Civil and Sustainable Urban Engineering

Research Article
Volume 6(2), 2026, 496−509
https://doi.org/10.53623/csue.v6i2.1466

Assessment of Barriers to the Implementation of Technology and Management Practices in Construction Projects: A Contractors' Perspective in Surabaya, Indonesia

Rafly Eksa Pratama*, Michella Beatrix

Civil Engineering Study Program, Faculty of Engineering, Universitas 17 Agustus 1945 Surabaya, Surabaya, Indonesia

*Correspondence: 1432100007@surel.untag-sby.ac.id

SUBMITTED: 7 October 2026; REVISED: 2 November 2026; ACCEPTED: 4 November 2026

ABSTRACT: The implementation of Technology and Management Practices (TMP) in the construction sector is a crucial strategy for improving project performance through technological optimization, efficient resource management, enhanced coordination, and structured management procedures. However, various barriers often hinder their effective implementation. This study aims to identify and evaluate the barriers to TMP implementation in construction projects in Surabaya, Indonesia, from contractors' perspectives. A quantitative approach was employed, involving 35 respondents actively engaged in the construction industry. A total of 31 barrier indicators were evaluated using the Relative Importance Index (RII) method. The RII values ranged from 0.331 to 0.549. Financial constraints emerged as the most significant barrier, with the highest RII value of 0.549, followed by challenges related to reducing environmental impacts (0.543) and high waste management costs (0.509). Conversely, thorough material planning was identified as the least significant barrier, with the lowest RII value of 0.331. The findings highlight financial constraints as the primary barriers to TMP implementation in construction projects. This study provides practical insights for contractors to prioritize improvement strategies, address implementation challenges, and enhance the effectiveness of TMP adoption in Surabaya's construction sector.

KEYWORDS: Construction projects; contractors; relative importance index; surabaya; technology and management practices; waste management

1. Introduction

The construction industry is characterized by complex and interconnected processes involving the coordination of resources, stakeholders, materials, technologies, and operational activities. Successful construction project delivery depends not only on achieving the conventional objectives of cost, quality, and time but also on effective information management, environmental sustainability, resource efficiency, and collaboration among project stakeholders [1]. Increasing project complexity, rising material costs, environmental concerns,

and demands for improved productivity have encouraged construction companies to adopt innovative technologies and more systematic management approaches. Technological advancements have significantly transformed construction planning, execution, monitoring, and decision-making processes, creating opportunities to improve operational efficiency and overall project performance [2].

The integration of digital technologies, particularly Building Information Modeling (BIM), material management systems, and decision-support tools, has demonstrated considerable potential to improve project coordination, minimize material losses, optimize resource allocation, and enhance construction productivity [2, 3]. However, technological adoption alone does not guarantee successful project implementation. Its effectiveness depends on appropriate management procedures, organizational readiness, workforce competencies, and coordination among project participants. These considerations highlight the importance of integrating technological innovations with structured management approaches through Technology and Management Practices (TMP) [4]. TMP encompasses various interconnected activities, including project planning, material management, environmental management, workforce development, technological readiness, and regulatory compliance, to support efficient and sustainable construction processes [5].

Despite its potential benefits, TMP implementation remains challenging, particularly in construction environments characterized by limited financial resources, inadequate infrastructure, insufficient technical expertise, and fragmented management systems. Financial constraints may restrict investments in advanced technologies, employee training, and sustainable construction practices, while organizational resistance and inadequate coordination can further reduce implementation effectiveness [6]. Previous studies have identified various factors influencing the adoption of construction technologies and management practices, including practitioner awareness, infrastructure availability, waste management costs, government policies, private sector participation, energy efficiency, land and material management, BIM adoption, occupational safety, and human resource capabilities [7]. These barriers are interconnected and may vary in significance depending on project characteristics, organizational capacity, and local construction conditions. Consequently, understanding their relative importance is essential for developing targeted interventions and allocating limited resources effectively.

Although previous studies have examined technological adoption, construction management, and sustainability-related challenges, the existing literature has generally addressed these issues through separate technological, organizational, environmental, or regulatory perspectives. A more integrated assessment is needed to understand how these barriers collectively influence TMP implementation. Furthermore, the relative importance of implementation barriers may differ across geographical locations and construction environments because of variations in financial capacity, infrastructure development, regulatory conditions, and contractor competencies. In Surabaya, Indonesia, a context-specific assessment of TMP implementation barriers from contractors' perspectives remains insufficiently documented [8]. This limitation creates a research gap regarding which barriers are perceived as most significant by contractors and how these barriers should be prioritized to support effective implementation.

Addressing this gap requires a systematic assessment that considers multiple implementation barriers within a unified analytical framework. The Relative Importance Index (RII) provides a quantitative approach for evaluating and ranking factors based on respondents' assessments, allowing researchers to identify the relative significance of different constraints [9]. Unlike approaches that examine individual barriers independently, the application of RII to a comprehensive set of TMP indicators enables a structured comparison of financial, technological, environmental, regulatory, and managerial challenges. This approach is particularly relevant for contractors who must prioritize improvement strategies under financial and operational constraints.

Rather than examining technological adoption or management challenges separately, the study evaluates their relative importance across multiple dimensions to identify the most critical implementation constraints. Accordingly, this study aims to identify, assess, and rank 31 barriers to TMP implementation in construction projects in Surabaya using the Relative Importance Index (RII) method. The findings are expected to contribute to the understanding of TMP implementation challenges in the local construction industry and provide practical insights for contractors, project managers, and policymakers in prioritizing interventions, improving resource allocation, and supporting more efficient and sustainable construction practices.

2. Materials and Methods

2.1. Research Design.

This study employed a descriptive quantitative research design to identify and prioritize barriers to the implementation of Technology and Management Practices (TMP) in construction projects in Surabaya, Indonesia. The quantitative approach enables the systematic collection and analysis of numerical data to evaluate respondents' perceptions of implementation challenges [10]. The study focused on barriers associated with construction management practices, including the Reduce, Reuse, and Recycle (3R) approach, Building Information Modeling (BIM), and Green Building Implementation (GBI). These components were examined to identify financial, technological, environmental, organizational, and managerial constraints affecting TMP implementation. The Relative Importance Index (RII) method was adopted to determine the relative significance of the identified barriers. RII is a quantitative ranking technique commonly used to evaluate the perceived importance of multiple factors based on questionnaire responses [13]. This approach facilitates the identification of priority barriers and provides a systematic basis for comparing implementation challenges across different dimensions [14].

2.2. Population and Sampling.

The target population comprised construction industry practitioners involved in construction projects in Surabaya, particularly contractors with relevant knowledge and experience in project implementation. In quantitative research, a population represents the complete group of individuals or entities sharing characteristics relevant to the research objectives, whereas a sample refers to a subset selected from that population for investigation [10, 11]. A total of 35 respondents participated in the study. The respondents were construction practitioners whose

professional experience enabled them to evaluate barriers associated with TMP implementation. Their responses provided the primary data for identifying and ranking the perceived implementation challenges. The sample was used to obtain a context-specific assessment of TMP barriers from the contractors' perspective rather than to establish statistically representative estimates for the entire construction industry.

2.3. Questionnaire Design and Data Collection.

Primary data were collected using a structured questionnaire comprising 31 indicators representing potential barriers to TMP implementation in construction projects. The indicators covered several dimensions, including financial constraints, technological readiness, environmental management, regulatory requirements, infrastructure availability, workforce competencies, and organizational management. The questionnaire was designed to capture respondents' perceptions of the barriers encountered during construction project implementation. Each indicator was assessed using a five-point Likert scale, ranging from 1 (Strongly Disagree), 2 (Disagree), 3 (Neutral), 4 (Agree), to 5 (Strongly Agree). The scale enabled respondents to indicate their level of agreement with statements describing potential TMP implementation barriers. Higher scores represented stronger agreement that the corresponding factor constituted an implementation barrier. The responses were subsequently compiled and analyzed to determine the relative importance of each indicator.

2.4. Data Analysis Using the Relative Importance Index.

The collected data were analyzed using descriptive statistics and the Relative Importance Index (RII) method to identify and rank the barriers affecting TMP implementation. RII provides a standardized measure of the relative importance of each indicator based on the distribution of respondents' questionnaire scores [13, 15]. Accordingly, the RII values range from 0.20 to 1.00 for the five-point scale used in this study. Higher RII values indicate greater perceived importance of the corresponding implementation barrier, whereas lower values indicate relatively lower importance. The calculated RII values were arranged in descending order to establish the priority ranking of the 31 barrier indicators. Indicators with higher RII values were assigned higher ranks, reflecting their greater perceived significance among respondents. Where indicators had identical RII values, they were considered equally important unless additional ranking criteria were explicitly applied. The ranking results were interpreted to identify the most significant barriers and examine their implications for TMP implementation in construction projects. The analysis provided a quantitative basis for identifying priority improvement areas and informing strategies to address financial, environmental, technological, and managerial challenges [16].

3. Results and Discussion

3.1. Research Context and Respondent Characteristics.

This study investigated the barriers to implementing Technology and Management Practices (TMP) in construction projects in Surabaya, Indonesia, from the perspective of construction contractors. Contractors were selected as the primary research participants because of their

direct involvement in project planning, resource allocation, technology adoption, site supervision, and operational management. Their professional experience provides valuable insights into the practical challenges affecting TMP implementation, particularly those associated with financial constraints, environmental management, technological readiness, and organizational coordination.

The questionnaire was distributed to 50 construction practitioners with relevant professional experience. Of these, 40 questionnaires were returned, representing an initial response rate of 80.00%. Respondents were subsequently screened according to two eligibility criteria: a minimum educational qualification of a bachelor's degree (S1) and at least five years of professional experience in the construction industry. Five respondents were excluded because they did not meet one or both criteria, resulting in 35 valid responses for analysis. The final valid response rate was 70.00% of the questionnaires distributed.

The respondents represented four professional positions within construction organizations, as illustrated in Figure 1. Site Engineers accounted for the largest proportion (40.00%, n = 14), followed by Site Supervisors (28.57%, n = 10), Project Managers (22.86%, n = 8), and Company Directors (8.57%, n = 3). The predominance of Site Engineers and Site Supervisors indicates that the dataset primarily reflects the perspectives of practitioners directly involved in daily construction operations, including material management, workforce coordination, site supervision, and the implementation of technical procedures.

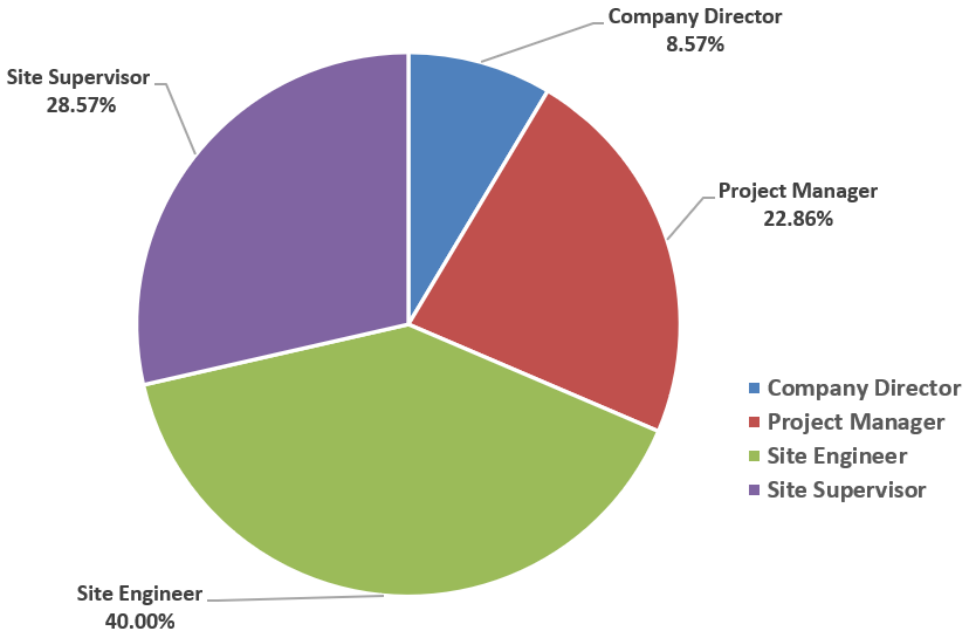


Figure 1. Percentage Profile of Respondents Position Diagram.

Meanwhile, the participation of Project Managers and Company Directors introduces managerial perspectives concerning project planning, financial decision-making, organizational policies, and strategic resource allocation. This distribution allows the study to capture perceptions of TMP implementation barriers across different organizational responsibilities. However, because operational personnel constitute the majority of respondents, the findings should be interpreted primarily as reflecting operational and project-level experiences rather than as equally representing all managerial levels.

3.2. Identification and Classification of TMP Implementation Barriers.

The assessment of TMP implementation barriers was conducted using 31 indicators identified from the relevant literature. These indicators were organized into five groups, designated X, Y, Z1, Z2, and Z3, to facilitate systematic evaluation and comparison. The indicators encompass various challenges associated with construction waste management, environmental sustainability, financial support, resource efficiency, project management, technological adoption, and occupational health and safety. Table 1 presents the classification of the 31 indicators and their corresponding literature sources. The X group consists of seven indicators addressing construction waste management and institutional constraints, including stakeholder awareness, waste management infrastructure, regulatory consistency, recycling facilities, private sector participation, waste management costs, and land availability for final disposal. These indicators represent barriers that may limit the adoption of sustainable waste management practices in construction projects.

Table 1. Barriers to TMP Implementation.

Code	Barriers Indicator	Source
X1	Lack of Awareness and Understanding Among Construction Stakeholders	[17]
X2	Inadequate Waste Management Infrastructure	[18]
X3	Inconsistent Policies and Regulations	[19]
X4	Limited Recycling Facilities	[17]
X5	Low Private Sector Participation	[17]
X6	High Waste Management Costs	[20]
X7	Insufficient Land for Final Disposal Sites	[17]
Y1	Environmental Impact Reduction	[21]
Y2	Resource Efficiency	[22]
Y3	Project Quality Improvement	[19]
Y4	Use of Eco-Friendly Materials	[23]
Y5	Energy Efficiency and Renewable Energy Usage	[23]
Y6	Financial Support	[24]
Y7	Land Management	[25]
Z1.1	Comprehensive Material Planning	[26]
Z1.2	Project Management Efficiency	[27]
Z1.3	Worker Awareness and Training	[28]
Z1.4	Collaboration with Relevant Stakeholders	[29]
Z1.5	Use of Eco-Friendly Technology and Energy	[30]
Z1.6	Government Policies and Regulations	[30]
Z1.7	Sustainable Construction Design	[31]
Z2.1	Application of Building Information Modeling (BIM) in Planning	[32]
Z2.2	Efficient Material Management	[33]
Z2.3	Seamless Stakeholder Coordination	[32]
Z2.4	Environmental Impact Analysis	[34]
Z2.5	Team Training and Performance Development	[32]
Z3.1	Energy Efficiency	[35]
Z3.2	Material Management Methods	[36]
Z3.3	Sustainable Design	[37]
Z3.4	Adequate Worker Occupational Health Safety Environment (HSE) System	[38]
Z3.5	Government Regulations and Policies	[39]

As shown in Table 1, the identified indicators cover both organizational and technical aspects of TMP implementation. Financial support, infrastructure availability, and regulatory consistency represent enabling conditions that may influence contractors' capacity to adopt sustainable construction practices. Meanwhile, material planning, workforce development, technological integration, and stakeholder coordination relate more directly to operational implementation. This distinction is important because barriers associated with organizational resources may require different interventions from those arising during construction activities.

Several indicators also address closely related issues across different groups. For example, energy efficiency appears in both Y5 and Z3.1, while government regulations are represented by X3, Z1.6, and Z3.5. Although these indicators may capture different dimensions of TMP implementation, their conceptual boundaries should be clearly defined to avoid redundancy in the assessment. Similarly, indicators such as environmental impact reduction, resource efficiency, and project quality improvement should be explicitly framed as challenges to achieving these objectives rather than as barriers in themselves. The classification presented in Table 1 establishes the analytical basis for the subsequent RII assessment. By evaluating all 31 indicators using a consistent rating procedure, the study seeks to identify which constraints are perceived as most significant by the participating contractors. The resulting rankings can help distinguish higher-priority implementation challenges from relatively less significant concerns and provide a basis for developing targeted improvement strategies.

3.3. Questionnaire Responses and Data Preparation.

Data were collected through a structured questionnaire administered to construction practitioners in Surabaya. Following the eligibility screening described in Section 3.1, responses from 35 qualified participants were retained for quantitative analysis. Each respondent evaluated the 31 TMP implementation barrier indicators using a five-point Likert scale, ranging from 1 (Strongly Disagree) to 5 (Strongly Agree) [17]. The questionnaire responses were organized according to the indicator codes presented in Table 1. For each indicator, the frequency of responses within the five rating categories was compiled to establish the distribution of respondents' assessments. These data formed the basis for calculating the Relative Importance Index (RII) and determining the relative ranking of the identified implementation barriers. Higher questionnaire scores were interpreted as indicating stronger agreement that a particular indicator represented a barrier to TMP implementation. The resulting RII values were subsequently compared to identify the constraints perceived as most significant by the surveyed contractors. This procedure provides a structured assessment of perceived implementation priorities, although the rankings should not be interpreted as direct measurements of the actual financial, environmental, or operational impacts of individual barriers.

3.4. Relative Importance Index Analysis of TMP Implementation Barriers.

The questionnaire responses from 35 construction practitioners were analyzed using the Relative Importance Index (RII) method to evaluate and rank the barriers to implementing Technology and Management Practices (TMP) in construction projects in Surabaya, Indonesia. The analysis covered 31 indicators representing financial, environmental, technological, regulatory, and managerial challenges. The results revealed variations in the perceived importance of these barriers, with RII values ranging from 0.331 to 0.549. Table 2 presents the complete ranking of the indicators based on their RII values and corresponding importance classifications. Financial Support (Y6) emerged as the highest-ranked barrier, with an RII value of 0.549, followed by Environmental Impact Reduction (Y1; 0.543), High Waste Management Costs (X6; 0.509), and the Use of Eco-Friendly Materials (Y4; 0.503). These four indicators recorded RII values above 0.500, suggesting that financial and environmental considerations were perceived as the most significant challenges to TMP implementation among the surveyed

contractors. Nevertheless, all four indicators were classified as having moderate importance, indicating that their significance should be interpreted relative to the other evaluated barriers.

Table 2. Ranking of barriers to Technology and Management Practices (TMP) implementation.

Rank	Code	Barrier indicator	RII	Importance level
1	Y6	Financial Support	0.549	Moderate
2	Y1	Environmental Impact Reduction	0.543	Moderate
3	X6	High Waste Management Costs	0.509	Moderate
4	Y4	Use of Eco-Friendly Materials	0.503	Moderate
5	X5	Low Private Sector Participation	0.463	Moderate
6	Z1.7	Sustainable Construction Design	0.423	Moderate
7	X3	Inconsistent Policies and Regulations	0.417	Moderate
7	X4	Limited Recycling Facilities	0.417	Moderate
9	X7	Insufficient Land for Final Disposal Sites	0.411	Moderate
10	Z2.5	Team Training and Performance Development	0.406	Moderate
11	Z2.4	Environmental Impact Analysis	0.400	Low
11	Z3.5	Government Regulations and Policies	0.400	Low
13	Y3	Project Quality Improvement	0.394	Low
13	Z1.3	Worker Awareness and Training	0.394	Low
13	Z2.3	Seamless Stakeholder Coordination	0.394	Low
13	Z3.4	Adequate Occupational Health, Safety, and Environment (HSE) Systems	0.394	Low
17	Z1.6	Government Policies and Regulations	0.389	Low
18	Z1.4	Collaboration with Relevant Stakeholders	0.383	Low
18	Z3.3	Sustainable Design	0.383	Low
20	Y5	Energy Efficiency and Renewable Energy Usage	0.377	Low
20	Z1.2	Project Management Efficiency	0.377	Low
20	Z2.2	Efficient Material Management	0.377	Low
23	Y7	Land Management	0.371	Low
23	Z3.2	Material Management Methods	0.371	Low
25	X1	Lack of Awareness and Understanding Among Construction Stakeholders	0.366	Low
25	Y2	Resource Efficiency	0.366	Low
27	Z1.5	Use of Eco-Friendly Technology and Energy	0.360	Low
27	Z2.1	Application of Building Information Modeling (BIM) in Planning	0.360	Low
29	X2	Inadequate Waste Management Infrastructure	0.343	Low
29	Z3.1	Energy Efficiency	0.343	Low
31	Z1.1	Comprehensive Material Planning	0.331	Low

Note: Indicators with identical RII values were assigned equal ranks. Importance classifications follow the categories adopted in the study.

The highest ranking of financial support suggests that funding availability is a major consideration in adopting sustainable construction technologies and management practices. TMP implementation may require substantial initial investment in equipment, workforce training, digital technologies, environmentally friendly materials, and modifications to existing construction procedures. These expenditures must often be accommodated within predetermined project budgets, where contractors must also prioritize materials, labor, equipment, and project completion schedules. Furthermore, the financial benefits of TMP implementation, including improved resource efficiency, reduced material waste, and lower operational costs, may only become evident over extended periods. Consequently, limited financial capacity may discourage contractors from investing in practices whose economic returns are not immediately apparent.

Environmental Impact Reduction (Y1) ranked second, indicating that achieving environmental objectives represents another important challenge. Reducing the environmental impacts of construction activities requires coordinated efforts involving material selection, waste minimization, resource efficiency, recycling arrangements, and environmental monitoring. Implementing these measures may increase operational complexity, particularly when contractors face limited technical expertise, inadequate supporting infrastructure, or insufficient environmental management resources. The relatively high ranking of this indicator suggests that integrating environmental objectives into routine construction activities remains a significant concern among the respondents.

High Waste Management Costs (X6) ranked third, reflecting the financial implications of managing construction waste throughout project implementation. Waste segregation, temporary storage, transportation, recycling, treatment, and final disposal can generate additional expenditures. These costs may increase when recycling facilities are limited or located far from construction sites, potentially reducing the economic attractiveness of sustainable waste management practices. The high ranking of this indicator also suggests a potential connection between financial limitations and environmental management challenges, as inadequate funding may restrict contractors' ability to adopt more efficient waste handling and recycling systems.

The Use of Eco-Friendly Materials (Y4) occupied the fourth position, with an RII value of 0.503. This finding indicates that incorporating environmentally friendly materials into construction activities is another relatively important implementation challenge. Potential difficulties include higher initial procurement costs, limited supplier availability, uncertainties regarding material performance, and insufficient familiarity with sustainable alternatives. These considerations may influence contractors' material selection decisions, particularly when project budgets and procurement specifications prioritize conventional materials.

Beyond the four highest-ranked indicators, Table 2 shows that Low Private Sector Participation (X5; 0.463), Sustainable Construction Design (Z1.7; 0.423), Inconsistent Policies and Regulations (X3; 0.417), and Limited Recycling Facilities (X4; 0.417) were also classified as moderately important. These findings highlight the relevance of institutional participation, regulatory consistency, and supporting infrastructure in facilitating TMP implementation. Limited collaboration between construction companies, government agencies, and waste management service providers may create additional difficulties in adopting sustainable construction practices. Similarly, inconsistent regulations and inadequate recycling facilities may reduce contractors' capacity to implement effective environmental management strategies.

In contrast, 21 indicators were classified as having low importance, with RII values ranging from 0.331 to 0.400. These indicators primarily concerned technological adoption, operational coordination, material management, workforce development, and energy efficiency. The Application of Building Information Modeling (BIM) in Planning (Z2.1) recorded an RII value of 0.360, while Inadequate Waste Management Infrastructure (X2) and Energy Efficiency (Z3.1) each recorded 0.343. Comprehensive Material Planning (Z1.1) received the lowest RII value of 0.331. These findings suggest that respondents considered these factors relatively less significant than financial and environmental constraints. However, lower RII values should not be interpreted as evidence that these practices are unimportant or

that their implementation presents no difficulties. Instead, they reflect the relative priorities identified within the surveyed group.

Taken together, the findings suggest that financial and environmental challenges may be closely interconnected in TMP implementation. Limited funding can restrict investments in sustainable materials, waste management systems, and environmentally responsible construction technologies, while environmental compliance and waste treatment requirements may generate additional project expenditures. Although the RII analysis does not establish causal relationships among these barriers, their relative rankings indicate that financial feasibility and environmental management should be considered together when developing improvement strategies.

From a practical perspective, the findings highlight the need for construction companies to incorporate sustainability-related expenditures into project budgeting and planning. Potential interventions include financial incentives for sustainable construction practices, improved access to recycling facilities, clearer environmental requirements in construction contracts, and stronger cooperation between contractors, suppliers, and regulatory authorities. Targeted workforce training and improved material management procedures may further support implementation by reducing operational inefficiencies and improving resource utilization.

Overall, the results indicate that TMP implementation barriers in Surabaya are multidimensional and cannot be addressed solely through technological improvements. Financial capacity, environmental requirements, institutional support, and organizational readiness should be considered collectively when developing strategies to improve construction project performance and sustainability. However, because the findings are based on the perceptions of 35 respondents, they should be interpreted within the study context rather than generalized to the entire construction industry. Further research involving larger samples and different project categories is recommended to examine the consistency of these rankings across broader construction environments.

3.6. Comparison of the Highest- and Lowest-Ranked TMP Implementation Barriers.

The RII analysis revealed differences in the perceived importance of the 31 barriers to Technology and Management Practices (TMP) implementation. Financial Support (Y6) emerged as the highest-ranked indicator, with an RII value of 0.549, followed by Environmental Impact Reduction (Y1; 0.543), High Waste Management Costs (X6; 0.509), and the Use of Eco-Friendly Materials (Y4; 0.503). These four indicators recorded RII values above 0.500, suggesting that financial and environmental considerations represent the most significant implementation challenges among the 35 surveyed construction practitioners. Their relatively high rankings highlight the potential importance of adequate financial resources, affordable waste management systems, and environmentally sustainable construction materials in supporting TMP implementation. In contrast, Comprehensive Material Planning (Z1.1) recorded the lowest RII value of 0.331, placing it in the 31st position. Inadequate Waste Management Infrastructure (X2) and Energy Efficiency (Z3.1) shared the 29th position, each with an RII value of 0.343. These findings indicate that respondents perceived these factors as relatively less significant than the highest-ranked financial and environmental barriers. The overall distribution of RII values across the 31 indicators is illustrated in Figure 2, highlighting the variation in perceived importance among the evaluated implementation barriers.

Nevertheless, lower RII values do not necessarily indicate that these factors are unimportant or have no influence on TMP implementation. Rather, they reflect their relative importance within the specific research context and respondent group. Overall, the findings suggest that contractors perceive financial and environmental constraints as more pressing than certain operational and technological challenges, emphasizing the need to prioritize resource allocation and environmental management when developing strategies to improve TMP implementation.



Figure 2. Distributional Pattern of RII Values.

3.8. Discussion and Interpretation.

Comprehensively, these empirical findings confirm a varied spectrum of relative importance among the 31 indicators concerning TMP implementation barriers. The variables occupying the highest RII scores are predominantly driven by foundational issues, including financial support, environmental carrying capacity, waste management cost allocations, private sector participation, and the integration of sustainable design. Conversely, indicators related to precise material planning, energy optimization, waste facility availability, and Building Information Modeling (BIM) adoption recorded lower relative RII values. This demonstrates that execution hurdles in TMP are not exclusively rooted in technological limitations; rather, they are closely intertwined with broader systemic elements such as financial readiness, regulatory frameworks, resource availability, environmental considerations, and organizational managerial capacity. Consequently, fostering TMP implementation across the construction ecosystem demands a more holistic and integrated strategic approach.

4. Conclusions

This study evaluated 31 barriers to the implementation of Technology and Management Practices (TMP) in construction projects in Surabaya, Indonesia, based on responses from 35 construction practitioners. The Relative Importance Index (RII) analysis revealed values ranging from 0.331 to 0.549, indicating differences in the perceived importance of the identified barriers. Financial Support (Y6) emerged as the highest-ranked barrier (RII = 0.549), followed by Environmental Impact Reduction (Y1; RII = 0.543), High Waste Management Costs (X6; RII = 0.509), and the Use of Eco-Friendly Materials (Y4; RII = 0.503). Conversely, Comprehensive Material Planning (Z1.1) recorded the lowest RII value (0.331). These findings suggest that financial and environmental considerations are perceived as more significant challenges than certain technological and operational factors. Accordingly, improving TMP implementation requires an integrated approach that strengthens financial support, promotes cost-effective environmental management, improves access to sustainable materials, and enhances institutional collaboration. The findings provide practical guidance for contractors and policymakers in prioritizing interventions and allocating resources to support sustainable construction practices. However, the relatively small sample size and reliance on perception-based assessments limit the generalizability of the results. Future research should involve larger and more diverse samples across different construction project types and geographical locations. Further investigations should also examine the relationships between implementation barriers, TMP adoption, and construction project performance to develop more comprehensive and evidence-based improvement strategies.

Author Contributions

Both authors contributed equally to the conceptualization, methodology, data collection, data analysis, interpretation of results, manuscript preparation, review, and editing. Both authors read and approved the final version of the manuscript.

Competing Interests

The authors declare that they have no known financial or non-financial competing interests that could have influenced the research presented in this manuscript.

Data Availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Declaration of Generative AI Use

Generative artificial intelligence (AI) tools were used to assist with language editing, grammatical correction, and improving the clarity and readability of the manuscript. The authors reviewed and verified the AI-assisted revisions and take full responsibility for the accuracy, originality, and integrity of the published content.

References

[1] Alsehaimi, A.; Baarimah, A.O.; Ramu, M.B.; Alajmi, M.; Ahmed, W. (2025). Integration of BIM in project management phases for achieving sustainable success in small construction projects: A SEM-based approach. *Ain Shams Engineering Journal*, *16*, 103649. https://doi.org/10.1016/j.asej.2025.103649.

[2] Attia, A.R. (2025). The impact of integrating artificial intelligence and building information modeling (BIM) systems on the development of construction methodologies. *Journal of Umm Al-Qura University for Engineering and Architecture*, *16*, 1537–1554. https://doi.org/10.1007/s43995-025-00193-2.

[3] Yu, M.; Wang, C.; Li, H. (2022). Circular economy in the construction industry: A review of decision support tools based on information and communication technologies. *Journal of Cleaner Production*, *349*, 131335. https://doi.org/10.1016/j.jclepro.2022.131335.

[4] Abdullah, M.; Yunus, R.; Al-Shameri, A.; Harouache, A. (2023). An empirical investigation to enhancing construction site performance through efficient material waste mitigation in the Malaysian construction industry. *International Journal of Sustainable Construction Engineering and Technology*, *14*. https://doi.org/10.30880/ijscet.2023.14.04.023.

[5] Datta, S.D.; Tayeh, B.A.; Hakeem, I.Y.; Abu Aisheh, Y.I. (2023). Benefits and barriers of implementing building information modeling techniques for sustainable practices in the construction industry—A comprehensive review. *Sustainability*, *15*, 12466. https://doi.org/10.3390/su151612466.

[6] Ghansah, F.A.; Owusu-Manu, D.; Ayarkwa, J. (2021). Project management processes in the adoption of smart building technologies: A systematic review of constraints. *Smart and Sustainable Built Environment*, *10*, 208–226. https://doi.org/10.1108/SASBE-12-2019-0161.

[7] Chidozie, I.J.; Gate, C.; Zakariyau, M. (2025). Barriers associated with the adoption of building information modelling (BIM) in the Nigerian construction sector. *International Research Journal of Innovations in Engineering and Technology*, *9*, 483–488. https://doi.org/10.47001/IRJIET/2025.905054.

[8] Eriqat, M.O.; Sweis, R.J.; Sweis, G.J. (2025). The challenges of adopting emerging technologies in the AEC industry: A literature review and bibliometric analysis. *Construction Innovation*, *25*, 1680–1706. https://doi.org/10.1108/CI-08-2023-0186.

[9] Albert, I.; Nathaniel, O.B.; Olonilebi, P. (2025). Investigation of building information modeling (BIM) in sustainable construction projects. *FUDMA Journal of Sciences*, *9*, 133–139. https://doi.org/10.33003/fjs-2025-0902-3121.

[10] Sapkota, M. (2024). Implications and critiques of quantitative research: A systematic review. *Journal of Learning Theory and Methodology*, *5*, 153–159. https://doi.org/10.17309/jltm.2024.5.3.09.

[11] Hossan, D.; Dato' Mansor, Z.; Jaharuddin, N.S. (2023). Research population and sampling in quantitative study. *International Journal of Business and Technopreneurship*, *13*.

[12] Slater, P.; Hasson, F. (2025). Quantitative research designs, hierarchy of evidence and validity. *Journal of Psychiatric and Mental Health Nursing*, *32*, 656–660. https://doi.org/10.1111/jpm.13135.

[13] Alghuried, A. (2023). Measuring the benefits and barriers of the implementation of BIM in sustainable practice in the construction industry of Saudi Arabia. *Sustainability*, *15*, 14323. https://doi.org/10.3390/su151914323.

[14] Al-Otaibi, A.; Bowan, P.A.; Alabdullatief, A.; Albaiz, M.; Salah, M. (2025). Barriers to sustainable building project performance in developing countries: A case of Ghana and the Kingdom of Saudi Arabia. *Sustainability*, *17*, 3539. https://doi.org/10.3390/su17083539.

[15] Erdei, G.; Gál, D.; Radácsi, L. (2024). Ranking the factors influencing construction project performance: A relative importance index approach. *Organization, Technology and Management in Construction*, *16*, 224–236.
[16] Dixit, S.; Mandal, S.; Thanikal, J.; Saurabh, K. (2019). Study of significant factors affecting construction productivity using relative importance index in Indian construction industry. *E3S Web of Conferences*, *140*, 09010. https://doi.org/10.1051/e3sconf/201914009010.
[17] Elseknidy, M.; Kineber, A.F.; Oke, A.E.; Elshaboury, N.; Abunada, Z.; Zamil, A.; Alhusban, M.; Ilori, S.A. (2024). Identifying the agile project management implementation barriers for sustainable residential buildings. *International Journal of Engineering Business Management*, *16*, 18479790241299634. https://doi.org/10.1177/18479790241299634.
[18] Fabiyi, O. (2024). Leveraging technology to improve and streamline operations in the African construction sector: A case-based approach. *African Journal of Housing and Sustainable Development*, *5*, 42–59. https://doi.org/10.52968/28464734.
[19] Firenze University Press Referee List. (accessed on Day Month Year) Available online: https://doi.org/10.36253/fup_referee_list.
[20] Igwe, J.; Gate, C.; Zakariyau, M. (2025). Barriers associated with the adoption of building information modelling (BIM) in the Nigerian construction sector. *International Research Journal of Innovations in Engineering and Technology*, *9*, 483–488. https://doi.org/10.47001/IRJIET/2025.905054.
[21] Sahin, C.; Yildirim, N. (2026). Revisiting digital technology adoption in the construction industry: Practice-informed, context-specific validation of existing knowledge. *Smart and Sustainable Built Environment*, ahead-of-print. https://doi.org/10.1108/SASBE-08-2025-0522.
[22] Saltelli, A.; Annoni, P.; Campolongo, F.; Ratto, M. (2012). A variance-based sensitivity index function for factor prioritization. *Reliability Engineering & System Safety*, *107*, 130–138. https://doi.org/10.1016/j.ress.2011.10.013.



© 2026 by the authors. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (http://creativecommons.org/licenses/by/4.0/).