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DETERMINANCE OF WASTE MANAGEMENT IN CONSTRUCTION

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Abstract: The purpose of this research is to analyze the determinants of construction waste management to support the achievement of Green Construction. This is based on the construction industry's activities becoming one of the main contributors to negative environmental impacts. The type of research used in this study is the descriptive quantitative research method. The population in this study is construction management companies operating in Indonesia. The sample was taken using the random sampling method with a total of 100 construction projects.The data analysis techniques used in this research are descriptive analysis and variance-based Structural Equation Modeling analysis. The research results show that sustainable development, which is an elaboration of the green construction concept, through the implementation of a waste management system, contributes to the creation of a good environment through aspects such as: Storage Handling; Reuse Material; Human Resource Competence; Field Implementation; and Work Methods. From the analysis conducted, these five aspects have a significant impact in minimizing material waste from construction activities.

Keywords: Storage; Reuse: Human Resource; Implementation; Work Method; Waste Material

I. INTRODUCTION

In supporting the achievement of green construction implementation, one of the efforts that can be made is through the management of waste generated from construction activities. Effective waste management through the optimal use of resources will support the creation of principle integration in green construction (Putri & Bayangkara, 2024). Construction and demolition waste can account for up to 30% of solid waste in landfills worldwide. This indicates that the waste comes from the construction industry. The amount of waste generated from construction can reach 29 million tons each year in Indonesia, and most of this waste has not been properly managed. The recycling rate of construction waste in Indonesia is still below target. Indonesia has only 14% of construction waste that can be recycled. Several factors can cause this to happen; one of them is the ineffective collection and processing system. In addition, greenhouse gas emissions produced by the construction sector affect the environment. 11% of the world's carbon emissions come from building materials and construction.

The construction industry makes a significant contribution to economic and social growth. It is very important and closely related to the global economy, generating wealth and large-scale jobs worldwide. However, the construction industry impacts the environment during the course of projects (Ametepey et al., 2020). Construction projects are always an inseparable part of the construction waste generated (Iodice et al., 2021). In addition to having a negative impact on the environment, construction waste also affects the contractors (Dodampegama et al., 2024).

Construction waste management is part of the effort to realize green construction (Ma et al., 2022b). By using construction waste management, the construction process can be carried out without harming the environment. This will improve the efficiency of material use and reduce the consumption of natural resources (Zhan et al., 2022).

Table. 1 Value of Material Expenditure

Provinsi *Province*	2021	2022*	Laju Pertumbuhan (%) *Growth Rate (%)*
(1)	(2)	(3)	(4)
Aceh	4.846.381	5.280.432	8,96
Sumatera Utara	27.397.857	30.024.768	9,59
Sumatera Barat	6.134.264	6.577.592	7,23
Riau	25.898.580	27.821.210	7,42
Jambi	5.134.954	5.541.356	7,91
Sumatera Selatan	11.215.465	11.897.808	6,08
Bengkulu	1.600.647	1.690.212	5,60
Lampung	9.321.291	10.192.592	9,35
Kepulauan Bangka Belitung	1.816.888	1.896.818	4,40
Kepulauan Riau	4.214.087	4.612.902	9,46
DKI Jakarta	302.610.252	338.913.651	12,00
Jawa Barat	68.104.773	75.116.044	10,29
Jawa Tengah	45.561.541	48.422.385	6,28
DI Yogyakarta	4.353.407	4.626.864	6,28
Jawa Timur	91.360.956	100.632.388	10,15
Banten	20.320.057	21.860.793	7,58
Bali	7.577.523	8.438.216	11,36
Nusa Tenggara Barat	6.600.764	7.179.472	8,77
Nusa Tenggara Timur	5.052.993	5.466.450	8,18
Kalimantan Barat	10.087.351	10.603.530	5,12
Kalimantan Tengah	6.534.201	7.102.267	8,69
Kalimantan Selatan	9.493.131	10.027.320	5,63
Kalimantan Timur	19.518.200	20.805.240	6,59

The type of material and the storage location of the material are two main factors that must be considered in construction waste management (Allo & Bhaskara, 2022).. The work

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procedures and implementation carried out during the construction process can help reduce resource usage (Saputra, 2023). Moreover, the efficient implementation of construction activities is influenced by attitudes, quality human resources, and actions (Waty & Sulistio, 2020)

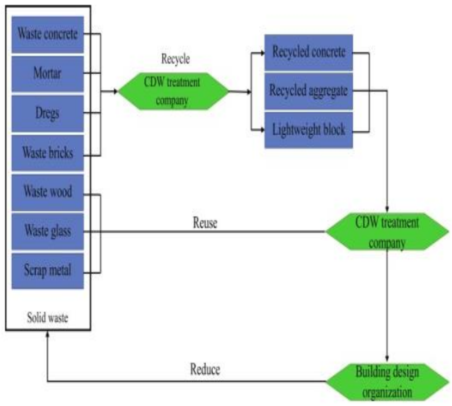

Figure 1. *Waste* Construktion

Non-degradable materials produced from repair, alteration, or construction processes during a construction project are called construction waste (Guo et al., 2023). There are three main factors according to the EPA in categorizing construction waste, namely: 1) Type of Structure (residential, commercial, or industrial buildings); 2) Size of the structure (low rise, high rise); 3) Ongoing activities. (konstruksi, renovasi, perbaikan atau pembongkaran) (Li & Takeuchi, 2023). Construction material waste that cannot be used in the construction project is unavoidable but can be minimized in quantity (Estrada et al., 2023). In the Environmental Protection Act, construction waste is categorized as follows: 1) substances that are unused or dirt or an unwanted excess that arises from the application of a process; 2) substances or objects that are likely to break, wear out, contaminate, or cause other damage but do not include explosive objects; 3) anything that is discarded or, if not managed, has the potential to become waste unless it can still be utilized. (Ismaeel & Kassim, 2023). Currently, in Indonesia, many contractors are starting to prioritize the concept of green construction/green building (Suliyanto, 2022). The application of the green building concept can be implemented in various aspects, from building materials, design, to building maintenance by utilizing advanced technology (Waqar et al., 2023). Green construction is an effort to create construction activities that consider environmental aspects and human health (Yin et al., 2024). Green construction is synonymous with sustainability, which prioritizes the balance between short-term gains and long-term risks, with various efforts to avoid harming future health, safety, and well-being (Yuan et al., 2024). Environmental construction planning by maximizing building waste management is expected to result in building system planning that is efficient in the use of energy, water, recyclable materials, reused materials, and reducing excessive materials (Ramos et al., 2023) dan (Ray et al., 2024).

Management of construction waste is important for construction project implementers to pay attention to. Starting from the estimation phase to the implementation in the field. (Le-Khac et al., 2024) and (Moschen-Schimek et al., 2023). This is done so that the leftover materials are minimized, preventing excessive accumulation of waste at the project site and ultimately saving costs (Gumusburun & Anaç, 2024). The occurrence of construction material waste can be caused by one or a combination of several factors (Al-Raqeb et al., 2023). Construction waste management is part of the effort to achieve green construction (Ma et al., 2022). With construction waste management, the construction process can be carried out without disregarding the negative effects on the environment (Le-Khac et al., 2024). Construction waste management will impact the efficiency of material use, thereby further reducing the natural resources used. In addition, it will reduce the waste generated during the construction process due to the efficient use of materials (Zhan et al., 2022).

Green construction refers to engineering construction activities aimed at maximizing resource conservation and reducing negative environmental impacts through scientific management and technological advancements while ensuring basic quality and safety requirements to achieve energy savings, land savings, water savings, material savings, and environmental protection goals (Shi et al., 2013). Green construction is the active application of the sustainable development concept in the construction industry. Traditional construction projects overlook environmental impacts and only prioritize cost, quality, and schedule as the main objectives (Xu et al., 2019). By implementing sustainability goals and carrying out green construction, construction workers and other stakeholders in the construction process are required to reduce environmental impact (Chen et al., 2023).

Based on the concept of green construction as a design concept that considers environmental and health impacts, saves natural resources, improves air quality, and creates a healthy construction environment, this can be achieved through good waste management practices. In achieving sustainable development, which is an elaboration of the green construction concept, a waste management system can contribute to the creation of a good environment. Waste management is important for construction project implementers to pay attention to. (Moschen-Schimek et al., 2023b).

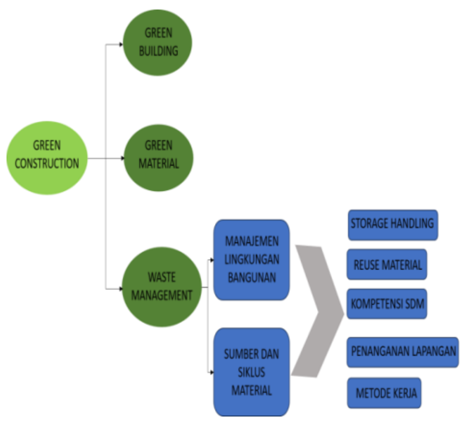

Figure 2. Framework

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Construction waste management aims to reduce the impact of natural resource use, particularly the materials used in the construction process, through reduce, reuse, and recycle. Therefore, preventing excessive material use not only reduces waste and environmental impact but also benefits the parties involved in construction (Thives et al., 2022).

II. RESEARCH METHODS

This research uses a quantitative approach because it measures data using a numerical scale. Additionally, this research falls under a correlational quantitative approach. This linking method or research as a correlation aims to connect one element with another to produce new forms and shapes that are different from the previous ones (Purwono et al., 2019). The population in this study is the management of construction projects. The sample of this research is a construction project on a national scale. The sample size in this study is 100 respondents. This sampling method will enable researchers to draw more reliable and informative conclusions by ensuring that each subclass is adequately represented in the selected sample (Sugiono, 2018). This research analyzes data quantitatively using the statistical method, Structural Equation Modelling Partial Least Square (SEMPLS). SEMPLS is a robust analytical method because it is not based on many assumptions (Siagian & Ningrum, 2022).

III. RESULT AND DISCUSSION

1. *Outer Model*

The analysis of the measurement model (Outer Model) aims to evaluate the construct variables being studied, the validity (accuracy), and the reliability (dependability) of a variable.

a. Construct Validity and Reliability

Construct Validity and Reliability are tests to measure the reliability of a construct. The reliability of construct scores must be sufficiently high. The criteria for reliability and validity can be seen from Cronbach Alpha > 0.7, Rho_A > 0.7, Composite Reliability > 0.6, Average Variance Extracted (AVE) > 0.5.

Table I. Construct Validity And Reliability

	Cronbach's Alpha	rho_A	Reliabilitas Komposit	Rata-rata Varians Diekstrak (AVE)
Storage Handling (X1)	0,956	0,998	0,978	0,958
Reuse Manajemen (X2)	0,918	0,928	0,961	0,924
Kompetensi SDM (X3)	0,821	0,821	0,918	0,848
Penanganan lapangan (X4)	0,919	0,960	0,960	0,924
Metode Kerja (x5)	0,906	1.103	0,952	0,909
Waste Manajemen (Y)	0,981	0,982	0,984	0,913

Based on the data for Construct Validity and Reliability in the table, it was found that all variables have values (Cronbach Alpha and Rho_A > 0.7), values (Composite Reliability > 0.6), and values (Average Variance Extracted / AVE > 0.5). Therefore, the Validity and Reliability of all variables are good.

b. Diskriminant Validity

To determine the discriminant validity of the research construct, it can be seen from the acquisition of the Heretroit-Monotrait Ratio (HTMT) value. If the Heretroit-Monotrait Ratio (HTMT) value < 0.90, then the construct can be considered valid.

Table 2. Heretroit-Monotrait Ratio (Htmt)

	(X1)	(X2)	(X3)	(X4)	(X5)	(Y)
Storage Handling (X1)						
Reuse Manajement (X2)	**0.085**					
Kompetensi SDM (X3)	**0.15**	**0.184**				
Field Handling (X4)	**0.052**	**0.033**	**0.068**			
Method (x5)	**0.136**	**0.234**	**0.13**	**0.073**		
Waste Manajemen (Y)	**0.197**	**0.189**	**0.172**	**0.232**	**0.15**	

Based on the results of the *Heretroit-Monotrait Ratio* (HTMT) in the Table, results were obtained that showed that the total value (HTMT) of the research variable was less than 0.90. Thus, the research construct used was valid.

2. *Inner Model*

Structural model analysis or (inner model) aims to test research hypotheses. The parts that need to be analyzed in the structural model are the coefficient of determination (R-Square) and hypothesis testing.

a. R-Square

The coefficient of determination (R-Square) aims to evaluate the accuracy of a model's predictions. In other words, to evaluate how the variation in the dependent variable is influenced by the variation in the independent variable in a path model. If the R^2 value = 0.75, then the model is substantial (strong), if R^2 = 0.50, then the model is moderate, if R^2 = 0.25, then the model is weak (Juliandi, 2018).

TABLE 3. ***R-SQUARE***

	R-Square	R-Square Adjusted
Waste Manajemen (Y)	0,233	0,192

Based on the table, the R-Square result for waste management is 0.233. This indicates that the accuracy of the

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independent variable X in explaining the Waste Management variable (Y) is 23.3%

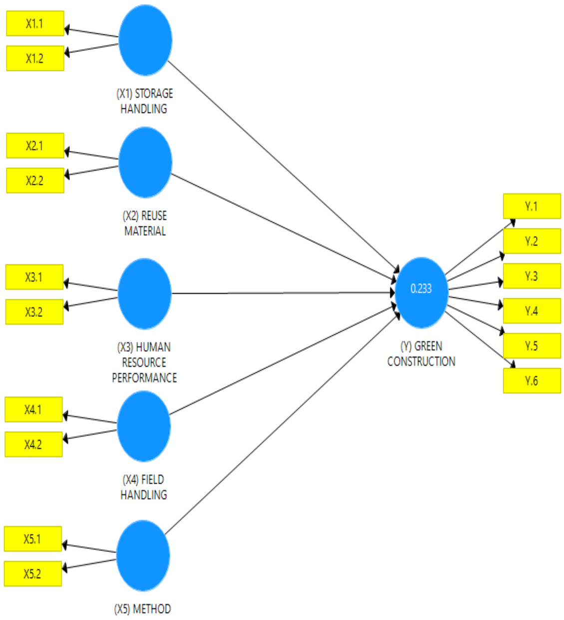

Figure 4. R-Square

b. *F-Square*

F-Square is a measure used to assess the relative impact of an influencing variable (exogenous) on the influenced variable (endogenous). The change in F-Square value when a certain exogenous variable is removed from the model can be used to evaluate whether the removed variable has a substantive impact on the endogenous construct. The criteria are as follows: if $f^2 = 0.02$, it indicates a small effect of the exogenous variable on the endogenous variable; if $f^2 = 0.15$, it indicates a moderate effect of the exogenous variable on the endogenous variable; if $f^2 = 0.35$, it indicates a large effect of the exogenous variable on the endogenous variable.

TABLE 4. ***R-Square***

	Waste Manajemen (Y)
Storage Handling (X1)	**0.101**
Reuse Manajemen (X2)	**0.103**
Kompetensi SDM (X3)	**0.062**
Penanganan lapangan (X4)	**0.082**
Metode Kerja (X5)	**0.061**

Based on the table above, it can be seen that the f-square effect of the exogenous variable Storage Handling on Waste Management is 0.101. This means that there will be a change in the value of Waste Management by 10.1% if the Storage Handling variable is removed from the construct. The substantive impact of the Storage Handling variable is indicated in the moderate category.

The influence of the f-square of the exogenous variable Reuse Management on Waste Management is 0.103. This means that there will be a change in the value of Waste Management by 10.3% if the Reuse Management variable is removed from the construct. The substantive impact of the Reuse Management variable is indicated in the moderate category. The f-square effect of the exogenous variable Human Resource Competence on Waste Management is 0.062. This means that there will be a change in the value of Waste Management by 6.2% if the variable Human Resource Competence is removed from the construct. The substantive impact of the Human Resource Competence variable is indicated in the small category. The f-square effect of Implamantation on Waste Management is 0.082. This means that there will be a change in the value of Waste Management by 8.2% if the Implamantation variable is removed from the construct. The substantive impact of the Implamantation variable is indicated in the small category. The f-square influence of the Work Method on Waste Management is 0.082 This means that there will be a change in the value of Waste Management by 8.2% if the Work Method is removed from the construct. The substantive impact of the Work Method is indicated in the small category. The acquisition of the F-Square value in this study can also be seen in the following figure:

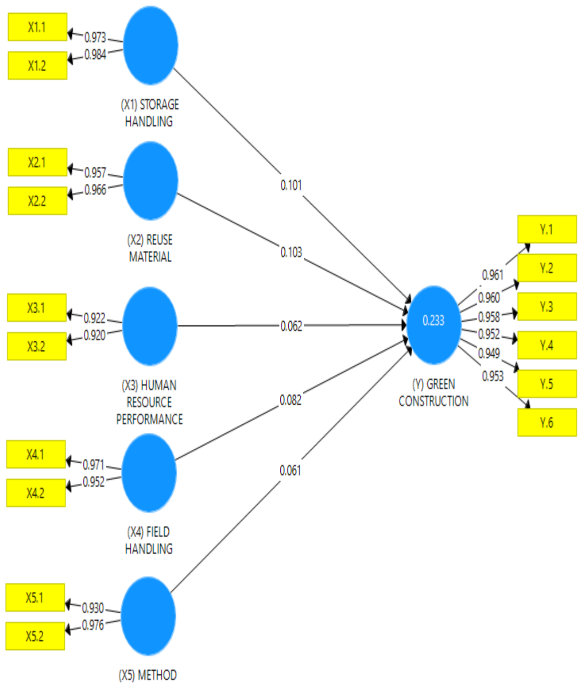

Figure 5. *F-Square*

3. *Hypothesis Measurement Analysis*

a. *Direct Effect*

Direct effect analysis is useful for testing the hypothesis of the direct influence of an exogenous variable on an endogenous variable. The criteria for measuring direct

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influence can use the value of the path coefficient. (Path Coefficient).

If the path coefficient value is positive, then the value of one variable towards another variable is in the same direction, so if the value of an exogenous variable increases, the value of the endogenous variable will also increase. If the path coefficient value is negative, then the influence of one variable on another variable is in the opposite direction, so if the value of the exogenous variable increases, the value of the endogenous variable will decrease.

Table 5. ***Direct Effect***

	Ordinal Sampel	*Sampel Mean*	*Standart Deviasi*	*T-Statistik*	*P Values*
X1 → Y	0.285	0.29	0.117	2,437	0.015
X2 → Y	0.293	0.29	0.121	2,421	0.016
X3 → Y	0.224	0.231	0.1	2,249	0.025
X4 → Y	0.252	0.252	0.105	2.405	0.017
X5 → Y	0.224	0.228	0.105	2,135	0.033

The results of the field survey conducted on construction projects in Indonesia showed the implementation of storage handling with a Likert scale value of 3.94, categorized as Appropriate. The influence of Storage Handling on Waste Management has a P-Value (0.015) < α (0.05), indicating that the implementation of Storage Handling has a significant impact on Waste Management. The survey and analysis of the influence of Storage Handling on construction material Waste Management have a path coefficient (Ordinal Sample) of 0.285 (positive). Therefore, optimizing and improving storage handling in construction projects can increase the achievement of waste management implementation in construction by 28.5%.

The results of the data analysis indicate that Reuse Material has an impact on Waste management with a P-Value (0.016) < α (0.05). The impact of Reuse Material in construction on Waste management has a path coefficient (Ordinal Sample) of 0.293 (positive), which means that the reuse of construction materials affects waste management by 29.30%.

In the management of construction waste in this study, it was found that the presence of human resources with competence and expertise in their field has an impact on the implementation of waste management in the construction sector. This is evident from the P-Values obtained (0.016) < α (0.05), with the impact of human resources on waste management being 29.3%, while the remainder is influenced by other variables outside the research construct.

Then, the field implementation carried out during the construction activities had a significant impact on construction waste management with a P-Value (0.016) < α. (0.05). The magnitude of the influence or impact caused is 25.2% based on the acquisition of an ordinal sample value of 0.252.

In addition, in the implementation of construction projects, various methods can be applied according to the cases that occur on the ground. The work method is carried out based on the agreed operational standards and procedures, and the use of appropriate equipment and materials. Work methods carried out with good SOPs and the use of appropriate materials and equipment have an impact on the implementation of waste management. In this study, the results show the influence of the Work Method on Waste Management with a P-Value (0.016) < α (0.05), indicating that the Work Method has a significant influence with an effect size of 29.3%, while the remainder is influenced by other variables outside the research construct.

The Direct Influence of Endogenous Variables on Exogenous Variables in the Research Construct can be seen in the following figure:

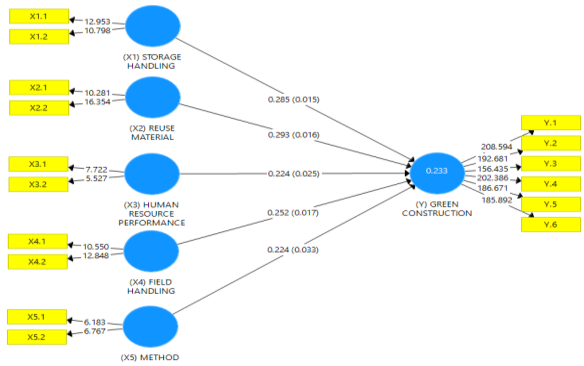

Figure 6. *Direct effect*

III. CONCLUSIONS

The concept of Green Construction has become an important part of a comprehensive effort to reduce the negative impact caused by the construction process itself. In achieving sustainable development, which is an elaboration of the green construction concept, the implementation of a waste management system can contribute to the creation of a good environment through several aspects consisting of 1) Storage Handling; 2) Reuse Material; 3) Human Resource Competence; 4) Field Implementation; and 5) Work Methods. From the analysis conducted, these five aspects have a significant impact in minimizing material waste from construction activities. Waste management, also known as waste management, is one of the important aspects of the green development. WASTE can be defined as the loss or waste of various resources, such as materials, time (including labor and equipment), and capital, caused by activities that incur costs but do not add value to the final product for construction service users. Sometimes, people mistakenly use the wrong materials on-site when working on a construction project. It is impossible to completely avoid waste during a construction project, but waste can be minimized if the causes are identified before the project begins. Based on the researcher's direct experience in this research process, there are several limitations encountered that can serve as factors for future researchers to pay more attention to in order to refine their research, as this study itself certainly has shortcomings that need to be continuously improved in future studies. Some limitations in the research include: (1) The number of respondents, which is only 100 people, is certainly insufficient to accurately represent the actual situation. (2) The research object is only focused on the social media Instagram, which is just one of many other social media platforms that also have a lot of buying and selling activities, such as Facebook, Twitter, and Kaskus. (3) In the data collection process, the information provided by respondents through questionnaires sometimes does not reflect the respondents' actual opinions. This occurs due to differences in thinking, assumptions, and understanding among each respondent. terms of the research conducted by the researchers, there are several suggestions that can be provided. It is expected that future research will include elements on the implementation of green construction, factors that hinder the implementation of green construction, and various approaches to managing waste materials generated from various construction activities. Further research is needed to provide more comprehensive results and solutions.

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