Performance Evaluation of Construction Waste Management through a Sustainable Development Approach (Case Study: Green Plesungan Housing Project Development)

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ABSTRACT

The continuous growth of infrastructure development in Indonesia has led to a significant increase in construction waste, impacting project costs and environmental sustainability. This study aims to evaluate the performance of construction waste management using a sustainable development approach in the Green Plesungan Housing Project. The research employed a quantitative approach through site observations, technical data collection, and questionnaire distribution to 30 construction stakeholders. The evaluation began with the calculation of waste materials, waste levels, and waste costs, followed by statistical analyses including instrument testing, classical assumption testing, multiple linear regression, simultaneous and partial tests, the coefficient of determination test, as well as the formulation of recommended steps to minimize waste. The study identified 16 types of construction waste, with structural works being the largest contributors. The total waste cost reached 3.48% of the material contract value of Rp. 33,617,860.77, with lightweight bricks contributing the highest cost at 1.06%, amounting to Rp. 10,275,739.37. Statistical results indicated that six out of seven variables significantly influenced the implementation of sustainable practices, with a contribution of 95.4%. Site supervision, on-site execution, and environmental conditions were identified as the dominant factors contributing to waste production. The proposed strategies to minimize waste include enhancing planning accuracy, improving logistics management, promoting disciplined and efficient execution, and strengthening site supervision. This study provides valuable insights for developing integrated construction waste management strategies that not only reduce waste costs but also support the realization of sustainable and efficient housing development in the future.

Keywords: construction management, construction waste, sustainable development, waste management and waste material.

INTRODUCTION

Infrastructure development in Indonesia continues to grow, driven by the government's efforts to accelerate economic growth and improve public welfare [1], [2]. In the 2024 State Budget (APBN), the infrastructure allocation reached Rp423.4 trillion, with the Ministry of Public Works and Housing (PUPR) receiving the largest portion of Rp147.37 trillion [3]. Although this contributes positively to the macroeconomy [4], large-scale infrastructure development also poses potential risks to environmental quality if not managed sustainably [5], [6].

Sustainable development has emerged as a global response to various environmental issues [7]. As part of its global commitment, Indonesia adopted the Sustainable Development Goals (SDGs) through Presidential Regulation No. 59 of 2017 [4]. One of the main challenges in the construction industry is the management of construction waste, which results from material inefficiencies and poor work execution [8], [9], [10]. Materials account for approximately 50% of total construction project costs [11], making proper material management essential to minimizing both waste and costs [12], [13].

The rapid urbanization in Indonesia further increases the complexity of housing and infrastructure demands [4]. It is projected that by 2025, 60% of the population will reside in urban areas, leading

to a continuous rise in housing needs. This situation demands construction project management that is not only technically efficient but also environmentally friendly.

Previous studies have shown that material wastage in construction projects can result from various factors. Handayani and Angreni identified causes such as estimation errors, over-ordering, poor material quality, and weather-induced damage [14]. Meanwhile, Hadut and Koemargono found that construction waste handling approaches vary significantly across regions [15].

Lean construction has also been applied to identify dominant types of waste, with defects and waiting time being the largest contributors to material waste according to Allo and Bhaskara [16]. Widhiawati et al. emphasized the importance of human factors, including workers' skills and work methods, in preventing waste production [10].

However, there is still limited research specifically evaluating the performance of construction waste management using a sustainable development approach in small-scale housing projects, particularly those that integrate waste quantification, evaluation of causative factors, and the formulation of strategic steps from various project execution perspectives. Therefore, this study was conducted to address this research gap, using the Green Plesungan Housing Project as a case study.

RESEARCH METHODS

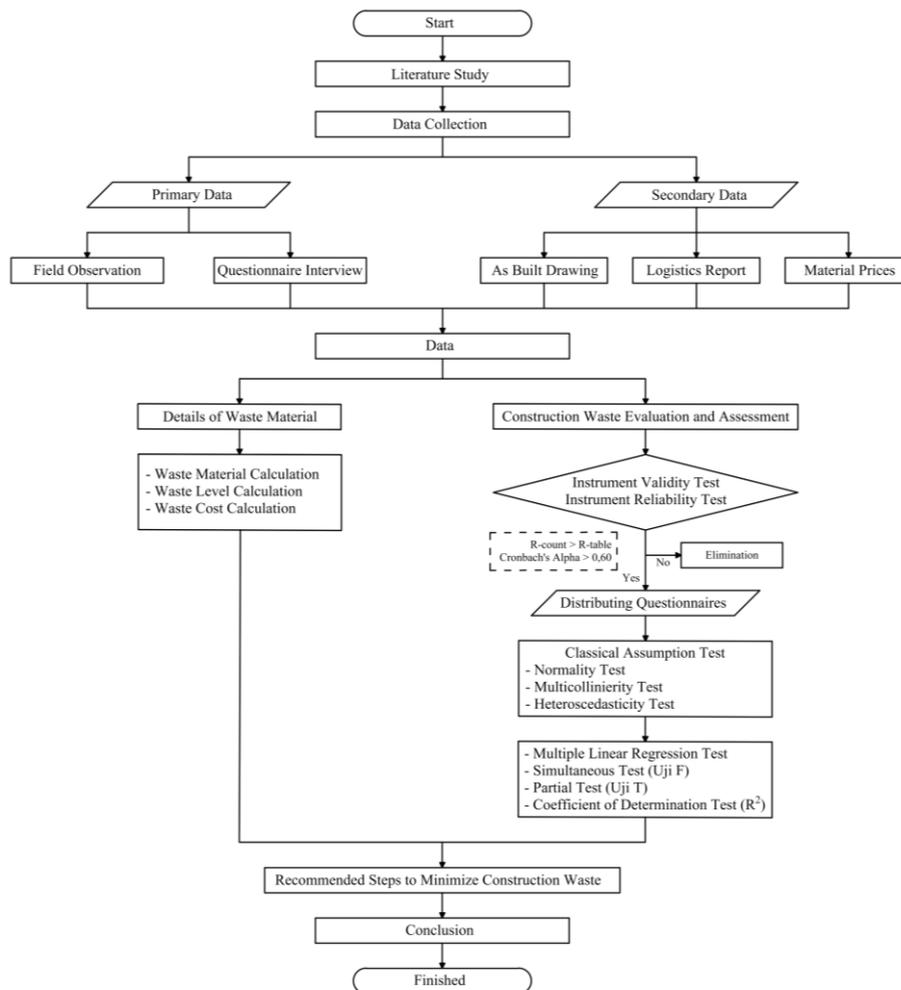The overall research method of this study is presented in the Figure 1 below.

Figure 1. Flow chart

Materials

This research was conducted on the Green Plesungan Housing Project, which consists of 24 housing units of type 30/60. The study utilized two types of data: primary data and secondary data. Primary data were collected through site observations and questionnaires distributed to 30 respondents who were directly involved in the construction of the Green Plesungan Housing Project. Secondary data included technical documents such as as-built drawings, logistics reports, and material price data from the project's partner suppliers.

The questionnaire instrument was developed based on seven independent variables of construction waste management derived from previous studies. These variables include design and document, material procurement, material management, material handling, storage and transportation, on-site execution, environmental conditions, and site supervision. The dependent variable in this study is the approaches of sustainable development.

Methods

This study employed a quantitative approach. Site observations were conducted to calculate the volume and types of construction waste produced, including waste from lightweight bricks, iron cuttings, and other leftover materials. Questionnaires were distributed to various stakeholders, including planners, contractors, logistics staff, project administrators, craftsmen, laborers, and partner material suppliers. The aim was to understand their perceptions and practices regarding construction waste management and to develop recommended steps to minimize construction waste.

The total number of respondents was 30, determined using a population technique, covering various project roles to obtain a comprehensive perspective. The questionnaire was developed using a Likert scale and underwent instrument testing through validity and reliability tests [17].

Data Analysis

Data analysis in this study was carried out in four main stages:

1. Calculation of Waste Material. This stage involved detailing the volume of waste materials, the percentage of waste (waste level), and their economic value (waste cost) [18].
2. Interviews and Instrument Testing. Interviews were conducted to validate the factors causing construction waste, as identified from the literature review, which were then developed into questionnaire items. Instrument testing was performed to ensure the accuracy of the collected data, including validity and reliability tests.
3. Statistical Testing. Questionnaire data were analyzed using classical assumption tests (normality test, multicollinearity test, and heteroscedasticity test), multiple linear regression analysis, simultaneous testing (F-test), partial testing (T-test), and the coefficient of determination (R^2 test) to determine the influence of each construction waste management variable on the application of sustainable development principles.
4. Formulation of Recommended Steps. A series of recommended steps were formulated based on project work stages that can be implemented to minimize construction waste in housing projects.

RESULT AND DISCUSSION

General Description

This project is located in a semi-urban area with a relatively high level of construction activity, yet it is still surrounded by a fairly natural environment, as shown in Figure 2. This condition highlights the importance of applying sustainable development principles in construction waste management. Prior to conducting further analysis, preliminary stages included interviews to identify the relevant factors for the questionnaire and instrument testing to ensure the feasibility of the questionnaire.

Figure 2. Green Plesungan Housing

The factors contributing to construction waste used in the questionnaire were validated through in-depth interviews with representatives from the planning, execution, logistics, and project administration teams. The results indicated a consensus on seven key factors causing construction waste, as presented in Table 1. This validation served as the basis for developing the questionnaire instrument.

Table 1. Factors Contributing to Construction Waste

Code	Factors Contributing to Construction Waste
X1	Design and Document
X2	Material Procurement
X3	Material Management
X4	Material Handling, Storage, and Transportation
X5	On-Site Execution
X6	Environmental Conditions
X7	Site Supervision
Y	Sustainable Development Approach

Source: Hadut & Koesmargono [15], Handayani & Angreni [14]

The validity test is considered valid if the calculated R-count is greater than the R-table value and the significance level is less than 0.05. The R-count and significance values were obtained from the data analysis results. The R-table value of 0.361 was determined by referring to the distribution table. Based on Table 2, it is shown that for each variable code used in the research instrument, the R-count is greater than the R-table value and the significance level is less than 0.05. This indicates that the instrument can be used as a valid measurement tool.

Table 2. Instrument Validity Test

Code	R-count	R-table	Significance	Result
X1.1	0.709	0.361	< 0.001	Valid
X1.2	0.924	0.361	< 0.001	Valid
X1.3	0.734	0.361	< 0.001	Valid
X1.4	0.829	0.361	< 0.001	Valid
X1.5	0.857	0.361	< 0.001	Valid
X2.1	0.829	0.361	< 0.001	Valid
X2.2	0.639	0.361	< 0.001	Valid
X2.3	0.847	0.361	< 0.001	Valid
X2.4	0.775	0.361	< 0.001	Valid
X2.5	0.766	0.361	< 0.001	Valid
X3.1	0.610	0.361	< 0.001	Valid
X3.2	0.667	0.361	< 0.001	Valid
X3.3	0.899	0.361	< 0.001	Valid

Code	R-count	R-table	Significance	Result
X3.4	0.818	0.361	< 0.001	Valid
X3.5	0.663	0.361	< 0.001	Valid
X4.1	0.595	0.361	< 0.001	Valid
X4.2	0.776	0.361	< 0.001	Valid
X4.3	0.729	0.361	< 0.001	Valid
X4.4	0.712	0.361	< 0.001	Valid
X4.5	0.788	0.361	< 0.001	Valid
X5.1	0.742	0.361	< 0.001	Valid
X5.2	0.812	0.361	< 0.001	Valid
X5.3	0.834	0.361	< 0.001	Valid
X5.4	0.677	0.361	< 0.001	Valid
X5.5	0.705	0.361	< 0.001	Valid
X6.1	0.641	0.361	< 0.001	Valid
X6.2	0.643	0.361	< 0.001	Valid
X6.3	0.741	0.361	< 0.001	Valid
X6.4	0.666	0.361	< 0.001	Valid
X6.5	0.873	0.361	< 0.001	Valid
X7.1	0.720	0.361	< 0.001	Valid
X7.2	0.867	0.361	< 0.001	Valid
X7.3	0.721	0.361	< 0.001	Valid
X7.4	0.807	0.361	< 0.001	Valid
X7.5	0.636	0.361	< 0.001	Valid
Y1	0.781	0.361	< 0.001	Valid
Y2	0.622	0.361	< 0.001	Valid
Y3	0.535	0.361	< 0.001	Valid
Y4	0.636	0.361	< 0.001	Valid
Y5	0.781	0.361	< 0.001	Valid

Source: Data Processed Results, 2025

The reliability test is considered reliable if the Cronbach's Alpha value is greater than 0.60. The Cronbach's Alpha value was obtained from the data analysis results. Based on Table 3, it is shown that for each variable code used in the research instrument, the Cronbach's Alpha value exceeds 0.60. This indicates that the research instrument is reliable and can be used as a measurement tool.

Table 3. Instrument Reliability Test

Code	Cronbach's Alpha	Level	Result
X1	0.857	0.600	Reliable
X2	0.823	0.600	Reliable
X3	0.773	0.600	Reliable
X4	0.762	0.600	Reliable
X5	0.802	0.600	Reliable
X6	0.761	0.600	Reliable
X7	0.799	0.600	Reliable
Y	0.615	0.600	Reliable

Source: Data Processed Results, 2025

Details of Waste Material

Various types of leftover materials were found during the construction process, such as lightweight brick scraps, iron fragments, and others, as shown in Figure 3. The quantity calculations are presented to detail the waste material, waste level, and waste cost.

Figure 3. Lightweight Brick Scraps

Waste Material Calculation: This calculation was conducted to determine the quantity and types of leftover materials produced during the construction process. Based on Table 4, it was found that out of 57 materials used in the construction, 16 materials produced waste.

Table 4. Waste Material Calculation

No.	Material	Unit	Volume		
			Delivery	Installed	Waste
1	Lightweight Brick	m³	240.00	227.69	12.31
2	Sand	m³	192.00	168.72	23.28
3	Gravel	m³	72.00	60.68	11.32
4	Light Steel C-Channel	pcs	384.00	358.40	25.60
5	Split Stone	m³	72.00	66.28	5.72
6	D6 Rebar - Size = 8/12	kg	1728.00	1632.00	96.00
7	D10 Steel	pcs	1272.00	1252.09	19.91
8	PVC Pipe 4"	pcs	72.00	60.00	12.00
9	Binding Wire	kg	288.00	211.74	76.26
10	Red Brick	pcs	11040.00	10536.00	504.00
11	PVC Pipe ¾"	pcs	96.00	84.00	12.00
12	NYM Cable 2 × 1.5	m'	720.00	660.00	60.00
13	PVC Pipe 3"	stem	72.00	69.00	3.00
14	Cement 40 kg	sack	1200.00	1195.77	4.23
15	D6 Rebar - Size = 12/15	kg	600.00	591.00	9.00
16	GRC Eaves	sheet	120.00	118.03	1.97

Source: Data Processed Results, 2025

The detailed waste material data were used to classify the waste based on the type of work. Based on Table 5, there are five work classifications that produce waste materials, namely: wall works, structural works, roofing works, plumbing installation works, and electrical installation works. It was found that among these five classifications, structural works contributed the largest amount of waste material.

Table 5. Work Classification of Waste Material

No.	Work	Material	Unit	Waste Material
1	Wall	Lightweight Brick	m³	12.31
		Red Brick	pcs	504.00
2	Structure	Sand	m³	23.28
		Gravel	m³	11.32
		Split Stone	m³	5.72
		D6 Rebar - Size = 8/12	kg	96.00
		D10 Steel	pcs	19.91

No.	Work	Material	Unit	Waste Material
		Binding Wire	kg	76.26
		Cement 40 kg	sack	4.23
		D6 Rebar - Size = 12/15	kg	9.00
3	Roofing	Light Steel C-Channel	pcs	25.60
		GRC Eaves	sheet	1.97
4	Water Installation	PVC Pipe 4"	pcs	12.00
		PVC Pipe ¾"	pcs	12.00
		PVC Pipe 3"	pcs	3.00
5	Electrical Installation	NYM Cable 2 × 1.5	m'	60.00

Source: Data Processed Results, 2025

Waste Level Calculation: This calculation was conducted to determine the percentage comparison between the produced waste material and the delivered material volume during the construction process. Based on Table 6, it was found that among the 16 leftover materials, the highest waste levels exceeding 10% were recorded for binding wire, 4" PVC pipes, gravel, ¾" PVC pipes, and sand.

Table 6. Waste Level Calculation

No.	Material	Unit	Volume Delivery	Volume Waste	Waste Level
1	Binding Wire	kg	288.00	76.26	26.48%
2	PVC Pipe 4"	pcs	72.00	12.00	16.67%
3	Gravel	m³	72.00	11.32	15.72%
4	PVC Pipe ¾"	pcs	96.00	12.00	12.50%
5	Sand	m³	192.00	23.28	12.13%
6	NYM Cable 2 × 1,5	m'	720.00	60.00	8.33%
7	Split Stone	m³	72.00	5.72	7.94%
8	Light Steel C-Channel	pcs	384.00	25.60	6.67%
9	D6 Rebar - Size = 8/12	kg	1728.00	96.00	5.56%
10	Lightweight Brick	m³	240.00	12.31	5.13%
11	Red Brick	pcs	11040.00	504.00	4.57%
12	PVC Pipe 3"	pcs	72.00	3.00	4.17%
13	GRC Eaves	sheet	120.00	1.97	1.64%
14	D10 Steel	pcs	1272.00	19.91	1.57%
15	D6 Rebar - Size = 12/15	kg	600.00	9.00	1.50%
16	Cement 40 kg	sack	1200.00	4.23	0.35%

Source: Data Processed Results, 2025

Waste Cost Calculation: This calculation was conducted to determine the economic impact of the produced waste materials. Based on Table 7, it was found that the total waste cost amounted to Rp. 33,617,860.77, representing 3.48% of the material costs. Lightweight bricks contributed the highest waste cost percentage at 1.06%, with a cost value of Rp. 10,275,739.37.

Table 7. Waste Cost Calculation

No.	Material	Unit	Unit Price	Waste Material Volume	Waste Material Price	Waste Cost
1	Lightweight Brick	m³	Rp. 835,000.00	12.31	Rp. 10,275,739.37	1.06%
2	Sand	m³	Rp. 300,000.00	23.28	Rp. 6,985,443.81	0.72%
3	Gravel	m³	Rp. 300,000.00	11.32	Rp. 3,395,242.21	0.35%
4	Light Steel C-Channel	pcs	Rp. 100,000.00	25.60	Rp. 2,560,000.00	0.26%
5	Split Stone	m³	Rp. 350,000.00	5.72	Rp. 2,000,542.81	0.21%
6	D6 Rebar - Size = 8/12	kg	Rp. 18,000.00	96.00	Rp. 1,728,000.00	0.18%
7	D10 Steel	pcs	Rp. 85,000.00	19.91	Rp. 1,692,633.33	0.18%
8	PVC Pipe 4"	pcs	Rp. 140,000.00	12.00	Rp. 1,680,000.00	0.17%

No.	Material	Unit	Unit Price	Waste Material Volume	Waste Material Price	Waste Cost
9	Binding Wire	kg	Rp. 20,000.00	76.26	Rp. 1,525,173.33	0.16%
10	Red Brick	pcs	Rp. 750.00	504.00	Rp. 378,000.00	0.04%
11	PVC Pipe ¾"	pcs	Rp. 27,000.00	12.00	Rp. 324,000.00	0.03%
12	NYM Cable 2 × 1.5	m'	Rp. 5,000.00	60.00	Rp. 300,000.00	0.03%
13	PVC Pipe 3"	pcs	Rp. 90,000.00	3.00	Rp. 270,000.00	0.03%
14	Cement 40 kg	sack	Rp. 55,000.00	4.23	Rp. 232,889.18	0.02%
15	D6 Rebar - Size = 12/15	kg	Rp. 18,000.00	9.00	Rp. 162,000.00	0.02%
16	GRC Eaves	sheet	Rp. 55,000.00	1.97	Rp. 108,196.72	0.01%
				Total Price	Rp. 33,617,860.77	3.48%

Source: Data Processed Results, 2025

Evaluation of Construction Waste Management

The evaluation was conducted to assess the performance of construction waste management using a sustainable development approach in the Green Plesungan Housing Project. Several statistical tests were employed in this evaluation, including classical assumption tests (normality test, multicollinearity test, and heteroscedasticity test), multiple linear regression analysis, coefficient of determination test (R^2), and simultaneous test (F-test).

The normality test indicates a normal distribution if the significance value is greater than 0.05. To assess whether the data are normally distributed, the Kolmogorov-Smirnov Test was conducted. Based on Table 8, the significance value was found to be 0.124, which is greater than 0.05, indicating that the residual data are normally distributed.

Table 8. Normality Test

Number of Respondents	Test Statistic	Significance
30	0.142	0.124

Source: Data Processed Results, 2025

The multicollinearity test was conducted by examining the Variance Inflation Factor (VIF) values of each independent variable. The data are considered free from multicollinearity if the VIF value is less than 10 and the tolerance value is greater than 0.01. Based on Table 9, all variables had VIF values below 10 and tolerance values above 0.01. This indicates that the data do not exhibit multicollinearity, as each independent variable is not highly correlated with one another, suggesting that the regression model is considered good.

Table 9. Multicollinearity Test

Variable	VIF	Tolerance	Result
X1	1.527	0.655	Non-Multicollinearity
X2	1.633	0.613	Non-Multicollinearity
X3	1.704	0.587	Non-Multicollinearity
X4	1.434	0.697	Non-Multicollinearity
X5	2.180	0.459	Non-Multicollinearity
X6	1.615	0.619	Non-Multicollinearity
X7	1.628	0.614	Non-Multicollinearity

Source: Data Processed Results, 2025

The heteroscedasticity test was conducted by examining the scatterplot graph of the predicted dependent variable (ZPRED) against the residual errors (SRESID). Based on Figure 4, the residual data are evenly distributed and do not form any specific pattern. This indicates that there are no signs of heteroscedasticity, as the residuals are randomly and evenly dispersed, suggesting that the regression model is considered good.
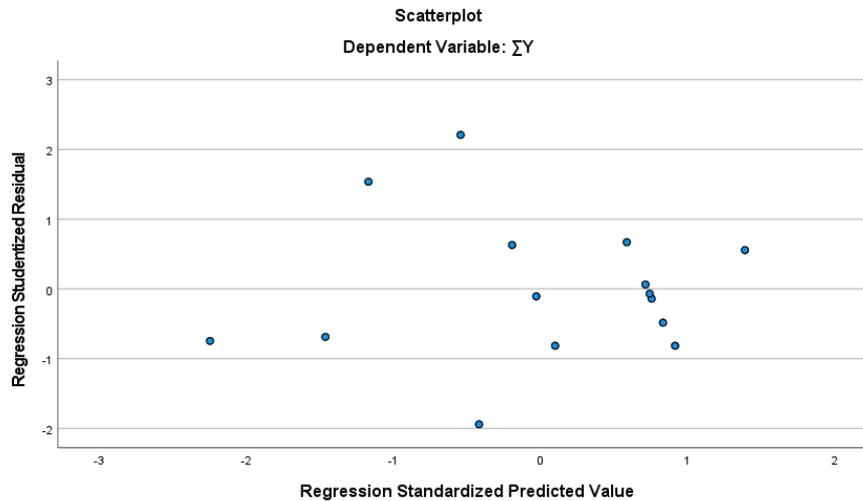
Figure 4. Scatterplot Graph

The multiple linear regression analysis was conducted to determine whether there is an influence of construction waste management variables (X) on the sustainable development approach variable (Y). Based on Table 10, the results of the multiple linear regression analysis are as follows:

$$Y = 27.250 + 0.052X1 + 0.089X2 + 0.077X3 + 0.324X4 - 0.230X5 - 0.270X6 - 0.384X7.$$

This equation was then interpreted to evaluate the performance of construction waste management using a sustainable development approach. The value of each coefficient indicates the strength of the influence exerted. Positive coefficients indicate a strengthening effect, while negative coefficients indicate a reducing effect on the sustainable development approach.

Table 10. Multiple Linear Regression Test

Model		Unstandardized Coefficients	
		B	Std. Error
Constant		27.250	1.153
X1	Design and Document	0.052	0.027
X2	Material Procurement	0.089	0.032
X3	Material Management	0.077	0.035
X4	Material Handling, Storage, and Transportation	0.324	0.030
X5	On-Site Execution	-0.230	0.036
X6	Environmental Conditions	-0.270	0.033
X7	Site Supervision	-0.384	0.031

Source: Data Processed Results, 2025

The coefficient of determination test (R^2) was conducted to measure the extent to which the model can explain the influence of construction waste management variables on the sustainable development approach variable. Based on Table 11, the coefficient of determination was found to be 0.954. This indicates that the influence of construction waste management variables on the sustainable development approach variable is 95.40%.

Table 11. Coeffiecient of Determination Test

Model	R	R Square	Adjusted R Square	Std. Error
1	0.977	0.954	0.940	0.322

Source: Data Processed Results, 2025

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The simultaneous test (F-test) was conducted to determine the simultaneous effect of the implementation of construction waste management on the principles of the sustainable development approach. This test used two hypotheses: H_0, which states that "The implemented construction waste management does not meet the principles of the sustainable development approach," and H_1, which states that "The implemented construction waste management meets the principles of the sustainable development approach." The F-test was performed by comparing the calculated F-count with the F-table value. If the F-count is greater than the F-table value, H_0 is rejected and H_1 is accepted, with a significance level below 0.05. The F-count and significance values were obtained from the data analysis results. The F-table value of 2.44 was determined based on the distribution table with 30 respondents and 7 independent variables. Based on Table 12, it was found that the F-count is 65.476 with a significance level of less than 0.001, which satisfies the requirement that F-count > F-table and the significance value is less than 0.05. This indicates that H_0 is rejected and H_1 is accepted, meaning that the construction waste management implemented in the Green Plesungan Housing Project meets the principles of the sustainable development approach.

Table 12. Simultaneous Test (F-Test)

Model	Sum of Squares	df	F	Sig.
Regression	47,583	7	65,476	< 0,001
Residual	2,284	22		
Total	29,867	29		

Source: Data Processed Results, 2025

Assessment of Factors Contributing to Construction Waste

The partial test (T-test) was conducted to determine the partial effect of the implementation of construction waste management on the principles of the sustainable development approach. This test used two hypotheses: H_0, which states that "Construction waste management factors do not influence the principles of the sustainable development approach," and H_1, which states that "The implemented construction waste management factors influence the principles of the sustainable development approach." The T-test was performed by comparing the calculated T-count with the T-table value. If the T-count is greater than the T-table value, H_0 is rejected and H_1 is accepted, with a significance level below 0.05. The T-count and significance values were obtained from the data analysis results. The T-table value of 2.074 was determined based on the distribution table for 30 respondents and 7 independent variables. Based on Table 13, it was found that one factor accepted H_0, while six factors accepted H_1.

Table 13. Partial Test (T-Test)

Model		t	Sig.
Constant		23.635	< 0.001
$\sum X1$	Design and Document	1.913	0.069
$\sum X2$	Material Procurement	2.812	0.010
$\sum X3$	Material Management	2.206	0.038
$\sum X4$	Material Handling, Storage, and Transportation	10.812	< 0.001
$\sum X5$	On-Site Execution	-6.380	< 0.001
$\sum X6$	Environmental Conditions	-8.260	< 0.001
$\sum X7$	Site Supervision	-12.316	< 0.001

Source: Data Processed Results, 2025

The Effective Contribution test was conducted to determine the partial contribution or influence of construction waste management variables on the sustainable development approach variable. Effective contribution measures the impact within a regression analysis. The sum of the effective contributions of all construction waste management variables equals the total R-squared value. Based on Table 14, the factors influencing construction waste management's effect on sustainable development approaches, in descending order, are site supervision, on-site execution, environmental conditions.

Table 14. Effective Contribution Test

	Effective Contribution	Persentage (%)
X1	Design and Document	-0.3
X2	Material Procurement	6.8
X3	Material Management	0.0
X4	Material Handling, Storage, and Transportation	1.4
X5	On-Site Execution	23.7
X6	Environmental Conditions	17.5
X7	Site Supervision	46.3
	R square	**95.4**

Source: Data Processed Results, 2025

Recommended Steps

Based on interviews with 30 respondents, a set of recommended actions has been formulated for each stage of construction work to minimize construction waste in residential housing projects. These recommendations are developed by considering the findings from the quantitative data analysis presented earlier, while also aligning with the principles of the 3R (Reduce, Reuse, Recycle) within an environmentally sustainable development approach.

Table 15. Recommended Steps

Construction Stage	Recommended Steps	3R Category
Planning	- Prepare a detailed and accurate Construction Budget Plan	Reduce
	- Accurately estimate material requirements and implement BIM technology	Reduce
	- Conduct site inspections to align design with site conditions	Reduce
	- Select appropriate materials that meet the design specifications	Reduce
	- Carefully plan electrical installations and the arrangement of lightweight bricks	Reduce
Logistics Management	- Procure materials according to project needs and progress	Reduce
	- Implement material based storage	Reduce
	- Apply the first-in first-out (FIFO) system	Reduce
	- Ensure material security and control to prevent damage or loss	Reduce
	- Conduct regular stock and distribution control	Reduce
	- Use prefabricated products	Reduce
	- Perform rebar fabrication in a workshop	Reduce
Execution	- Provide briefings or instructions to ensure workers understand material waste management	Reduce
	- Employ skilled workers who understand material characteristics	Reduce
	- Maintain workforce stability (minimize worker turnover)	Reduce
	- Use metal or plastic formwork to reduce wood waste	Recycle
	- Reuse wooden formwork for other projects	Reuse
	- Use leftover iron bars as reinforcement anchors for lightweight bricks	Reuse
	- Use leftover lightweight brick for backfilling	Reuse
	- Use leftover light steel pieces for patching or joint reinforcement	Reuse

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Construction Stage	Recommended Steps	3R Category
Supervision	- Conduct regular work evaluations	Reduce
	- Supervise the quality and quantity of materials to ensure alignment with the design	Reduce

Source: Data Processed Results, 2025

Based on Table 15, it can be seen that the most frequently applied principle among the 3R (Reduce, Reuse, Recycle) is Reduce, which focuses on preventing construction waste from the earliest stages of the building process. Each phase of a construction project presents opportunities to implement waste minimization strategies. Implementing these recommended strategies consistently not only contributes to minimizing construction waste but also enhances the overall efficiency, quality, and sustainability of future construction projects.

CONCLUSION

A total of 16 types of waste materials were produced during the construction project, with lightweight bricks contributing the highest waste percentage at 1.06%, amounting to Rp. 10,275,739.37. Among these waste materials, structural works were identified as the largest contributor to waste production. The performance evaluation of construction waste management implemented in the Green Plesungan Housing Project demonstrated that it meets the principles of the sustainable development approach, with an influence of 95.4%. The assessment of the contributing factors to construction waste indicated that the three most influential variables reducing the sustainable development approach value, in order, are site supervision, on-site execution, environmental conditions. Recommended steps to minimize construction waste in housing projects, are categorized into project implementation stages, including planning, logistics management, execution, and supervision. It was found that each stage in the project execution process presents opportunities to apply construction waste minimization strategies. By improving planning accuracy, implementing well-organized logistics management, ensuring disciplined and efficient execution, and strengthening strict supervision, construction projects can become not only more environmentally friendly in applying sustainable development principles but also more cost-efficient.

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