Evaluation of Material Waste in the Renovation Project of the BJKW Building, East Java Province Using Pareto Method and Fishbone Diagram

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ABSTRACT

Material is one of the main resources in construction projects, serving as a fundamental component in building structures. Proper planning and supervision in material usage are essential to prevent waste and minimize material loss. A high level of material waste can have a significant negative impact, particularly on the financial aspects of a project, as a large portion of the budget is allocated to material procurement. If material waste is not well controlled, it can lead to budget overruns beyond the initial plan, thereby affecting the overall efficiency and success of the project.

This research was conducted on the renovation project of the BJKW Building in East Java. The study focused on material waste occurring in structural and architectural works. The objective of the research is to identify the dominant material waste and determine the key contributing factors to that waste.

This study employed a combination of two analytical methods: the Pareto method and the Fishbone Diagram. The Pareto method was used to identify the types of materials with the highest potential for financial loss due to waste. Meanwhile, the Fishbone Diagram was applied to analyze the root causes of material waste.

The results of the study indicate that the material contributing the most to waste was plain reinforcing bar, with a total residual material cost of IDR 7,227,099.75. The main contributing factors to this dominant material waste were identified as people, environment, and method.

***Keywords**: Materials, Waste Material, Factor Causing Waste Material*

1. Introduction

The construction industry plays a vital role in the development of infrastructure that supports economic and social growth. In its execution, construction projects require a variety of resources, including labor, equipment, and most importantly, materials. Materials are a key component in construction and significantly influence the success of a project. However, one of the most common issues encountered is material waste (Chen et al., 2023). This waste can occur at various stages of a project, from planning and procurement to storage and on-site execution.

Material waste in construction projects can be attributed to several factors, including inadequate planning, errors in material quantity estimation, mismatched material specifications, and inefficient work methods. In addition, external factors such as weather conditions and environmental challenges also contribute to material wastage (Singh & Patel, 2022). Uncontrolled material waste can negatively impact project efficiency, increase costs, extend project durations, and cause harmful environmental effects.

In the context of renovation projects, material waste poses even more complex challenges compared to new construction projects. Renovation often involves demolition of existing structures and the reuse of salvageable materials. However, in many cases, reusable materials end up as waste due to ineffective management (Li et al., 2021). Therefore, it is essential to adopt appropriate methods to identify the materials with the highest waste levels and analyze the contributing factors.

This study aims to identify the types of materials most prone to wastage in the renovation project of the BJKW Building in East Java Province and to analyze the underlying causes. The Pareto method is used to determine the materials that contribute the most to overall waste in terms of financial impact. Meanwhile, the Fishbone Diagram is employed to investigate the root causes of the dominant material waste.

By understanding the patterns of material waste and their causes, this study is expected to provide recommendations for project management in reducing material waste. Improved material management not only enhances efficiency and reduces costs but also contributes to environmental sustainability by minimizing construction waste

2. Methods

This study employs a combined approach using two methods: the Pareto method and the Fishbone Diagram. The Pareto method is a statistical technique used to identify the primary causes of a problem. By recognizing the most influential factors, corrective actions can be effectively prioritized. The Pareto principle (80/20 rule) states that approximately 80% of the impact typically arises from 20% of the most significant causes or factors (Crisvin et al., 2024).

Meanwhile, the Fishbone Diagram serves as an analytical tool that systematically examines risks and their triggering factors through a cause-and-effect approach. This diagram is applied to identify the factors contributing to material waste. By emphasizing cause-and-effect relationships, this method facilitates the identification and visualization process, thereby enhancing the understanding of various potential causes related to the issue.

Data Collection

Data collection is a crucial step in this research, involving both primary and secondary data as follows:

a. Primary Data
Primary data were obtained directly through interviews with key informants involved in the renovation project of the BJKW Building in East Java. These interviews aimed to gather information regarding project implementation, material management, and the potential for leftover materials.

b. Secondary Data
Secondary data were collected from project documents, such as the Bill of Quantities (BoQ), records of purchased materials, and installed materials (based on as-built drawings). This data complements the primary data and supports further analysis of material management.

Analysis Using the Pareto Method

The Pareto method was used to identify the most dominant types of leftover materials by visualizing them in a Pareto chart. The waste material data were grouped and ranked based on cost, from the highest to the lowest. A cumulative graph was then created to show each material's contribution to the total waste. The results of this analysis help focus management efforts on the most impactful materials, thereby improving efficiency and reducing waste in construction projects.

Identifying the Causes of Material Remainder Using Fishbone Diagram

The identification of material waste causes was carried out using the Fishbone Diagram to classify problems based on their root causes. This approach facilitates the analysis by tracing the contributing factors that lead to waste. The diagram was developed based on interviews with project personnel on site, ensuring that the analysis reflects actual field conditions. As a result, it provides a relevant foundation for formulating future waste reduction strategies.

Flow Chart of Research

The research flowchart can be seen in Figure 1

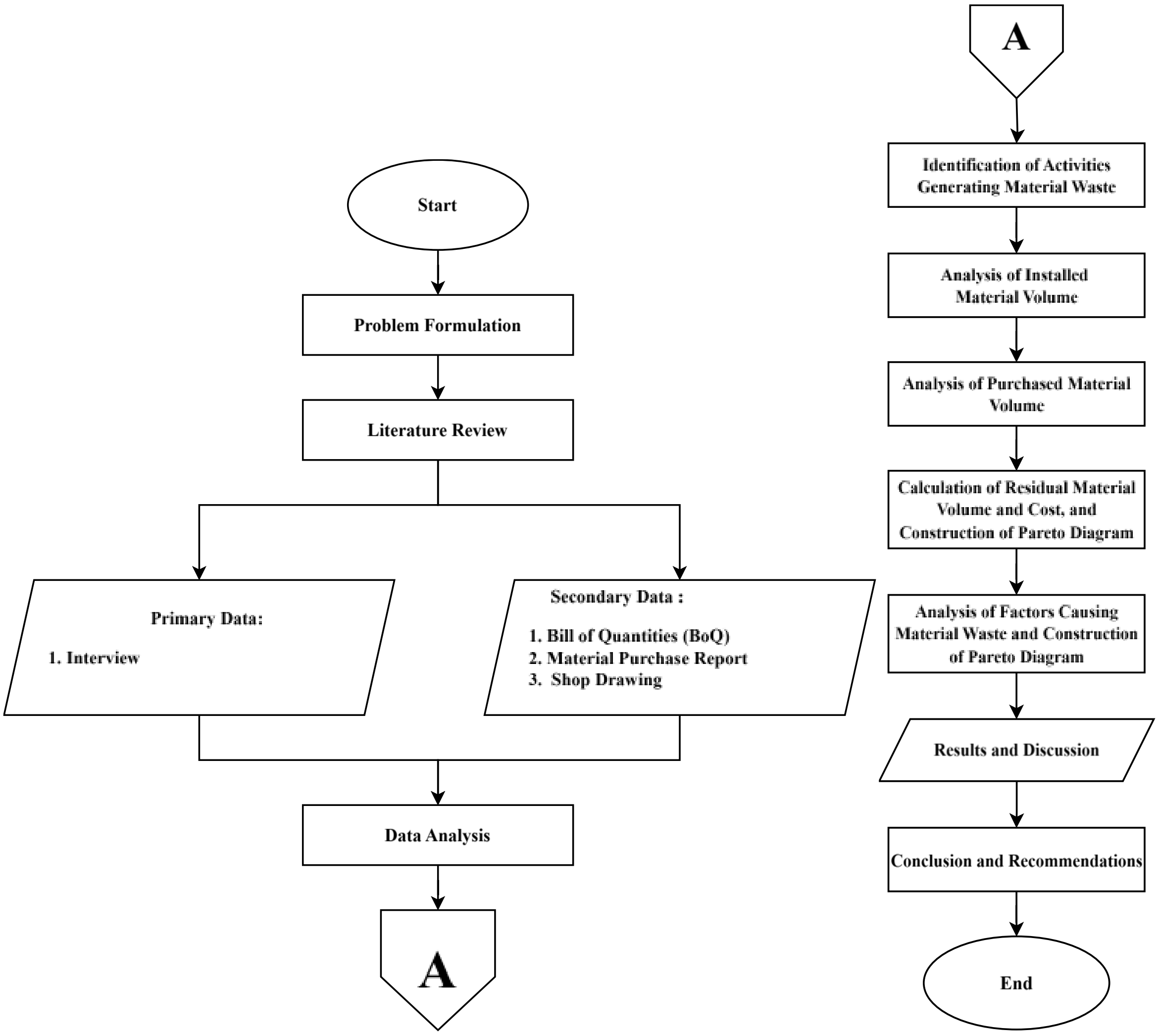

Figure 1 Flow Chart of Research
Source: Author's Analysis, 2025

3. Results

In this study, five types of materials were identified as having the potential to generate waste based on interview results, namely hollow galvalume, deformed reinforcing steel bars, plain reinforcing steel bars, gypsum boards, and lightweight bricks. Once these materials were established, the next step was to calculate their required volumes for all related works by referring to the project's Budget Plan (RAB), in order to obtain a comprehensive summary of material requirements.

Table 1 Summary of Total Material Requirements by Work Category

No	Material	Volume	Satuan
1	Hollow Galvalume	7,446.33	m
2	Deformed Reinforcing Bar	3,126.7	kg
3	Plain Reinforcing Bar	1,687.97	kg
4	Gypsum Board	1561.04	m^2
5	Lightweight Brick	310.781	m^2

Source: Author’s Analysis, 2025

After the material requirement recap is obtained, the next step is to calculate the installed material volume, which is determined based on measurements from the project’s shop drawings.

Table 2 Summary of Installed Material Volumes

No	Material	Volume	Satuan
1	Hollow Galvalume	8,823.28	m^2
2	Deformed Reinforcing Bar	6,508.49	kg
3	Plain Reinforcing Bar	1,295.689	kg
4	Gypsum Board	1,588.158	m^2
5	Lightweight Brick	433.923	m^2

Source: Author’s Analysis, 2025

After the recap of installed material volumes is obtained, the next step is to calculate the volume of purchased materials based on data from project logistics reports After the recap of installed material volumes is obtained, the next step is to calculate the volume of purchased materials based on data from project logistics reports and material purchase receipts.

Table 3 Total Summary of Material Purchase Volumes

No	Material	Volume	Satuan
1	Hollow Galvalume	9,400	m^2
2	Deformed Reinforcing Bar	7,213.2	kg
3	Plain Reinforcing Bar	2,036.93	kg
4	Gypsum Board	1,684.8	m^2
5	Lightweight Brick	448	m^2

Source: Author’s Analysis, 2025

After the total volume of purchased materials is determined, the next step is to calculate the volume and cost of the remaining materials. The remaining material volume is obtained by subtracting the volume of installed materials from the volume of purchased materials. Meanwhile, the cost of the remaining materials is calculated by multiplying the remaining volume by the unit purchase price of each material.

Table 4 Analysis of Volume Differences and Waste Material Costs

No	Material	Unit	Purchase Volume	Installed Volume	Δ Volume	Unit Price	Total Price
1	Hollow Galvalume	m	9,400	8,823.280	576.72	IDR 4,750.00	IDR 2,739,420.00
2	Deformed Reinforcing Bar	kg	7,213.2	6,508.49	704.71	IDR 9,750.00	IDR 6,870,922.50
3	Plain Reinforcing Bar	kg	2,036.93	1,295.69	741.241	IDR 9,750.00	IDR 7,227,099.75
4	Gypsum Board	m^2	1,684.8	1,588.158	96.642	IDR 22,570.00	IDR 2,181,209.94
5	Lightweight Brick	m^2	448	433.923	14.077	IDR 93,300.00	IDR 1,313,384.10

Source: Author's Analysis, 2025

After obtaining the volume discrepancies and the cost of residual materials, the next step is to construct the Pareto diagram. Prior to this, the data must first be sorted in descending order based on total cost. Once sorted, the subsequent step is to calculate the percentage (weight) of each type of residual material in relation to the total cost, followed by the computation of its cumulative weight. These weights are calculated using the following formula:

Weight of Residual Material (%) = $\frac{Cost\ of\ Residual\ Material}{Total\ Residual\ Material\ Cost}$ x 100%

Table 5 Cost, Weight Percentage, and Cumulative Weight of Residual Materials

No	Material	Residual Material Cost	Weight (%)	Cumulative Weight (%)
1	Plain Reinforcing Bar	IDR 7,227,099.75	35.55%	35.55%
2	Deformed Reinforcing Bar	IDR 6,870,922.50	33.73%	69.34%
3	Hollow Galvalume	IDR 2,739,420.00	13.47%	82.81%
4	Gypsum Board	IDR 2.181.209,94	10.73%	93.54%
5	Lightweight Concrete Block	IDR 1.313.384,10	6.46%	100%

Source: Author's Analysis, 2025

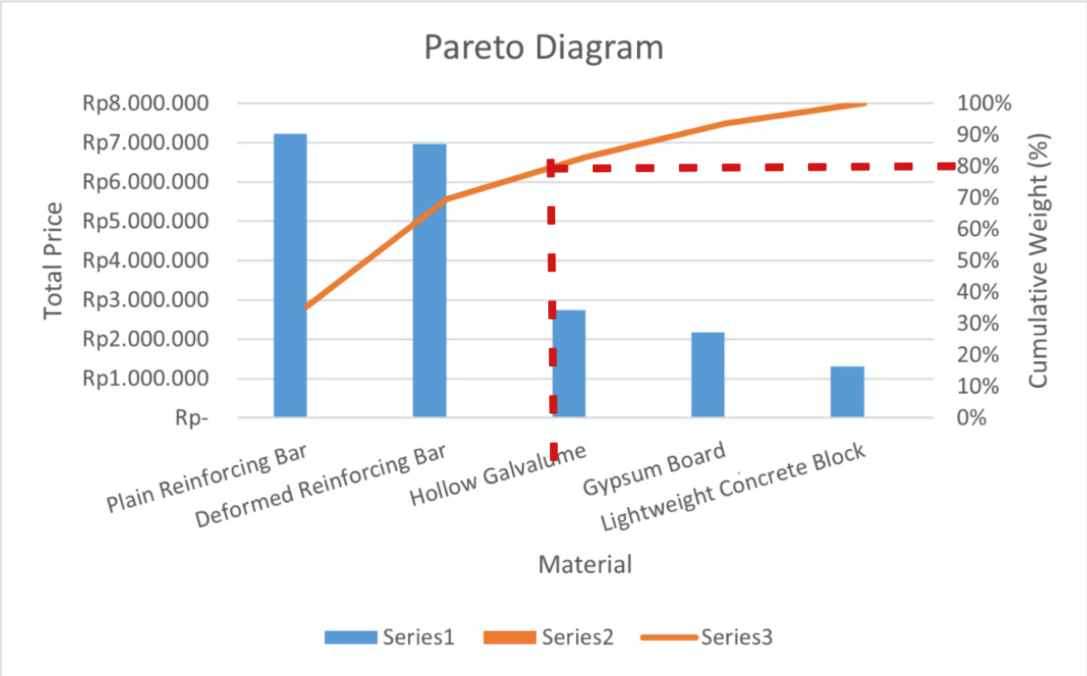

Figure 1 Data Analysis Using a Pareto Diagram
Source: Author's Analysis, 2025

The identification of residual material causes was carried out to understand the underlying reasons for waste, particularly regarding plain reinforcing bars, which were identified as the dominant material through Pareto analysis. This process was conducted through semi-structured interviews with contractors and consultants, as they have direct insight into site conditions, especially in relation to material usage. The interviews focused on identifying the primary causes of waste and tracing their root causes.

Plain Reinforcing Bar

- Man
  Cutting errors made by workers due to a lack of skill or insufficient attention to detail resulted in off-cuts that could not be reused, leading to material waste.
- Method
  Design changes during the project caused previously cut bars to no longer match the updated requirements, resulting in a significant amount of unused material.
- Measurement
  Inaccurate volume estimations and poorly managed design revisions led to over-purchasing and rework, which ultimately caused material accumulation and waste.

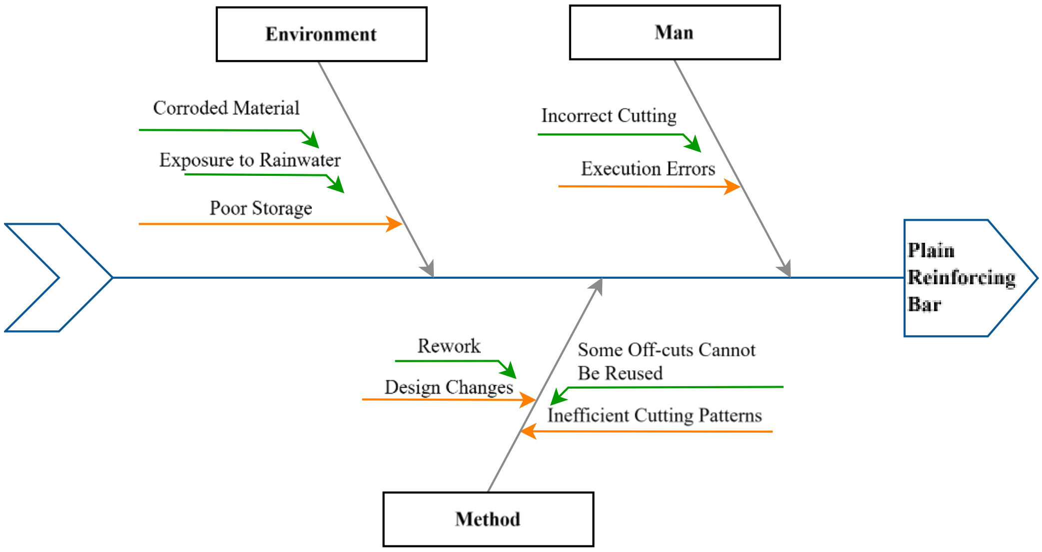

Figure 2 Fishbone Diagram of Plain Reinforcing Bar Material Waste
Source: Author's Analysis, 2025

4. Discussion

This study indicates that plain reinforcing bars contributed the highest amount of material waste, with a total cost of IDR 7,227,099.75. This finding aligns with several previous studies in which plain reinforcing bars were often identified as the primary source of material waste, although in other studies, deformed reinforcing bars were reported as the dominant material.

The main factors contributing to material waste in this project stemmed from three aspects: labor (man), construction methods (method), and supervision (measurement). From the labor aspect, waste occurred due to cutting errors caused by a lack of worker skill or negligence, resulting in off-cuts that could not be reused. In terms of methods, design changes during project execution rendered the pre-prepared materials unsuitable for the updated requirements. From the supervision perspective, inaccurate volume estimations and imprecise design revisions led to material over-purchasing and inefficient dismantling and reinstallation work, which ultimately caused material accumulation and waste.

For future research, it is recommended to conduct studies on larger-scale projects. This would allow for a broader scope of analysis, enabling cross-project comparisons and offering a more comprehensive understanding of material waste management under various field conditions.

5. Conclusion

Based on the results of the study, it can be concluded that the most dominant material contributing to waste in the Renovation Project of the BJKW Building, East Java Province, is plain reinforcing bar. The primary causes of material waste in plain reinforcing bars are influenced by several factors. From the construction method (method) aspect, waste arises due to design changes during the project and inefficient cutting practices. From the labor (man) aspect, execution errors during construction activities are one of the main contributors.

Meanwhile, from the environmental (environment) aspect, improper material storage also contributes to the occurrence of material waste.

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