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Assessment of Construction Waste Management Practices in Klaten, Indonesia

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ABSTRACT: Construction waste management is an essential component of sustainable construction, as ineffective handling of residual materials reduces resource efficiency and increases potential environmental burdens. This study evaluates construction waste management practices across 21 building projects in Klaten Regency, Indonesia, based on stakeholder perceptions of four factors: labor, materials, methods, and management. A quantitative descriptive approach was employed using a structured questionnaire comprising 20 initial indicators assessed on a five-point Likert scale. Following item validity testing, 16 indicators were retained for descriptive analysis. The material factor achieved the highest mean score (3.89; good), whereas labor (2.29), methods (2.54), and management (2.47) were classified as poor. The lowest-scoring indicators were the appointment of personnel specifically responsible for waste management (1.62), the inclusion of waste management provisions in contracts (1.76), arrangements for third-party waste disposal (1.86), and the availability of waste sorting facilities (2.05). These findings indicate that conventional material protection and quality control practices are better established than dedicated waste management responsibilities, on-site waste segregation, and contractual governance mechanisms. Recommended improvements include establishing clear responsibilities for waste management, providing designated waste sorting and temporary storage areas, incorporating measurable waste management requirements into construction contracts, and systematically documenting waste generation, handling, and final disposal destinations. Given the limited sample size and reliance on stakeholder perceptions rather than direct measurements of waste generation and disposal, the findings should be interpreted as exploratory evidence from the surveyed projects rather than generalized estimates for all construction projects in Klaten Regency.

KEYWORDS: Construction waste; building projects; project governance; material management; circular economy

1. Introduction

Construction activities generate substantial quantities of waste through material handling, cutting, installation, storage, renovation, and demolition processes. Ineffective construction waste management contributes to excessive material consumption, increased project costs,

inefficient resource utilization, and environmental degradation. The accumulation and improper disposal of construction waste may also increase transportation demands, landfill pressure, and associated environmental burdens. Consequently, improving construction waste management has become an essential component of sustainable construction practices and the transition toward a circular economy. Recent studies have emphasized the importance of minimizing waste generation, enhancing material recovery, and integrating circular economy principles into construction project planning and implementation [1–3].

Despite increasing awareness of sustainable construction, the effective implementation of construction waste management remains challenging, particularly at the project level. Construction waste management involves more than the application of waste treatment and disposal technologies; it also requires appropriate organizational structures, operational procedures, stakeholder participation, and resource allocation. Previous research has highlighted the importance of identifying waste generation mechanisms, evaluating existing management practices, and developing practical strategies that can be incorporated into daily construction activities [4, 5]. These findings suggest that effective waste management should be integrated throughout the construction process, including material procurement, transportation, storage, utilization, waste segregation, collection, and final disposal. However, differences in project characteristics, available resources, and management capabilities may influence the consistency and effectiveness of these practices.

Previous studies have investigated construction waste management from various perspectives, including waste generation characteristics, management performance, waste minimization strategies, and factors influencing implementation at construction sites [6, 7]. These investigations have contributed to identifying technical and organizational approaches for improving waste management performance. Studies conducted in Indonesia have also demonstrated the importance of evaluating construction waste management within specific institutional, operational, and project contexts [8]. Nevertheless, construction projects may exhibit considerable differences in their management practices, depending on organizational commitment, workforce capabilities, material handling procedures, and the availability of supporting facilities. Therefore, evaluating construction waste management requires consideration of multiple operational and managerial dimensions rather than relying exclusively on waste treatment or disposal practices.

Labor-related factors play an important role in determining the effectiveness of construction waste management. Workers are directly involved in material handling, installation, waste separation, and daily site operations, making their awareness, technical competence, and participation essential to waste minimization efforts. Inadequate training, unclear responsibilities, and limited coordination among project personnel may contribute to inefficient material utilization and improper waste handling. Previous studies have examined the influence of workforce participation, organizational practices, and construction management approaches on waste-related outcomes [9–11]. These findings indicate that effective construction waste management requires not only technical procedures but also clearly assigned responsibilities and consistent involvement of personnel at different organizational levels.

Material management represents another critical dimension because improper procurement, transportation, storage, and handling can result in material deterioration, damage, and unnecessary waste generation. Appropriate material protection, storage arrangements,

inventory control, and quality assurance procedures can reduce avoidable material losses and improve resource efficiency. Previous research has discussed the relationship between material management practices, construction resource utilization, and waste minimization [12, 13]. However, effective material management does not necessarily indicate that comprehensive waste management practices have been implemented. Construction projects may maintain adequate material storage and protection procedures while still experiencing weaknesses in waste segregation, collection, documentation, and disposal arrangements. This distinction highlights the importance of evaluating material management alongside other dimensions of construction waste management.

Construction methods and site facilities also influence waste prevention and handling practices. The availability of designated waste collection areas, sorting facilities, temporary storage locations, and appropriate disposal arrangements can facilitate the separation and management of construction waste. Nevertheless, the effectiveness of these facilities depends on their accessibility, operational suitability, maintenance, and integration into construction activities. Inadequate site planning and poorly coordinated waste handling procedures may reduce the effectiveness of waste minimization efforts, even when basic facilities are available. Previous investigations have examined practical approaches for improving construction waste management and emphasized the importance of integrating waste prevention and handling procedures into construction operations [14,15].

In addition to operational considerations, management commitment and contractual governance are essential for establishing accountability in construction waste management. Clearly defined responsibilities, contractual requirements, monitoring procedures, and documentation systems can encourage consistent implementation across project activities. The inclusion of waste management provisions in construction contracts may also clarify the obligations of contractors, subcontractors, and waste service providers. Furthermore, appropriate arrangements for waste transportation and disposal through authorized third parties can support regulatory compliance and responsible waste handling. Previous studies have emphasized the role of organizational strategies and management interventions in promoting sustainable construction practices and improving resource recovery [16, 17].

The successful implementation of construction waste management also depends on coordination among project stakeholders, including project managers, contractors, supervisors, workers, and waste service providers. Differences in stakeholder responsibilities, technical understanding, and organizational priorities may influence the adoption of waste management practices. Consequently, improving construction waste management requires an integrated approach that connects workforce participation, material management, operational procedures, and organizational governance. Recent studies have examined sustainability-related construction practices and implementation challenges, providing further evidence of the importance of stakeholder coordination and institutional support [18–20].

Despite these contributions, an important research gap remains in understanding how different dimensions of construction waste management perform simultaneously within specific local project contexts. Existing research has examined various technical, operational, and managerial aspects of construction waste management; however, the relative strengths and weaknesses of labor, material, method, and management practices require further empirical investigation at the local level. In particular, limited context-specific evidence is presented here regarding how these four dimensions are implemented across building construction projects in

Klaten Regency, Indonesia. Assessing these dimensions collectively is important because relatively satisfactory performance in material management may coexist with deficiencies in workforce responsibilities, waste handling procedures, and contractual arrangements. Without such an assessment, project stakeholders may encounter difficulties identifying which management practices require the most immediate attention.

The novelty of this study lies in its integrated, project-level assessment of four interconnected dimensions of construction waste management—labor, material, method, and management—within the specific context of building construction projects in Klaten Regency. Rather than examining waste management as a single operational activity, the study evaluates the relative performance of individual practices to identify differences between established material management procedures and less-developed organizational or operational arrangements. This approach provides a context-specific understanding of implementation weaknesses and supports the prioritization of practical improvements. The contribution is primarily empirical and managerial, offering localized evidence that may assist construction stakeholders in identifying deficiencies in existing waste management practices.

Therefore, this study aims to evaluate construction waste management practices across 21 building construction projects in Klaten Regency, Indonesia, using four assessment dimensions: labor, material, method, and management. Specifically, the study seeks to (1) assess stakeholder perceptions of existing construction waste management practices, (2) determine the relative performance of the four assessment dimensions, (3) identify indicators representing critical implementation weaknesses, and (4) propose practical recommendations for improving construction waste management at the project level. The findings are expected to provide preliminary empirical evidence to support more effective resource utilization, clearer management responsibilities, improved waste handling procedures, and sustainable construction practices within the surveyed projects.

2. Materials and Methods

2.1. Research Design and Study Context.

This study employed a quantitative descriptive research design to evaluate stakeholder perceptions of construction waste management practices in building construction projects in Klaten Regency, Central Java, Indonesia. The descriptive approach was selected to systematically assess existing waste management practices, identify implementation challenges, and determine areas requiring improvement based on responses from project stakeholders. This approach enables the identification of prevailing management conditions and variations in stakeholder perceptions without establishing causal relationships between the investigated variables. The study was conducted across 21 building construction projects located in Klaten Regency. The geographical location of the study area and the spatial distribution of the participating construction projects are illustrated in Figure 1. The study area provides a practical context for examining construction waste management at the project level, particularly in relation to material handling, waste segregation, storage, collection, and disposal practices. These activities were considered relevant to understanding how construction waste management is implemented during building construction operations.

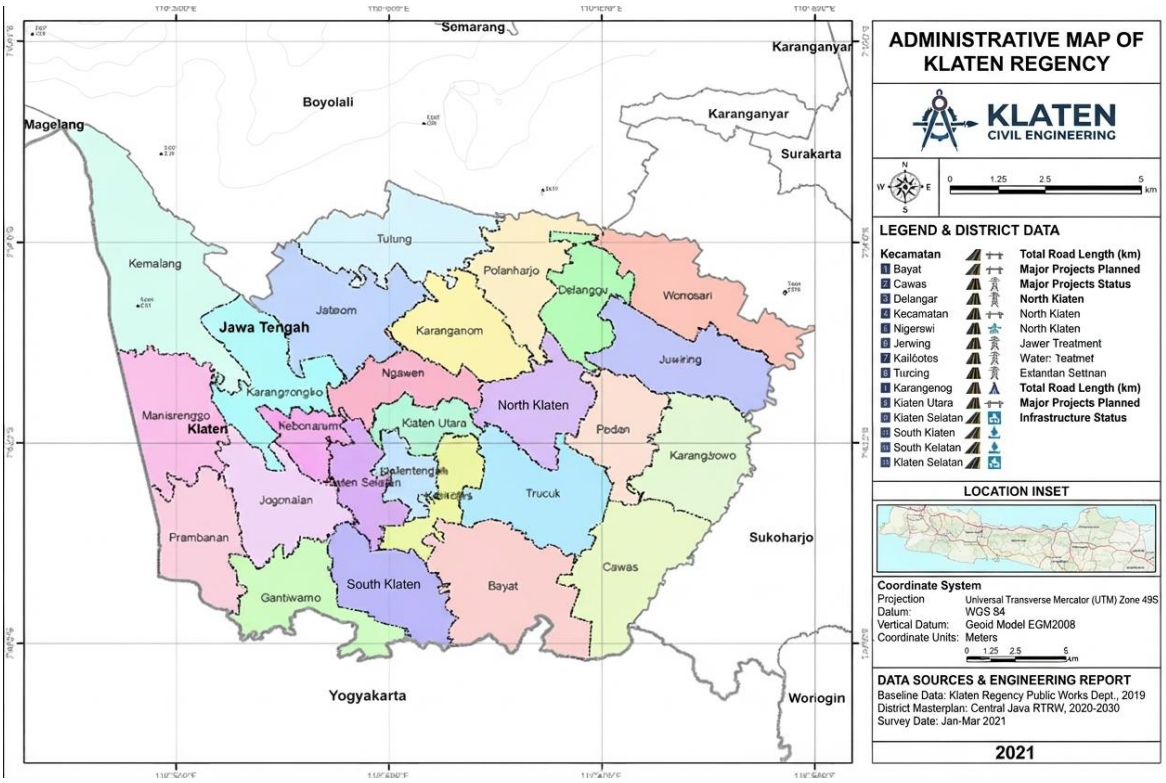


Figure 1. Geographical Location of Klaten Regency, Central Java, Indonesia, and Distribution of the Surveyed Building Construction Projects.

2.2. Research Procedure.

The research procedure was developed systematically to ensure consistency between the study objectives, data collection instruments, analytical methods, and interpretation of findings. As illustrated in Figure 2, the research process consisted of several interconnected stages, beginning with a literature review and identification of relevant construction waste management factors, followed by questionnaire development, data collection, instrument evaluation, descriptive analysis, identification of critical indicators, and formulation of practical recommendations.

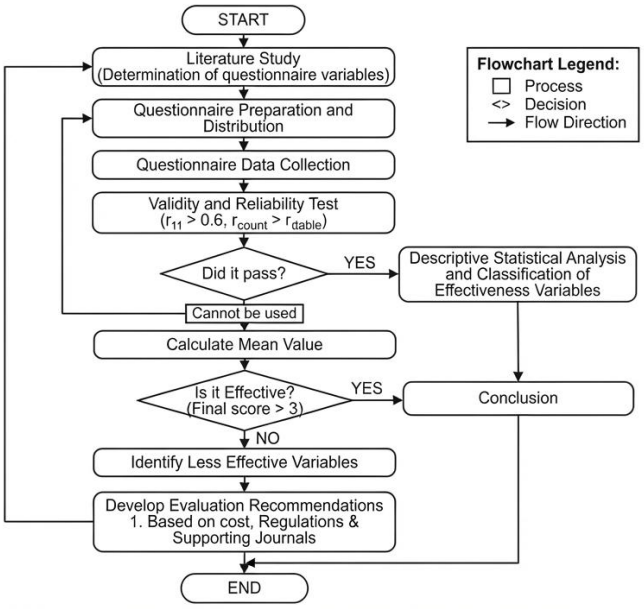


Figure 2. Flowchart of the Research Methodology and Analytical Procedures.

The initial stage involved reviewing relevant scientific literature to identify factors commonly associated with construction waste management in building projects. Particular attention was given to operational and managerial aspects, including material procurement, handling and storage, waste minimization, segregation, collection, transportation, and disposal. The identified factors provided the conceptual basis for developing the questionnaire and establishing the indicators used to evaluate waste management practices. The questionnaire was subsequently distributed to the selected project representatives to obtain primary data concerning their perceptions of existing practices and implementation challenges. Following data collection, the questionnaire responses were examined through validity and reliability testing to evaluate the adequacy and internal consistency of the measurement instrument. Validity testing was used to assess whether individual questionnaire items were sufficiently associated with their intended measurement constructs, whereas reliability testing was conducted to evaluate the consistency of responses across related items. These procedures were performed before the main descriptive analysis to support the quality and interpretability of the collected data.

2.3. Respondents and Data Collection.

Primary data were collected through questionnaires administered to 21 respondents representing 21 building construction projects in Klaten Regency, Central Java, Indonesia. The respondents consisted of 11 project implementers, one project supervisor, and nine contractor directors. These respondents were selected based on their involvement in project execution, supervision, or contractor management, which provided them with relevant knowledge of construction activities and waste management practices. As illustrated in Figure 3, project implementers accounted for the largest proportion of respondents (52.38%), followed by contractor directors (42.86%) and project supervisors (4.76%). This distribution reflects the representation of both operational and managerial perspectives in the assessment of construction waste management practices.

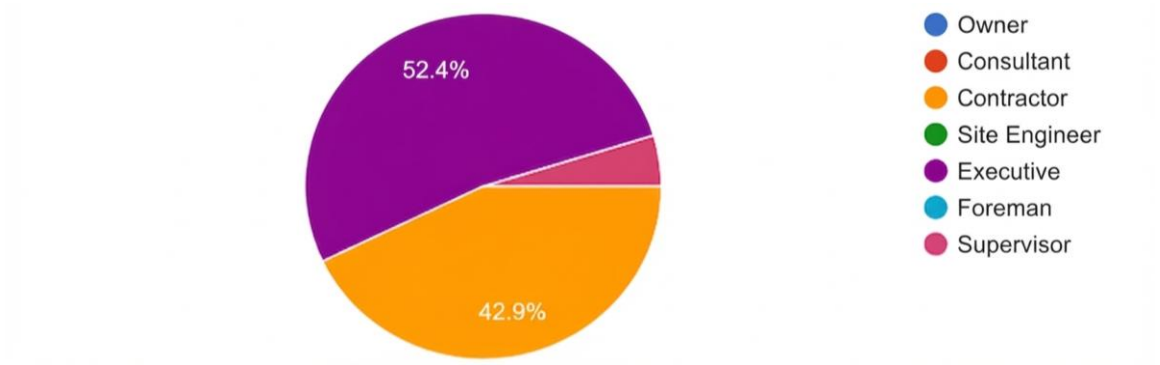


Figure 3. Distribution of Respondents by Project Position.

Respondents' construction experience was also recorded to characterize their professional backgrounds and potential familiarity with construction operations and waste management practices. As shown in Figure 4, 12 respondents (57.14%) had 1–5 years of experience, followed by four respondents (19.05%) with 5–10 years, three respondents (14.29%) with more than 10 years, and two respondents (9.52%) with 0–1 year. The predominance of respondents with 1–5 years of experience indicates that the findings primarily reflect the perceptions of

stakeholders with relatively limited to moderate industry experience, while more experienced respondents provide additional perspectives on established construction practices..

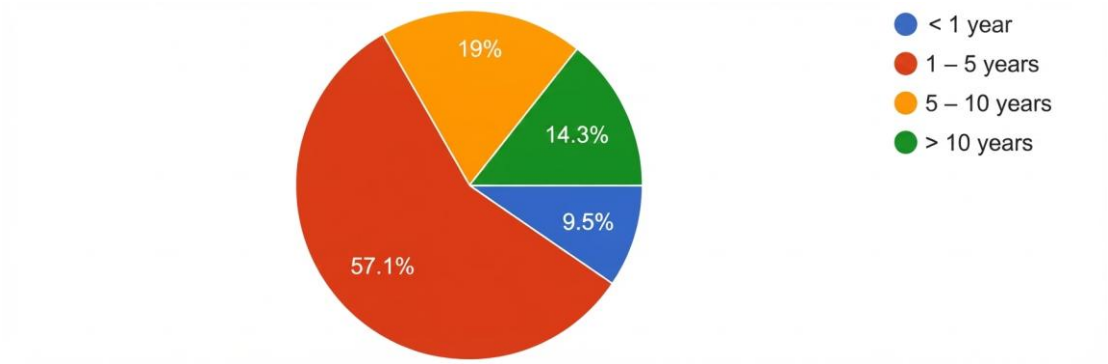


Figure 4. Distribution of Respondents by Construction Experience.

The study employed a non-probability sampling approach involving accessible stakeholders with relevant project responsibilities. One respondent was selected from each project to avoid duplicate project-level responses. However, this approach limited the ability to compare managerial and operational perspectives within individual projects. Furthermore, the relatively small sample size (n = 21) restricts the generalizability of the findings. Therefore, the results were interpreted descriptively rather than as representative estimates of construction waste management practices throughout Klaten Regency. Future research should consider larger samples covering different project sizes, contractor categories, and construction stages to improve the representativeness and robustness of the findings.

2.4. Questionnaire Development and Constructs.

The questionnaire was developed based on a comprehensive literature review and adapted to the characteristics of building construction projects in Klaten Regency. The initial instrument comprised 20 indicators distributed equally across four factors: labor, material, method, and management. The labor factor addressed worker involvement, cooperation, waste prevention behavior, and responsibility allocation. The material factor focused on material protection during storage and stacking, material quality, inventory control, and prevention of material damage. The method factor examined waste segregation, sorting facilities, temporary storage, accessibility, and early provision of waste storage facilities. Meanwhile, the management factor covered contractual provisions, incentives, documentation, third-party disposal arrangements, and waste collection procedures. These factors were selected to represent the human, material, operational, and organizational dimensions of construction waste management identified in previous studies [6, 7, 15]. Each indicator was evaluated using a five-point Likert scale, with higher scores representing more favorable assessments of waste management practices. The questionnaire was designed to capture respondents' perceptions of the implementation of waste management measures within their respective projects. Following validity testing, four indicators (1.3, 1.5, 2.3, and 2.5) were excluded, resulting in 16 retained indicators for subsequent analysis. This screening process was intended to improve the measurement quality of the instrument while maintaining coverage of the four principal waste management factors.

2.5. Validity and Reliability Testing.

Validity and reliability testing were conducted to evaluate the adequacy and internal consistency of the questionnaire before descriptive analysis. Item validity was assessed using Pearson correlation analysis, with a critical correlation coefficient (r-table) of 0.433 at the 5% significance level, as specified in the original statistical analysis. Indicators with calculated correlation coefficients exceeding this threshold were considered valid. Of the 20 initial indicators, 16 satisfied the validity criterion, while four indicators (1.3, 1.5, 2.3, and 2.5) were excluded from further analysis. Reliability was evaluated using Cronbach's alpha-if-item-deleted statistics, which ranged from 0.882 to 0.899, exceeding the study's minimum acceptance criterion of 0.60. These results suggest satisfactory internal consistency under the applied assessment procedure. However, alpha-if-item-deleted statistics represent reliability estimates after removing individual items and should not be interpreted as the overall Cronbach's alpha of the complete instrument. Furthermore, given the relatively small sample size (n = 21), the validity and reliability estimates should be interpreted cautiously and verified through future studies involving larger samples.

2.6. Data Analysis and Interpretation.

The collected data were analyzed using descriptive statistical methods to evaluate stakeholder perceptions of construction waste management practices. Mean scores were calculated for each retained indicator and subsequently summarized according to the four principal factors: labor, material, method, and management. This approach enabled comparisons of perceived implementation levels and identification of indicators requiring greater management attention. The mean scores were classified into four interpretation categories, ranging from very poor to very good. Scores between 1.00 and 1.99 indicated very poor performance, while scores between 2.00 and 2.99 represented poor performance. Scores ranging from 3.00 to 3.99 were categorized as good, whereas scores between 4.00 and 5.00 indicated very good performance. These categories provided a consistent framework for interpreting the descriptive results and comparing waste management indicators across the participating projects. The interpretation framework was used to identify relatively strong and weak aspects of construction waste management. Indicators with lower mean scores were considered priority areas for improvement, while those with higher scores reflected more favorable stakeholder assessments of existing practices. Factor-level comparisons were also conducted to identify broader management dimensions requiring attention. However, the analysis was limited to descriptive comparisons, and the reported mean scores should not be interpreted as evidence of causal relationships or direct measurements of actual waste generation, reduction efficiency, or environmental performance..

3. Results and Discussion

3.1. Instrument and Respondent Profile.

Following the validity screening, 16 of the 20 initial questionnaire indicators were retained for subsequent analysis. The reported Cronbach's alpha-if-item-deleted values ranged from 0.882 to 0.899, indicating satisfactory internal consistency under the applied assessment procedure. The study involved 21 respondents representing 21 building construction projects in Klaten

Regency, comprising 11 project implementers, one project supervisor, and nine contractor directors. Most respondents (12 of 21, or 57.14%) had 1–5 years of construction experience. The diversity of respondent positions provided operational and managerial perspectives on construction waste management practices. However, the relatively small sample size and the inclusion of only one respondent per project limited opportunities for cross-validation of stakeholder perceptions. Consequently, the findings should be interpreted as descriptive evidence of waste management conditions in the surveyed projects rather than as representative estimates of all construction projects in Klaten Regency.

3.2. Comparison of the Four Factors.

The four construction waste management factors were evaluated using their respective mean scores to identify relative strengths and weaknesses in implementation. Table 2 presents the ranking and interpretation of the four factors. the material factor achieved the highest mean score (3.89), indicating relatively favorable implementation of material handling and protection practices. In contrast, the method (2.54), management (2.47), and labor (2.29) factors were classified as poor. The labor factor recorded the lowest score, suggesting that worker coordination and the assignment of waste management responsibilities require particular attention.

Table 2. Comparison and Ranking of Construction Waste-Management Factors.

Rank	Factor	Mean	Category	Interpretation
1	Material	3.89	Good	Relative strength in material protection and quality control
2	Method	2.54	Poor	Site segregation and temporary-storage arrangements need improvement
3	Management	2.47	Poor	Contractual provisions and disposal oversight are weak
4	Labor	2.29	Poor	Dedicated responsibility and coordination are limited

The differences are further illustrated in Figure 5, which shows a clear distinction between material management and the other three factors. The material factor exceeded the method, management, and labor factors by 1.35, 1.42, and 1.60 points, respectively. This pattern suggests that practices associated with material protection and quality control are perceived as better implemented than activities requiring coordinated responsibilities, dedicated waste management facilities, documentation, and contractual oversight. Nevertheless, these findings reflect stakeholder perceptions and do not directly quantify waste reduction, material recovery, or environmental performance.

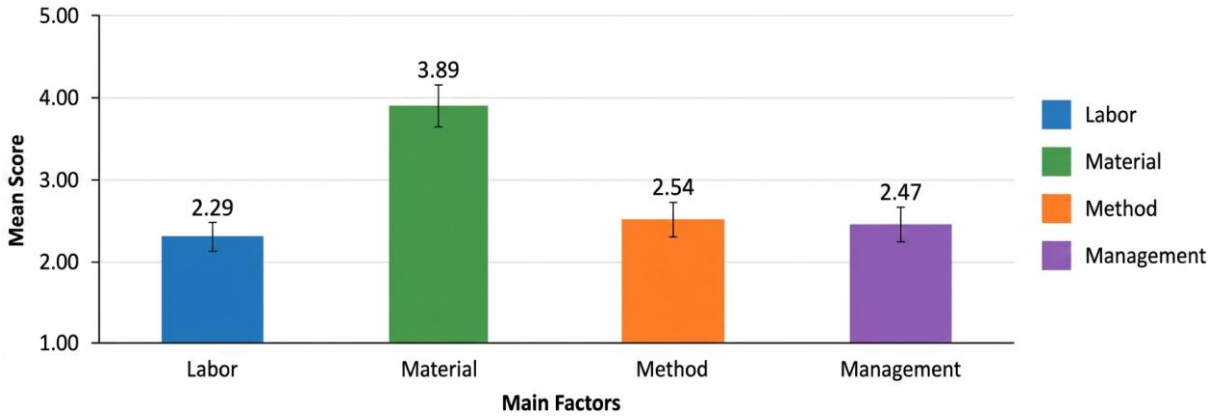


Figure 5. Comparison of Mean Scores for Labor (2.29), Material (3.89), Method (2.54), and Management (2.47).

3.3. Labor factor.

The labor factor was evaluated to determine the extent to which personnel responsibilities, worker cooperation, and waste prevention practices were implemented. Table 3 presents the mean scores and rankings of the three retained labor indicators. the labor factor recorded an overall mean score of 2.29, categorized as poor. The appointment of personnel specifically responsible for construction waste management received the lowest score (1.62), indicating a perceived lack of formally assigned waste management responsibilities. This finding does not necessarily imply the complete absence of waste management activities but suggests that dedicated accountability may not be consistently established. In construction projects, waste-related responsibilities may be distributed among site managers, supervisors, workers, and subcontractors, potentially reducing coordination and consistency in implementation.

Table 3. Labor-factor Indicator Scores.

Rank	Indicator	Mean	Category
1	Appointment of personnel specifically responsible for construction waste management	1.62	Very poor
2	Cooperation between workers and construction waste managers	2.48	Poor
3	Prevention of construction waste generation by workers	2.76	Poor

Worker cooperation and waste prevention practices received mean scores of 2.48 and 2.76, respectively, both classified as poor. These findings suggest that effective waste management requires more than individual awareness, particularly when workers lack clear operational instructions, appropriate facilities, and coordinated supervision. Previous studies have emphasized the interdependence of behavioral and organizational factors in construction waste management [11, 18]. Similarly, research on contractor practices in developing countries has identified planning and stakeholder participation as important waste minimization strategies [7]. The present findings support these observations and identify the formal assignment of waste management responsibilities as a priority for improvement in the surveyed projects.

3.4. Material Factor.

The material factor examined practices related to material protection, quality assurance, and prevention of material damage during construction activities. The indicator-level results are summarized in Table 4, providing an overview of the relative performance of material handling practices. the material factor achieved an overall mean score of 3.89, representing the highest performance among the four assessed factors. Adequate protection during storage and stacking received the highest indicator score (4.14), followed by the use of quality, durable, and standardized materials (4.05). Both indicators were classified as very good, suggesting that conventional material handling and quality control practices were relatively well established in the participating projects. These practices may receive greater attention because they are directly associated with preventing material damage, reducing rework, and minimizing immediate financial losses. However, the prevention of the use of broken materials recorded a comparatively lower mean score (3.48), although it remained within the good category. This variation indicates that material management performance was not uniformly strong across all indicators. Furthermore, effective material protection does not necessarily indicate comprehensive implementation of circular waste management practices. Waste segregation,

reuse, recycling, and material recovery require additional operational arrangements beyond conventional quality control. Previous studies have emphasized the importance of integrating material management with circular economy principles, recovery systems, and stakeholder coordination [1–3, 12, 19]. Accordingly, the relatively high material factor score should be interpreted as evidence of favorable perceived material handling practices rather than confirmation of comprehensive circular economy implementation.

Table 4. Material-factor Indicator Scores.

Rank	Indicator	Mean	Category
1	Adequate protection of materials during storage and stacking	4.14	Very good
2	Use of quality, durable, and standardized materials	4.05	Very good
3	Prevention of the use of broken materials	3.48	Good

3.5. Method Factor.

The method factor assessed the implementation of operational procedures and physical facilities supporting construction waste management, particularly waste segregation, sorting, temporary storage, and accessibility. Table 5 presents the mean scores of the five retained indicators, highlighting the operational practices requiring improvement.

Table 5. Method-factor Indicator Scores.

Rank	Indicator	Mean	Category
1	Provision of waste-sorting facilities according to waste type	2.05	Poor
2	Provision of temporary waste-storage facilities	2.38	Poor
3	Separation of waste according to type	2.67	Poor
4	Storage of waste in accessible project areas	2.67	Poor
5	Provision of waste-storage facilities from the early construction phase	2.95	Poor

Waste separation and accessible waste storage each received a mean score of 2.67, while the early provision of waste-storage facilities achieved the highest score within this factor (2.95). Despite these differences, all five indicators remained within the poor category, suggesting that operational weaknesses extend across several aspects of waste handling. Previous studies have identified waste collection facilities, operational planning, and integration of waste minimization procedures into construction activities as important determinants of effective management [6, 7, 10, 14, 15]. Consistent with these findings, the present study highlights the need to prioritize dedicated sorting facilities, accessible temporary storage areas, and systematic waste segregation procedures. Such improvements could strengthen operational consistency and provide a practical foundation for subsequent waste recovery and recycling initiatives.

3.6. Management Factor.

The management factor was evaluated to assess the implementation of contractual requirements, waste disposal arrangements, worker incentives, documentation, and waste collection practices. Table 6 presents the mean scores and performance categories of the five management indicators, highlighting the areas requiring improvement. the management factor recorded an overall mean score of 2.47, categorized as poor. Contractual provisions concerning construction waste management received the lowest score (1.76), followed by contractual provisions for third-party waste disposal (1.86). Both indicators were classified as very poor,

suggesting that waste management responsibilities and procedures may not be adequately incorporated into formal project agreements. Inadequate contractual arrangements can create uncertainty regarding responsibility for waste segregation, collection, transportation, documentation, and disposal verification, potentially reducing accountability and implementation consistency.

Table 6. Management-factor Indicator Scores.

Rank	Indicator	Mean	Category
1	Contractual provisions concerning construction waste management	1.76	Very poor
2	Contractual provisions concerning third-party waste disposal methods	1.86	Very poor
3	Incentives for workers to reduce or recycle construction waste	2.76	Poor
4	Recording of construction waste management information	2.81	Poor
5	Activities to shorten the waste collection period	3.14	Good

The low score for third-party disposal provisions also indicates potential weaknesses in waste traceability and downstream monitoring. Without clearly defined contractual obligations, contractors may have limited information regarding waste destinations and subsequent treatment, reuse, or recycling activities. Although this study did not directly assess regulatory compliance or verify disposal destinations, the findings highlight the importance of strengthening waste management governance. Previous studies have emphasized the integration of policy requirements, stakeholder responsibilities, and monitoring mechanisms to improve construction waste management performance [5, 9, 16]. Similarly, circular construction approaches require coordinated segregation, recovery, and traceability systems throughout the waste management process [2, 10, 12].

Worker incentives and waste management documentation received mean scores of 2.76 and 2.81, respectively, indicating further opportunities for improvement. In contrast, activities aimed at shortening the waste collection period achieved the highest score within this factor (3.14), categorized as good. This finding suggests that routine waste removal may be relatively better implemented than formal management and monitoring procedures. However, timely waste collection does not necessarily ensure appropriate treatment, recycling, or recovery. Therefore, improvements should prioritize contractual accountability, standardized documentation, and verification of waste destinations rather than focusing exclusively on collection efficiency.

3.7. Critical Indicators and Improvement Priorities.

Critical indicators were identified by ranking the six lowest mean scores across the four construction waste management factors. This approach was used to determine the most pressing implementation weaknesses and establish priorities for corrective actions. Table 7 summarizes the critical indicators, their mean scores, assigned priority levels, and recommended interventions. the appointment of dedicated waste management personnel emerged as the most critical indicator, with the lowest mean score (1.62). This was followed by contractual waste management provisions (1.76) and third-party disposal arrangements (1.86). These three indicators were assigned immediate priority because their very poor ratings suggest fundamental weaknesses in organizational responsibility and governance. Meanwhile, inadequate waste-sorting facilities (2.05), temporary storage (2.38), and worker coordination (2.48) were classified as high-priority concerns requiring operational improvements. These

priority classifications were established from descriptive rankings rather than formal risk assessments.

Table 7. Critical Indicators and Recommended Intervention Priorities.

Overall rank	Critical indicator	Mean	Priority	Recommended intervention
1	Dedicated waste management personnel	1.62	Immediate	Assign accountable personnel and define responsibilities
2	Contractual waste management provisions	1.76	Immediate	Establish measurable contractual requirements and monitoring
3	Third-party disposal provisions	1.86	Immediate	Require approved disposal destinations and transfer records
4	Waste-sorting facilities	2.05	High	Provide labeled containers and designated sorting areas
5	Temporary waste storage	2.38	High	Establish accessible and safe temporary storage facilities
6	Worker–waste manager cooperation	2.48	High	Conduct regular toolbox meetings and coordination activities

The findings reveal a consistent pattern in which material handling practices perform relatively well, while organizational coordination, operational facilities, and management accountability remain comparatively weak. This suggests that construction waste management challenges in the surveyed projects may be associated more strongly with implementation arrangements than with conventional material protection practices. Previous studies have similarly identified organizational, behavioral, and operational barriers as interconnected constraints affecting construction waste management [4, 8, 14, 18]. However, the present study did not directly test the underlying causes of these weaknesses.

The results also emphasize the importance of integrating corrective actions rather than implementing isolated measures. Providing waste-sorting facilities may have limited effectiveness without clearly assigned responsibilities, worker instructions, and appropriate collection arrangements. Likewise, contractual requirements may not translate into effective practices without adequate facilities and monitoring. Therefore, improvements should combine personnel accountability, contractual provisions, operational infrastructure, and documentation to establish a more coordinated waste management system.

3.8. Improvement Framework and Practical Implications.

Based on the identified critical indicators, an integrated improvement framework was developed to strengthen construction waste management practices in building projects. The framework connects the major weaknesses identified through the questionnaire with practical improvement strategies, emphasizing organizational responsibility, operational facilities, contractual requirements, and monitoring procedures. Figure 6 illustrates the conceptual relationships between these weaknesses and the proposed strategies, providing a structured approach to improving construction waste management performance. the proposed framework integrates organizational, operational, and governance measures to address the identified implementation gaps. Organizational improvements focus on assigning responsible personnel and strengthening worker coordination, while operational measures emphasize the provision of waste-sorting facilities and accessible temporary storage areas. Governance improvements involve incorporating waste management requirements into project contracts, establishing clear responsibilities for third-party disposal, and maintaining appropriate documentation. These components are interconnected, as effective waste segregation requires not only adequate

facilities but also worker participation, defined responsibilities, and consistent monitoring. The framework therefore emphasizes coordinated interventions rather than isolated corrective actions.



Figure 6. Conceptual Framework Linking Critical Findings to Improvement Strategies in Construction Waste Management.

To translate the conceptual framework into practical implementation measures, Table 8 presents the recommended improvement actions, responsible stakeholders, and expected outcomes. The proposed actions were developed based on the lowest-scoring indicators identified in the survey, with particular attention to personnel accountability, contractual arrangements, waste-sorting infrastructure, and documentation procedures.

Table 8. Recommended Improvement Actions, Responsible Stakeholders, and Expected Outcomes.

Problem and evidence	Priority action	Responsible stakeholders	Expected implementation outcome
No clearly dedicated waste-management role (1.62)	Name a competent waste-management focal person; define responsibilities and routine checks	Project manager; contractor; site supervisor	Clear accountability and more consistent implementation
Weak worker coordination (2.48)	Hold toolbox meetings at mobilization and when work phases change	Site supervisor; foremen; subcontractors	Workers understand sorting, prevention, and collection procedures
Weak contractual provisions (1.76)	Include waste plan, role allocation, segregation, records, and performance review in contracts	Client/owner; consultant; main contractor; subcontractors	Waste requirements become explicit and monitorable
Weak third-party disposal provisions (1.86)	Specify provider duties and retain transfer notes, receipts, and destination information	Contractor; procurement team; waste service provider	Improved traceability and ability to verify downstream handling
Limited sorting facilities (2.05)	Provide labelled containers or sorting bays matched to expected waste streams	Contractor; site manager; logistics team	Less mixing and better potential for reuse/recycling
Limited temporary storage (2.38)	Allocate accessible, safe storage areas in the site logistics plan before construction	Project planner; site manager; HSE team	More orderly handling and fewer disruptions to segregation
Limited documentation (2.81)	Keep a simple waste register and review it at regular site meetings	Waste focal person; site supervisor; contractor management	Routine monitoring and evidence for improvement

As summarized in Table 8, the recommended interventions prioritize improvements that can be integrated into existing construction management procedures. Assigning a competent waste management coordinator represents an important initial measure because clearly defined responsibilities can support more consistent implementation of waste segregation, collection, and documentation activities. For smaller construction projects, appointing a full-time

specialist may not be economically feasible; therefore, waste management responsibilities may be incorporated into an existing supervisory position. Regular toolbox meetings and operational briefings can further strengthen worker participation and coordination, particularly during changes in construction activities.

The findings also highlight the importance of contractual governance and operational infrastructure. Construction contracts should establish specific waste management obligations, including segregation requirements, collection procedures, disposal responsibilities, and documentation standards, rather than relying solely on general environmental commitments. In parallel, waste-sorting and temporary storage facilities should be incorporated into site logistics planning before construction begins. Maintaining records of waste removal and final destinations can improve traceability and facilitate performance evaluation. These recommendations are consistent with previous research emphasizing contractor performance, stakeholder coordination, policy instruments, and integrated circular waste management systems [6, 7, 15, 16].

Overall, the proposed framework provides a practical basis for addressing the organizational and operational weaknesses identified in the surveyed construction projects. Its implementation could support more systematic waste handling, clearer accountability, and improved opportunities for material recovery. However, because the framework was developed from descriptive survey findings, its effectiveness has not yet been empirically validated. Future studies should evaluate the proposed interventions through pilot implementation, site audits, and quantitative measurements of waste generation, segregation, and recovery performance.

3.9. Study limitations and implications.

Several limitations should be considered when interpreting the findings. First, the study involved only 21 respondents representing 21 building construction projects in Klaten Regency. Because the sampling procedure was non-probabilistic, the findings cannot be generalized to all construction projects in the region. Second, the assessment relied on stakeholder perceptions rather than direct measurements of construction waste generation, segregation efficiency, recycling rates, or disposal practices. Consequently, the reported scores reflect perceived implementation conditions rather than independently verified environmental performance. Third, respondent-level data were unavailable for calculating measures of variability, such as standard deviations and confidence intervals, limiting the depth of statistical interpretation.

Despite these limitations, the study provides preliminary evidence of differences in perceived construction waste management practices across labor, material, method, and management factors. The findings identify organizational responsibility, contractual governance, and operational facilities as priority areas for improvement. Future research should involve larger and more diverse project samples, incorporate multiple respondents per project, and combine questionnaire assessments with site observations, waste audits, and material-flow measurements. Further evaluation of the proposed improvement framework would also help determine its practical effectiveness in reducing construction waste and supporting circular economy implementation.

4. Conclusions

This study assessed construction waste-management practices in 21 building projects in Klaten Regency using labor, material, method, and management factors. The material factor recorded the highest mean (3.89; good), while labor (2.29), method (2.54), and management (2.47) were classified as poor. The largest performance gap was between conventional material handling and the organizational, operational, and governance systems needed to manage waste throughout the project. The lowest indicator was appointment of personnel specifically responsible for waste management (1.62), followed by contractual waste-management provisions (1.76), third-party disposal provisions (1.86), and sorting facilities (2.05). These results identify priorities for intervention: assign clear responsibility, include enforceable waste-management requirements in contracts, verify third-party handling, provide sorting and temporary-storage facilities, strengthen worker coordination, and maintain routine waste records. The findings provide project-level evidence from the surveyed Klaten projects but should be interpreted cautiously because of the small, non-probability sample and reliance on perceptions. The study did not directly measure waste generation, recovery, or legal compliance. Future research should include a larger and more diverse project sample, report full instrument-development and validation procedures, and triangulate survey scores with site audits and quantitative waste-flow data.

Author Contribution

Muhammad Rizki Hidayat: Conceptualization, Methodology, Data Collection, Data Analysis, Writing – Original Draft, and Visualization. Mochammad Solikin: Conceptualization, Methodology, Supervision, Validation, and Writing – Review & Editing. Yenny Nurchasanah: Methodology, Validation, Supervision, and Writing – Review & Editing. All authors reviewed and approved the final manuscript.

Competing Interest

The author declares no competing interest.

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