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Analysis of Waste-Causing Factors Using the Lean Construction

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A B S T R A C T

Building construction projects often face inefficiencies that lead to waste and disrupt project execution. Waste occurs when resources are expended without generating proportional value. This study aims to analyze the most important types of waste by applying the Lean Construction approach and analyzing the actions to handle them. Lean Construction classifies waste into seven categories: overproduction, inventory, defects, motion, transportation, waiting, and over-processing. A questionnaire was developed based on identified waste indicators, with responses analyzed using the Relative Importance Index (RII) to determine the most critical contributing factors. Further analysis of waste handling measures was conducted through a literature review, followed by a Focus Group Discussion (FGD) and decision-making using the Pareto method. The results of this study indicate that scattered materials in the project area, which obstruct the movement of other materials, are identified as the most critical factor contributing to waste. In addition, eight waste handling measures were identified based on the Pareto analysis.

1. Introduction

Building construction is a vital sector in Indonesia's infrastructure and economic development[1]. Rapid urbanization and population growth have driven increasing demand for various building types, such as hospitals, offices, residential complexes, and commercial facilities [2], [3]. Buildings vary in form, size, and function, adapting over time to factors like climate, materials, land conditions, cost, and aesthetics [4]. However, construction activities heavily rely on natural resources and often result in considerable material waste due to process inefficiencies [5]. Activities that consume resources without generating value are considered waste [6], which can lead to excessive costs and hinder overall project progress.

International studies have demonstrated that waste in construction significantly contributes to cost overruns [7]. In the United Kingdom, material waste accounts for an additional 15% of construction costs on over-budget projects. Similarly, a study by the Hong Kong

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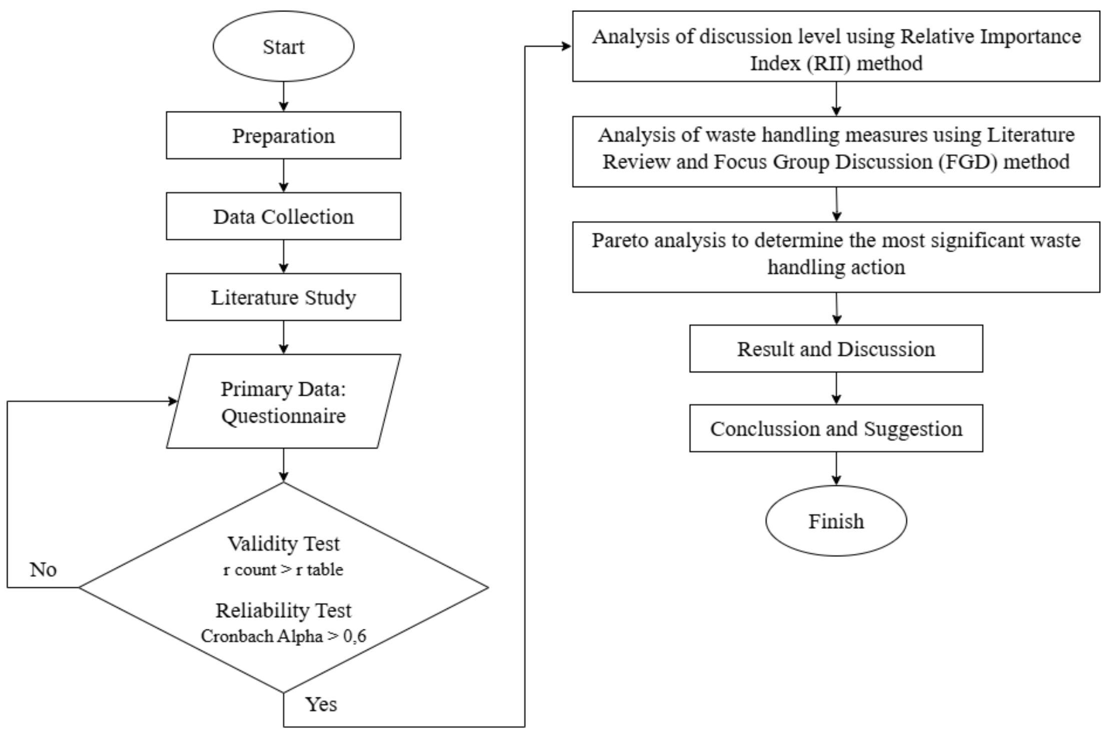
Polytechnic and the Hong Kong Construction Association reported an 11% cost overrun due to material waste. In the Netherlands, research by Bossink and Bounwers found that material waste contributes to 20–30% of total project costs. Waste in construction not only escalates construction costs but also increases expenses related to waste management and disposal [8]. Causes of construction waste include poor design, inefficient procurement, improper handling, and ineffective execution. Moreover, the accumulation of unused materials impacts the construction workflow and contributes to environmental burdens due to limited disposal facilities [9].

To address these issues, Lean Construction offers a suitable approach by emphasizing careful planning and minimizing non-value added activities, thereby reducing waste and enhancing value delivery [8], [10], [11]. This study aims to analyse the factors contributing to waste using the Lean Construction framework within the Ji'rona Building Project of 'Aisyiyah Bojonegoro Hospital and to identify strategies for waste handling, to make construction processes more efficient, effective, and targeted.

2. Research Method

2.1. Research Flowchart

The following is the research flowchart employed in this research.



Source : Processed by Researcher (2025).

Figure 1. Research Flowchart

Figure 1 displays the flowchart outlining the systematic methodology used in the research process. The following are the steps in this research:

1. Preparation, involving the formulation of the research problem, objectives, and methodology.
2. Data Collection, conducted through a questionnaire distributed at the Ji'rona Building Construction Project, 'Aisyiyah Hospital, Bojonegoro.
3. Data Analysis, using RII method to identify critical waste factors, FGD method and Pareto analysis to determine the most significant waste handling measures.

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4. Results and Discussion, where findings are interpreted in relation to the research objectives.
5. Conclusion and Recommendations, summarizing key waste factors based on RII results and providing suggestions for waste handling measures.

2.2. Lean Construction

Lean construction is a method for designing production systems that aim to minimize waste of materials, time, and effort, while maximizing the generation of value [12], [13]. The construction industry generates a substantial amount of waste due to material usage. The implementation of Lean Construction within the industry serves two fundamental objectives: increasing value and reducing waste [5], [14], [15], [16], [17]. The lean construction approach identifies seven types of waste: overproduction, excess inventory, unnecessary motion, waiting time, transportation, overprocessing, and defects [18]. Accordingly, in managing waste on construction projects, the lean approach does not view waste solely as material excess, but also considers the waste of time, resources, and movement [19].

2.3. Likert Scale

The Likert scale serves as a tool to assess attitudes, views, and perceptions of individuals or groups toward certain social phenomena [20]. In a research context, these phenomena are identified in advance by the researcher and are known as research variables. These variables are then broken down into specific indicators using the Likert scale for measurement purposes.

2.4. Relative Importance Index

Data analysis is conducted after data from all respondents or other sources have been collected. This method is used to determine the ranking of a group of factors or variables based on their perceived level of influence or importance according to the respondents [21]. The ranking of each factor is determined by the magnitude of the RII value obtained—the higher the RII score, the greater the factor's perceived impact. The following RII formula is among the most commonly used [22]:

$$\mathrm{RII} = \frac{\Sigma W}{A.N}$$

When:
RII = Relative Importance Index
W = The weighted score based on the Likert scale responses from all respondents
A = The highest possible weight on the Likert scale
N = Total respondents

2. 5. Focus Group Discussion

The FGD method can be utilized as it involves various stakeholders directly engaged in the implementation of the project. Through the in-depth dialogue that emerges within this forum, researchers are able to validate previous findings while simultaneously uncovering new insights that enrich the understanding of the issues under investigation. This method aims to formulate waste handling measures based on a literature review, aligned with stakeholder perspectives.

2. 6. Pareto Analysis

The Pareto analysis, commonly referred to as the 80/20 principle, is a decision-making tool used to identify the most significant factors contributing to a particular outcome. Rooted in the observation that approximately 80% of consequences arise from 20% of causes, this method

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enables researchers and practitioners to prioritize efforts on the most impactful issues. In the context of organizational improvement or problem-solving, Pareto analysis facilitates a focused allocation of resources by distinguishing the "vital few" from the "trivial many." By visualizing data through a Pareto chart, stakeholders can make evidence-based decisions aimed at maximizing efficiency and effectiveness within a given system.

3. Description and Technical

3. 1. Population and Samples

The population in this study consists of individuals involved in the planning and execution of the project who are considered knowledgeable about the factors contributing to construction waste. The selected respondents for data collection include the project owner, contractors, supervisors, and planners. A total of 20 respondents participated in this study, comprising 1 owner, 15 contractors, 3 supervisors, and 1 planner.

3. 2. Sampling Techniques

The sampling technique used in this study involved direct data collection from the field by the researcher through a questionnaire. The questionnaire contained questions related to the factors causing waste in the Ji'rona Building Construction Project of 'Aisyiyah Bojonegoro Hospital.

3. 3. Variable Waste

According to [18], waste in lean construction is categorized into seven types, namely:

1. Over Production

Over production refers to waste generated when more products or materials are produced than what is ordered or required by the client. This leads to unnecessary use of resources and increased storage costs without corresponding value.

2. Inventory

Inventory waste occurs due to excessive storage of materials or products. This form of waste reflects inefficiencies in material management, where stored items are not utilized effectively or timely, leading to increased risk of damage or obsolescence.

3. Defect

Defect waste arises from damaged, faulty, or non-conforming materials or products. This type of waste necessitates rework or replacement, resulting in additional time, cost, and resource consumption.

4. Motion

Motion waste refers to unnecessary or excessive movement of workers, equipment, or tools during construction activities. These non-value-adding movements contribute to productivity loss and inefficiencies in the construction process.

5. Transportation

Transportation waste is associated with the unnecessary movement or relocation of materials, equipment, or products. This type of waste does not add value to the project and often results in increased time and handling costs.

6. Waiting

Waiting waste is caused by delays in the construction process, such as waiting for materials, instructions, approvals, or equipment. These idle times disrupt workflow continuity and reduce overall project efficiency.

7. Over Processing

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Over processing waste occurs when construction activities involve tasks or procedures that are unnecessary or exceed the required specifications. This leads to inefficiencies by using more resources, time, or labor than what is needed to meet project requirements.

Table 1. Factor Causing Waste

No	Code	Waste-Causing Factors	References
I	X1	Overproduction	
1	X1.1	Inexperienced supervisors	[5], [13], [23]
2	X1.2	Production of goods at a faster rate or in greater quantities than required	[13], [24], [25]
3	X1.3	Design changes made to the original design	[24], [26]
4	X1.4	Lack of material optimization in the project	[6], [25]
5	X1.5	Use of materials that do not meet the specified standards	[25], [26]
II	X2	Inventory	
6	X2.1	Inadequate storage facilities	[5], [13], [25]
7	X2.2	Materials damaged due to prolonged storage	[6], [24], [25], [26]
8	X2.3	Storage exceeding warehouse capacity	[24], [26]
9	X2.4	Lack of coordination or standard operating procedures (SOP) for the storage of tools and materials	[13], [25]
10	X2.5	Loss of tools and materials	[5], [6]
III	X3	Defect	
11	X3.1	Work results or materials that do not meet established standards	[23], [25]
12	X3.2	Lack of worker skills and competencies	[23], [24], [26]
13	X3.3	Use of materials that do not meet specifications	[5], [24], [25], [26]
14	X3.4	Non-conformity in work execution processes	[23], [24], [25]
15	X3.5	Materials damaged due to weather conditions	[5], [13]
IV	X4	Motion	
16	X4.1	Workers' insufficient understanding of their tasks	[6], [23], [25]
17	X4.2	Inefficient workplace layout	[24], [25], [26]
18	X4.3	Unclear or non-standard work instructions	[5], [6]
19	X4.4	Unproductive worker movements	[24], [25]
20	X4.5	Inconsistent work methods	[24], [26]
V	X5	Transportation	
21	X5.1	Scattered materials within the project area that obstruct the movement of other materials	[6], [23], [25]
22	X5.2	Materials not delivered directly to the project site	[5], [23], [24], [26]
23	X5.3	Mismatched material delivery schedules	[5], [24], [26]
24	X5.4	Excessive distance between material suppliers and the project site	[24], [25], [26]
25	X5.5	Ineffective site layout that hinders workers' mobility during material handling	[24], [25], [26]
VI	X6	Waiting	
26	X6.1	Work activities delayed due to adverse weather conditions	[24], [25]
27	X6.2	Waiting for instructions	[5], [6], [25]

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No	Code	Waste-Causing Factors	References
28	X6.3	Poor planning and scheduling	[5], [24], [26]
29	X6.4	Damage to materials and equipment causing delays	[6], [23], [25]
30	X6.5	Delayed arrival of materials at the project site	[5], [6], [24], [25], [26]
VII	X7	Over Processing	
31	X7.1	Rework due to errors in the work process	[13], [24], [25]
32	X7.2	Performing unnecessary activities within the work process	[5], [6]
33	X7.3	Non-compliance with work procedures	[24], [26]
34	X7.4	Use of inappropriate equipment	[24], [26]
35	X7.5	Insufficient field supervision	[24], [25]

Source : Processed by Researcher (2025).

Table 1 presents a compilation of the key factors contributing to waste in construction projects, classified according to the seven categories of waste commonly identified in lean construction. Each main variable (X1 to X7) represents a specific type of waste, while the sub-variables (e.g., X1.1, X2.2) describe the specific contributing factors or manifestations of each type of waste. Each factor is supported by references from relevant literature, emphasizing its recognition and significance in previous research studies.

3. 4. Instrument Analysis Tool

Validity testing is used to determine whether a questionnaire is legitimate and accurately measures what it is intended to measure. A questionnaire is considered valid if the statements within it are capable of reliably revealing the constructs the questionnaire aims to assess. In this study, the validity test involved a sample of 20 respondents from the Ji'rona Building Construction Project at 'Aisyiyah Bojonegoro Hospital. The validity test was conducted using the Pearson Correlation method with the assistance of SPSS version 26. The validity assessment criteria are as follows:

- An item is considered valid if the calculated r count > r table.
- An item is considered invalid if the calculated r count < r table.

Reliability testing is used to measure the consistency of the questionnaire, which serves as an indicator of the variables or constructs being measured. A variable is considered reliable if the responses to the questionnaire items are consistently similar. A high reliability score indicates that the measurement process produces dependable data. The reliability was assessed using the Cronbach's Alpha (α) statistical test, where a value greater than 0.6 indicates acceptable reliability [20].

3. 5. Data Analysis Techniques

Data analysis is conducted after all responses or data from various sources have been collected. In this study, all data obtained from the questionnaires will be analysed using descriptive analysis to understand respondents' perceptions of each indicator. Subsequently, the RII method will be applied to determine the level of waste. Finally, appropriate waste handling measures will be identified through a literature review approach.

4. Results and Discussions

This chapter presents the results of data analysis derived from questionnaires distributed at the Ji'rona Building Construction Project of 'Aisyiyah Hospital Bojonegoro.

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Table 2. Ranking of Waste-Causing Factors Based on the RII Method

Code	Waste-Causing Factors	Coef.	Rank
X5.1	Scattered materials within the project area that obstruct the movement of other materials	0.85	1
X7.1	Rework due to errors in the work process	0.83	2
X1.3	Design changes made to the original design	0.8	3
X5.3	Mismatched material delivery schedules	0.73	4
X6.2	Waiting for instructions	0.7	5
X6.5	Delayed arrival of materials at the project site	0.66	6
X7.2	Performing unnecessary activities within the work process	0.66	6
X5.4	Excessive distance between material suppliers and the project site	0.64	8
X2.3	Storage exceeding warehouse capacity	0.62	9
X7.3	Non-compliance with work procedures	0.62	9
X4.4	Unproductive worker movements	0.61	11
X4.5	Inconsistent work methods	0.61	11
X3.2	Lack of worker skills and competencies	0.6	13
X4.3	Unclear or non-standard work instructions	0.6	13
X4.1	Workers' insufficient understanding of their tasks	0.58	15
X1.2	Production of goods at a faster rate or in greater quantities than required	0.57	16
X3.5	Materials damaged due to weather conditions	0.57	16
X7.5	Insufficient field supervision	0.57	16
X3.4	Non-conformity in work execution processes	0.56	19
X2.4	Lack of coordination or standard operating procedures (SOP) for the storage of tools and materials	0.55	20
X5.2	Materials not delivered directly to the project site	0.55	20
X6.1	Work activities delayed due to adverse weather conditions	0.55	20
X7.4	Use of inappropriate equipment	0.55	20
X2.2	Materials damaged due to prolonged storage	0.54	24
X5.5	Ineffective site layout that hinders workers' mobility during material handling	0.53	25
X3.1	Work results or materials that do not meet established standards	0.52	26
X6.3	Poor planning and scheduling	0.51	27
X2.1	Inadequate storage facilities	0.48	28
X1.4	Lack of material optimization in the project	0.44	30
X2.5	Loss of tools and materials	0.44	30
X6.4	Damage to materials and equipment causing delays	0.47	30
X1.5	Use of materials that do not meet the specified standards	0.42	32
X4.2	Inefficient workplace layout	0.41	33
X3.3	Use of materials that do not meet specifications	0.4	34
X1.1	Inexperienced supervisors	0.38	35

Source : Processed by Researcher (2025).

Table 2 presents the ranking of waste-causing factors in the construction project, derived using the RII method. The analysis identifies X5.1 (Scattered materials within the project area that obstruct the movement of other materials) as the most importance factor, with the highest RII value of 0.85, indicating it is perceived as the most significant contributor to waste on the construction site.

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Table 3. Waste Handling Measures Based on FGD Method

Code	Waste Handling Measures	Score	Rank
P8	Arranging layout and stacking of materials in storage areas or warehouses	96	1
P11	Training workers on the most efficient use of equipment	95	2
P13	Transferring valuable leftover materials to a salvage company (for sale)	92	3
P17	Optimization of material usage	89	4
P18	Implementation of efficient construction methods	89	5
P28	Allocating materials for future projects	87	6
P15	Controlling the accuracy of material quantities delivered to the project site	84	7
P12	Providing a designated area for material cutting	81	8
P5	Communication during meetings aimed at reducing material waste	79	9
P9	Scanning transfer distance/travel from raw materials to project site	70	10
P20	Accurate material identification	66	11
P29	Selecting materials with minimal or no packaging	66	12
P2	Listing required products according to the specified standards	64	13
P26	Recycling, with value equal to previous production	64	14
P14	Upcycling, enhancing value compared to previous production	62	15
P21	Recording materials that can be reused, recycled, or classified as waste	60	16
P27	Packaging efficiency	59	17
P3	Filing claims to request replacement of materials that do not meet specifications from suppliers or distributors	57	18
P22	Scheduling material delivery	56	19
P16	Secure storage of products/materials	55	20
P4	Re-inspecting all equipment used before project implementation	53	21
P19	Estimating types and quantities of waste materials to be generated	52	22
P10	Utilizing deconstructed materials	49	23
P1	Submitting a contract addendum	48	24
P23	Utilizing salvageable leftover materials	40	25
P7	Increasing the accuracy of estimation and ordering	37	26
P6	Referring to suppliers and recycling parties	36	27
P25	Using environmentally friendly alternative fuels as substitutes for diesel in material transport	33	28
P24	Collaborating with suppliers to purchase surplus materials	31	29

Source : Processed by Researcher (2025).

Table 3 presents the ranking results of waste handling measures. Subsequently, a Pareto analysis is conducted to identify the primary priorities in waste handling measures. By applying the 80/20 principle, the aim of this analysis is to determine the waste handling measures that contribute most significantly to the overall impact of all actions taken.

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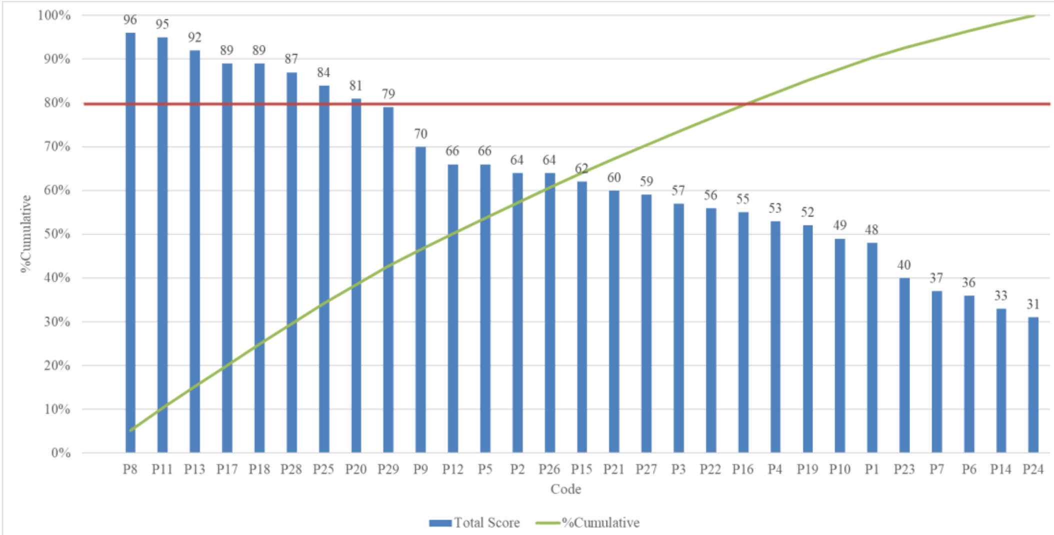

Source : Result Research (2025).

Figure 2. Pareto Chart

Figure 2 illustrates the Pareto chart, which identifies eight waste handling measures with the most significant impact. These actions include: arranging layout and stacking of materials in storage areas or warehouses, training workers on the most efficient use of equipment, transferring valuable leftover materials to a salvage company (for sale), optimization of material usage, implementation of efficient construction methods, allocating materials for future projects, controlling the accuracy of material quantities delivered to the project site, and providing a designated area for material cutting.

5. Conclusion and Suggestion

5.1 Conclusion

The waste factors identified in the project include overproduction, inventory, defect, motion, transportation, waiting, and over-processing, encompassing a total of 35 sub-variables contributing to construction waste. According to the RII analysis, the highest-ranked waste factor is scattered materials within the project area that obstruct the movement of other materials, with an RII coefficient of 0.85. Conversely, the lowest-ranked factor is inexperienced supervisors, with an RII coefficient of 0.38. Based on the literature review, followed by the FGD method and decision-making using the Pareto analysis, eight waste handling measures with the highest significance were identified, include: arranging layout and stacking of materials in storage areas or warehouses, training workers on the most efficient use of equipment, transferring valuable leftover materials to a salvage company (for sale), optimization of material usage, implementation of efficient construction methods, allocating materials for future projects, controlling the accuracy of material quantities delivered to the project site, and providing a designated area for material cutting.

5.2 Suggestion

To improve the quality of data collection, it is suggested that questionnaires be completed when respondents have sufficient time and are not under pressure, so they can provide more thoughtful and accurate responses. The outcomes of this study are expected to serve as valuable insights for stakeholders involved in construction projects, particularly in identifying and addressing the key causes of construction waste.

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ISSN (*Print*) 2503-2399

References

[1] Ikhsan, & Sabang, R. A. M. (2025). Barriers to Sustainable Construction Implementation in Makassar: A Comparative Study of State-Owned and Private Contractors, *Civilla: Jurnal Teknik Sipil Universitas Islam Lamongan*, 10(2), 2503–2399. DOI: https://doi.org/10.30736/cvl.v2i2.

[2] Galaxy, A. B., Wibowo, M. A., & Suharyanto. (2021). Penghambat Dan Pendorong Green Supply Chain Management (Studi Kasus: Aluminium Formwork), *Wahana Teknik Sipil: Jurnal Pengembangan Teknik Sipil*, 26(2), 189–208. DOI: https://doi.org/10.32497/wahanats.v26i2.3133.

[3] Prastowo, T. Y. (2023). Sustainable Transformation in the Construction Industry: Reducing Environmental Impact and Enhancing Cost Performance Through Waste Utilization and Lean Construction, *Civilla: Jurnal Teknik Sipil Universitas Islam Lamongan*, 8(2), 157–170. DOI: https://doi.org/10.30736/cvl.v2i2.

[4] Fatriady, M. R., Rachman, M. R., Jamal, M., Muliawan, I. W., Mustika, W., & Mabui, D. S. S. (2022). *Teknologi Bangunan Dan Material*, Tohar Media. URL: https://books.google.co.id/books?id=I2JbEAAAQBAJ.

[5] Mudzakir, A. C., Setiawan, A., Wibowo, M. A., & Khasani, R. R. (2017). Evaluasi Waste dan Implementasi Lean Construction (Studi Kasus: Proyek Pembangunan Gedung Serbaguna Taruna Politeknik Ilmu Pelayaran Semarang), *Jurnal Karya Teknik Sipil*, 6(2), 145–158. URL: http://ejournal3.undip.ac.id/index.php/jkts.

[6] Adlin, R. A. (2016). Analisa Waste Material Konstruksi dengan Aplikasi Metode Lean Construction (Studi Kasus: Proyek Pembangunan Showroom Auto 2000), *Doctoral Dissertation, Universitas Sumatera Utara*. URL: http://repositori.usu.ac.id/handle/123456789/17881.

[7] Jagad, S. A., & Putra, I. N. D. P. (2024). Analysis Waste Level of Column Reinforcement Work Planning with Software Cutting Optimization, *CogITo Smart Journal*, 10(2), 433–446. DOI: https://doi.org/10.31154/cogito.v10i2.813.433-446.

[8] Aithal, P. S., & Mishra, A. K. (2022). Assessing the Magnitude of Waste Material Using Lean Construction, *International Journal of Case Studies in Business, IT, and Education (IJCSBE)*, 6(1), pp. 578–589. DOI: https://doi.org/10.2139/ssrn.4163083.

[9] Devia, Y. P., Unas, S. E., & Nariswari, W. (2012). Identifikasi Sisa Material Konstruksi dalam Upaya Memenuhi Bangunan Berkelanjutan, *Rekayasa Sipil*, 4(3), 195–203. URL: https://rekayasasipil.ub.ac.id/index.php/rs/article/view/173.

[10] Allo, R. I. G., & Bhaskara, A. (2022). Waste Material Analysis with the Implementation of Lean Construction, *Jurnal Teknik Sipil*, 18(2), 343–355. DOI: https://doi.org/10.28932/jts.v18i2.4494.

[11] Chen, Y., Qiu, D., & Chen, X. (2024). Integrating Lean Construction with Sustainable Construction: Drivers, Dilemmas and Countermeasures, *Sustainability*, 16(21), 9387. DOI: https://doi.org/10.3390/su12156171.

ISSN (*Online*) 2620-7222
ISSN (*Print*) 2503-2399

[12] Angguningtyas, T. R. P., & Beatrix, M. (2024). Analisis Waste Material dengan Pendekatan Lean Construction pada Proyek Pembangunan Rumah Dinas, *Journal of Scientech Research and Development*, 6(1), 505–512. URL: https://idm.or.id/JSCR/index.php/JSCR/article/view/360/305.

[13] Nuciferani, F. T., Aulady, M. F. N., Choiriyah, S., & Sumarsono, D. S. B. (2022). Penerapan Lean Construction pada Proyek Perumahan Terhadap Waste Material, *Prosiding Seminar Nasional Sains Dan Teknologi Terapan*. URL: https://ejurnal.itats.ac.id/sntekpan/article/view/3524.

[14] Winanda, L. A. R., Pangestu, Y. A., Wijayaningtyas, M., Yuwono, E., & Erfan, M. (2024). Waste Analysis to Support the Implementation of Lean Construction on Building Project, *E3S Web of Conferences*, EDP Sciences, 01025. DOI: http://dx.doi.org/10.1051/e3sconf/202447601025.

[15] Garcés, G., & Peña, C. (2023). A Review on Lean Construction for Construction Project Management, *Revista Ingeniería de Construcción*, 38(1). DOI: http://dx.doi.org/10.7764/ric.00051.21.

[16] Huda, G., & Berawi, M. A. (2021). Quickly Understanding of Lean Construction to Improve Project Cost Performance: A Literature Review, *ITB Graduate School Conference*, 61–75. URL: https://gcs.itb.ac.id/proceeding-igsc/igsc/article/download/8/6/.

[17] Garcés, G., Forcael, E., Osorio, C., Castañeda, K., & Sánchez, O. (2025). Systematic Review of Lean Construction: An Approach to Sustainability and Efficiency in Construction Management, *Journal of Infrastructure Preservation and Resilience*, 6(1), 1–28. DOI: https://doi.org/10.1186/s43065-025-00119-1.

[18] Akanbi, O. A., Oyedolapo, O., & Steven, G. J. (2019). Lean Principles in Construction, *Sustainable Construction Technologies, Elsevier*, 317–348. DOI: https://doi.org/10.1016/B978-0-12-811749-1.00010-9.

[19] Wu, X., Zhao, W., Ma, T., & Yang, Z. (2019). Improving the Efficiency of Highway Construction Project Management Using Lean Management, *Sustainability*, 11(13), 3646. DOI: https://doi.org/10.3390/su11133646.

[20] Sugiyono, D. (2020). *Metode Penelitian Pendidikan Pendekatan Kuantitatif, Kualitatif dan R&D*, Alfabeta, Bandung. URL: https://digilib.unigres.ac.id/index.php?p=show_detail&id=43.

[21] Khatib, B. Al, Poh, Y. S., & El-Shafie, A. (2020). Delay Factors Management and Ranking for Reconstruction and Rehabilitation Projects Based on the Relative Importance Index (RII), *Sustainability*, 12(15), 6171. DOI: https://doi.org/10.3390/su12156171.

[22] Sustiawan, F., & Husin, A. E. (2021). Analisa RII (Relative Important Index) terhadap Faktor-faktor yang Berpengaruh dalam Mengimplementasikan BIM 4D dan M-PERT pada Pekerjaan Struktur Bangunan Hunian Bertingkat Tinggi, *Jurnal Aplikasi Teknik Sipil*, 19(4), 417–426. DOI: https://doi.org/10.12962/j2579-891X.v19i4.9336.

[23] Kusuma, D. P. A. (2019). Implementasi Lean Construction untuk Meminimalkan Waste pada Proyek Konstruksi (Studi Kasus: Proyek Pembangunan Gedung Kejaksaan Tinggi

ISSN (*Online*) 2620-7222
ISSN (*Print*) 2503-2399

Riau), *Doctoral Dissertation, Universitas Islam Riau*. URL: http://repository.uir.ac.id/id/eprint/9284.

[24] Setiono, S., Rifai, M., & Wibawa, L. A. (2023). Identifikasi Waste dalam Penerapan Lean Construction (Studi Kasus: Proyek Pembangunan Tower X, Jakarta Pusat), *Matriks Teknik Sipil*, 11(3), 262–269. DOI: https://doi.org/10.20961/mateksi.v11i3.76526.

[25] Akbar, S. B. M. (2022). Analisis Waste dengan Pendekatan Lean Construction pada Proyek Pembangunan Jembatan Sungai Manggar Balikpapan, *Info-Teknik*, 23(1), 113–126. DOI: https://doi.org/10.20527/infotek.v23i1.13972.

[26] Susanti, A. R., & Suripto, S. (2021). Evaluasi Waste dan Implementasi Lean Construction Proyek Gedung Kampus X, *Jurnal Rivet*, 1(02), 65–72. DOI: https://doi.org/10.47233/rivet.v1i02.331.