Waste Analysis to Support the Implementation of Lean Construction on Building Project

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Abstract. In the implementation of a project, it cannot be separated from the name of obstacles or failures. Failure can be caused by waste, including material delays, work repetition, low labour productivity, implementation strategies and poor project planning. Lean Construction handles projects by minimizing waste and trying to produce the maximum value possible. This research aims to identify waste factors in building construction and then analyse the dominant factors of waste. The data was collected using a questionnaire from 23 respondents involved in projects execution and then analysed using the Simple Additive Weighting (SAW) method to find the dominant waste factor in building construction projects in Malang City. According to the calculation, the result shows that the most dominant factor of waste from construction projects in Malang City is waiting criteria with a value of 0,278. Furthermore, the identified results will be used to determine the appropriate strategy towards zero waste.

1 Introduction

Nowadays, the development of infrastructure is increasingly widespread to support the economic system of country, one of which is building construction. This development is generally deliberately made to support specific activities such as shopping, providing health facilities and other activities.

Construction projects are activities that have been planned from the beginning. Therefore, it must be organized according to its purpose. Construction projects need many resources such as materials, labour, supporting equipment, experts and costs that must be carried out in detail [1]. Construction projects generally have a limited time period and must be completed on time as planned. However, in its implementation, many obstacles or failures are encountered, such as waste (material delays, low labour productivity, imperfect project planning, etc).

The success of project implementation can be measured based on a balance of timeliness of completion, cost efficiency and effectiveness of resources. In a project execution, something that does not have added value means Non-Value-Adding Activities or it is defined as waste. [2] suggests that waste on construction projects in the form of time delays,

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costs, quality, lack of safety, repair work, unnecessary transportation, wrong methods or equipment management and poor construction. Furthermore, lots of waste occur on projects, including defects, over-production, waiting, inventory, motion, inappropriate processing, transportation and non-utilized talent that can cause delays and make a waste [3]. Continuous neglect of waste will result in losses, including project cost overruns and project delays that can be seen at the end of project. Therefore, the problem of waste in construction needs to be resolved. One of the waste analyses that have been developed is the implementation of lean construction. Lean Construction is an effort to handle tasks well, minimizing waste of materials, time and resources, so that the maximum value is achieved [3].

According to the background, it is necessary to analyze the factors that cause waste in construction project and determine the dominant factors construction waste as an effort to achieve project optimization.

2 Literature Review

2.1 Lean Construction

Lean Construction is a construction method that is currently being developed to support the implementation of sustainable construction. Handling construction activities by minimizing waste is a basic concept in lean construction. An effort to eliminate construction waste are carried out in terms of material, time and resources to encourage maximum value [4] [5] [6] [7] [8]. According to [9], the lean principles are value, the value stream, flow, pull and perfection

According to the book of Toyota Way [3], there are eight waste, namely:

1. Defect

   Producing defective goods or requiring repair can result in wasted time and effort. Repairing or repeating work, building unfit items, additional manufacturing processes, and more intense inspections result in wasted and unproductive use of resources.
2. Overproduction

   Producing goods without orders or demand can result in waste, such as surplus labour not being used efficiently, unnecessary storage capacity increases, and transportation costs due to excessive inventory.
3. Waiting

   Workers watch automated machines running or wait for the next process step, the following component sourcing tool, not performing work due to material shortages, process delays, machine failures and (capacity bottlenecks).
4. Inventory

   Excess materials, work-in-progress, or finished products can result in negative impacts such as increased delivery times, obsolete or expired goods, damage to goods, advanced transportation and storage costs, and delays in delivery or processing.
5. Motion

   Any unnecessary actions performed by employees while performing their duties, such as searching, picking up, or arranging components, tools, and so on, are also considered a form of waste.
6. Inappropriate processing,

   Inefficient handling due to wrong tools and improper product design, causing unnecessary movement and creating defective goods.
7. Transportation

Transporting work in progress over long distances creates inefficient transportation or movement of materials, components, or finished products into or out of warehouses or between processes.

8. Non-utilized talent

   Wasting time, ideas, skills, and opportunities for improvement and learning by not engaging or listening to your employees.

2.2 Simple Additive Weighting (SAW)

There are some analysis methods in decision making, such as an Analytic Hierarchy Process (AHP), WP method, TOPSIS method, Simple Additive Weighting (SAW), etc. Simple Additive Weight (SAW) method is also known as the weighted sum method. The conscious idea of the Simple Additive Weight (SAW) method is to find the weighted sum of work values with all attributes for each alternative. The Simple additive Weight (SAW) method requires that the decision matrix (X) be normalized to a scale that can be compared with all existing classification alternatives [10].

The advantage of Simple Additive Weighting (SAW) compared to other decision-making method is its ability to make more precise assessments due to predetermined values of criteria and preference weights. Moreover, the SAW can also deliver the best alternative from several identified alternatives, due to the ranking process which is generated after the weight value for each attribute [11] [12] [13] [14] [15]. There are some steps in Simple Additive Weighting (SAW) method, namely:

1. Define alternatives (Ai)
2. Determine the criteria (Cj)
3. Assess according to each alternative (Ai) and also criteria (Cj)
4. Determine the weight or degree of importance (W) for each criterion
5. Create a decision matrix consisting of a suitability rating table for each criterion alternative. The value of each alternative (Ai) according to each given criterion (Cj)

$$X = \begin{pmatrix} X_{11} & & X_{12} & & X_{13} \\ & \dots & & \dots & \vdots \\ X_{i1} & & X_{i2} & & X_{i3} \end{pmatrix} \quad (1)$$

6. Normalize the decision matrix by calculating the normalised performance rating value (rij) of alternative Ai using criteria Cj.

$$rij = \frac{Xij}{Max\ Xij} \quad (2)$$

7. The results of matrix normalisation are entered into the normalised matrix (R)

$$R = \begin{pmatrix} r_{11} & r_{12} & \dots & r_{1j} \\ r_{11} & r_{12} & \dots & r_{2j} \\ \vdots & \vdots & \dots & \vdots \\ r_{i1} & \dots & \dots & r_{ij} \end{pmatrix} \quad (3)$$

8. The final preference value (Vi) is obtained by multiplying the normalised matrix row elements (R) by the preference weights (W) corresponding to the matrix column elements (W).

$$Vi = \sum_{i=1}^{n} wj.\ rij \quad (4)$$

The excellent Vi calculation result indicates that alternative Ai is the best alternative.

3 Material and Methods

The initial step in this research was exploring literature reviews from previous studies in journals and books related to lean construction and waste factors in building construction projects. An extensive literature reviews related to waste factors in construction phase will complete the research objectives and initial output to determine appropriate handling strategies and enrich construction management knowledge.

The data sources collected in this study include primary and secondary data. Primary data is a questionnaire by distributing question forms to respondents who give the assessment. This questionnaire is addressed to respondents, namely supervisory consultants, contractors and experts in construction management from the three building construction projects in Malang City, which are used as the research object. The secondary data came from literature studies, which is solving the problems by tracing previously research sources in the form of books or journals that have been published in related with waste factors in construction projects.

Based on the list of result from the questionnaire filling data, the Simple Additive Weighting (SAW) method is used to determine the dominant waste factor that occurs in building construction projects in accordance with the principles at the phase of analysis.

4 Result and Discussion

From the results of the literature study, 65 alternatives (factors causing building construction waste) were identified, namely (Ai); these alternatives came from previously published journals via Google Scholar with the keywords "waste" and "Lean Construction" with the upload period from 2015 to 2023 and from these journals sorted according to the research conducted. From previous studies, 65 waste factors were found, which were used as variables; these factors are shown in Table 1.

Table 1. Factors causing construction waste (Ai)

No.	Factors Causing Construction Waste	References
I.	***Defect***	
1.	Materials that do not comply with quality standards (A1)	[16], [17], [4], [18]
2.	Lack of labour (A2)	[16]
3.	Allocation of personnel for repair work (A3)	[16]
4.	Material Storage (A4)	[16], [4]
5.	Tool use error (A5)	[19]
6.	Rework occurred due to a work instruction error (A6)	[17], [18]
7.	Change of material type or specification (A7)	[17]
8.	Coordination with involved parties (A8)	[20], [4], [18]
9.	Construction method precision (A9)	[20], [4], [18]
10.	Superintendent delay (A10)	[20], [4]

No.	Factors Causing Construction Waste	References
11.	Completeness and clarity of working drawings (A11)	[20], [4], [18]
12.	Job instruction error (A12)	[18]
14.	Providing unclear information (A14)	[18]
15.	Understanding of working drawings (A15)	[18]
16.	Lousy weather (A16)	[20], [4], [18]
II.	***Waiting***	
17.	Design changes (A17)	[16], [17], [20], [4], [18]
18.	Material delays arriving at the location (A18)	[16], [20], [4]
19.	Poor planning and scheduling (A19)	[16], [20], [18]
20.	Delivery schedule (A20)	[16], [20], [4]
21.	Tool operation (A21)	[19]
22.	Labor Waiting for Instructions (A22)	[17], [18]
23.	Delay in arrival of heavy equipment (A23)	[17], [18]
24.	Machine damage during use (A24)	[17], [18]
25.	Heavy equipment does not fulfil a proper function in the field (A25)	[17], [18]
26.	Machine operator availability (A26)	[17]
27.	Availability of machine repair parts (A27)	[17]
28.	Machine productivity (A28)	[17]
29.	There was a change in the price of wages, materials and tools (A29)	[17]
30.	RAB calculation error occurred (A30)	[17]
31.	Weather (A31)	[20], [4], [18]
32.	Tool shortage (A32)	[20], [4]
33.	Delay in arriving at the location (A33)	[18]
34.	Incomplete contract documents (A34)	[18]
35.	Addition of job types (A35)	[18]
36.	Slow decision making (A36)	[18]

No.	Factors Causing Construction Waste	References
37.	Slow distribution of working drawings (A37)	[18]
III.	***Inventory***	
38.	Material planning and scheduling (A38)	[16]
39.	Material delivery arrives on site (A39)	[16]
40.	Storage exceeds warehouse volume (A40)	[16]
41.	Material damaged by prolonged storage (A41)	[16]
42.	Excess material/material (A42)	[18]
IV.	***Motion***	
43.	Working layouts (A43)	[16]
44.	Workplace management (A44)	[16]
45.	Working method (A45)	[16], [20]
46.	Effective use of tools (A46)	[16]
47.	Recurring project support facility setup (A47)	[19]
48.	Remaining materials/ ingredients (A48)	[18]
V.	***Inappropriate Processing***	
49.	Appropriateness of equipment for execution of work (A49)	[16]
50.	Work procedures (A50)	[16]
51.	Poor equipment maintenance (A51)	[16]
52.	Failure to combine device (A52)	[16]
VI.	***Transportation***	
53.	Materials that do not go directly to the project site (A53)	[16]
54.	Equipment mobilisation too far (A54)	[16]
55.	Material orders too far away (A55)	[16]
56.	Labour mobilisation too far (A56)	[16]
VII.	***Non-Utilized talent***	
57.	Labor Skills (A57)	[16], [20], [4], [18]
58.	Labor discipline (A58)	[16], [20], [4]
59.	Excessive overtime (A59)	[16]
60.	Workers do not perform work according to SOP (A60)	[19]
61.	Labor productivity (A61)	[17]
62.	Labour does not comply with the rules (A62)	[17]

No.	Factors Causing Construction Waste	References
63.	The workforce makes it difficult to cooperate in one teamwork (A63)	[17]
64.	Supervisor experience (A64)	[20], [4], [18]
65.	Poor distribution of labour (A65)	[4], [18]

Based on the provisions stated in the book source, the type of waste (criteria) that will be used in decision-making is (Cj). These criteria are taken from the book of Toyota Way [3], as in Table 2.

Table 2. Construction waste factor (Cj)

No.	Type of waste
1.	Defect (C1)
2.	Waiting (C3)
3.	Inventory (C3)
4.	Motion (C4)
5.	Inappropriate Processing (C5)
6.	Transportation (C6)
7.	Non-Utilized Talent (C7)

From distributing questionnaires to 23 respondents from the three building construction projects in Malang City, the average value of criteria (Cj) and alternatives (Ai) are derived in Table 3 and Table 4. In Table 4, only ten variables are shown, then the same calculation is generated until all altevatives.

Table 3. Mean value of criteria (Cj)

Criteria	Defect (C1)	Waiting (C2)	Inventory (C3)	Motion (C4)	Inappropriate Processing (C5)	Transportation (C6)	Non-Utilized Tallent (C7)
Weight	11,95%	27,82%	8,69%	20,65%	9,13%	8,91%	12,82%
Decimal	0,120	0,278	0,087	0,207	0,091	0,089	0,128
Rank	4	1	7	2	5	6	3

Table 4. Mean value of alternative (Ai)

Alternative	Average
A1	5,870
A2	9,696
A3	17,739
A4	13,783

Alternative	Average
A5	9,435
A6	14,435
A7	18,696
A8	8,391
A9	12,957
A10	5,783

From the average of the respondents' alternative assessments results, it is entered into decision matrix and the matrix normalization is generated with the formula:

$$rij= \frac{Xij}{Max\ Xij} \quad (5) \qquad (1)$$

Description:
Xij : Value of attributes owned by each criterion
Max Xij : The most significant value of each criterion
From the normalization calculation, the value of matrix normalisation is found as in Table 5. Table 5 only shows ten alternatives and the same calculation method generated up to alternative 65.

Table 5. Matrix normalisation result

Alternative	C1	C2	C3	C4	C5	C6	C7
R1	0,138	0,000	0,000	0,000	0,000	0,000	0,000
R2	0,229	0,000	0,000	0,000	0,000	0,000	0,000
R3	0,418	0,000	0,000	0,000	0,000	0,000	0,000
R3	0,352	0,000	0,000	0,000	0,000	0,000	0,000
R4	0,223	0,000	0,000	0,000	0,000	0,000	0,000
R5	0,341	0,000	0,000	0,000	0,000	0,000	0,000
R6	0,441	0,000	0,000	0,000	0,000	0,000	0,000
R7	0,198	0,000	0,000	0,000	0,000	0,000	0,000
R8	0,285	0,000	0,000	0,000	0,000	0,000	0,000
R9	0,136	0,000	0,000	0,000	0,000	0,000	0,000
R10	0,084	0,000	0,000	0,000	0,000	0,000	0,000

From the results of the criterion preference weights and the consequences of normalizing the decision matrix of each alternative, the calculation of the preference value for each criterion is using this formula: (2)

$$Vi= \sum_{i=1}^{n} wj.\ rij \quad (6)$$

Description:
Vi = Final value of alternative
Wj = Weight that has been determined
Rij = Normalization matrix

The final value according to the last calculation with Simple Additive Weighting (SAW) method indicates the dominant factor from 7 criteria (Cj) with 65 alternatives (Vi) which is shown in Table 6.

Table 6. The dominant waste factor

Rank	Factor waste construction		Preference Value	Alternative Ranking
1.	Waiting (C2 = 27,826)			
	1.	Weather (A31)	0,278	1
2.	Motion (C4 = 20,652)			
	1.	Recurring project support facility setup (A47)	0,207	1
3.	Non-utilized Talent (C7 = 12,826)			
	1.	Excessive overtime (A59)	0,128	1
4.	Defect (C1 = 11,957)			
	1.	Lousy weather (A16)	0,120	1
5.	Inappropriate Processing (C5 = 9,130)			
	1.	Poor equipment maintenance (A51)	0,091	1
6.	Transportation (C6 = 8,913)			
	1.	Labour mobilisation too far (A56)	0,089	1
7.	Inventory (C3 = 8,696)			
	1.	Material delivery arrives on site (A39)	0,087	1

According to all calculation came from the questionnaires distribution to respondents who have been carried out on all criteria and alternatives to waste factors that occur in building construction projects in Malang City, it is conclude that the dominant factor is "waiting" criteria with a preference value of 0.278. Based on the alternatives, it is found each criterion such as (A31) with a value of 0.278 on "waiting" criteria, (A47) with a value of 0.207 on "motion" criteria, (A59) with a value of 0.128 on "non-utilized talent" criteria, (A16) with a value of 0.120 on "defect" criteria, (A51) with a value of 0.091 on "inappropriate processing" criteria, (A56) with a value of 0.089 on "transportation" criteria, and (A39) with a value of 0.087 on "inventory" criteria. The results indicate some factors that must be paid attention and taken into consideration due to the opportunity of construction waste.

5 CONCLUSION

Waste factors that become criteria in the project include defects, waiting, inventory, motion, inappropriate processing, transportation and non-utilized talent. as well as 65 waste variables that cause construction waste.

Based on distributing questionnaires to respondents followed by waste analysis using the Simple Additive Weighting (SAW) method for building construction in Malang City, the identified dominant factor is "waiting" criteria, with a preference value of 0.278. Based on the results of this study, further research will continue with strategies simulation to minimize construction waste in building projects.

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