JOURNAL LA MULTIAPP

VOL. 07, ISSUE 03 (734-746), 2026
DOI: 10.37899/journallamultiapp.v7i3.3349

Analysis of Factors Causing Material Waste Using the Pareto Method and a Fishbone Diagram in Building Construction Projects

Amelia Ayuni Agustina[1], Aryati Indah K[1]

[1]*Civil Engineering Study Program, Faculty of Engineering, Gunung Jati Swadaya University, Cirebon, Indonesia*

**Corresponding Author: Amelia Ayuni Agustina*
Email: amelia.122130007@ugj.ac.id

Article Info

Article history:
Received 2 June 2026
Received in revised form 25 June 2026
Accepted 14 July 2026

Keywords:
Construction Project
Fishbone Diagrams
Material Waste
Pareto Analys

Abstract

Material waste is one of the major problems in construction projects that can lead to increased costs, project delays, and reduced project efficiency. This study aims to analyze the factors causing material waste in building construction projects using the Pareto and Fishbone Diagram methods, with a case study of Hotel X Construction Project in West Java. The research employed a quantitative method with a descriptive-analytical approach through field observations, project documentation, interviews, and questionnaires distributed to respondents directly involved in project material management. Pareto analysis was used to identify materials contributing the greatest losses, while the Fishbone Diagram was applied to analyze the root causes of material waste based on factors of man, method, material, machine, and management. The results showed that the total loss caused by material waste reached IDR 32,109,075.00, with D22 reinforcing steel contributing 36,64% and concrete contributing 28,76%, resulting in a cumulative contribution of 65,40%. The main factors causing waste included improper material cutting, weak field supervision, inefficient work methods, material damage during delivery, and suboptimal material management. Based on the findings, waste control recommendations include the implementation of cutting plans, improvement of work supervision, optimization of material storage systems, and enhancement of coordination among project divisions. This research is expected to serve as a reference for improving material use efficiency and minimizing losses in building construction projects.

Introduction

The construction industry is one of the sectors that has a very high level of material use in every development process (Shooshtarian et al., 2025; Garcés et al., 2025; Bajjou & Chafi, 2026). However, in its implementation, there is often material waste or material waste which can cause an increase in project costs, delays in the implementation of work, and a decrease in the quality of construction results. Almost all construction projects produce material residues that are difficult to avoid, both due to technical and non-technical factors. Leftover, damaged, or non-reusable materials indicate that the material management in the project has not been running optimally. This condition not only causes financial losses, but also has a negative impact on the environment around the project (Luita et al., 2021; Mortaheb & Mahpour, 2016; Putri & Jalasena, 2025).

According to (Tambuwun et al., 2024), material waste can be caused by various factors, such as errors in material cutting, damage during the delivery process, excessive ordering of materials, measurement errors, low labor skills, and inadequate material storage systems. The

ISSN: 2716-3865 (Print), 2721-1290 (Online)

types of materials that are most often wasted in construction projects include concrete, wood, iron (Putra et al., 2018), red brick, ceramic, and light steel. This condition is influenced by the lack of worker experience, the existence of material defects from suppliers, and poor planning of material needs (Mokosuli et al., 2023; Ekwuno, 2022; Kanike, 2023;; Chukwuka et al., 2023).

The large contribution of materials to the total project cost and the high losses due to waste materials indicate the importance of an analysis to identify the most dominant type of material to be residual and the factors causing it (Akhtar et al., 2022; Bonfante et al., 2026). The Pareto method is used to determine the materials that contribute the greatest to total waste losses based on the 80/20 principle. On the other hand, Fishbone Diagram is used to identify the root causes of material waste from various aspects, such as man, work method, machinery or equipment, materials, and measurement (Permana Putra et al., 2024; Arafat et al., 2026; Syarifa & Imaroh, 2026).

The use of a combination of the Pareto method and the Fishbone Diagram allows for a more thorough analysis (Rajasyah, 2026; Rani et al., 2026; Silaningsih et al., 2026). The Pareto Chart serves to determine the priority of the main problem, while the Fishbone Diagram is used to systematically trace the causative factors. Through this research, it is hoped that applicable recommendations can be obtained for construction actors in minimizing material waste, such as through the application of more efficient design and the reuse of residual materials to support the concept of sustainable and environmentally friendly construction (Barathi et al., 2026; Schützenhofer et al., 2022; Arici, 2023).

Methods

This study employed a quantitative method with a descriptive-analytical approach to identify and analyze the factors causing material waste in building construction projects. A case study was conducted on the Hotel X Construction Project in West Java. The quantitative approach was used to calculate the volume and cost of material waste, while the descriptive approach was applied to explain the factors contributing to waste generation through Pareto Analysis and Fishbone Diagram techniques.

The study utilized both primary and secondary data. Primary data were collected through field observations, semi-structured interviews, and questionnaires distributed to respondents directly involved in material management activities. Secondary data were obtained from project documents, including the Bill of Quantities (BOQ), material procurement records, work progress reports, shop drawings, and material usage reports. Field observations were conducted to identify material usage and waste generation during project implementation, while interviews were carried out to obtain information regarding material handling, storage, supervision, and waste control practices. The questionnaire was used as supporting data to identify the dominant causes of material waste and to support the development of the Fishbone Diagram.

The population consisted of all project personnel involved in material planning, procurement, storage, supervision, and utilization in the Hotel X Construction Project. A purposive sampling technique was employed using criteria that respondents were directly involved in material management activities, had at least one year of construction project experience, and understood the material procurement and utilization process. A total of 30 respondents participated in this study, consisting of site engineers, supervisors, logistics staff, warehouse personnel, foremen, and field workers.

The questionnaire was developed based on five categories commonly associated with material waste in construction projects, namely man, method, material, machine, and management. The instrument consisted of indicators related to worker skills and experience, work methods,

ISSN: 2716-3865 (Print), 2721-1290 (Online)

material quality and storage, equipment conditions, and project management practices. Responses were measured using a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Questionnaire data were analyzed descriptively to determine the most dominant factors contributing to material waste. Factors with the highest average scores were subsequently incorporated into the Fishbone Diagram analysis.

Before data analysis, the questionnaire instrument was tested for validity and reliability. The validity test was conducted using the Pearson Product Moment correlation method. An item was considered valid if the calculated correlation coefficient (r-count) exceeded the critical value of r-table at a significance level of 0.05. Reliability testing was performed using Cronbach's Alpha coefficient, and the instrument was considered reliable when the Alpha value exceeded 0.70. All statistical analyses were conducted using IBM SPSS Statistics software.

The Pareto Analysis was applied to identify the materials contributing the largest financial losses due to waste. Waste volume was calculated as the difference between onsite material volume and installed material volume using the equation: Waste Volume (WV) = Onsite Volume (OV) – Installed Volume (IV). The waste cost for each material was then calculated by multiplying the waste volume by the unit price of the material, expressed as Waste Cost (WC) = Waste Volume (WV) × Unit Price (UP). Subsequently, the contribution percentage of each material was determined by dividing the waste cost of each material by the total waste cost and multiplying the result by 100 percent. Cumulative percentages were then calculated sequentially from the highest to the lowest contribution percentage. Materials contributing approximately 80 percent of the total waste cost were classified as dominant materials (vital few) according to the Pareto principle and selected for further analysis.

After identifying the dominant materials, the Fishbone Diagram method was used to determine the root causes of material waste. The analysis was conducted using five categories: man, method, material, machine, and management. The identification of causal factors was based on the results of observations, interviews, and questionnaire responses. Factors that appeared most frequently and received the highest questionnaire scores were classified into the corresponding Fishbone categories. The Fishbone Diagram was then used to systematically analyze the relationship between these causal factors and material waste occurrence, thereby providing a basis for developing recommendations to improve material management and reduce waste in construction projects.

Results and Discussion

Respondent Characteristics

The study involved 30 respondents who were directly engaged in material management activities in the Hotel X Construction Project. The respondents consisted of 5 site engineers (16.67%), 4 supervisors (13.33%), 6 logistics and warehouse staff (20.00%), 5 foremen (16.67%), and 10 field workers (33.33%). These respondents were selected because they were directly involved in material planning, procurement, storage, distribution, supervision, and utilization during project implementation. Therefore, the information obtained from respondents was considered representative for identifying the causes of material waste in the project.

Table 1. Respondent Characteristics

Position	Number of Respondents	Percentage (%)
Site Engineer	5	16.67
Supervisor	4	13.33
Logistics/Warehouse Staff	6	20.00

ISSN: 2716-3865 (Print), 2721-1290 (Online)

Foreman	5	16.67
Field Worker	10	33.33
Total	30	100.00

Validity and Reliability Test

Prior to data analysis, the questionnaire instrument was tested for validity and reliability using IBM SPSS Statistics software. The questionnaire consisted of 20 items representing five factors of material waste, namely man, method, material, machine, and management.

The validity test was conducted using the Pearson Product Moment correlation method. The results indicated that all questionnaire items had correlation coefficients greater than the critical r-table value at a significance level of 0.05, indicating that all items were valid and suitable for data collection.

Reliability testing was performed using Cronbach's Alpha. The obtained Cronbach's Alpha coefficient exceeded the minimum threshold value of 0.70, indicating that the questionnaire instrument was reliable and had good internal consistency.

Table 2. Summary of Validity and Reliability Test Results

Variable Group	Number of Items	Valid Items	Cronbach's Alpha	Conclusion
Material Waste Factors	20	20	0.821	Reliable

The results confirm that the questionnaire instrument was both valid and reliable for identifying the factors contributing to material waste in the construction project.

Questionnaire and Interview Results

Questionnaire and interview results were analyzed to identify the dominant factors contributing to material waste. Respondents were asked to evaluate various potential causes of waste based on the five Fishbone categories. The analysis showed that management and method factors received the highest average scores among all categories.

Management-related issues identified by respondents included weak material planning, inadequate monitoring of material usage, insufficient coordination among project divisions, and the absence of a structured waste control system. Meanwhile, method-related issues included inaccurate measurements, inefficient cutting practices, lack of cutting plans, and rework due to installation errors.

Interview findings supported the questionnaire results. Most respondents indicated that reinforcing steel waste frequently occurred because cutting activities were performed without detailed cutting optimization plans. Respondents also reported that coordination between procurement, logistics, and field implementation teams was often insufficient, resulting in excessive material ordering and inefficient material utilization.

Table 3. Average Questionnaire Scores of Waste Factors

Factor	Mean Score	Category
Management	4.32	Very High
Method	4.21	High
Man	3.98	High
Material	3.76	Moderate
Machine	3.54	Moderate

Based on these findings, management and method factors were identified as the dominant contributors to material waste. Consequently, these factors became the primary focus of the Fishbone Diagram analysis presented in the following section.

ISSN: 2716-3865 (Print), 2721-1290 (Online)

Identification of Waste Material

This research was conducted on the X Hotel Construction Project in West Java with a focus on the analysis of waste materials using the Pareto and Fishbone Diagram methods. The research data was obtained from the volume of material purchases and the volume of materials installed in the field. The difference between the two is calculated as the volume of waste material. Based on the results of data processing, four main materials were obtained that experienced waste, namely concrete, D22 reinforcing iron, D16 reinforcing iron, and light bricks. Waste material volume data is presented in the following table.

Table 4. Identification of Waste Material

Material	Unit	Installed Volume	Onsite Volume	Waste Volume
Concrete	m^3	2,290.75	2,300.00	9.25
D22 Reinforcing Steel	kg	167,182.40	167,995.00	812,6
D16 Reinforcing Steel	kg	107,735.80	108,450.05	714,2
Lightweight Brick	m^3	853.35	865.00	11,65

Furthermore, the calculation of waste costs is carried out based on the volume of waste and the unit price of the material. The calculation results show that the total loss due to material waste reached Rp32,109,075,00.

Table 5. Calculation of waste costs based on waste volume and unit price of materials

Material	Waste Volume	Unit Price (IDR)	Total Waste Cost (IDR)
Concrete	9.25	...	9,250,000
D22 Reinforcing Steel	812,6	...	11,782,700
D16 Reinforcing Steel	714,2	...	8,213,875
Lightweight Brick	11,65	...	2,912,500
Total			**32,109,075**

Waste cost was calculated by multiplying the waste volume of each material by its corresponding unit price. The results indicate that reinforcing steel generated the highest losses, with D22 reinforcing steel contributing IDR 11,782,700 and concrete contributing IDR 9,250,000. Together, these two materials accounted for 65,40% of the total waste cost, indicating that waste reduction efforts should primarily focus on reinforcing steel works.

Pareto Diagram Analysis

Pareto analysis is performed to determine the materials that contribute the greatest losses to the total waste material of the project. The Pareto Principle states that most losses are generally caused by a small number of dominant factors. The results of the analysis showed that Iron D22 had a loss contribution of 36,64%, while concrete was 28,76%. Thus, the cumulative contribution of the two materials reached 65,40% of the total waste material loss of the project.

Table 6. Pareto Analysis

Material	Percentage	Cumulative Percentages
Iron D22	36,64%	36,64%
Concrete	28,76%	65,40%
Iron D16	25,54%	90,94%
Light Brick	9,06%	100%

ISSN: 2716-3865 (Print), 2721-1290 (Online)

Based on the Pareto 80/20 principle, Iron D22 and Concrete are included in the category of vital few because they contribute the largest losses to the total waste material of the project. Meanwhile, iron D16 and light bricks are included in the useful many category because their contribution is relatively smaller. These findings show that material waste control in construction projects should be focused on ironing work, especially on the cutting, fabrication, and installation of reinforcing iron.

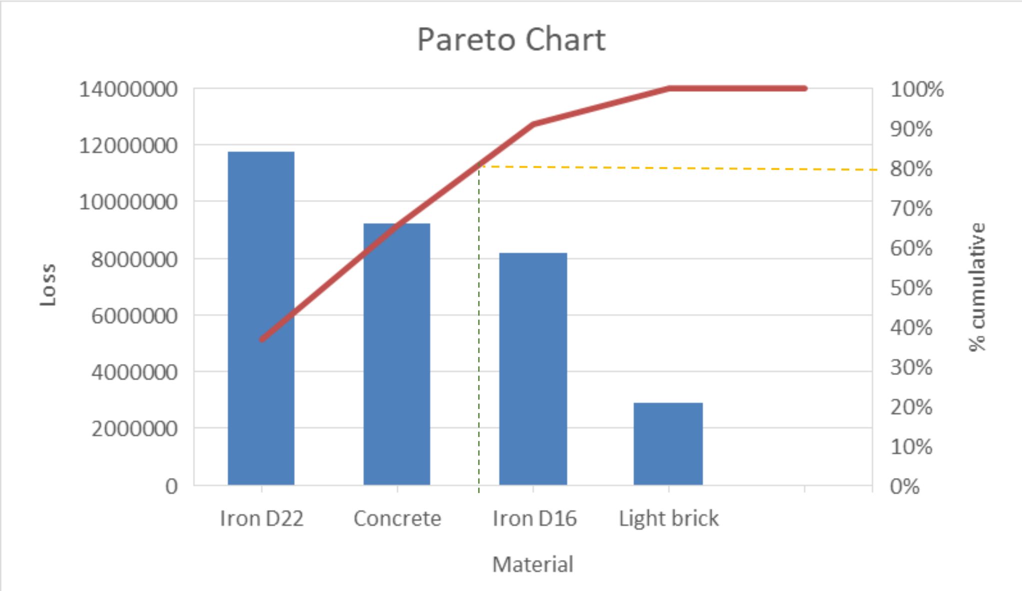

Figure 1. Diagram Pareto

Analysis of Factors Causing Waste Material

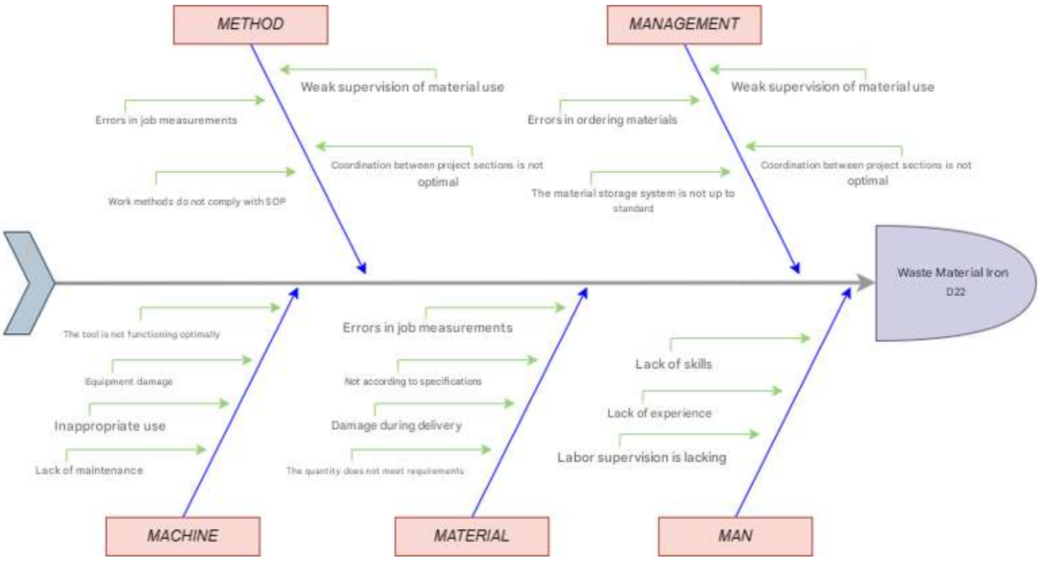

Figure 2. Fishbone Diagram

Source: Processed Author (2026)

The analysis of the factors that cause material waste in this study was carried out using the Fishbone Diagram method with a 5M approach, namely Man (labor), Method (work method), Material, Machine (equipment), and Management (management). This approach is used to identify the root causes of material waste in construction work, especially in reinforcing iron work which based on the results of Pareto analysis is included in the category *A Few Vital Parts*. Fishbone Diagrams help to systematically describe cause-and-effect relationships so that the factors that cause waste can be analyzed in a more in-depth and directed way. Through

ISSN: 2716-3865 (Print), 2721-1290 (Online)

this analysis, it is known that material waste in construction projects is not only caused by one specific factor, but is influenced by a combination of several interrelated factors during the project implementation process (Aulia et al., 2016; Gulghane & Khandve, 2015; Hadi & Susanto, 2025).

Man Factor (Labor)

The labor factor is one of the main causes of material waste in construction projects. The lack of worker skills in cutting, bending, and installing the reinforcing iron leads to many leftover pieces of material that cannot be reused. In addition, workers who do not have adequate work experience tend to make mistakes in reading the work drawings or determining the size of the material cut, resulting in a considerable waste of materials. The low understanding of workers regarding the efficiency of material use also causes there to be a lot of leftover materials that can actually be reused but are finally thrown away (Hartono et al., 2016; Juran, 1974).

In addition, weak field supervision also increases the potential for material waste. Suboptimal supervision causes material misuse to often not be immediately noticed, so that waste continues to occur during the work process. This condition shows that the quality of human resources has a huge influence on the level of efficiency of material use in construction projects. The results of this study are in line with the research (Mokosuli et al., 2023) which states that low worker experience is one of the main causes of material waste in construction work, especially in ironing work. The study also explained that the lack of field supervision caused work errors not to be corrected immediately, increasing the volume of material waste repeatedly.

Method Factor

Inefficient working methods also contribute greatly to the increase in material waste in construction projects. Measurement errors in the field cause the use of materials to exceed the planned requirements. In addition, the method of installing materials that are not in accordance with work procedures causes installation errors that lead to rework (*Rework*) and increased material waste. In the work of reinforcing iron, the absence of *Cutting Plan* is one of the main causes of high trim loss or remaining material pieces. The iron cutting process carried out without detailed planning causes the length of the cut to be suboptimal resulting in a lot of material residue that cannot be reused. In addition, the coordination of work methods between project teams that has not been running optimally causes the implementation of work often not in accordance with the initial planning (Kerzner & Salad, 2009; Kurniawan et al., 2026).

The results of this study are in line with the research (Hadi & Susanto, 2025) which explains that the application *Cutting Plan*, work operational standards, and a more planned fabrication system is able to significantly reduce material waste in reinforcing iron work. Therefore, effective and standardized work methods are one of the important factors in efforts to control material waste in construction projects.

Material Factors

Material factors are also an important cause of material waste in construction projects. The discrepancy between the material specifications received from the supplier and the specifications in the working drawings causes the material to not be used optimally, causing waste. In addition, low or inconsistent material quality causes the material to be easily damaged during the work process. Material damage also often occurs during the shipping process due to improper transportation methods or inadequate packaging systems. Materials that are damaged when they arrive at the project site are generally not reusable, increasing the volume of waste material. In addition, a poor material storage system causes materials to be easily damaged by weather, humidity, or accumulation that does not meet standards.

ISSN: 2716-3865 (Print), 2721-1290 (Online)

In ironing work, poor storage conditions can cause the iron to corrode so that the quality of the material decreases and does not meet the specifications of the work. Therefore, material quality control from the procurement, delivery, to storage process is an important factor in minimizing material waste in construction projects.

Factor Machine (Equipment)

The factor of work equipment (*machine*) also affects the occurrence of waste material. Work equipment that does not function optimally causes the work process to be less precise, especially in the cutting and fabrication of reinforcing iron. A piece that is worn or damaged can result in an inappropriate cut size, increasing the amount of material left. In addition, the lack of regular maintenance of the work tool causes the performance of the tool to decrease and increases the risk of damage during the work process. The condition of the work tool that is not in accordance with the work specifications can also result in errors in cutting and installing materials that have a direct impact on the increase in material waste.

The improper use of work tools not only decreases work efficiency, but can also slow down the construction process and increase project operational costs. Therefore, regular inspection and maintenance of work tools is an important step to maintain the quality of work and reduce the potential for material waste in the field.

Management Factors

Questionnaire results also indicated that labor-related issues remained significant contributors to material waste. Respondents highlighted insufficient worker experience, limited understanding of efficient material utilization, and weak field supervision as factors contributing to cutting and installation errors. These findings support the Fishbone analysis, which identified labor competency and supervision as important causes of waste generation during reinforcing steel works (Rafael Gavilan & Bernold, 1994; Scott, 2016).

The results of the study show that the largest waste material in the Hotel X Development Project comes from the reinforcing iron work, especially Iron D22 and Concrete with a cumulative contribution of 65.40% of the total waste material losses of the project. The high contribution of the two materials shows that ironing work has a higher level of waste risk than other materials. This condition occurs because the process of fabricating, cutting, and installing reinforcing iron is highly dependent on the level of precision of workers, the accuracy of work methods, and the quality of material control in the field. A small mistake in the iron cutting process can result in non-reusable scrap residue, significantly increasing the amount of material waste. In addition, ironing work generally uses a standard measure of material length so that if the cutting process is not planned properly, the potential for trim loss will be greater (Ratnaningsih et al., 2026).

The findings of this study are in line with the research of Permana Putra et al. (2024) which states that reinforcing iron is one of the dominant materials causing waste in building construction projects. The study explained that the high waste in ironing work is caused by cutting errors, design changes, weak field supervision, and the absence of detailed material cutting planning through cutting plans. In addition, research by Mokosuli et al. (2023) also stated that lack of labor experience and less efficient work methods are the main factors causing the high amount of material waste in construction work. This strengthens the results of this study that ironing work has a high level of complexity so that it requires more controlled material management than other jobs.

Based on the questionnaire and interview results, the management and method categories obtained the highest average scores among the five Fishbone factors. Respondents indicated that weak material planning, inadequate supervision of material usage, lack of coordination among project divisions, and the absence of a structured waste control system were the most

ISSN: 2716-3865 (Print), 2721-1290 (Online)

frequent causes of material waste. These findings were also confirmed through interviews with site engineers, supervisors, and logistics personnel, who reported that material ordering was often not aligned with actual field requirements and that leftover materials were rarely monitored systematically. Consequently, management-related issues became one of the dominant causes identified in the Fishbone Diagram. The method factor was also identified as a major contributor to waste generation. Questionnaire responses showed that inaccurate measurements, inefficient cutting practices, and the absence of detailed cutting plans frequently resulted in excessive reinforcing steel waste. Interview findings further revealed that reinforcing steel cutting was often performed without optimization planning, causing significant trim losses. This finding is consistent with the Pareto analysis, which showed that D22 and Concrete reinforcing steel accounted for 65.40% of the total material waste loss. Therefore, improving cutting plans and standardizing work procedures are essential strategies for reducing waste in reinforcing steel works (Muhammad Syarif et al., 2024; Lee et al., 2026; Meléndez et al., 2026).

In addition to the method and management factors, the labor factor (man) also influences the occurrence of waste material. The lack of worker skills in cutting and installing reinforcing iron leads to a lot of material residue that cannot be reused. The low work experience of workers also causes errors in reading the work drawings and determining the size of the material cut. This condition shows that the quality of human resources has a huge influence on the efficiency of material use in construction projects.

Material and equipment (machine) factors also affect the increase in material waste in the field. Materials that do not meet specifications, low material quality, and material damage during the delivery process cause materials to not be used optimally. In addition, malfunctioning work tools cause the material cutting process to be less precise, resulting in more material waste. Lack of regular maintenance of work tools also leads to a decrease in tool performance and increases the risk of work errors during the construction process.

The results of this study show that material waste control does not only depend on field workers, but also requires an integrated material management system starting from the planning, procurement, storage, distribution, to supervision of the use of materials in the field. Comprehensive material waste control is not only able to reduce project cost losses, but can also increase the efficiency of work implementation and support the implementation of construction that is more effective, sustainable, and environmentally friendly.

The consistency between the Pareto analysis, questionnaire responses, and interview findings strengthens the validity of the study results. Pareto analysis identified reinforcing steel as the dominant source of waste, while questionnaires and interviews revealed that management and method factors were the primary causes of this waste. These findings indicate that material waste in construction projects is not solely a technical issue but is also closely related to planning quality, supervision effectiveness, coordination among project stakeholders, and the implementation of material control procedures.

Recommendations for Material Waste Control

Based on the results of the Pareto and Fishbone Diagram analysis, some recommendations that can be made to minimize material waste in construction projects include implementing a cutting plan before the iron cutting process is carried out so that the material cutting pattern is more efficient and produces less material waste. In addition, it is necessary to increase field supervision during fabrication and material installation work so that work errors can be corrected immediately before causing greater material waste.

The project also needs to conduct regular briefings to workers regarding the importance of efficient use of materials and material cutting procedures that are in accordance with the

ISSN: 2716-3865 (Print), 2721-1290 (Online)

working drawings. The remaining pieces of iron that are still suitable for use should be separated and grouped by size so that they can be reused for other work such as bolts, cuttings, and other non-structural elements (Sutanto et al., 2018; Tafesse et al., 2022).

In addition, the material storage system needs to be repaired so that the material is not easily damaged by weather, humidity, or accumulation that does not meet standards. Regular maintenance of work tools also needs to be carried out to maintain the precision of the work and reduce material cutting errors. On the management side, coordination between project parts such as logistics, procurement, field implementers, and project supervisors needs to be improved so that material control can run more optimally.

The implementation of these recommendations is expected to be able to improve the efficiency of material use, reduce project losses due to waste materials, and support the implementation of a construction system that is more effective, economical, and environmentally friendly.

Conclusion

Based on the results of the study, it can be concluded that the waste material in the Hotel X Construction Project is dominated by reinforcing iron materials, especially Iron D22 and Concrete , with a cumulative loss contribution of 65.40% of the total waste material of the project based on Pareto analysis. The main factors causing material waste come from the aspects of labor, work methods, materials, equipment, and management, such as material cutting errors, lack of field supervision, inefficient work methods, material damage during delivery, and weak project material management system. The analysis of the Fishbone Diagram shows that the factors of work methods and management are the factors that have the most influence on the high amount of material waste in ironing work. Therefore, it is necessary to implement a cutting plan, increase work supervision, optimize the material storage system, maintain work tools regularly, and improve coordination between project parts to minimize material waste and increase the efficiency of construction project implementation.

References

Akhtar, W., Lazoglu, I., & Liang, S. Y. (2022). Prediction and control of residual stress-based distortions in the machining of aerospace parts: A review. *Journal of Manufacturing Processes*, *76*, 106-122.

Arafat, Y., Das, A., Assiri, M. A., & Mia, R. (2026). Applications of lean manufacturing in the textile garments industry. *The International Journal of Advanced Manufacturing Technology*, *143*(9), 4735-4774. https://doi.org/10.1007/s00170-026-17713-6

Arici, A. (2023). Environmentally friendly construction sites: Sustainability and green practices. *International Scientific Journal Vision*, *8*(2), 67-80.

Aulia, N. A., Harimurti, & Negara, K. P. (2016). Analysis and Evaluation of Construction Material Residue Using the Pareto Method and Fishbone Diagram (Case Study on the Postgraduate Building Construction Project of the Islamic University of Malang). *Journal of Civil Engineering Students*, *1*, 1–9.

Bajjou, M. S., & Chafi, A. (2026). Enhancing environmental sustainability through lean construction principles: an industry-based SEM analysis. *Engineering, Construction and Architectural Management*, *33*(1), 171-206. https://doi.org/10.1108/ECAM-06-2024-0705

Barathi, A., Kundu, D., Pooja, K., Surya, M., Jacob, S., Samanta, P., ... & Kuila, A. (2026). Toward sustainable industry: integrating industrial symbiosis, biorefineries, and

ISSN: 2716-3865 (Print), 2721-1290 (Online)

circular economy for SDG alignment. *Sustainable Energy & Fuels*, *10*(8), 1816-1844.

Bonfante, F., Ferrara, G., Tulliani, J. M., & Palmero, P. (2026). A comprehensive review of direct aqueous mineral carbonation of industrial wastes using principal component analysis. *Journal of Sustainable Cement-Based Materials*, *15*(1), 294-318. https://doi.org/10.1080/21650373.2025.2567002

Chukwuka, O. J., Ren, J., Wang, J., & Paraskevadakis, D. (2023). A comprehensive research on analyzing risk factors in emergency supply chains. *Journal of Humanitarian Logistics and Supply Chain Management*, *13*(3), 249-292. https://doi.org/10.1108/JHLSCM-10-2022-0108

Ekwuno, A. O. (2022). Research to study the damage caused to the construction projects due to the lack of workers on site. *International Journal of Scientific and Research Publications*, *12*(12), 361-382.

Garcés, G., Forcael, E., Osorio, C., Castañeda, K., & Sánchez, O. (2025). Systematic review of Lean Construction: an approach to sustainability and efficiency in construction management. *Journal of Infrastructure Preservation and Resilience*, *6*(1), 1-28. https://doi.org/10.1186/s43065-025-00119-1

Gulghane, A. A., & Khandve, P. V. (2015). Management for Construction Materials and Control of Construction Waste in Construction Industry: A Review. *Journal of Engineering Research and Applications*, *5*.

Hadi, I., & Susanto, S. (2025). Optimizing Lean Construction Strategies in Minimizing the Waste of Reinforcing Iron Materials in Hospital Construction Projects. *Journal of Construction*, *23*(2), 27–36. https://doi.org/10.33364/konstruksi/v.23-2.2572

Hartono, W., Sugiyarto, & Baskoro, S. (2016). Analysis and Identification of Remaining Construction Materials for the Construction of Office Buildings and Official Houses of Gilingan Village. *Journal of Civil Engineering Matrix*, 263–270.

Juran. (1974). *The Non-Pareto Principle*.

Kanike, U. K. (2023). Factors disrupting supply chain management in manufacturing industries. *Journal of Supply Chain Management Science*, *4*(1-2), 1-24. https://doi.org/10.18757/jscms.2023.6986

Kerzner, H., & Saladis, F. P. (2009). *A System Approach to Planning, Scheduling and Controlling* (10th ed.). J. Wiley & Sons.

Kurniawan, D., Malingkas, G. Y., & Tjakra, J. (2026). Analysis of the remaining construction materials using the Pareto method and fishbone diagram in the construction project of the Hermana Lembean General Hospital. *Journal of Technology*, *24*(95), 313–319. https://doi.org/10.35793/jts.v24i95.67122

Lee, J., Oh, J. S., & Lee, D. Y. (2026). Towards Sustainable Machining: A Comprehensive Review of Energy-Reduction Strategies in Machine Tools. *International Journal of Precision Engineering and Manufacturing-Green Technology*, 1-45. https://doi.org/10.1007/s40684-025-00816-y

Luita, P., Singarimbun, N., Waluyo, R., Brita, A., & Gawei, P. (2021). *Analysis of Waste Material Handling of Consumable and Non-Consumable Materials in Simple Housing Projects in Palangka Raya City*. *16*(2), 83–92.

Meléndez, W., Saavedra, R., Garcés, G., & Herrera, R. (2026). Comparative analysis of quantity take-off in reinforcing steel bars in apartment buildings based on CAD and

ISSN: 2716-3865 (Print), 2721-1290 (Online)

BIM method: a case study. *International Journal of Construction Management*, *26*(5), 751-771. https://doi.org/10.1080/15623599.2025.2535746

Mokosuli, T. A. P. J. M., Mangare, J. B., & Tjakra, J. (2023). Evaluation of the remaining construction materials using the Pareto method and fishbone diagram in the construction project of type 72/125 houses in Sawangan Permai Housing. *TEKNO, 21*, 850–856.

Mortaheb, M. M., & Mahpour, A. (2016). Integrated Construction Waste Management, A Holistic Approach. *Scientia Iranica A*, *5*.

Muhammad Syarif, P., Nurjanah Ahmad, S., Utomo, P. K., Purnama, H., Pratama Sari, D., Bachtiar, E., Isdyanto, A., Londongsalu, J., Aryadi, A., Rahmadi Herlambang, A., Eko Prasetyo, B., & Marlany Rachman, R. (2024). *Construction Materials* (S. Gusty (ed.); 1st ed.). CV. Tohar Media.

Permana Putra, D., Dwiantoro, E., & Hariza, E. R. (2024). Evaluation of Waste Material in Construction Projects Using Pareto Method and Fishbone Diagram (Case Study: Al-Muslimun Boarding School Flats Central Bengkulu). *Journal of Science and Technology Research*, *9*(2), 258–267. https://doi.org/10.32528/penelitianipteks.v9i2.2131

Putra, I. G. A. P., Dharmayanti, G. A. P. C., & Dewi, A. A. D. P. (2018). Handling Waste Material in Multi-Storey Building Construction Projects. *Spektran Journal*, *6*(2), 176–185.

Putri, C. A. R., & Jalasena, S. S. (2025). Material Efficiency of Architectural Work in the Construction of Residential Houses in Cluster X. *TECHNOLOGIC, 16*, 112–117.

Rafael Gavilan, B. M., & Bernold, L. E. (1994). *Source Evaluation of Solid Waste in Building Construction*.

Rajasyah, T. A. (2026). DEFECT ANALYSIS OF RUBBER PRODUCTS USING FISHBONE AND PARETO CHART METHODS AT CV ANM TECH. *Multidisciplinary Research Studies in Social Sciences*, *2*(2), 101-111. https://doi.org/10.71312/mrscholar.v2i2.552

Rani, H. A., Syammaun, T., Rachman, F., & Bahagia, I. (2026). Quantitative evaluation of material waste and its root causes in bridge construction using pareto and fishbone framework. *Malaysian Journal of Sustainable Environment*, *13*(2), 163-176. https://doi.org/10.24191/myse.v13i2.9673

Ratnaningsih, A., Rahma, A. F., & Soetjipto, J. W. (2026). Optimization of the Use of Reinforcing Iron for Waste Materials Using Cutting Optimization Pro Software in Building Projects. *Journal of Civil Engineering*, *16*, 36–50. https://doi.org/10.29103/tj.v16i1.1313

Sapuay, S. E. (2016). Construction Waste – Potentials and Constraints. *Environmental Sciences*, *35*, 714–722. https://doi.org/10.1016/j.proenv.2016.07.074

Schützenhofer, S., Kovacic, I., Rechberger, H., & Mack, S. (2022). Improvement of environmental sustainability and circular economy through construction waste management for material reuse. *Sustainability*, *14*(17), 11087. https://doi.org/10.3390/su141711087

Shooshtarian, S., Wong, P. S., & Maqsood, T. (2025). Circular economy in modular construction: An Australian case study. *Journal of Building Engineering*, *103*, 112182.

ISSN: 2716-3865 (Print), 2721-1290 (Online)

Silaningsih, E., Hawari, I., & Kartini, T. (2026). ANALYSIS AND CONTROL OF FILLING PROCESS DEFECTS USINGSEVEN QUALITY CONTROL TOOLS AT PT ABC. *Majapahit Journal of Islamic Finance and Management*, *6*(2), 2864-2888.

Sutanto, K. R., Nugraha, P., & Andi, A. (2018). Case Study of Waste Material in Steel Structure Fabrication Process in EPC (Engineering, Procurement, Construction) Companies. *Journal of Civil Engineering*, *25*(1), 33. https://doi.org/10.5614/jts.2018.25.1.5

Syarifa, A., & Imaroh, T. S. (2026). Problem Analysis and Manual Warehouse System Improvement Strategy Towards Smart & Sustainable Warehouse. *International Journal of Indonesian Business Review*, *5*(1), 21-50. https://doi.org/10.54099/ijibr.v5i1.1520

Tafesse, S., Girma, Y. E., & Dessalegn, E. (2022). Analysis of the Socio-Economic and Environmental Impacts of Construction Waste and Management Practices. *Heliyon*, *8*(3), 1–10. https://doi.org/10.1016/j.heliyon.2022.e09169

Tambuwun, E. M., Walangitan, D. R. O., & Masuara, I. (2024). Evaluation of the remaining construction materials using the Pareto method and fishbone diagram in the Kawanua Emerald City Shophouse Construction Project. *TEKNO*, *22*(88), 761–767.

ISSN: 2716-3865 (Print), 2721-1290 (Online)