materials	Resell the remaining materials that are still good	After Implementation
		Store materials that are still good until the next project	After Implementation

Source: Researcher's calculation, 2024

Evaluation Matrix is used to overcome the causes of waste in the form of recommendations that need to be made to minimize waste that occurs in the construction project of the Syifaul Qulub Surabaya Islamic boarding school. The weight score value is obtained from the product of the weight factor with the rank value, while the weight factor and rank value are the values we take from observing the conditions that occur in the project directly based on a scale of 1 to 10. So, in the same way, the weight score value is generated to determine which improvements will be used to minimize waste in each activity that has been mapped in the process activity mapping.

Table 13. Evaluation Matrix for Difficulty in Material Moving

Criteria	Weight factor	Alternative Solution			
		Material storage is placed close to the work site		Cleaned the work floor by removing waste materials	
		Ranking	Weight score	Ranking	Weight score
(1)	(2)	(3)	(4) (2X3)	(5)	(6) (2X5)
Cost	7	6	42	5	35
Time	7	6	42	4	28
Impact on risk	7	7	49	5	35
Risk	7	7	49	3	21
Total			182		119
GO/NOT GO		GO		NOT GO	

Source: Researcher's calculation, 2024

Based on the evaluation matrix of difficulties in moving materials above, the solution to overcome Waste Motion and Waste Transportation on the project is that material storage is placed close to the work site.

Table 14. Missing equipment evaluation matrix

Criteria	Weight factor	Alternative Solution			
		Purchasing new equipment		provide a special place for tool storage	
		Ranking	Weight score	Ranking	Weight score
(1)	(2)	(3)	(4) (2X3)	(5)	(6) (2X5)

Cost	6	3	18	6	36
Time	6	4	24	7	42
Impact on risk	6	5	30	5	30
Risk	6	6	36	4	24
Total			108		132
GO/NOT GO			NOT GO	GO	

Source: Researcher's calculation, 2024

Based on the missing equipment evaluation matrix, the solution to overcome waste, Waiting, Motion, and Inventory due to the loss of equipment on the project is to provide a special place for equipment.

Table 15. Broken equipment evaluation matrix

Criteria	Weight factor	Alternative Solution			
		Using equipment carefully		Maintaining equipment on a scaled basis	
		Ranking	Weight score	Ranking	Weight score
(1)	(2)	(3)	(4) (2X3)	(5)	(6) (2X5)
Cost	6	6	36	6	36
Time	6	7	42	7	42
Impact on risk	6	6	36	5	30
Risk	6	6	36	4	24
Total			150		132
GO/NOT GO			GO	NOT GO	

Source: Researcher's calculation, 2024

Based on the evaluation matrix of damaged equipment, the solution to overcome waste, waiting, Motion, and inappropriate process due to damaged equipment on the project is to use equipment carefully.

Table 16. Evaluation matrix for excess material purchase

Criteria	Weight factor	Alternative Solution			
		Resell the remaining materials that are still good		Store materials that are still good until the next project	
		Ranking	Weight score	Ranking	Weight score
(1)	(2)	(3)	(4) (2X3)	(5)	(6) (2X5)
Cost	6	8	48	6	36
Time	6	8	48	7	42
Impact on risk	6	6	36	5	30
Risk	6	6	36	4	24
Total		168		132	
GO/NOT GO			GO	NOT GO	

Source: Researcher's calculation, 2024

Based on the evaluation matrix of excess material purchases, the solution to overcome this Inventory waste is to resell the remaining materials that are still good. Of course, the proceeds from the sale of this leftover material can reduce the amount of project losses. Some of the recommended actions above should be carried out by the project implementer to overcome the waste of the Syifaul Qulub Surabaya boarding school construction project.

CONCLUSION

This study analyzed cost and time waste in the construction of Pondok Pesantren Syifaul Qulub Surabaya using the Lean Construction approach. The findings indicate that waiting time was the most significant contributor to inefficiencies, accounting for 41.8% of total waste and resulting in a 33-day project delay. Other major causes included excess material purchases, difficulty in material movement, equipment loss and damage, and inefficient worker utilization. The analysis revealed that 21% of

construction activities consisted of non-value-added (NVA) tasks, impacting overall project efficiency. The key waste categories included Unnecessary Movement (13.7%), Excessive Transportation (12.2%), Material Defects (11%), Storage Inefficiencies (10.9%), and Overproduction (6.8%).

To address these inefficiencies, this study recommends several waste reduction strategies, including optimizing material storage by establishing dedicated storage areas closer to work zones to reduce transportation time and unnecessary movement. Improving equipment management through a centralized inventory system and implementing routine maintenance schedules can help minimize equipment loss and breakdowns. Additionally, enhancing worker productivity by adopting digital scheduling tools, real-time work tracking, and incentive programs can significantly improve efficiency. Integrating Lean Construction principles, such as prefabrication and just-in-time (JIT) material delivery, would streamline supply chain logistics and prevent excess stockpiling, ensuring that materials arrive only when needed. Furthermore, engaging local authorities, contractors, and project managers in Lean Construction adoption through standardized waste-reduction protocols and government-supported training initiatives could accelerate its implementation across the Indonesian construction sector.

Despite the benefits of these solutions, several challenges must be addressed to ensure successful implementation within the local context. One major challenge is limited awareness and training among construction workers and site managers regarding Lean Construction techniques. Establishing structured training programs through industry workshops and vocational training centers can help bridge this knowledge gap. Another challenge is budget constraints, as investing in digital tracking systems or prefabrication technology may require significant upfront costs. A phased implementation strategy, starting with low-cost process optimizations such as improved material placement and workflow adjustments, can gradually introduce Lean practices without imposing financial burdens. Additionally, resistance to change remains a barrier, as many contractors prefer traditional construction methods due to familiarity and perceived reliability. Implementing pilot projects that demonstrate the cost-saving and efficiency benefits of Lean Construction can encourage broader industry acceptance.

By implementing these tailored solutions, construction projects in Indonesia—particularly those in high-density, accessibility-constrained areas like Pondok Pesantren Syifaul Qulub Surabaya—can significantly reduce waste, enhance efficiency, and improve project outcomes. The findings of this research contribute to a broader understanding of Lean Construction's applicability in Indonesia and provide a framework for waste reduction strategies that can be adapted to similar construction projects nationwide.

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