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FACTORS CAUSING CONSTRUCTION WASTE: A CASE STUDY IN ACEH BESAR REGENCY

***Hafnidar A. Rani[1], Tamalkhani Syammaun[2], Darwis[3], Muhammad Hafidz Mubarak[4] & Muhammad Shafly Aqsha[5]**
***Corresponding Author**
[1,2,3,4]Department of Civil Engineering, Universitas Muhammadiyah Aceh, Banda Aceh, Indonesia,
[5]Department of Computer Science, Universiti Tun Hussein Onn Malaysia, Johor, Malaysia
hafnidar.ar@unmuha.ac.id

[2]tamalkhani@unmuha.ac.id, [3]darwisalma05@gmail.com
[4]hafidz.messi@gmail.com, [5]muhshaqsha@gmail.com
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ABSTRACT

Construction waste poses significant losses in terms of material, time, and finances, stemming from various direct and indirect activities. To address this issue effectively, it is imperative to identify the root causes of construction waste. This study aims to ascertain the factors contributing to construction waste and determine the most dominant causes thereof. The research problem revolves around identifying the factors causing construction waste and pinpointing the primary contributors to this issue. The study seeks to shed light on the factors influencing construction waste, with a particular focus on the Santriwati Dayah Darul Muttaqin Dormitory Development Project in Aceh Besar Regency. The factors examined in this research include waiting time, materials, human resources, construction implementation, management, design and documentation, residuals, and external factors. The analytical methods employed comprise correlation analysis, multiple regression analysis, and descriptive analysis. The findings of the descriptive analysis revealed that construction waste primarily arises from issues related to materials, construction implementation, and management in the aforementioned project. Among these factors, management emerged as the most dominant. This study provides valuable insights into the factors influencing construction waste in Aceh Besar Regency, contributing to *the development of targeted strategies for waste reduction and improved project efficiency.*

Keywords: *Construction waste, Construction implementation, Materials*

INTRODUCTION

Building construction projects encompass a highly intricate scope of work, which inherently risks generating waste and undermining value (Rani, 2021). Value, in this context, denotes the intended outcomes to be realized through implementing a construction project such as delivering a functional and aesthetically pleasing structure within budget and schedule. Waste refers to elements that fail to contribute to these objectives, including inefficiencies, errors, and excess materials (Situmeang, et al., 2021).

The complexity of building projects has significantly expanded in the modern era due to the involvement of various professions and the extensive information that goes into a construction project itself. The majority of procedures in a building project are done by hand, which increases the risk of human error and can result in faulty judgments and delays (Zhi, et al., 2022).

There has been a trend in the production of construction waste due to large-scale building and infrastructure development projects. Because building is a dynamic activity, it is difficult to estimate the quantity and composition of waste produced accurately (Harun, et al., 2017). Various forms of waste pervade construction projects, including prolonged waiting times for instructions, materials, and tools, material losses or damages, inefficient material usage, as well as instances of idle labor, delayed work, rework, and workplace accidents (Apni & Puspasari, 2019).

Additionally, instances of wasted time due to equipment damage during project execution further exacerbate the issue (Isya, et al., 2019). Such waiting waste inevitably leads to project delays, compelling contractors to extend project timelines and incur additional expenses, such as vehicle rentals (Lestari, 2017), heavy equipment usage, fuel, daily labor wages, and equipment maintenance costs (Muhammad, et al., 2019).

Realizing how waste negatively affects a project's whole lifecycle, it is essential to take proactive steps to solve this issue (Mahyuddin, et al., 2024). Accumulated waste not only occupies valuable project space but also necessitates costly disposal processes, particularly considering the typically considerable distances to disposal sites (Yuan, et al., 2024). Effective waste management strategies encompass various approaches, including waste reuse, recycling, sale, and proper disposal (Nawaz, et al., 2023).

Illustratively, the construction of the Dayah Darul Muttaqin Santriwati Dormitory in Gampong Cot Puklat, Blang Bintang District, Aceh Besar Regency, is undertaken by CV . Main Wahana Consultant exemplifies the inevitability of construction waste in project execution. Consequently, identifying prevalent construction waste and its underlying causes becomes pivotal. By pinpointing these factors, it becomes feasible to mitigate construction waste, thereby enhancing the project's success in meeting time, cost, and quality criteria.

Against this backdrop, this research seeks to address two core questions: Firstly, what are the factors contributing to construction waste in the Dayah Darul Muttaqin Santriwati Dormitory Development Project? Secondly, what are the primary factors driving construction waste in this project? Thus, the objectives of this study are twofold: to identify the factors contributing to construction waste in the Santriwati Dayah Darul Muttaqin Dormitory Development Project and to ascertain the dominant factors underlying construction waste in this project.

According to Hadut and Koesmargono (2018) and Rani, et al., (2023), construction waste can be categorized into three primary groups: labor, materials, and equipment. Waste in construction extends beyond the mere quantity of material waste within a project; it also encompasses wasted time (Lestari, et al., 2022). Various activities contribute to construction waste, including excess production, waiting times, material handling, processing, storage, and worker placement (Garcia-Diaz, et al., 2024).

The principal categories of waste in the construction sector comprise damage or defects and material waste (Rani, 2017). Additionally, challenges such as delays, waiting periods, poor material allocation, unnecessary material handling, redundant movements or transfers, errors in selecting work methods, and equipment mismanagement contribute to inefficiencies and can be considered forms of waste (Perdana et al., 2018 and Rani, et al., 2019). According to Ismaeel and Kassim (2023), construction waste manifests in two forms: Physical construction waste and non-value-adding activities occur universally across the construction industry, regardless of: size of the project organization, scale and duration of the contract, type of building, and condition of the building (whether new construction, renovation, or under maintenance).

Governments at the national and international levels have implemented several laws and regulations to make buildings more sustainable, after realizing the harm that construction waste causes to the environment (Wahi, et al., 2016). Construction waste that emerges from the construction site has become a major concern to the nation due to its negative footprints on the environment (Chen, et al., 2021). It is indisputable that improper management of massive volumes of building trash would have detrimental consequences for the environment . Thus, those involved in the construction business must regulate and oversee the creation of construction waste.

Based on the research by Nawawi, et al. (2021) and Natalia et al. (2017), various factors have contributed to the construction waste. Nawawi, et al. (2021) identified design factors, material procurement, material handling, implementation, residuals, and other factors as potential causes of material waste. Meanwhile, Natalia, et al. (2017) identified eight groups of construction waste factors:

1. Human resources: This category encompasses factors such as slow, ineffective, or undisciplined work, a lack of workforce skills, and poor distribution of labor or supervision quality.
2. Management: Factors in this category primarily revolve around addressing poor planning and scheduling.
3. Design and documentation: This category includes factors related to design changes and unclear working drawings.
4. Waiting time: Factors here involve waiting for instructions and materials.
5. Materials: This category encompasses factors like excess materials and materials not meeting specifications.
6. Construction implementation: Factors in this category include work accidents and damaged equipment.
7. Residuals: Factors include leftover materials and errors in ordering goods.

8. External: This category encompasses factors such as poor location conditions, weather, and damage or loss by other parties.

The research findings highlight these factors as significant contributors to construction waste. Table 1 presents a summary of the factors influencing construction waste as identified by Nawawi et al. (2021) and Natalia et al. (2017).

Table 1. Factors Causing Construction Waste

No	Variables	Indicators
1	Waiting time	Time waiting for instructions
		Waiting time for materials
		Waiting time for equipment repair
		Waiting time for workers to arrive at the location
		Waiting time for drawing revisions/design changes
		Time waiting for the equipment to arrive at the location
2	Materials	Excess material
		Scattering of materials
		Material does not comply with specifications
		Loss of material on site
		Stacking of materials on site
		There is often loss of material on site
		The rest of the material is scattered around
		Material damage at the location
3	Human Resources	Slow/ineffective/undisciplined workers
		Lack of workforce skills
		Poor distribution of labor
		Low quality of supervision
		Low subcontractor capabilities
		Unemployed workforce
		Job instruction errors
		Errors during work execution
		Late supervisor
		Inexperienced supervisor
		Lack of foremen
4	Construction execution	There was a work accident

		Equipment often breaks down
		Unreliable equipment
		Delay in carrying out work
		Incomplete contract documents
		Field measurements are inaccurate
		Rework and repair work
5	Management	Poor planning and scheduling
		The information provided is not clear regarding the terms and conditions
		Poor coordination between parties involved in the project
		Slow decision making
		Improper/inappropriate construction methods
6	Design and Documentation	Errors in contract documents
		Incompleteness of contract documents
		Design changes
		Complex image details
		Insufficient image information
		Bad design
		Lack of coordination with contractors and lack of knowledge about construction
6	Design and Documentation	The remaining cut material cannot be used again
		Errors when cutting material
		Errors in ordering goods. due to not understanding the specifications
		Remaining material due to the use process
7	Residual	The remaining cut material cannot be used again
		Errors when cutting material
		Errors in ordering goods. due to not understanding the specifications
		Remaining material due to the use process
8	External	Location conditions is not good
		Weather
		Damage/loss by other parties
		Soil Conditions
		Soil Depth
		Type of soil

Source: Nawawi et al., (2021), Natalia et al., (2017) The research investigated various factors contributing to construction waste, including waiting time, materials, human resources, construction implementation, management, residuals, and external factors. Employing a quantitative method, the researchers distributed a structured set of questionnaires to respondents involved in the Dayah Darul Muttaqin Santriwati Dormitory Development Project in Aceh Besar Regency. The respondents comprised 7 implementing contractors, 6 planning consultants, and 4 supervisory consultants, all of whom possess direct experience and expertise in managing and implementing construction projects.

The quantitative method was selected due to their ability to provide systematic and structured insights into the factors that influenced the construction waste. By collecting numerical data through questionnaires, each of the factor's impact on waste generation could be quantitatively measured. Moreover, employing statistical analyses such as correlation and regression allowed for the exploration of complex relationships among variables., Therefore, this might enhance our understanding on the underlying mechanisms driving construction waste.

It is important to acknowledge the scope and limitations of the methodology employed. While quantitative method offered valuable insights into the relationships between variables, they might not capture the full complexity of the construction waste phenomenon. Additionally, the reliance on self-reported data through questionnaires may introduce bias or limitations in response accuracy. Furthermore, the study focussed on a specific construction project in Aceh Besar Regency; this might limit the generalizability of the findings to other contexts or projects.

A set of structured questionnaires was distributed to the respondents, ensuring standardized data collection procedures. A descriptive analysis was conducted to summarize the characteristics of the sample and the distribution of variables. In addition, a correlation analysis was employed to examine the relationships between predictor variables and construction waste, while multiple linear regression analysis was used to assess the combined influence of these variables on waste generation.

RESULT AND DISCUSSION

Respondents' Characteristics

The respondents involved in this study comprised contractors, consultants, planning, and supervisory consultants who were engaged in the implementation of the Dayah Darul Muttaqin Santriwati Dormitory Development Project, Aceh Besar Regency, totaling to 17 individuals. The selection of the stakeholders was based on their direct involvement and expertise in construction project management and execution.

However, it is important to note that while the respondents' characteristics were analyzed based on gender, age, the highest level of education, and working experience, a detailed analysis on these stakeholder based on categories was not conducted. This limitation should be acknowledged because it may impact the ability in making generalization of the findings and the extent to which the findings can be applied to other construction projects or contexts.

From the responses of the 17 participants, it was observed that all the respondents were male (100.00%), as illustrated in Figure 1 below.

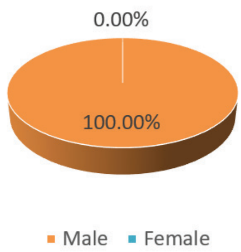

Figure 1. Percentage of Gender

Source: Author

Based on the age distribution of the respondents, the majority fell within the age range between 31-40 years, with a total of 11 respondents (64.71%). Following this, there were 3 respondents aged 41-50 years (17.65%), while 2 other respondents were between 21-30 years (11.76%). Additionally, 1 respondent was over 50 years (5.88%). The distribution of age percentages is depicted in Figure 2 below.

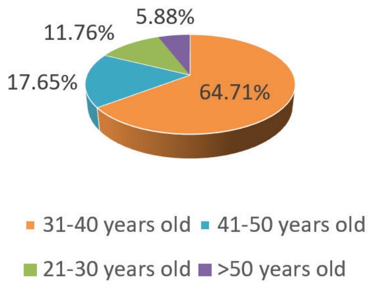

Figure 2. Percentage of Age

Source: Author

Based on the respondents' highest level of education, the majority of the respondents (9) possessed a bachelor's degree (52.94%). Following this, 5 respondents had a high school education (29.41%), while 2 respondents held a master's degree (11.76%). Lastly, 1 respondent had a D3 education (5.88%). The distribution of the highest levels of education percentages is illustrated in Figure 3 below.

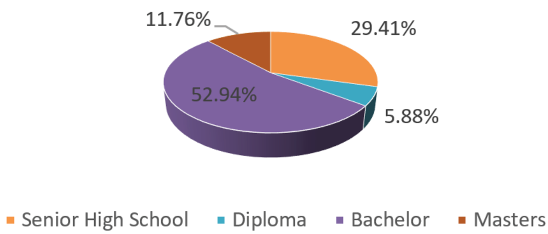

Figure 3. Percentage of Highest Level of Education

Source: Author

Based on the respondents' working experience, the majority, comprising 7 respondents (41.18%), had a working experience of 3-5 years. This was followed by 6 respondents (23.53%) with more than 8 years of working experience and 4 respondents (35.29%) with working experience of 6–8 years. The distribution of work experience percentages is presented in Figure 4 below.

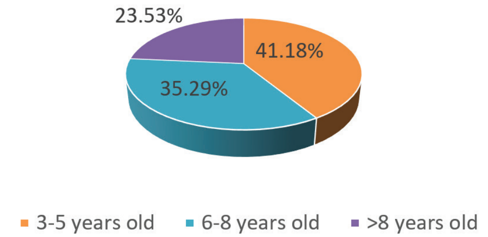

Figure 4. Percentage of Work Experience

Source: Author

Mean Values for Variables

The descriptive analysis was conducted to calculate the mean value, representing the average value of the respondents' characteristics, and to determine the percentage index of the total responses provided by the respondents for the items in the questionnaire. The output results from the data processing using the SPSS Version 25 program are presented in Table 2 below.

Table 2. Mean Value

Variables	Mean	Std. Deviation
X1	2.99	0.90
X2	2.60	0.83
X3	3.03	1.02
X4	3.32	0.78
X5	3.36	0.71
X6	3.26	0.81
X7	3.25	0.75
X8	3.38	0.76
Y	2.93	0.89

Source: Author

Based on the overall mean values obtained from the descriptive analysis table, the lowest mean value is found in variable X2 (materials), with a mean value of 2.60. Conversely, the highest mean values are recorded in variable X8 (external), with a mean value of 3.76. These results indicate that the majority of respondents perceived X4, X5, X6, X7, and X8 to have a significant influence on the occurrence of construction waste.

Pearson Correlation Analysis

Pearson correlation measures the linear relationship between two continuous variables and is commonly used in correlation analysis when both variables are normally distributed. This enables the researchers to assess the correlation between an independent variable (X) and a dependent variable (Y) based on the acquired data. The hypothesis was tested using the product moment correlation technique and multiple correlation with the assistance of the IBM Statistical Product and Service Solution (SPSS) Version 25 program. The decision-making criteria in this correlation test are based on the calculated correlation coefficient (r) value. If the calculated r value is greater than the r table, there is a correlation between the variables; conversely, if the calculated r value is less than the critical r value, the results indicate no correlation. Pearson correlation measures the linear relationship between two continuous variables and is commonly used in correlation analysis when both variables are normally distributed.

The correlation between waiting time (X1), materials (X2), human resources (X3), construction execution (X4), management (X5), design and documentation (X6), residual (X7), and external (X8), with construction waste (Y) were computed using SPSS Version 25 as illustrated in Table 3.

Table 3. Correlation Analysis

Variables	Product Moment Correlation	Sig. (2-tailed)	Strength of Relationship
	Y		
X1	0.466	0.060	Medium
X2	0.549	0.023	Medium
X3	0.445	0.074	Medium
X4	0.444	0.074	Medium
X5	0.325	0.203	Weak
X6	0.395	0.117	Weak
X7	0.181	0.487	Very weak
X8	0.011	0.965	Very weak

Source: Author

The correlation analysis revealed that project management and design/documentation although were positively correlated with construction waste, it exhibited weaker relationships compared to other factors. The project management displayed a low positive correlation. This indicates that it has a role in waste generation but its impact might be less significant than other variables. Similarly, design and documentation showed a low positive correlation. This implied that the planning and documentation phases did contribute to waste generation but to a lesser extent.

Furthermore, the analysis showed a very weak positive correlation between residuals and construction waste. This indicates that residual factors have minimal influence on waste generation. Interestingly, the external factors showed no significant positive correlation with the construction waste. This illustrates that external factors to the construction process such as environmental conditions or market dynamics may not influence directly on waste generation.

Although, the correlations observed provide insights into the relationships between variables, it is important to acknowledge that the strength of these correlations is relative . The justification for whether the correlation is weak or strong is based on the magnitude of the correlation coefficient (r). A correlation coefficient that is closer to 1 indicates a stronger correlation, while a coefficient closer to 0 suggests a weaker correlation. Therefore, when referring to correlations as weak or strong, it is based on the magnitude of the correlation coefficient.

Table 4. Model Summary of Correlations

R	R-Square	Adjusted R-Square	Std. Error of the Estimate	Change Statistics		
				R-Square Change	F Change	Sig. F Change
0.804	0.647	0.293	2.914	0.647	1.830	0.205

Source: Author

From the model summary table above, it is evident that the R-value is 0.804. This R-value indicates a strong positive relationship between the variables of waiting time, materials, human resources, construction implementation, project management, design and documentation, residuals, and external factors with construction waste. A high R-value suggests that these variables collectively have a significant impact on the occurrence of construction waste.

An R-squared value of 0.647, indicates that approximately 64.70% of the variability in construction waste in Aceh Besar Regency can be explained by the combined influence of the independent variables included in the multiple linear regression model. This means that the variables of waiting time, materials, human resources. construction implementation, project management, design and documentation, residuals, and external factors collectively account for about 64.70% of the observed variation in construction waste in Aceh Besar Regency.

Overall, this is a moderately strong explanatory power of the model, suggesting that the included independent variables are reasonably effective in explaining the variation in construction waste observed in the area. However, it is important to note that there are other factors not included in the model that may also contribute to the remaining 35.30% of variables in construction waste.

Multiple Regression Analysis

Table 5 below represents the coefficients of each predictor variable in the multiple regression equation. The standardized coefficients are provided for each variable, allowing for a comparison of the relative importance of each predictor. The standard error column indicates the standard error associated with each coefficient estimate. The t-value column displays the t-values associated with each coefficient, and the p-value column shows the p-values associated with each t-value, indicating the significance of each predictor variable in the model.

These results help to understand the extent to which waiting time, materials, human resources, construction implementation, project management, design and documentation, residuals. and external factors collectively influence construction waste.

Table 5. Multiple Regression Analysis

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
Constant	13.979	13.093		1.068	0.317

X1	0.218	0.804	0.184	0.271	0.793
X2	0.190	0.788	0.221	0.241	0.815
X3	0.152	0.222	0.248	0.683	0.514
X4	0.699	0.473	0.570	1.477	0.178
X5	0.878	0.692	0.641	1.269	0.240
X6	-0.148	0.482	-0.181	-0.307	0.767
X7	-0.575	1.016	-0.281	-0.566	0.587
X8	-1.449	0.626	-0.896	-2.313	0.049

Source: Author

The multiple linear regression equation, derived from the values obtained in Table 5, can be formulated as follows:

$$Y = 13.979 + 0.218X1 + 0.190X2 + 0.152X3 + 0.699X4 + 0.878X5 - 0.148X6 - 0.575X7 - 1.449X8$$

In this equation:

•Y represents the predicted value of construction waste.
•X1 represents the waiting time variable.
•X2 represents the materials and supplies variable.
•X3 represents the human resources variable.
•X4 represents the construction implementation variable.
•X5 represents the project management variable.
•X6 represents the design and documentation variable.
•X7 represents the residual variable.
•X8 represents the external variable.

This equation functions as a predictive tool. This allows the researchers to estimate the quantity of construction waste generated that are based on the values of predictor variables such as waiting time, materials and supplies, human resources, construction implementation, project management, design and documentation, residual factors, and external factors.

The selection in choosing multiple linear regression analysis to analyse the data was made in order to explore the relationships between the multiple predictor variables and construction waste simultaneously. This method allowed the researchers to assess each predictor variables contribution, while controlling the effects of other variables. By incorporating multiple variables into the analysis, the researchers could gain a more comprehensive understanding of the factors influencing the construction waste in Aceh

Besar Regency. Additionally, the regression coefficients provide insights into the magnitude and direction of the relationships between the predictor variables and construction waste. As a result, this allowed the researchers to obtain several strategies for waste minimization and resource optimization in construction projects.

The constant value of 13.979 in the regression model indicates that when all predictor variables (waiting time, materials and ingredients, human resources, construction implementation, project management, design and documentation, residual, and external) are set to zero, the predicted construction waste would be 13.979. Furthermore, the regression coefficients for each variable obtained in this study highlight the individual impacts. For instance, a unit increased in waiting time corresponded to a 21.8% increase in construction waste. This was shown by its coefficient of 0.218. Similarly, a one-unit increase in materials and ingredients is associated with a 19.0% increase in construction waste, as reflected by its coefficient. The coefficients for human resources, construction implementation, project management, design and documentation, residual, and external variables also offered valuable insights into their respective influences on construction waste. These interpretations deepen our understanding of how each predictor variable contributes to overall construction waste, considering their coefficients in the multiple linear regression equation.

In other words, the coefficients provided information about the magnitude and direction of the relationship between each of the predictor variable with the outcome variable (construction waste). A positive coefficient indicated a positive relationship, meaning that an increase in the predictor variable is associated with an increase in construction waste, while a negative coefficient would show the negative relationship.

However, the criteria for testing the t-count value against the t-table revealed that all the t-count values were less than 0.706, and the significance levels were greater than 0.05. Therefore, this shows that there is no significant effect of each variable on the dependent variable. In other words, based on Table 5, none of the independent variables (waiting time, materials, human resources, construction implementation, project management, design and documentation, residuals, or external factors) showed a significant influence on the construction waste.

These findings showed that there is a need for a more nuanced understanding of construction waste dynamics in Aceh Besar Regency. The regression model offers insights into the individual impacts of various factors, however, the lack of significant influences suggested that other unaccounted variables may play a crucial role in waste generation. It is possible that the variables included in the regression model may not fully be accountable for the variability observed in the construction waste. Additionally, the small sample size of samples could potentially impact the analysis. Thus, future research with a larger sample size may provide better insights on the factors influencing construction waste. In addition, efforts to minimize waste in construction projects should adopt a holistic approach, by considering a broader range of factors beyond those examined in this study. By addressing these limitations and incorporating additional variables, future research can contribute to a more robust waste management strategies and tailored specifically to the context of Aceh Besar Regency.

CONCLUSION

The findings from the descriptive analysis indicate that the respondents perceive construction execution, management, design and documentation, residuals, and external factors key roles in influencing the occurrence of construction waste. These insights offer valuable understanding on the factors that may shape the construction waste dynamics in Aceh Besar Regency.

Moreover, the correlation analysis uncovers positive relationships between various independent variables and construction waste. Notably, variables associated with waiting time, materials, human resources, construction implementation, project management, design and documentation, and residuals demonstrate moderate to low correlations with construction waste, indicating their role in the waste generation process.

However, the multiple linear regression analysis highlights that each variable may not individually exhibit a significant impact on the construction waste, they contribute to better understanding on the observed variation in the waste generation within the Aceh Besar District. The analysis indicates that collectively the independent variables constitute of 64.70% of the observed variables had addressed in the issue of construction waste. This suggests that the variables considered do offer some insights on the factors that may influence the construction waste within the area. However, it is important to acknowledge that other unaccounted factors may also contribute to the remaining 35.30% variables in the construction waste.

These findings informed the importance of considering multiple factors simultaneously in addressing the construction waste in Aceh Besar Regency. Managing waiting time effectively, selecting materials, choosing human resources, planning construction execution, handling project management, design and documentation, residuals, and considering the external factors can play a pivotal role in reducing the waste generation and enhance the overall project efficiency and sustainability.

Furthermore, recognizing the influence of external factors such as adverse site conditions and damage or loss caused by external entities is essential for formulating comprehensive strategies to minimize construction waste and to foster environmentally responsible construction practices in the region.

In conclusion, this study provides valuable insights into the multifaceted nature of the construction waste in Aceh Besar Regency. By examining the various factors that influence the waste generation and its relationships, the research provides a deeper understanding of waste management practices in the construction projects. However, it is imperative to acknowledge the limitations of the study such as potential biases from the respondents' perceptions and the exclusion of certain factors from the analysis. Moving forward, future research could delve further into these areas to refine the waste management strategies and promote sustainable development especially in the construction sector.

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AUTHOR CONTRIBUTIONS

All the authors contributed to the final write-up of the manuscript. Below is the breakdown:

1. Hafnidar A. Rani: Conceptualization, methodology, validation, writing - review and editing.
2. Tamalkhani Syammaun: Formal analysis, writing - original draft preparation.
3. Darwis: Resources, data curation and collection.
4. Muhammad Hafidz Mubarak: Investigation, and visualization.
5. Muhammad Shafly Aqsha: Supervision, and project administration.

CONFLICT OF INTEREST

The authors declare no conflict of interest for the written manuscript.

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