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ANALYSIS OF FACTORS INFLUENCING THE IMPLEMENTATION OF SUSTAINABLE CONSTRUCTION MANAGEMENT TOWARDS PROJECT WASTE MANAGEMENT IN THE NATIONAL CAPITAL CITY

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ABSTRACT

The construction industry currently contributes 13% to the world's Gross Domestic Product (GDP), uses 36% of global energy and produces 39% of energy-related CO2 emissions. The application of Environment, Social, and Governance (ESG) principles is increasing in construction management to achieve sustainability. The construction sector brings diverse impacts on the environment, especially through significant construction waste. The relocation of the National Capital City (IKN) to East Kalimantan has the principles of smart city, forest city, and sponge city which carry the concept of sustainable construction. So this study will analyze the factors that influence the implementation of sustainable construction management on project waste management in IKN. The method used is a survey method with a quantitative method approach and the research variables used are based on the results of a literature review. So that from the results of the analysis it is concluded that the factors that influence sustainable construction management on waste management are Energy Efficiency, where the indicator that has the highest value is the use of energy-efficient plants, machinery and equipment. This is because the implementation of work at IKN cannot be separated from a development approach that prioritizes the use of wise, efficient resources and minimal environmental impact.

KEYWORDS *IKN, Sustainable Construction, Waste, Construction Management.*

INTRODUCTION

The construction industry currently contributes 13% to the world's Gross Domestic Product (GDP) , uses 36% of global energy and produces 39% of energy-related CO2 emissions . The application of Environment, Social, and Governance (ESG) principles is increasing in construction management to achieve sustainability. The construction sector brings diverse impacts on the environment, mainly through significant construction waste. Construction waste accounts for

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more than a third of the world's total waste, with the European Union and United Arab Emirates showing high volumes of construction waste while in Indonesia, construction waste reaches 29 million tons per year. The relocation of the National Capital to East Kalimantan has the principles of smart city, forest city, and sponge city. The development of IKN is based on (1) designing according to natural conditions, (2) Unity in Diversity, (3) connected, active, and accessible, (4) low carbon emissions, (5) circular and resilient, (6) safe and affordable, (7) comfort and efficiency through technology, and (8) economic opportunities for all so that based on these parameters IKN has a sustainable city development concept. The IKN project has a sustainable construction concept but in the implementation of construction, it is carried out by several BUMN contractor companies so that utilities, technology, waste management and work methods are required to be integrated. This research analyzes the factors that influence the implementation of sustainable construction management on project waste management in IKN.

Project Management

Project management is a process that integrates tools, resources, and techniques to achieve predetermined goals. Activities in project management include planning, organization, implementation, and control. Project management includes managing all aspects of a project, including planning, organizing, implementing, and controlling. A project manager is responsible for the oversight and management of the entire process, from initial conception to project completion. The project management process consists of several stages, including planning, organizing, implementing, supervising, and closing. To carry out project management effectively, a project manager must have adequate skills and knowledge of project management, time and cost management techniques, risk management, as well as the ability to lead and manage project teams. . The aspects included in the scope of project management include commencement of project time, planning of project scope, defining the project scope, and verifying and controlling the project during its execution process.

Sustainable Construction Management

Project management involves the processes, methods, knowledge, skills, and experience required to achieve project-specific goals. Sustainable project management means implementing projects that support future generations and provide economic, environmental, and social benefits to society. This research assesses sustainable project management based on the economic, environmental, and social benefits of construction companies. Reducing the use of natural resources, wastewater, biodiversity and energy is a step towards sustainable project management. The company's relationship with local communities, management of labor practices, and human rights management are important elements that support sustainable project management (Banihashemi et al., 2017). A sustainability indicator is a characteristic that can be measured or assessed qualitatively that indicates a desired outcome to achieve sustainability goals. Bueno et al. (2015) explain that sustainability indicators are measurable components of social, economic, or environmental systems, which are used to track and monitor changes in projects. Effective indicators should be relevant, reliable, based on accessible data, and easy to understand. Sustainability indicators should be applied across all phases of a construction project, i.e. initiation, planning, execution, operation, and demolition (Srivastava et al., 2022). Various studies have identified these indicators according to project phases; however, this research focuses on the planning and implementation phases as attention to these processes will result in more sustainable products (Kapatsa et al., 2023).

Table 1: Construction Project Sustainability Assessment Indicators

Variables	**Indicator**
Energy efficiency	Use of renewable energy such as solar and wind power Energy saving initiatives Energy consumption monitoring plan Use of energy-efficient plant, machinery, and equipment
Water Efficiency	Gray water reuse Water control and monitoring plan Stormwater runoff management Collecting rainwater
Sustainable Materials and Resources	Recyclable materials Utilization of natural resources High quality durable material Locally available materials
Waste Production and Management	Garbage collection Recycling and reuse of waste Use of construction techniques that reduce waste

Source: (Aji, 2015; Anggraini, 2019; Kapatsa et al., 2023)

Project Waste Management Strategy

The problem of Construction and Demolition (C&D) waste can be addressed through effective resource exploitation, material recovery, and energy saving. Waste minimization methods, waste separation strategies, and resource management can recover between 80 to 90% of the waste currently disposed of (Ratnasabapathy et al., 2020; Aribowo, 2024; Safitri, 2020) This is necessary to reduce the impact of climate change due to construction materials (Kurniyaningrum, 2024). Waste reduction strategies are the most effective and efficient techniques, and achieve the main goal of minimizing construction waste. Therefore, this measure can provide benefits ranging from design for assembly and deconstruction, off-site construction, as well as the use of precast building elements and modular buildings. . Establishing a Construction Waste Management (CWM) plan requires appropriate methods to measure and track construction waste and its diversion rate, which is an up-to-date record of the amount and type of waste materials that can be recycled or reused. It also helps in predicting the future waste generation rate (WGR) and developing waste reduction strategies. In this regard, C&D waste can be measured by volume and weight of waste components (Ismaeel, 2019). The process of waste diversion from authorized landfill facilities can be calculated by various methods, e.g. source reduction, treatment, remediation, reuse, waste-to-energy recycling, and waste trading (Awino & Apitz, 2023). Therefore, Waste Diversion Rate (WDR) is one of the metrics suggested by recent studies to assess the effectiveness of waste management strategies. It shows the proportion of total waste diverted to total waste generated, and often covers the entire waste if the cycle takes the output into account. This emphasizes the fact that the type and effectiveness of waste conversion techniques can affect the WDR whose accuracy may change according to the data used (Ratnasabapathy et al., 2020). Furthermore, the amount of C&D waste generated can be calculated as the product of time (number of weeks), number of trucks, and the weight of one hauling truck, this equation has been used in previous studies to calculate the Construction Waste Index (CWI) as the product of the amount of C&D waste (tons) and the built-up area (m2) (Ismaeel & Kassim, 2023).

RESEARCH METHODS

Methods

The method applied in this study uses a survey method. This research uses quantitative methods as a research approach based on the philosophy of positivism, used to study certain populations or samples (Sugiyono, 2018). Data collection uses research instruments, and analysis is carried out quantitatively/statistically with the aim of analyzing the factors that influence the implementation of sustainable construction management in project waste management in the National Capital City.

Definition and Operationalization of Variables

Independent variable

Independent variables are variables that affect or cause changes or the emergence of dependent variables (Sugiyono, 2019). In this study, the independent variables are energy efficiency (EE), water efficiency (EA), sustainable materials and resources (BSB), and waste production and management (PPS).

Dependent variable

The dependent variable is the variable that is influenced or that becomes the result of the independent variable (Sugiyono, 2019). The dependent variable is construction project waste management (PLP).

Operational Variables

Table 2: Operational Research Variables

Variables	Indicator	Code	Source
Energy Efficiency (EE)	Use of renewable energy such as solar and wind power	EE1	Aji (2015) Anggraini (2019)
	Energy saving initiatives	EE2	
	Energy consumption monitoring plan	EE3	

Variables	Indicator	Code	Source
	Use of energy-efficient plant, machinery, and equipment	EE4	
Water Efficiency (EA)	Gray water reuse	EA1	Kapatsa et al. (2023)
	Water control and monitoring plan	EA2	
	Stormwater runoff management	EA3	
	Collecting rainwater	EA4	
Sustainable Materials and Resources (BSB)	Recyclable materials	BSB1	Aji (2015) Anggraini (2019)
	Utilization of natural resources	BSB2	
	High quality durable material	BSB3	
	Locally available materials	BSB4	
Waste Production and Management (PPS)	Garbage collection	PPS1	Kapatsa et al (2022)
	Recycling and reuse of waste	PPS2	
	Use of construction techniques that reduce waste	PPS3	
Waste Management Project (PLP)	Project team awareness of construction waste	PLP1	Omer et al., (2022)
	Adoption of off-site construction practices (prefabrication)	PLP2	
	Adoption of on-site construction practices (*mobile* recycling)	PLP3	
	Certification related to construction waste recycling	PLP4	
	Adopt a database to collect construction waste	PLP5	
	Improve company policy on construction waste recycling	PLP6	

Research Population and Sample

In this study, the population is the entire project team on a construction project in the National Capital City (IKN) of 30 people. Total *sampling* is a method in which the number of samples is equal to the population. All 30 project teams on construction projects in the National Capital City (IKN) were sampled in this study.

Sampling Technique

In this study, researchers used non-probability sampling techniques. According to Sugiyono (2020), it is a technique in which each member of the population does not have the same opportunity to be selected as a sample. The sampling technique used in this study was total sampling. Sugiyono (2020) explains that total sampling, or census, is a method in which all members of the population are sampled. This method is usually used when the population is relatively small, which is no more than 30 people, and all members of the population are included as samples. Therefore, the sampling technique used in this study involved 30 project teams.

Data Collection Methods

The data used in this research is primary data, which means that the data is obtained directly from the source that is the object of research. The data collection process was carried out using a questionnaire method, in which the researcher compiled a number of written questions given to respondents. The results of this questionnaire were then processed using the SPSS Version 22 program. This questionnaire consists of questions in positive and negative forms which are measured using a five-point Likert scale.

Data Processing and Analysis

Data Analysis of Factors Affecting the Implementation of Sustainable Construction Management

Each respondent rated a number of indicators relating to sustainable construction management practices. These ratings were then calculated to obtain the mean and Index of Relative Importance (IKR) of each factor. Analyzing the data to determine the ranking of the questionnaire is done by calculating the Index of Relative Importance (IKR) value. To obtain the IKR value, the following formula was used:

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n} \quad \text{......................................(1)}$$

Description:
X = Average size of factor scores
Xi = The size of the factor score at the 1st respondent
n = Number of respondents

$$IKR = \frac{\bar{x}}{M} \quad \text{......................................(2)}$$

Description:
IKR = Relative Importance Index
Xi = Average size of factor scores
M = 4 (on influencing factors)

The variable that has the highest IKR value is ranked 1, and so on up to the lowest IKR value in order. If there are two or more variables with the same IKR value, the rank is determined by summing up the rankings that will represent the variable, then dividing by the number of variables that have the same value.

Scoring of Questionnaire Answers for Factors Affecting the Implementation of Sustainable Construction Management is presented in the following Table:

Table 3. IKR Result Scoring

Value	Level of Influence
3,50 < X < 4,00	Very Influential
2,50 < X < 3,50	Influential
1,50 < X < 2,50	Less Influential
1,00 < X < 1,50	No Effect

Data Analysis of the Influence of Sustainable Construction Management Implementation Factors on Project Waste Management

a. Validity Test

The validity test is carried out by looking at the Pearson product moment (r) correlation which measures the closeness of the correlation between the question score and the total score of the observed variable. The provisions applied are that a questionnaire item is declared valid if the r value has a significance level of less than 5%.

b. Reliability Test

The reliability test will be carried out using the Cronbach's alpha statistical test with the provision that the variable under study is declared reliable if the Cronbach's alpha value is above 0.6. (Sugiyono, 2019).

c. Descriptive Analysis

Data analysis using descriptive statistics is carried out by categorizing research data to obtain information about subject groups on the variables studied. The purpose of this index number analysis is to understand the general perception of respondents regarding the variables studied. To describe respondents' perceptions of the questions asked, an index analysis was carried out. This index analysis uses the following formula (Ferdinand, 2011).

P = F/N X 100% ....(2)

Description:
P = Percentage
F = Frequency or number of answers
N = Number of Respondents

d. T test

The t test is one of the statistical techniques used to test the significance of the regression coefficient in linear regression analysis. The t test helps in determining whether the regression coefficient of an independent variable in a linear regression model is statistically significant or not (Ghozali, 2018). The t test is used to test the null hypothesis (H0) that the regression coefficient of a particular independent variable is equal to zero, which indicates that the independent variable has no significant effect on the dependent variable. The hypothesis form is as follows:
Null hypothesis (H0): $\beta = 0$ (there is no effect of the independent variable on the dependent variable).

Null hypothesis (H0): β ≠ 0 (there is no effect of the independent variable on the dependent variable).

RESULTS AND DISCUSSION

Forum Group Discussion

Forum Group Discussion (FGD) is a form of discussion, discussing topics related to sustainable construction management in terms of construction waste management factors, with the hope of creating constructive discussions and collecting opinions within a certain time limit, in this case several resource persons who are experienced in the construction field for more than 10 years were selected. The following are the research variables based on the FGD results.

Table 4. Research Variables Based on FGD Results

Variables	Indicator	Code
Energy Efficiency (EE)	Use of renewable energy such as solar and wind power	EE1
	Energy saving initiatives	EE2
	Energy consumption monitoring plan	EE3
	Use of energy-efficient plant, machinery, and equipment	EE4
	Operational maintenance of construction equipment	EE5
Water Efficiency (EA)	Gray water reuse	EA1
	Water control and monitoring plan	EA2
	Stormwater runoff management	EA3
	Collecting rainwater	EA4
Sustainable Materials and Resources (BSB)	Recyclable materials	BSB1
	Utilization of natural resources	BSB2
	High quality durable material	BSB3
	Locally available materials	BSB4
	Material usage	BSB5
	Procurement of goods as needed	BSB6
	Material control in the project	BSB7
Waste Production and Management (PPS)	Garbage collection	PPS1
	Recycling and reuse of waste	PPS2
	Use of construction techniques that reduce waste	PPS3
	Prepare waste treatment facilities and infrastructure	PPS4
	Organizational structure involved	PPS5
	Local regulations governing waste.	PPS6
Waste Management Project (PLP)	Project team awareness of construction waste	PLP1
	Adoption of off-site construction practices (prefabrication)	PLP2
	Adoption of on-site construction practices (*mobile* recycling)	PLP3

Variables	Indicator	Code
	Certification related to construction waste recycling	PLP4
	Adopt a database to collect construction waste	PLP5
	Improve company policy on construction waste recycling	PLP6

Validity Test

To conduct a validity test. The question items in the questionnaire will be declared valid if:

Valid : r count > r table,

Invalid : r count < r table

Table 5. Validity Test Results

No.	Variable	Statementn	Counter	<>	R table	Conclusion
1.	**EE**	EE 1	0.780	>	0.3610	Valid
2.		EE 2	0.789	>	0.3610	Valid
3.		EE 3	0.780	>	0.3610	Valid
4.		EE 4	0.776	>	0.3610	Valid
5.		EE 5	0.781	>	0.3610	Valid
The calculated R value of the EE variable for all variables> R table (0.3610). so that all *statements* are Valid						
1.	**EA**	EA 1	0.777	>	0.3610	Valid
2.		EA 2	0.774	>	0.3610	Valid
3.		EA 3	0.776	>	0.3610	Valid
4.		EA 4	0.779	>	0.3610	Valid
The calculated R value of the EA variable of all variables> R table (0.3610). so that all *statements* are Valid						
1.	**BSB**	BSB 1	0.773	>	0.3610	Valid
2.		BSB 2	0.774	>	0.3610	Valid
3.		BSB 3	0.771	>	0.3610	Valid
4.		BSB 4	0.771	>	0.3610	Valid
5.		BSB 5	0.773	>	0.3610	Valid
6.		BSB 6	0.770	>	0.3610	Valid
7.		BSB 7	0.777	>	0.3610	Valid
The calculated R value of the BSB variable for all variables> R table (0.3610). so that all *statements* are Valid						
1.	**PPS**	PPS 1	0.789	>	0.3610	Valid
2.		PPS 2	0.783	>	0.3610	Valid
3.		PPS 3	0.780	>	0.3610	Valid
4.		PPS 4	0.772	>	0.3610	Valid
5.		PPS 5	0.776	>	0.3610	Valid
6.		PPS 6	0.773	>	0.3610	Valid
The calculated R value of the PPS variable for all variables> R table (0.3610). so that all *statements* are Valid						

No.	Variable	Statementn	Counter	<>	R table	Conclusion
1.	PLP	PLP 1	0.740	>	0.3610	Valid
2.		PLP 2	0.211	<	0.3610	Invalid
3.		PLP 3	0.742	>	0.3610	Valid
4.		PLP 4	0.744	>	0.3610	Valid
5.		PLP 5	0.742	>	0.3610	Valid
6.		PLP 6	0.754	>	0.3610	Valid

There is a calculated R value < R table (0.3610) on the PLP variable, namely the PLP 2 *statement* so that the *statement* is invalid, while the other 5 *statements* are all> 0.3610, meaning valid.

Reliability Test

Nunnally in Ghozali (2011) argues that if the measured variable has an alpha value greater than 0.60, the instrument used is declared reliable. The results of the instrument reliability test are presented in the following table:

Table 6. Reliability Test

No.	Variable	Cronbach's Alpha	<>	Standardized Cronbach's Alpha	Ket
1	EE	0.767	>	0.6	*Reliable*
2	EA	0.762	>	0.6	*Reliable*
3	BSB	0.763	>	0.6	*Reliable*
4	PPS	0.762	>	0.6	*Reliable*
5	PLP	0.766	>	0.6	*Reliable*

Test t

The t value resulting from this test is compared to a specified threshold value (usually 0.05 or 0.01) to determine whether the difference between the two groups is statistically significant.

Table 7. Results of the t-test

Model		Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
		B	Std. Error	Beta	t	Sig.	Tolerance	VIF
1	(Constant)	1.233	2.300		.536	.593		
	EE	.098	.081	.111	1.218	.002	.293	3.413
	EA	.440	.078	.437	5.672	.000	.413	2.422
	BSB	.679	.082	.459	4.248	.001	.114	2.973
	PSP	.410	.107	.346	3.843	.000	.303	3.304

Respondents' Perceptions of Factors Affecting the Implementation of Sustainable Construction Management in Project Waste Management

Table 8. Respondents' Perception of Factors Affecting the Implementation of Sustainable Construction Management in Project Waste Management

No.	Indicator	Importance Assessment					Total
		1 TB	2 KB	3 CB	4 B	5 SB	
	Energy Efficiency (EE)						
EE1	Use of renewable energy such as solar and wind power	0	8	10	10	2	30
EE2	Energy saving initiatives	0	0	6	12	12	30
EE3	Energy consumption monitoring plan	1	2	8	12	7	30
EE4	Use of energy-efficient plant, machinery, and equipment	2	0	2	14	12	30
EE5	Operational maintenance of construction equipment	2	2	3	16	7	30
	Water Efficiency (EA)						
EA1	Gray water reuse	0	6	10	10	4	30
EA2	Water control and monitoring plan	1	1	7	10	11	30
EA3	Stormwater runoff management	0	2	6	12	10	30
EA4	Collecting rainwater	3	1	4	14	8	30
Sustainable Materials and Resources (BSB)							
BSB1	Recyclable materials	1	1	2	20	6	30
BSB2	Utilization of natural resources	2	2	4	16	6	30
BSB3	High quality durable material	1	1	1	14	13	30
BSB4	Locally available materials	1	2	4	15	8	30
BSB5	Appropriate use of materials	0	1	5	13	11	30
BSB6	Procurement of goods as needed	0	5	5	11	9	30
BSB7	Material control in the project	0	0	8	11	11	30
Waste Production and Management (PPS)							
PPS1	Organized waste collection	2	2	3	14	9	30
PPS2	Recycling and reuse of waste	1	0	5	17	7	30
PPS3	Use of construction techniques that reduce waste	0	0	4	11	15	30
PPS4	Waste management facilities and infrastructure	1	1	2	14	12	30
PPS5	Organizational structure involved	0	1	0	14	15	30
PPS6	Regulations governing waste.	0	3	4	10	13	30

Based on the analysis of the table above, respondents' perceptions of the factors influencing the implementation of sustainable construction management in project waste management show variations in the level of importance. Some of the indicators that have a fairly high value are "Energy saving initiatives, use of energy-efficient plant, machinery and equipment, high-quality old materials, material control in the project, use of construction techniques that reduce waste, organizational structures involved, and regulations governing waste".

Analysis of Factors Affecting the Implementation of Sustainable Construction Management in Project Waste Management

Factors Affecting the Implementation of Sustainable Construction Management in Project Waste Management

No.	Code	Indicator	Assessment			Weighting
			$\frac{\sum}{Xi}$	X	IKR	
	Energy Efficiency (EE)					
1	EE1	Use of renewable energy such as solar and wind power	72	3,132	0,777	Influential
2	EE2	Energy saving initiatives	98	3,882	0,921	Very Influential
3	EE3	Energy consumption monitoring	95	3,626	0,913	Very Influential
4	EE4	Use of energy-efficient plant, machinery, and equipment	104	3,942	0,945	Very Influential
5	EE5	Operational maintenance of construction equipment	98	3,854	0,989	Very Influential
	Water Efficiency (EA)					
6	EA1	Gray water reuse	94	3,481	0,782	Influential
7	EA2	Water control and monitoring	87	3,354	0,797	Influential
8	EA3	Stormwater runoff management	82	3,167	0,845	Influential
9	EA4	Collecting rainwater	64	2,378	0,577	Less Influential
	Sustainable Materials and Resources (BSB)					
10	BSB1	Recyclable materials	89	3,243	0,822	Influential
11	BSB2	Utilization of natural resources	97	3,756	0,917	Very Influential
12	BSB3	High quality durable material	95	3,805	0,944	Very Influential
13	BSB4	Locally available materials	78	2,113	0,659	Less Influential
14	BSB5	Appropriate use of materials	102	3,829	0,954	Very Influential
15	BSB6	Procurement of goods as needed	97	3,832	0,778	Very Influential
16	BSB7	Material control in the project	99	3,723	0,845	Very Influential
	Waste Production and Management (PPS)					

No.	Code	Indicator	Assessment			Weighting
			$\sum Xi$	X	IKR	
17	PPS1	Organized waste collection	96	3,356	0,877	Influential
18	PPS2	Recycling and reuse of waste	72	2,314	0,634	Less Influential
19	PPS3	Use of construction techniques that reduce waste	105	3,899	0,985	Very Influential
20	PPS4	Prepare waste management facilities and infrastructure	57	1,316	0,533	No Effect
21	PPS5	Organizational structure involved	109	3,543	0,781	Very Influential
22	PPS6	Regulations governing waste.	83	3,143	0,743	Influential

Then each variable is ranked according to the highest X value, which is presented in the table below

Table 10: Highest and Lowest Ranking

Factor	Average Value	Rating
EE4	3.942	1
PPS3	3.899	2
EE2	3.882	3
EE5	3.854	4
BSB6	3.832	5
BSB5	3.829	6
BSB3	3.805	7
BSB2	3.756	8
BSB7	3.723	9
EE3	3.626	10
PPS5	3.543	11
EA1	3.481	12
PPS1	3.356	13
EA2	3,354	14
BSB1	3.243	15
EA3	3.167	16
PPS6	3.143	17
EE1	3.132	18
EA4	2,378	19
PPS2	2.314	20
BSB4	2.113	21
PPS4	1.316	22

EE4 (Use of energy-efficient plant, machinery and equipment) has the highest average score (3.942) and is ranked 1, PPS3 (Use of construction techniques that reduce waste) with an average score of 3.899 is ranked 2 and EE2 (Energy saving initiatives) is ranked 3 and EE5 (Operational maintenance of construction equipment) is ranked 4.

CONCLUSION

The factor that influences sustainable construction management on waste management is energy efficiency. In the IKN project, the indicator that has the highest value is the use of energy-efficient plants, machinery and equipment. This is because the implementation of work at IKN cannot be separated from a development approach that prioritizes the use of wise, efficient resources and minimal environmental impact. Procurement of materials from modular / precast factories in most building projects has a huge impact on the disposal of construction waste materials, because there is no waste from the implementation process in the field. The implementation of routine measurements is carried out with drone equipment and photogrammetric technology where information on field conditions and topographic data is made by recording ultrasonic waves (LIDAR) so that fewer resources are needed compared to conventional implementation. And can reduce construction waste (forest encroachment, use of operational vehicles to measure, potential waste oil, paper, other supporting materials).

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ANALYSIS OF FACTORS INFLUENCING THE IMPLEMENTATION OF SUSTAINABLE CONSTRUCTION MANAGEMENT TOWARDS PROJECT WASTE MANAGEMENT IN THE NATIONAL CAPITAL CITY

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ABSTRACT

The construction industry currently contributes 13% to the world's Gross Domestic Product (GDP), uses 36% of global energy and produces 39% of energy-related CO2 emissions. The application of Environment, Social, and Governance (ESG) principles is increasing in construction management to achieve sustainability. The construction sector brings diverse impacts on the environment, especially through significant construction waste. The relocation of the National Capital City (IKN) to East Kalimantan has the principles of smart city, forest city, and sponge city which carry the concept of sustainable construction. So this study will analyze the factors that influence the implementation of sustainable construction management on project waste management in IKN. The method used is a survey method with a quantitative method approach and the research variables used are based on the results of a literature review. So that from the results of the analysis it is concluded that the factors that influence sustainable construction management on waste management are Energy Efficiency, where the indicator that has the highest value is the use of energy-efficient plants, machinery and equipment. This is because the implementation of work at IKN cannot be separated from a development approach that prioritizes the use of wise, efficient resources and minimal environmental impact.

KEYWORDS *IKN, Sustainable Construction, Waste, Construction Management.*

INTRODUCTION

The construction industry currently contributes 13% to the world's Gross Domestic Product (GDP) , uses 36% of global energy and produces 39% of energy-related CO2 emissions . The application of Environment, Social, and Governance (ESG) principles is increasing in construction management to achieve sustainability. The construction sector brings diverse impacts on the environment, mainly through significant construction waste. Construction waste accounts for

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more than a third of the world's total waste, with the European Union and United Arab Emirates showing high volumes of construction waste while in Indonesia, construction waste reaches 29 million tons per year. The relocation of the National Capital to East Kalimantan has the principles of smart city, forest city, and sponge city. The development of IKN is based on (1) designing according to natural conditions, (2) Unity in Diversity, (3) connected, active, and accessible, (4) low carbon emissions, (5) circular and resilient, (6) safe and affordable, (7) comfort and efficiency through technology, and (8) economic opportunities for all so that based on these parameters IKN has a sustainable city development concept. The IKN project has a sustainable construction concept but in the implementation of construction, it is carried out by several BUMN contractor companies so that utilities, technology, waste management and work methods are required to be integrated. This research analyzes the factors that influence the implementation of sustainable construction management on project waste management in IKN.

Project Management

Project management is a process that integrates tools, resources, and techniques to achieve predetermined goals. Activities in project management include planning, organization, implementation, and control. Project management includes managing all aspects of a project, including planning, organizing, implementing, and controlling. A project manager is responsible for the oversight and management of the entire process, from initial conception to project completion. The project management process consists of several stages, including planning, organizing, implementing, supervising, and closing. To carry out project management effectively, a project manager must have adequate skills and knowledge of project management, time and cost management techniques, risk management, as well as the ability to lead and manage project teams. . The aspects included in the scope of project management include commencement of project time, planning of project scope, defining the project scope, and verifying and controlling the project during its execution process.

Sustainable Construction Management

Project management involves the processes, methods, knowledge, skills, and experience required to achieve project-specific goals. Sustainable project management means implementing projects that support future generations and provide economic, environmental, and social benefits to society. This research assesses sustainable project management based on the economic, environmental, and social benefits of construction companies. Reducing the use of natural resources, wastewater, biodiversity and energy is a step towards sustainable project management. The company's relationship with local communities, management of labor practices, and human rights management are important elements that support sustainable project management (Banihashemi et al., 2017). A sustainability indicator is a characteristic that can be measured or assessed qualitatively that indicates a desired outcome to achieve sustainability goals. Bueno et al. (2015) explain that sustainability indicators are measurable components of social, economic, or environmental systems, which are used to track and monitor changes in projects. Effective indicators should be relevant, reliable, based on accessible data, and easy to understand. Sustainability indicators should be applied across all phases of a construction project, i.e. initiation, planning, execution, operation, and demolition (Srivastava et al., 2022). Various studies have identified these indicators according to project phases; however, this research focuses on the planning and implementation phases as attention to these processes will result in more sustainable products (Kapatsa et al., 2023).

Table 1: Construction Project Sustainability Assessment Indicators

Variables	Indicator
Energy efficiency	Use of renewable energy such as solar and wind power Energy saving initiatives Energy consumption monitoring plan Use of energy-efficient plant, machinery, and equipment
Water Efficiency	Gray water reuse Water control and monitoring plan Stormwater runoff management Collecting rainwater
Sustainable Materials and Resources	Recyclable materials Utilization of natural resources High quality durable material Locally available materials
Waste Production and Management	Garbage collection Recycling and reuse of waste Use of construction techniques that reduce waste

Source: (Aji, 2015; Anggraini, 2019; Kapatsa et al., 2023)

Project Waste Management Strategy

The problem of Construction and Demolition (C&D) waste can be addressed through effective resource exploitation, material recovery, and energy saving. Waste minimization methods, waste separation strategies, and resource management can recover between 80 to 90% of the waste currently disposed of (Ratnasabapathy et al., 2020; Aribowo, 2024; Safitri, 2020) This is necessary to reduce the impact of climate change due to construction materials (Kurniyaningrum, 2024). Waste reduction strategies are the most effective and efficient techniques, and achieve the main goal of minimizing construction waste. Therefore, this measure can provide benefits ranging from design for assembly and deconstruction, off-site construction, as well as the use of precast building elements and modular buildings. . Establishing a Construction Waste Management (CWM) plan requires appropriate methods to measure and track construction waste and its diversion rate, which is an up-to-date record of the amount and type of waste materials that can be recycled or reused. It also helps in predicting the future waste generation rate (WGR) and developing waste reduction strategies. In this regard, C&D waste can be measured by volume and weight of waste components (Ismaeel, 2019). The process of waste diversion from authorized landfill facilities can be calculated by various methods, e.g. source reduction, treatment, remediation, reuse, waste-to-energy recycling, and waste trading (Awino & Apitz, 2023). Therefore, Waste Diversion Rate (WDR) is one of the metrics suggested by recent studies to assess the effectiveness of waste management strategies. It shows the proportion of total waste diverted to total waste generated, and often covers the entire waste if the cycle takes the output into account. This emphasizes the fact that the type and effectiveness of waste conversion techniques can affect the WDR whose accuracy may change according to the data used (Ratnasabapathy et al., 2020). Furthermore, the amount of C&D waste generated can be calculated as the product of time (number of weeks), number of trucks, and the weight of one hauling truck, this equation has been used in previous studies to calculate the Construction Waste Index (CWI) as the product of the amount of C&D waste (tons) and the built-up area (m2) (Ismaeel & Kassim, 2023).

RESEARCH METHODS

Methods

The method applied in this study uses a survey method. This research uses quantitative methods as a research approach based on the philosophy of positivism, used to study certain populations or samples (Sugiyono, 2018). Data collection uses research instruments, and analysis is carried out quantitatively/statistically with the aim of analyzing the factors that influence the implementation of sustainable construction management in project waste management in the National Capital City.

Definition and Operationalization of Variables

Independent variable

Independent variables are variables that affect or cause changes or the emergence of dependent variables (Sugiyono, 2019). In this study, the independent variables are energy efficiency (EE), water efficiency (EA), sustainable materials and resources (BSB), and waste production and management (PPS).

Dependent variable

The dependent variable is the variable that is influenced or that becomes the result of the independent variable (Sugiyono, 2019). The dependent variable is construction project waste management (PLP).

Operational Variables

Table 2: Operational Research Variables

Variables	Indicator	Code	Source
Energy Efficiency (EE)	Use of renewable energy such as solar and wind power	EE1	Aji (2015) Anggraini (2019)
	Energy saving initiatives	EE2	
	Energy consumption monitoring plan	EE3	

Variables	Indicator	Code	Source
	Use of energy-efficient plant, machinery, and equipment	EE4	
Water Efficiency (EA)	Gray water reuse	EA1	Kapatsa et al. (2023)
	Water control and monitoring plan	EA2	
	Stormwater runoff management	EA3	
	Collecting rainwater	EA4	
Sustainable Materials and Resources (BSB)	Recyclable materials	BSB1	Aji (2015) Anggraini (2019)
	Utilization of natural resources	BSB2	
	High quality durable material	BSB3	
	Locally available materials	BSB4	
Waste Production and Management (PPS)	Garbage collection	PPS1	Kapatsa et al (2022)
	Recycling and reuse of waste	PPS2	
	Use of construction techniques that reduce waste	PPS3	
Waste Management Project (PLP)	Project team awareness of construction waste	PLP1	Omer et al., (2022)
	Adoption of off-site construction practices (prefabrication)	PLP2	
	Adoption of on-site construction practices (*mobile* recycling)	PLP3	
	Certification related to construction waste recycling	PLP4	
	Adopt a database to collect construction waste	PLP5	
	Improve company policy on construction waste recycling	PLP6	

Research Population and Sample

In this study, the population is the entire project team on a construction project in the National Capital City (IKN) of 30 people. Total *sampling* is a method in which the number of samples is equal to the population. All 30 project teams on construction projects in the National Capital City (IKN) were sampled in this study.

Sampling Technique

In this study, researchers used non-probability sampling techniques. According to Sugiyono (2020), it is a technique in which each member of the population does not have the same opportunity to be selected as a sample. The sampling technique used in this study was total sampling. Sugiyono (2020) explains that total sampling, or census, is a method in which all members of the population are sampled. This method is usually used when the population is relatively small, which is no more than 30 people, and all members of the population are included as samples. Therefore, the sampling technique used in this study involved 30 project teams.

Data Collection Methods

The data used in this research is primary data, which means that the data is obtained directly from the source that is the object of research. The data collection process was carried out using a questionnaire method, in which the researcher compiled a number of written questions given to respondents. The results of this questionnaire were then processed using the SPSS Version 22 program. This questionnaire consists of questions in positive and negative forms which are measured using a five-point Likert scale.

Data Processing and Analysis

Data Analysis of Factors Affecting the Implementation of Sustainable Construction Management

Each respondent rated a number of indicators relating to sustainable construction management practices. These ratings were then calculated to obtain the mean and Index of Relative Importance (IKR) of each factor. Analyzing the data to determine the ranking of the questionnaire is done by calculating the Index of Relative Importance (IKR) value. To obtain the IKR value, the following formula was used:

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n} \quad \text{......................................(1)}$$

Description:
X = Average size of factor scores
Xi = The size of the factor score at the 1st respondent
n = Number of respondents

$$IKR = \frac{\bar{x}}{M} \quad \text{......................................(2)}$$

Description:
IKR = Relative Importance Index
Xi = Average size of factor scores
M = 4 (on influencing factors)

The variable that has the highest IKR value is ranked 1, and so on up to the lowest IKR value in order. If there are two or more variables with the same IKR value, the rank is determined by summing up the rankings that will represent the variable, then dividing by the number of variables that have the same value.

Scoring of Questionnaire Answers for Factors Affecting the Implementation of Sustainable Construction Management is presented in the following Table:

Table 3. IKR Result Scoring

Value	Level of Influence
3,50 < X < 4,00	Very Influential
2,50 < X < 3,50	Influential
1,50 < X < 2,50	Less Influential
1,00 < X < 1,50	No Effect

Data Analysis of the Influence of Sustainable Construction Management Implementation Factors on Project Waste Management

a. Validity Test

The validity test is carried out by looking at the Pearson product moment (r) correlation which measures the closeness of the correlation between the question score and the total score of the observed variable. The provisions applied are that a questionnaire item is declared valid if the r value has a significance level of less than 5%.

b. Reliability Test

The reliability test will be carried out using the Cronbach's alpha statistical test with the provision that the variable under study is declared reliable if the Cronbach's alpha value is above 0.6. (Sugiyono, 2019).

c. Descriptive Analysis

Data analysis using descriptive statistics is carried out by categorizing research data to obtain information about subject groups on the variables studied. The purpose of this index number analysis is to understand the general perception of respondents regarding the variables studied. To describe respondents' perceptions of the questions asked, an index analysis was carried out. This index analysis uses the following formula (Ferdinand, 2011).

P = F/N X 100% ....(2)

Description:
P = Percentage
F = Frequency or number of answers
N = Number of Respondents

d. T test

The t test is one of the statistical techniques used to test the significance of the regression coefficient in linear regression analysis. The t test helps in determining whether the regression coefficient of an independent variable in a linear regression model is statistically significant or not (Ghozali, 2018). The t test is used to test the null hypothesis (H0) that the regression coefficient of a particular independent variable is equal to zero, which indicates that the independent variable has no significant effect on the dependent variable. The hypothesis form is as follows:

Null hypothesis (H0): $\beta = 0$ (there is no effect of the independent variable on the dependent variable).

Null hypothesis (H0): $\beta \neq 0$ (there is no effect of the independent variable on the dependent variable).

RESULTS AND DISCUSSION

Forum Group Discussion

Forum Group Discussion (FGD) is a form of discussion, discussing topics related to sustainable construction management in terms of construction waste management factors, with the hope of creating constructive discussions and collecting opinions within a certain time limit, in this case several resource persons who are experienced in the construction field for more than 10 years were selected. The following are the research variables based on the FGD results.

Table 4. Research Variables Based on FGD Results

Variables	Indicator	Code
Energy Efficiency (EE)	Use of renewable energy such as solar and wind power	EE1
	Energy saving initiatives	EE2
	Energy consumption monitoring plan	EE3
	Use of energy-efficient plant, machinery, and equipment	EE4
	Operational maintenance of construction equipment	EE5
Water Efficiency (EA)	Gray water reuse	EA1
	Water control and monitoring plan	EA2
	Stormwater runoff management	EA3
	Collecting rainwater	EA4
Sustainable Materials and Resources (BSB)	Recyclable materials	BSB1
	Utilization of natural resources	BSB2
	High quality durable material	BSB3
	Locally available materials	BSB4
	Material usage	BSB5
	Procurement of goods as needed	BSB6
	Material control in the project	BSB7
Waste Production and Management (PPS)	Garbage collection	PPS1
	Recycling and reuse of waste	PPS2
	Use of construction techniques that reduce waste	PPS3
	Prepare waste treatment facilities and infrastructure	PPS4
	Organizational structure involved	PPS5
	Local regulations governing waste.	PPS6
Waste Management Project (PLP)	Project team awareness of construction waste	PLP1
	Adoption of off-site construction practices (prefabrication)	PLP2
	Adoption of on-site construction practices (*mobile* recycling)	PLP3

Variables	Indicator	Code
	Certification related to construction waste recycling	PLP4
	Adopt a database to collect construction waste	PLP5
	Improve company policy on construction waste recycling	PLP6

Validity Test

To conduct a validity test. The question items in the questionnaire will be declared valid if:
Valid : r count > r table,
Invalid : r count < r table

Table 5. Validity Test Results

No.	Variable	Statementn	Counter	<>	R table	Conclusion
1.	**EE**	EE 1	0.780	>	0.3610	Valid
2.		EE 2	0.789	>	0.3610	Valid
3.		EE 3	0.780	>	0.3610	Valid
4.		EE 4	0.776	>	0.3610	Valid
5.		EE 5	0.781	>	0.3610	Valid
The calculated R value of the EE variable for all variables> R table (0.3610). so that all *statements* are Valid						
1.	**EA**	EA 1	0.777	>	0.3610	Valid
2.		EA 2	0.774	>	0.3610	Valid
3.		EA 3	0.776	>	0.3610	Valid
4.		EA 4	0.779	>	0.3610	Valid
The calculated R value of the EA variable of all variables> R table (0.3610). so that all *statements* are Valid						
1.	**BSB**	BSB 1	0.773	>	0.3610	Valid
2.		BSB 2	0.774	>	0.3610	Valid
3.		BSB 3	0.771	>	0.3610	Valid
4.		BSB 4	0.771	>	0.3610	Valid
5.		BSB 5	0.773	>	0.3610	Valid
6.		BSB 6	0.770	>	0.3610	Valid
7.		BSB 7	0.777	>	0.3610	Valid
The calculated R value of the BSB variable for all variables> R table (0.3610). so that all *statements* are Valid						
1.	**PPS**	PPS 1	0.789	>	0.3610	Valid
2.		PPS 2	0.783	>	0.3610	Valid
3.		PPS 3	0.780	>	0.3610	Valid
4.		PPS 4	0.772	>	0.3610	Valid
5.		PPS 5	0.776	>	0.3610	Valid
6.		PPS 6	0.773	>	0.3610	Valid
The calculated R value of the PPS variable for all variables> R table (0.3610). so that all *statements* are Valid						

No.	Variable	Statementn	Counter	<>	R table	Conclusion
1.	PLP	PLP 1	0.740	>	0.3610	Valid
2.		PLP 2	0.211	<	0.3610	Invalid
3.		PLP 3	0.742	>	0.3610	Valid
4.		PLP 4	0.744	>	0.3610	Valid
5.		PLP 5	0.742	>	0.3610	Valid
6.		PLP 6	0.754	>	0.3610	Valid

There is a calculated R value < R table (0.3610) on the PLP variable, namely the PLP 2 *statement* so that the *statement* is invalid, while the other 5 *statements* are all> 0.3610, meaning valid.

Reliability Test

Nunnally in Ghozali (2011) argues that if the measured variable has an alpha value greater than 0.60, the instrument used is declared reliable. The results of the instrument reliability test are presented in the following table:

Table 6. Reliability Test

No.	Variable	Cronbach's Alpha	<>	Standardized Cronbach's Alpha	Ket
1	EE	0.767	>	0.6	*Reliable*
2	EA	0.762	>	0.6	*Reliable*
3	BSB	0.763	>	0.6	*Reliable*
4	PPS	0.762	>	0.6	*Reliable*
5	PLP	0.766	>	0.6	*Reliable*

Test t

The t value resulting from this test is compared to a specified threshold value (usually 0.05 or 0.01) to determine whether the difference between the two groups is statistically significant.

Table 7. Results of the t-test

		Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
Model		B	Std. Error	Beta	t	Sig.	Tolerance	VIF
1	(Constant)	1.233	2.300		.536	.593		
	EE	.098	.081	.111	1.218	.002	.293	3.413
	EA	.440	.078	.437	5.672	.000	.413	2.422
	BSB	.679	.082	.459	4.248	.001	.114	2.973
	PSP	.410	.107	.346	3.843	.000	.303	3.304

Respondents' Perceptions of Factors Affecting the Implementation of Sustainable Construction Management in Project Waste Management

Table 8. Respondents' Perception of Factors Affecting the Implementation of Sustainable Construction Management in Project Waste Management

No.	**Indicator**	**Importance Assessment**					**Total**
		1 TB	**2 KB**	**3 CB**	**4 B**	**5 SB**	
	Energy Efficiency (EE)						
EE1	Use of renewable energy such as solar and wind power	0	8	10	10	2	30
EE2	Energy saving initiatives	0	0	6	12	12	30
EE3	Energy consumption monitoring plan	1	2	8	12	7	30
EE4	Use of energy-efficient plant, machinery, and equipment	2	0	2	14	12	30
EE5	Operational maintenance of construction equipment	2	2	3	16	7	30
	Water Efficiency (EA)						
EA1	Gray water reuse	0	6	10	10	4	30
EA2	Water control and monitoring plan	1	1	7	10	11	30
EA3	Stormwater runoff management	0	2	6	12	10	30
EA4	Collecting rainwater	3	1	4	14	8	30
Sustainable Materials and Resources (BSB)							
BSB1	Recyclable materials	1	1	2	20	6	30
BSB2	Utilization of natural resources	2	2	4	16	6	30
BSB3	High quality durable material	1	1	1	14	13	30
BSB4	Locally available materials	1	2	4	15	8	30
BSB5	Appropriate use of materials	0	1	5	13	11	30
BSB6	Procurement of goods as needed	0	5	5	11	9	30
BSB7	Material control in the project	0	0	8	11	11	30
Waste Production and Management (PPS)							
PPS1	Organized waste collection	2	2	3	14	9	30
PPS2	Recycling and reuse of waste	1	0	5	17	7	30
PPS3	Use of construction techniques that reduce waste	0	0	4	11	15	30
PPS4	Waste management facilities and infrastructure	1	1	2	14	12	30
PPS5	Organizational structure involved	0	1	0	14	15	30
PPS6	Regulations governing waste.	0	3	4	10	13	30

Based on the analysis of the table above, respondents' perceptions of the factors influencing the implementation of sustainable construction management in project waste management show variations in the level of importance. Some of the indicators that have a fairly high value are "Energy saving initiatives, use of energy-efficient plant, machinery and equipment, high-quality old materials, material control in the project, use of construction techniques that reduce waste, organizational structures involved, and regulations governing waste".

Analysis of Factors Affecting the Implementation of Sustainable Construction Management in Project Waste Management

Factors Affecting the Implementation of Sustainable Construction Management in Project Waste Management

No.	Code	Indicator	Assessment			Weighting
			$\sum Xi$	X	IKR	
	Energy Efficiency (EE)					
1	EE1	Use of renewable energy such as solar and wind power	72	3,132	0,777	Influential
2	EE2	Energy saving initiatives	98	3,882	0,921	Very Influential
3	EE3	Energy consumption monitoring	95	3,626	0,913	Very Influential
4	EE4	Use of energy-efficient plant, machinery, and equipment	104	3,942	0,945	Very Influential
5	EE5	Operational maintenance of construction equipment	98	3,854	0,989	Very Influential
	Water Efficiency (EA)					
6	EA1	Gray water reuse	94	3,481	0,782	Influential
7	EA2	Water control and monitoring	87	3,354	0,797	Influential
8	EA3	Stormwater runoff management	82	3,167	0,845	Influential
9	EA4	Collecting rainwater	64	2,378	0,577	Less Influential
	Sustainable Materials and Resources (BSB)					
10	BSB1	Recyclable materials	89	3,243	0,822	Influential
11	BSB2	Utilization of natural resources	97	3,756	0,917	Very Influential
12	BSB3	High quality durable material	95	3,805	0,944	Very Influential
13	BSB4	Locally available materials	78	2,113	0,659	Less Influential
14	BSB5	Appropriate use of materials	102	3,829	0,954	Very Influential
15	BSB6	Procurement of goods as needed	97	3,832	0,778	Very Influential
16	BSB7	Material control in the project	99	3,723	0,845	Very Influential
	Waste Production and Management (PPS)					

No.	Code	Indicator	Assessment			Weighting
			$\sum Xi$	X	IKR	
17	PPS1	Organized waste collection	96	3,356	0,877	Influential
18	PPS2	Recycling and reuse of waste	72	2,314	0,634	Less Influential
19	PPS3	Use of construction techniques that reduce waste	105	3,899	0,985	Very Influential
20	PPS4	Prepare waste management facilities and infrastructure	57	1,316	0,533	No Effect
21	PPS5	Organizational structure involved	109	3,543	0,781	Very Influential
22	PPS6	Regulations governing waste.	83	3,143	0,743	Influential

Then each variable is ranked according to the highest X value, which is presented in the table below

Table 10: Highest and Lowest Ranking

Factor	Average Value	Rating
EE4	3.942	1
PPS3	3.899	2
EE2	3.882	3
EE5	3.854	4
BSB6	3.832	5
BSB5	3.829	6
BSB3	3.805	7
BSB2	3.756	8
BSB7	3.723	9
EE3	3.626	10
PPS5	3.543	11
EA1	3.481	12
PPS1	3.356	13
EA2	3,354	14
BSB1	3.243	15
EA3	3.167	16
PPS6	3.143	17
EE1	3.132	18
EA4	2,378	19
PPS2	2.314	20
BSB4	2.113	21
PPS4	1.316	22

EE4 (Use of energy-efficient plant, machinery and equipment) has the highest average score (3.942) and is ranked 1, PPS3 (Use of construction techniques that reduce waste) with an average score of 3.899 is ranked 2 and EE2 (Energy saving initiatives) is ranked 3 and EE5 (Operational maintenance of construction equipment) is ranked 4.

CONCLUSION

The factor that influences sustainable construction management on waste management is energy efficiency. In the IKN project, the indicator that has the highest value is the use of energy-efficient plants, machinery and equipment. This is because the implementation of work at IKN cannot be separated from a development approach that prioritizes the use of wise, efficient resources and minimal environmental impact. Procurement of materials from modular / precast factories in most building projects has a huge impact on the disposal of construction waste materials, because there is no waste from the implementation process in the field. The implementation of routine measurements is carried out with drone equipment and photogrammetric technology where information on field conditions and topographic data is made by recording ultrasonic waves (LIDAR) so that fewer resources are needed compared to conventional implementation. And can reduce construction waste (forest encroachment, use of operational vehicles to measure, potential waste oil, paper, other supporting materials).

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