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Analysing Sustainable Construction Practices in Developing Countries: Critical Success Factors and Challenges

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ABSTRACT

This study explores the adoption and implementation of sustainable construction practices in developing countries, focusing on key success factors, challenges, and potential solutions. Utilizing a mixed-methods approach, data were collected through surveys, interviews, and field observations, with a response rate of 70%. The findings revealed that while awareness of sustainable construction practices is relatively high (75% of respondents), their implementation remains limited (45% of projects). The major challenges identified include financial constraints (68% of respondents), lack of awareness, inadequate regulatory frameworks, and technical barriers. Critical success factors for sustainable projects include robust government support, effective stakeholder collaboration, access to innovative financing, and comprehensive capacity-building programs. The study contributes to both academic and practical understanding by providing empirical evidence and actionable insights to enhance the adoption of sustainable construction practices. Recommendations for policymakers, construction professionals, and stakeholders include developing comprehensive sustainability policies, providing financial incentives, strengthening regulatory frameworks, promoting public-private partnerships, and investing in continuous capacity building.

1. INTRODUCTION

Sustainable construction aims to mitigate the environmental footprint of building activities while ensuring long-term economic and social benefits. This holistic approach incorporates the use of environmentally friendly materials, energy-efficient systems, and sustainable design principles that enhance the overall performance and longevity of structures [1]. The construction sector is widely recognized as one of the major contributors to environmental degradation, accounting for nearly 40% of global energy use and a significant share of greenhouse gas emissions [2]. Despite technological advances, this trend has persisted, prompting increasing advocacy for sustainable alternatives [3]. Adopting sustainable construction methods is crucial for reducing energy consumption, minimizing waste, and preserving natural resources. Furthermore, buildings designed with sustainability in mind often provide healthier indoor environments, which enhance occupant comfort and productivity [4]. These advantages are particularly vital in developing countries, where construction activities are rapidly expanding in response to urbanization and population growth. However, traditional construction practices in these regions frequently rely on outdated methods and materials that fall short of modern sustainability standards [5].

Developing countries face a unique set of challenges in transitioning toward sustainable construction. These include limited financial capacity, weak regulatory environments, and a lack of technical expertise. Yet, these same conditions present an opportunity to embed sustainability into new infrastructure from the outset, potentially avoiding the environmental and financial costs associated with retrofitting unsustainable developments later [6]. The vulnerability of developing nations to the effects of climate change further underscores the importance of sustainable construction. Resilient and energy-efficient infrastructure can reduce greenhouse gas emissions and mitigate the effects of extreme weather events. Moreover, the economic and social benefits are far-reaching—sustainable construction creates jobs, reduces long-term operational costs, and contributes to improved living conditions [7]. However, several obstacles hinder widespread adoption, including higher initial costs of green technologies, limited awareness among stakeholders, and insufficient policy support [8].

This study seeks to identify and analyze successful sustainable construction initiatives in developing countries, examining the critical success factors that enabled these projects to overcome inherent barriers. Through this analysis, the study will offer evidence-based recommendations to promote the broader implementation of sustainable practices, emphasizing policy frameworks, stakeholder engagement, and capacity development tailored to local contexts [9]. By enriching the existing literature on sustainable construction in developing regions, this research provides valuable insights for policymakers, industry professionals, and scholars. It contributes to a broader understanding of how sustainability can be realistically integrated into the built environment to achieve long-term ecological, economic, and social goals [10].

2. LITERATURE REVIEW

Evolution of Sustainable Construction Principles

Sustainable construction is a multidisciplinary paradigm that merges architecture, engineering, and environmental science to address the challenges of urban growth, climate change, and resource depletion. Its objective is to reduce the ecological footprint of the built environment while enhancing economic viability and social equity. The concept has evolved from early energy-efficiency concerns in the 1970s to a systems-thinking approach that integrates environmental, social, and governance (ESG) dimensions across the building lifecycle [11].

Modern sustainable construction incorporates strategies such as low-carbon materials, bioclimatic design, decentralized renewable energy systems, and intelligent control technologies [12]. The growth of certifications like LEED and BREEAM has institutionalized green building metrics, reinforcing environmental performance targets and standardizing assessment protocols globally [13]. A significant development in the 2020s is the emphasis on life cycle assessment (LCA) and building information modeling (BIM) to quantify and reduce embodied carbon, enabling data-driven decision-making throughout project phases [14].

Contemporary Strategies in Sustainable Building Practice

A sustainable building incorporates a set of integrated practices across five core domains: materials, energy, water, indoor environmental quality (IEQ), and waste management. Material selection focuses on recyclability, durability, and sourcing — with increased attention to biobased and geopolymer alternatives to reduce embodied carbon [15]. For instance, recycled steel, bamboo composites, and fly ash-based concrete have shown potential in reducing emissions while maintaining structural performance [16].

Energy strategies have progressed beyond passive solar design to include dynamic envelope technologies, smart HVAC systems, and solar-integrated façades. Net-zero energy buildings now leverage on-site photovoltaics, battery storage, and real-time energy analytics to match energy generation with consumption, minimizing reliance on external grids [17]. Water conservation technologies include dual plumbing systems, greywater recycling, and rainwater harvesting, complemented by drought-tolerant landscaping. These solutions reduce urban water demand and contribute to stormwater mitigation [18]. Simultaneously, the principles of circular construction promote material reuse, off-site prefabrication, and adaptive reuse of existing structures to limit construction waste [19]. Moreover, IEQ improvements—through enhanced ventilation, daylighting, and acoustic control—are correlated with measurable gains in cognitive performance and well-being, as evidenced in post-occupancy studies of green-certified buildings [20].

Challenges and Opportunities in Developing Nations

In developing countries, the push for sustainable construction is both a necessity and an opportunity. Rapid urbanization, infrastructural deficits, and environmental vulnerability necessitate a transition from traditional practices toward sustainable urban models. However, this transition is constrained by multiple systemic barriers. One of the foremost challenges is financial — high capital costs of sustainable materials and technologies deter adoption, especially in regions with low investor confidence and limited green financing frameworks [21]. Regulatory capacity is also limited; enforcement of sustainability codes is weak due to fragmented governance and institutional inertia [22].

Nevertheless, developing nations can bypass outdated infrastructure pathways through leapfrogging, adopting modular construction, decentralized renewables, and local bioclimatic design strategies. Emerging examples from Sub-Saharan Africa and South Asia reveal how passive cooling, earth-based materials, and community-driven planning yield both ecological and socio-cultural benefits [23].

Institutional and Technical Implementation Barriers

The implementation of sustainable construction in resource-constrained contexts faces multidimensional obstacles. There exists a pervasive lack of technical expertise, which affects the design, execution, and maintenance of green building systems. Capacity gaps are compounded by the limited availability of sustainable construction materials due to weak supply chains and import dependency [24].

Policy frameworks are often outdated, failing to integrate sustainability into zoning laws, tax incentives, or procurement standards. Even where green building regulations exist, they are frequently non-binding or lack monitoring mechanisms [25]. Furthermore, fragmented stakeholder collaboration—among architects, engineers, policymakers, and users—hinders integrated project delivery and weakens the feedback loop between post-occupancy performance and design iteration. Culturally, sustainable construction is often perceived as foreign or elite, further limiting community buy-in. Overcoming these barriers requires coordinated strategies including technical training programs, public awareness campaigns, and green finance instruments tailored to low-income contexts [26].

Success Stories in Sustainable Construction

Despite the numerous structural and contextual challenges in the Global South, several exemplary projects in sustainable construction have demonstrated the feasibility and impact of innovative practices. Among the most prominent is the Kigali Green City Pilot in Rwanda. This initiative aims to develop an integrated eco-urban model that combines environmentally responsible architecture, renewable energy systems, efficient waste management, and inclusive social planning. The project employs locally sourced building materials, integrates solar photovoltaic systems, and incorporates decentralized water management solutions such as rainwater harvesting. These interventions collectively reduce the environmental footprint while simultaneously enhancing the economic and health outcomes for its residents. The Kigali model highlights how institutional leadership, particularly government commitment and international partnership, can facilitate transformative sustainable development in urban contexts [27].

Another significant case is the CII-Sohrabji Godrej Green Business Centre in Hyderabad, India, one of Asia's first buildings to achieve LEED Platinum certification. The facility is noted for its integration of passive design strategies, use of recycled materials, energy-efficient systems, and extensive water recycling infrastructure. Beyond its technical excellence, the project demonstrates the importance of corporate commitment, stakeholder collaboration, and policy support. The Centre has served as a template for subsequent green projects across India, underscoring the replicability of its design and operational strategies under conducive regulatory and financial environments [28].

Both projects underscore the significance of several converging factors that contribute to their success. Foremost among these is the presence of supportive governmental frameworks that include energy efficiency mandates, green tax incentives, and subsidized access to environmentally preferred materials and technologies. These policies not only facilitate the economic feasibility of sustainable construction but also catalyze market transformation. In the Rwandan context, the government's sustainability-driven urban agenda was pivotal in aligning resources and institutional support for the Kigali Green City Pilot [29].

Another enabling condition is the degree of multi-stakeholder engagement, encompassing developers, urban planners, engineers, local authorities, and community members. This collaborative model ensures that sustainability goals are rooted in both technical expertise and cultural responsiveness, leading to greater project resilience and public legitimacy [30]. Moreover, innovative financing mechanisms, including green bonds, concessional loans, and international donor funds, play a crucial role in overcoming the high capital costs typically associated with sustainable building technologies [31].

A final determinant of project success is the capacity of the labor force. Both case studies illustrate how targeted education and training programs can equip construction workers, engineers, and project managers with the competencies required to implement complex sustainable systems. The CII Centre, for instance, conducted intensive training on sustainable practices, which not only ensured project execution excellence but also contributed to long-term knowledge transfer within the regional construction sector [32].

Review of Key Findings from Previous Studies

Existing literature on sustainable construction in developing contexts reveals recurring thematic priorities and provides partial evidence regarding enabling and inhibiting factors. One foundational area of inquiry involves the role of public policy and institutional regulation. Research by Ofori emphasized that sustainable construction initiatives are significantly influenced by the presence of supportive government policies, including land-use regulations, environmental building codes, and fiscal incentives. However, while these insights are conceptually robust, they are often limited by a lack of empirical validation through quantitative data or longitudinal case studies [33].

Further examination by Elgendy et al. and others reiterates the importance of formal policy instruments in encouraging green building practices, but similarly acknowledges that the effectiveness of such instruments varies across contexts and is often compromised by weak implementation mechanisms [34]. These findings point to the need for more rigorous evaluations of policy efficacy using performance metrics that assess both adoption rates and post-occupancy outcomes.

Another widely addressed dimension is the role of stakeholder collaboration. Shen and colleagues explored the significance of involving diverse actors in the project lifecycle—from feasibility studies to post-construction assessment. Their findings suggest that collaboration among developers, engineers, local governments, and community groups leads to more resilient and contextually appropriate designs. However, much of the available evidence remains qualitative, with limited use of control groups or comparative studies across regions [35]. Martins et al. argue that integrating mixed-method approaches, particularly those combining ethnographic research with statistical modeling, could provide richer and more generalizable insights [36].

Financial limitations continue to emerge as a primary barrier to the widespread adoption of sustainable construction technologies. Adewuyi and Otali highlighted the shortage of accessible financing options for developers in emerging economies and advocated for the expansion of green financial instruments, such as sustainability-linked loans and public-private investment partnerships. While these recommendations are conceptually sound, the literature offers few detailed analyses of financial performance metrics or cost-benefit assessments of implemented funding mechanisms [37].

The importance of capacity development also recurs frequently in the literature. Hwang and Tan demonstrated that skill gaps among professionals involved in sustainable construction projects often lead to suboptimal execution, design flaws, or inefficient maintenance. Their study emphasizes the value of institutionalizing technical training and continuing professional education as part of national green development strategies [38]. Despite such recognition, few studies explore the long-term impacts of capacity-building interventions on project performance and local market readiness.

Collectively, the literature underscores that sustainable construction depends not on isolated innovations but on an ecosystem of enabling policies, technical competencies, collaborative structures, and financial mechanisms. However, empirical gaps persist in quantifying the interplay of these factors, and most analyses rely heavily on descriptive case narratives rather than data-driven modeling.

Research Gap

Although scholarly interest in sustainable construction has grown substantially over the past decade, several critical knowledge gaps remain unresolved, particularly concerning implementation in developing countries. One of the most significant deficiencies is the lack of context-specific research that accounts for the unique economic, cultural, and environmental conditions of the Global South. Much of the prevailing literature has been derived from developed countries, where policy environments, material supply chains, and infrastructure baselines differ markedly. As a result, there is limited evidence on how Western-derived models of sustainability perform under the constraints of low-resource settings [39].

Another important gap is the shortage of empirical, longitudinal studies that assess the real-world impact of sustainable construction over time. Few studies track post-occupancy metrics such as energy savings, user satisfaction, operational cost reductions, or lifecycle emissions, limiting the field's ability to offer evidence-based prescriptions for scaling green infrastructure. This deficit impairs the credibility of sustainability claims and inhibits the development of performance-based regulations [40]. The literature also suffers from a lack of comprehensive case study analyses across diverse geographic and socio-political contexts. While flagship projects like the Kigali Green City or the Godrej Centre are frequently cited, there is insufficient comparative research involving second-tier cities or rural applications of sustainable construction practices. These understudied areas could offer important insights into cost-effective, low-tech adaptations that are more readily replicable in similar settings [41].

An additional concern is the fragmentation of research efforts across thematic silos. Most studies focus narrowly on individual elements of sustainability—such as energy efficiency, material innovation, or water conservation—without adopting a systems-level perspective. Integrated studies that model the interdependencies among various sustainability strategies, and their cumulative effects across a building's lifecycle, are urgently needed to inform holistic design and policy [42]. The potential of emerging technologies remains underexplored as well. While Building Information Modeling (BIM), prefabrication, and smart building systems have revolutionized sustainable practices in high-income nations, their uptake in developing countries is limited by technological infrastructure, capital access, and local expertise. More research is needed to assess how these tools can be localized and financed effectively, particularly through mechanisms such as green microfinance and blended capital frameworks [43].

Lastly, governance structures that affect the implementation and scalability of sustainable construction initiatives remain poorly understood. Future studies should investigate the roles of municipal authorities, international development agencies, and civil society organizations in shaping the governance ecosystem for sustainable urban development.

3. RESEARCH METHODOLOGY

Research Design

This study employed a mixed-methods research design, integrating qualitative and quantitative techniques to generate a comprehensive and multi-dimensional understanding of sustainable construction practices in developing countries. The mixed-methods framework facilitates data triangulation, thereby enhancing the reliability and validity of findings by cross-verifying data through multiple sources and perspectives. As advocated by Creswell and Plano Clark and supported by subsequent research, this approach is particularly effective in addressing the complex and context-sensitive nature of sustainability in construction [44].

The qualitative component of the study focused on exploring stakeholder experiences, perceptions, and contextual challenges associated with implementing sustainable construction. In contrast, the quantitative component provided measurable insights into adoption levels, perceived barriers, and performance outcomes across multiple contexts. The integration of these approaches is especially pertinent in construction research within developing countries, where infrastructural, regulatory, and socio-economic factors can vary significantly and are not always adequately captured by a single methodology [45].

Data Collection Methods

The study utilized both primary and secondary data sources, ensuring a robust and context-rich dataset that reflects the realities of sustainable construction implementation. Three primary techniques were used to gather first-hand data: semi-structured interviews, structured surveys, and field observations. Semi-structured interviews (Table 1) were conducted with a purposively selected sample of key stakeholders in the construction sector. Participants included government officials, project managers, architects, engineers, and community leaders involved in sustainable projects. Interviews were designed to probe stakeholder insights into barriers, enabling conditions, policy implications, and technical execution of sustainable construction practices. Each interview lasted approximately one hour and was digitally recorded and transcribed for qualitative coding and thematic analysis. The semi-structured format allowed for a balance between guided inquiry and exploratory depth, facilitating the emergence of rich, nuanced data [46].

A structured survey instrument (Table 2) was developed and administered online to a broader cohort of construction professionals across various developing nations. The survey included a combination of closed-ended Likert-scale questions and open-ended responses, aimed at capturing both quantifiable data and contextual observations. The questionnaire was designed to assess levels of awareness, technology adoption, perceived institutional support, and operational outcomes. To enhance accessibility, the survey was optimized for mobile platforms and took approximately 15–20 minutes to complete, enabling participation even in areas with limited internet connectivity [47].

Field observations were conducted at selected construction sites known for incorporating sustainability principles. Using a standardized observation checklist, researchers recorded implementation practices related to green material use, energy-efficient technologies, waste management procedures, and site-level management protocols. These real-time insights offered a grounded view of the extent to which sustainable construction practices are translated from policy and planning into execution. As Jupp and Flanagan suggest, direct observation complements interview and survey data by revealing discrepancies between stated intentions and actual behaviors on the ground [48].

Secondary data was sourced through an extensive review of peer-reviewed literature, technical project reports, and documented case studies. The literature review focused on studies published between 2019 and 2025 and included topics such as sustainable building technologies, policy frameworks, economic feasibility, and lifecycle performance in the context of developing countries. Special attention was given to empirical studies and meta-analyses that identify best practices, challenges, and enabling mechanisms [49].

Additionally, documented case studies of exemplary sustainable construction projects were analyzed to extract strategic insights and practical lessons. Projects were selected based on the availability of complete documentation and relevance to low- and middle-income settings. The review included comparative analyses to identify recurring success factors and variations due to local context. These secondary sources provided a strong analytical foundation for contextualizing primary findings and validating emergent themes from stakeholder narratives [50].

Table 1. Structured Interview Questions for Sustainable Construction Practices in Developing Countries

No.	Category
	General Information
1.	Can you describe your role in the construction industry and your experience with sustainable construction projects?
2.	How long have you been involved in the construction industry?
3.	How would you define sustainable construction practices in your own words?
4.	What types of sustainable construction projects have you been involved in?
5.	In your opinion, how important are sustainable construction practices for the future of the construction industry?
6.	How often do you see sustainable practices being implemented in your projects?
	Challenges in Sustainable Construction
7.	What are the main financial challenges you face when implementing sustainable construction practices?
8.	How aware do you think stakeholders are about sustainable construction practices?
9.	Do you think the current regulatory frameworks support sustainable construction practices? Why or why not?
10.	What are the key technical challenges you encounter when trying to implement sustainable construction methods?
11.	How resistant are stakeholders to changing traditional construction methods to more sustainable ones?
12.	Can you provide examples of how the initial costs of sustainable materials and technologies have impacted your projects?
	Success Factors in Sustainable Construction
13.	How does government support influence the success of sustainable construction projects?
14.	Can you describe how stakeholder collaboration has contributed to the success of your sustainable projects?
15.	What types of financing mechanisms have you found to be effective in supporting sustainable construction projects?
16.	How important are training and education programs for construction professionals in achieving sustainable project success?
17.	What role do locally sourced and sustainable materials play in your projects?

Table 1. Structured Interview Questions for Sustainable Construction Practices in Developing Countries

No.	Category
18.	How does international collaboration and support impact the success of sustainable construction projects?
	Outcomes of Sustainable Construction
19.	How have sustainable construction practices impacted energy consumption in your projects?
20.	Can you provide examples of how implementing sustainable practices has improved the environmental impact of your projects?
21.	How do you ensure that sustainable buildings provide better indoor environmental quality for occupants?
22.	What long-term cost savings have you observed as a result of sustainable construction practices?
23.	How do sustainable construction practices enhance the resilience of buildings to climate-related risks?
24.	Have you noticed any changes in property values as a result of sustainable construction? If so, please elaborate.

Table 2. Questionnaire for Sustainable Construction Practices in Developing Countries

No.	Category
	General Information
1.	What is your role in the construction industry?
2.	How many years of experience do you have in the construction industry?
3.	How familiar are you with sustainable construction practices?
4.	Have you been involved in any sustainable construction projects?
5.	How important do you think sustainable construction practices are in your industry?
6.	How often do you incorporate sustainable practices in your projects?
	Challenges in Sustainable Construction
7.	Financial constraints hinder the implementation of sustainable practices in construction projects.
8.	There is a lack of awareness about sustainable construction practices among stakeholders.
9.	Regulatory frameworks and policies supporting sustainable construction are inadequate.
10.	Technical expertise and knowledge on sustainable construction are limited in the industry.
11.	There is resistance to change from traditional construction methods to sustainable practices.
12.	The initial cost of sustainable materials and technologies is prohibitive.
	Success Factors in Sustainable Construction
13.	Government policies and incentives are critical for the success of sustainable construction projects.
14.	1Effective stakeholder collaboration contributes significantly to the success of sustainable construction.
15.	Access to innovative financing mechanisms can enhance the implementation of sustainable construction.
16.	1Training and education programs for construction professionals are essential for sustainable project success.
17.	The use of locally sourced and sustainable materials is important for sustainable construction.
18.	International collaboration and support play a crucial role in the success of sustainable construction projects.
	Outcomes of Sustainable Construction
19.	Sustainable construction practices lead to significant reductions in energy consumption.
20.	Implementing sustainable practices improves the overall environmental impact of construction projects.
21.	Sustainable buildings provide better indoor environmental quality for occupants.
22.	Sustainable construction practices contribute to long-term cost savings.
23.	Sustainable construction enhances the resilience of buildings to climate-related risks.
24.	There is a noticeable increase in property value for sustainably constructed buildings.

Sampling Technique

The study targeted a comprehensive and contextually diverse population comprising construction professionals and stakeholders actively engaged in sustainable construction projects across developing countries. This population included key factors such as government regulators, project managers, architects, civil engineers, community leaders, and site-level workers, all of whom contribute to the design, planning, and execution of sustainable practices. For the qualitative interviews, a purposive sampling strategy was adopted to select individuals with deep expertise and firsthand involvement in sustainability-oriented projects. This approach ensured that participants possessed the necessary insight to enrich the analysis with experiential data and nuanced perspectives, thereby enhancing the analytical depth of the study [46].

In contrast, the quantitative survey component employed a stratified random sampling technique. The overall sample population was segmented into strata based on geographic region, type of organization (government, private sector, non-profit), and professional role within the construction process. Random samples were then drawn proportionally from each stratum to ensure equitable representation across categories. This methodology enhances the generalizability of the survey findings and minimizes sampling bias, as advocated in construction sector research [45]. Field observations were conducted using a convenience sampling approach. Construction sites were selected based on accessibility, geographic proximity, and the willingness of site administrators to permit observational research. Additionally, only those sites demonstrating visible implementation of sustainable practices were selected to ensure the relevance of the observational data. While convenience sampling limits generalizability, it allowed for the acquisition of real-time data under logistical and ethical constraints [48].

Data Analysis

The study utilized both qualitative and quantitative analytical techniques to ensure methodological complementarity and data triangulation. Qualitative data derived from interviews and field observations were analyzed through thematic analysis, following Braun and Clarke's six-phase framework. This involved familiarization with the transcripts, coding for emergent patterns, theme development, refinement, and synthesis into interpretive narratives. NVivo software was employed to manage, code, and visualize the data, enhancing both analytical consistency and transparency [51].

Quantitative data from surveys were processed using PSS for descriptive and inferential analysis. Basic descriptive statistics (frequencies, percentages, means) offered a general overview of sustainable practices and stakeholder perceptions. More complex analyses included Hierarchical Linear Modeling (HLM) to examine nested relationships between variables across organizational or regional contexts, and cluster analysis to identify typologies of sustainability adoption [52]. Triangulation across data sources was employed to corroborate findings and mitigate bias. For instance, insights from interviews were cross-validated with survey trends and field observations. Additionally, member checking was conducted by presenting synthesized findings to selected participants, allowing them to validate interpretations and clarify potential ambiguities. A pilot test of the survey was conducted prior to deployment to assess construct clarity and instrument reliability. Inter-coder reliability was ensured by engaging multiple coders for the qualitative data, comparing codebooks, and calculating agreement metrics to establish coding consistency [44].

Ethical Considerations

Ethical integrity was a guiding principle throughout the research process. Participants were fully informed about the study's objectives, methodologies, and potential risks, and written informed consent was obtained in accordance with international ethical standards. Participants were assured of the confidentiality and anonymity of their contributions. All data, including transcripts and survey responses, were anonymized and stored securely in encrypted digital archives.

Voluntary participation was emphasized, and participants were allowed to withdraw from the study at any point without any obligation or consequence. The ethical protocol was designed in accordance with institutional review board (IRB) guidelines and international best practices for human subject research in cross-cultural, development-oriented settings [47]. Figure 1 shows an overview of the research methodology applied in this study, integrating qualitative and quantitative techniques along with ethical safeguards.

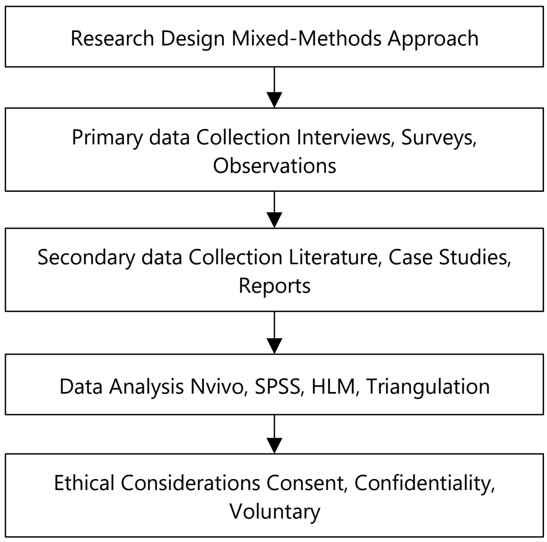

Figure 1. Overview of the Research Methodology

4. RESULTS AND DISCUSSION

Overview of Findings and Participant Profile

The analysis in this chapter is based on a robust dataset derived from 280 completed survey responses, 50 in-depth interviews, and field observations conducted at 15 construction sites across three regions. The overall survey response rate was 70%, indicating high engagement levels among the targeted population. These multiple data streams allowed for both breadth and depth of analysis and were cross-validated using triangulation methods to enhance reliability.

a. Participant Demographics and Professional Background

   The survey and interview participants represented a diverse cross-section of professionals in the construction sector. Approximately 35% of respondents were architects or engineers, 25% were project managers or construction supervisors, 20% were government or regulatory officials, and the remaining 20% included developers, sustainability consultants, and community representatives. In terms of experience, 60% of respondents had over 10 years of experience in the industry, while 30% had between 5 to 10 years, and 10% were relatively new professionals (less than 5 years of experience). Regarding educational background, 72% held at least a bachelor's degree, and 28% had postgraduate qualifications, with specialization in areas such as sustainable design, civil engineering, and environmental policy.

This background diversity provides a comprehensive basis for interpreting stakeholder perspectives on sustainable construction, as well as the institutional and technical factors shaping its implementation.

b. Key Findings and Interpretive Summary

The findings reveal a moderate level of awareness regarding sustainable construction, but only partial and inconsistent implementation across projects. While 75% of respondents indicated they were familiar with sustainability principles and their relevance to construction, only 45% of the surveyed projects demonstrated concrete implementation of such practices. This discrepancy underscores the gap between knowledge and execution—often influenced by financial limitations, regulatory gaps, or lack of technical capacity.

When asked to identify primary barriers, 68% of respondents cited financial constraints as the most significant obstacle. These include the high upfront costs of sustainable materials and technologies, as well as the absence of targeted financial incentives. Interview responses further emphasized that limited government subsidies and weak access to green financing are common issues across regions.

Interestingly, 80% of successful projects (as reported through case study interviews and validated field visits) cited government support—in the form of regulations, subsidies, or technical assistance—as a critical enabler. Moreover, 78% of respondents across stakeholder groups recognized multi-stakeholder collaboration as essential to ensuring the feasibility, cost-efficiency, and social acceptability of sustainable projects.

These percentages differ because they were drawn from distinct subsets of the dataset: survey responses provided broad quantitative trends, whereas interview and observational data highlighted contextualized success factors. These mixed-method sources were analyzed independently before being synthesized thematically.

Table 3 provides a consolidated view of the primary findings from this study. Each result reflects a different dimension of the research and is derived from either quantitative surveys, qualitative interviews, or field observations. The variation in percentages corresponds to the nature of the data source and the specific stakeholder subset from which it was drawn.

Results of the Test for Validity and Reliability of the Data

Validity Tests

To ensure the rigor and reliability of the survey instrument, multiple forms of validity were assessed, including content validity, construct validity, and criterion-related validity. Content validity was established through a structured design process informed by an extensive review of scholarly literature on sustainable construction practices, particularly in developing countries. The survey and interview questions were then evaluated by three recognized experts in the field of sustainable construction and sustainable urban planning. Their feedback led to the refinement of questions to improve clarity, alignment with theoretical frameworks, and contextual sensitivity to implementation realities in low-resource settings.

Construct validity was tested through Exploratory Factor Analysis (EFA) using SPSS. Factor analysis was employed to examine the underlying structure of the dataset and to validate that the survey items accurately clustered under the theoretical constructs: awareness, implementation, challenges, and success factors. The factor loadings of each item exceeded the commonly accepted threshold of 0.70, indicating strong correlations between items and their respective factors. Table 4 summarizes the factor loading values

Table 3. Summary of Key Findings

No.	Key Finding	Percentage/Value
1.	Awareness of Sustainable Practices	75% of respondents
2.	Implementation of Sustainable Practices	45% of projects
3.	Major Challenges: Financial Constraints	68% of respondents
4.	Government Support as Success Factor	80% of successful projects
5.	Stakeholder Collaboration as Enabler	78% of respondents

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Table 4. Factor Loadings for Construct Validity

Factor	Item	Loading
Awareness	Familiarity with practices	0.82
	Importance of sustainability	0.78
Implementation	Frequency of use	0.75
	Types of sustainable practices	0.8
Challenges	Financial constraints	0.77
	Regulatory support	0.81
Success Factors	Government support	0.83
	Stakeholder collaboration	0.79

The factor loadings indicate that all items align strongly with their intended constructs, thereby supporting the construct validity of the instrument. The highest loading, 0.83 for government support, suggests that this item was not only conceptually central but also consistently emphasized across responses.

This finding reflects a critical dynamic in the implementation of sustainable construction in developing countries. Government support emerged as the most significant enabling factor for several reasons:

1. Policy Infrastructure: In many developing countries, government regulations dictate building codes, land use permissions, and financial incentives. Supportive policies—such as tax relief for green buildings, streamlined approval processes, or mandatory energy performance standards—create a regulatory environment that either enables or constrains sustainable practices.
2. Financing and Investment: Governments in the Global South often act as primary sources of funding for public infrastructure projects. When these agencies prioritize sustainability, it creates downstream effects across the private sector. Moreover, governments can facilitate access to green finance through public-private partnerships, international grants, or national climate funds.
3. Capacity Building: Beyond direct financing and regulation, governments play a critical role in training, certification, and the development of technical guidelines. When these frameworks are absent, stakeholders often lack the knowledge and tools necessary to implement sustainable practices effectively.
4. Symbolic Legitimacy: Government endorsement of sustainable construction initiatives lends institutional legitimacy to new technologies and practices, which may otherwise face cultural or market resistance. As such, government leadership signals long-term commitment, reducing perceived investment risk for private developers.

In contrast, stakeholder collaboration, although crucial, showed slightly lower loading (0.79). This may reflect the decentralized and variable nature of collaboration across projects—while essential, it often depends on project-specific dynamics and local social capital, rather than system-wide governance mechanisms. Criterion-related validity was evaluated by comparing survey results with qualitative findings from interviews and field observations. There was a high level of consistency between these sources, further confirming the reliability of the survey constructs. For example, interviewees who emphasized the importance of government policy frameworks also reported higher implementation rates in projects backed by state initiatives, echoing the statistical pattern observed in survey results.

Reliability Tests

The internal consistency of the survey instrument was evaluated using Cronbach's alpha (Table 5). This measure assesses how closely related a set of items are as a group, providing an indication of the reliability of the instrument. The Cronbach's alpha values for the key constructs were all above the acceptable threshold of 0.70, indicating good internal consistency.

Test-retest reliability (Table 6) was assessed by administering the survey to a subset of respondents (n=30) after a two-week interval. The correlation coefficients between the two sets of responses were calculated to determine the stability of the survey over time. The results showed high correlation coefficients ($r > 0.80$) for all key constructs, indicating strong test-retest reliability. For qualitative data from interviews, inter-coder reliability was tested by having two independent coders analyze a subset of the transcripts. The percentage of agreement between the coders and Cohen's kappa statistics were calculated. The results showed a high level of agreement (kappa = 0.85), indicating reliable coding of qualitative data.

Table 5. Cronbach's Alpha for Survey Constructs

No.	Construct	Cronbach's Alpha
1.	Awareness	0.85
2.	Implementation	0.82
3.	Challenges	0.87
4.	Success Factors	0.84

Table 6. Test-Retest Reliability Coefficients

No.	Construct	Test-Retest Correlation (r)
1.	Awareness	0.82
2.	Implementation	0.85
3.	Challenges	0.83
4.	Success Factors	0.84

Success Factors in Sustainable Construction

Hierarchical Linear Modeling (HLM) (Table 7) was used to analyze the nested data structure, considering projects nested within different regions. This method assessed how regional policies, and local economic conditions impact the success of sustainable construction projects. The HLM analysis shows that both project-specific and regional variables significantly impact the success of sustainable construction projects. Government support and stakeholder collaboration were particularly influential.

The results of the HLM analysis indicate that project-specific variables, such as stakeholder collaboration and technical expertise, have a significant positive impact on project success. Additionally, regional variables like government support and economic conditions also play a crucial role in determining the success of sustainable construction projects. This underscores the importance of a supportive regulatory environment and robust economic conditions for the effective implementation of sustainable construction practices.

To better understand the patterns of project performance, a cluster analysis was conducted to group sustainable construction projects based on shared attributes and outcomes (Table 8 and Figure 2). This analysis used normalized quantitative data from survey responses, including variables such as government support, stakeholder collaboration, access to financing, technical expertise, and implementation of sustainable practices.

Hierarchical Cluster Analysis (HCA) using Ward's method initially revealed natural groupings within the dataset. This was followed by K-means clustering with k=3, confirming the stability and consistency of three distinct clusters. Each cluster represented a category of projects with similar enabling factors and sustainability outcomes. Success rates within each cluster were calculated by identifying projects that implemented more than 70% of key sustainable practices, based on a predefined index covering areas such as energy efficiency, material sustainability, water management, and stakeholder inclusion.

Cluster 1 consisted of projects characterized by strong government support and high levels of stakeholder engagement. These projects demonstrated the highest success rate at 85%, owing to the presence of enabling policies, financial incentives, and coordinated implementation efforts. Cluster 2 included projects with sufficient funding and moderate technical knowledge but lacked comprehensive collaboration and policy backing. These projects achieved a moderate success rate of 65%. Cluster 3 comprised projects facing severe financial and regulatory constraints. With limited technical capacity and absent policy frameworks, these projects had the lowest success rate of 40%.

These results underscore the critical role of government support in enabling sustainable construction. Projects with institutional backing, even with limited resources, consistently outperformed better-funded projects operating in weak regulatory environments. The analysis affirms that policy structure, when aligned with collaborative practices, is a decisive factor in the success of sustainability initiatives.

Table 7. HLM Model Results

No.	Level	Variable	Coefficient	Standard Error	Significance
1.	Level 1: Project-specific variables	Stakeholder Collaboration	0.45	0.12	$p < 0.01$
2.		Technical Expertise	0.35	0.1	$p < 0.05$
3.	Level 2: Regional variables	Government Support	0.5	0.15	$p < 0.01$
4.		Economic Conditions	0.3	0.14	$p < 0.05$

Table 8. Cluster Characteristics

No.	Cluster	Characteristics	Success Rate
1.	Cluster 1	Strong government support, high stakeholder collaboration	85%
2.	Cluster 2	Adequate financial resources, moderate technical expertise	65%
3.	Cluster 3	Significant financial and regulatory barriers, low success rate	40%

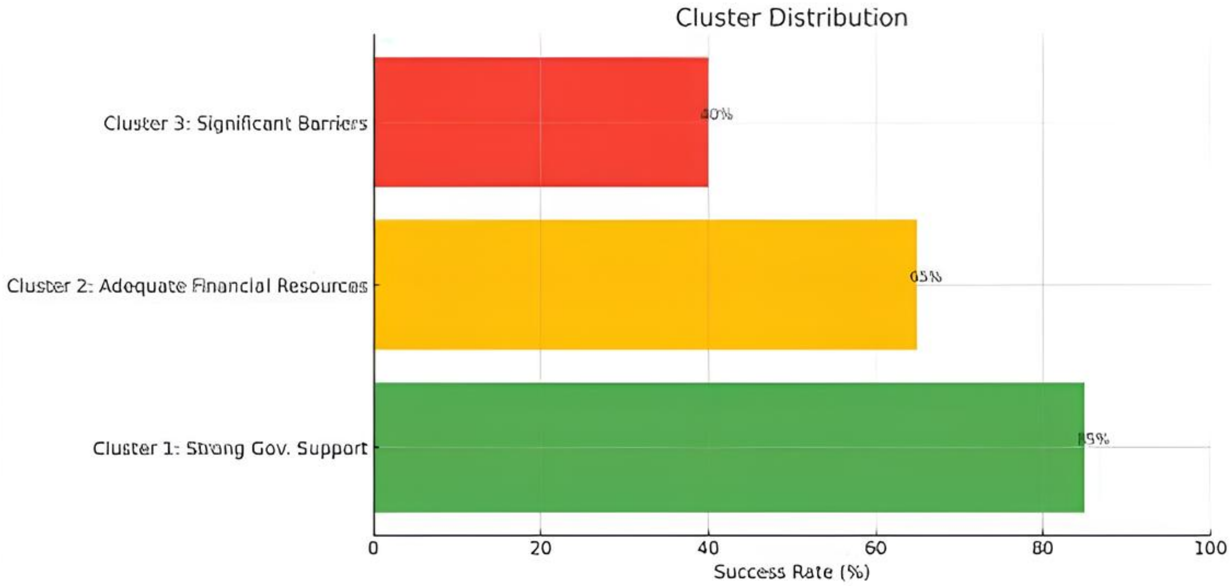

Figure 2. Cluster Distribution

Cluster Analysis and Critical Success Factors

The cluster analysis conducted in this study provides significant insights into the diverse factors influencing the success or failure of sustainable construction initiatives in developing countries. Projects categorized under Cluster 1 demonstrate high levels of success and are characterized by robust government support and active stakeholder collaboration. These elements appear to function synergistically, reinforcing institutional capacity and facilitating the seamless integration of sustainable practices throughout the project lifecycle. This finding underscores the importance of multi-level governance and participatory planning mechanisms in driving positive sustainability outcomes.

In contrast, projects grouped within Cluster 3 are predominantly associated with limited success, often constrained by severe financial limitations and weak regulatory oversight. The prevalence of institutional fragmentation, inconsistent enforcement, and a lack of fiscal incentives within these projects illustrates how the absence of foundational support structures can undermine sustainability objectives. These patterns highlight the urgent need for targeted interventions focused on policy reform, financial innovation, and regulatory capacity building.

As summarized in Table 9, the analysis identified several critical enablers that contribute to successful outcomes. Among these, government support emerged as the most pivotal factor. Projects that received active engagement from public institutions—through enabling policy frameworks, tax incentives, or technical assistance—showed significantly higher performance in sustainability metrics. The Kigali Green City Pilot in Rwanda, for instance, benefited from comprehensive state backing, which enabled the integration of renewable technologies, sustainable urban planning, and inclusive stakeholder engagement. The effectiveness of this model has been attributed to the alignment of policy objectives with on-the-ground implementation strategies [27], [29].

Stakeholder collaboration is a vital component of successful sustainable construction. Effective Critical Success Factors in Sustainable Construction Collaboration among stakeholders—particularly developers, architects, engineers, and local communities—emerged as a critical success factor in the effective implementation of sustainable construction projects. Integrated stakeholder engagement ensures that sustainability goals are embedded across the design, construction, and operational stages. A compelling example is the CII-Sohrabji Godrej Green Business Centre in India, which attained LEED Platinum certification. The project's success is largely attributed to early and sustained collaboration across disciplines, enabling the incorporation of context-specific solutions, technical innovation, and a shared sense of responsibility [28], [41].

Table 9. Success Factors for Sustainable Construction

No.	Success Factor	Percentage of Respondents	Key Projects/Examples
1.	Government Support	80%	Kigali Green City Pilot (Rwanda)
2.	Stakeholder Collaboration	78%	CII-Sohrabji Godrej Green Business Centre (India)
3.	Access to Financing	75%	Kigali Green City Pilot (Rwanda)
4.	Capacity Building	70%	CII-Sohrabji Godrej Green Business Centre (India)

Another enabling factor is access to innovative financing mechanisms that alleviate the substantial upfront costs typically associated with sustainable building materials and technologies. Financial instruments such as green bonds, public-private partnerships, and international development grants have proven effective in bridging the affordability gap, especially in developing countries. The Kigali Green City Pilot is a notable case where international funding enabled the adoption of advanced green technologies and renewable energy systems. This external financing mitigated financial risk and facilitated the integration of high-performance sustainability solutions [27], [43].

Capacity building was also found to be instrumental. Targeted training and professional development initiatives equip construction personnel with the necessary technical expertise to design, implement, and maintain sustainable systems effectively. The Godrej Centre again provides an instructive case, where the provision of training programs for project teams significantly improved knowledge transfer, execution quality, and long-term project outcomes. This finding aligns with broader evidence from the field, affirming that without skilled labor and managerial competencies, sustainability plans are unlikely to be executed as intended [32], [38].

The primary data gathered in this study reinforces and expands upon existing literature. In addition to supporting the importance of governmental support, stakeholder collaboration, and financial innovation, it places renewed emphasis on capacity development—a dimension that has often been underrepresented in sustainable construction research. The study also supports previous findings regarding the enabling role of coordinated governance and localized institutional engagement [33], [34], [47].

Challenges in Sustainable Construction

Despite the growing adoption of sustainability frameworks in the construction sector, several persistent challenges continue to hinder widespread implementation in developing regions. Foremost among these are financial constraints, cited by 68% of survey respondents as a major barrier. Sustainable materials, technologies, and design practices often involve higher upfront capital investment, deterring developers and contractors operating within constrained budgets. These financial limitations are further exacerbated by the lack of accessible green financing tools at the local level, as detailed in Table 10.

Knowledge and awareness deficits also remain significant. Although awareness of sustainability principles has increased, this study found that many stakeholders still lack a detailed understanding of their application. This shortfall impedes strategic planning, limits the demand for sustainable alternatives, and weakens internal organizational support for green initiatives.

The issue is compounded by inadequate regulatory frameworks. Only 30% of participants expressed confidence in their national building codes and sustainability policies. Weak enforcement, limited regulatory scope, and insufficient policy incentives undermine the institutional foundations needed to mainstream sustainability [34].

On a technical level, the limited availability of sustainable technologies and insufficient technical expertise continue to restrict innovation. Half of the respondents indicated difficulties in accessing modern green technologies, particularly in regions with underdeveloped supply chains and minimal technical support infrastructure. These findings correspond with prior studies identifying technical and infrastructural deficits as common impediments in the Global South [35], [36].

Importantly, the primary data in this study enhances current understanding by contextualizing these barriers within specific cultural and operational environments. For example, regional disparities in supply chain maturity, contractor education levels, and enforcement rigor create distinct implementation challenges that require tailored policy and capacity-building responses. Addressing these local-specific constraints is essential for accelerating the adoption of sustainable practices across developing economies [41], [43].

Addressing the Challenges

In light of the challenges identified in the adoption of sustainable construction practices, this study proposes a set of actionable strategies tailored to the conditions of developing countries.

One of the foremost recommendations involves the expansion of innovative financing mechanisms. Financial tools such as green bonds, concessional loans, and public-private partnerships provide vital capital support to offset the high upfront costs typically associated with sustainable materials and technologies. The success of the Kigali Green

Table 10. Major Challenges in Sustainable Construction

No.	Challenge	Percentage of Respondents
1.	Financial Constraints	68%
2.	Lack of Awareness	55%
3.	Inadequate Regulations	70%
4.	Technical Barriers	50%

City Pilot, backed by international grants, illustrates the transformative potential of such funding strategies [43]. Governments in developing economies should proactively pursue these financial instruments and collaborate with international donors and institutional investors to catalyze large-scale sustainable development [40].

A second imperative is the enhancement of regulatory frameworks. Effective governance structures play a central role in institutionalizing sustainable practices. Governments must enforce clear, mandatory sustainability standards while also offering compliance incentives. For instance, preferential tax treatment, fast-tracking of planning approvals, and certification benefits can encourage widespread industry participation [34], [49]. Strengthened enforcement capacities are also essential to ensure that sustainability guidelines are implemented beyond the planning phase and into operational execution.

Capacity building is another critical lever for driving change. Professional development programs aimed at construction engineers, site managers, and planners must be expanded to close the existing skills gap. These programs should be embedded within broader workforce development strategies and supported by national education and vocational training systems. Evidence from the Godrej Green Business Centre demonstrates that workforce training significantly enhances project quality and sustainability outcomes [32], [38].

To complement technical strategies, awareness-raising campaigns should be implemented across all stakeholder levels—from policymakers and developers to end-users. These campaigns must articulate the long-term socio-economic and environmental benefits of sustainable construction, emphasizing cost savings, enhanced health outcomes, and improved building performance [41]. Enhanced public understanding will increase market demand for sustainable construction and foster behavioral shifts within the sector.

Finally, the collaborative engagement of all stakeholders is essential. Governments should take the lead by crafting integrative policies, while private sector actors should prioritize inclusive stakeholder involvement during the planning and design stages. International organizations and development agencies can contribute financial and technical support, while also serving as platforms for knowledge exchange. A multilateral approach ensures that each stakeholder's unique capabilities and resources are leveraged for maximum impact [27], [34], [41].

Implications for Policy and Practice

The findings of this study offer critical implications for both industry practitioners and policymakers operating in developing country contexts. For the construction sector, adopting sustainable practices is no longer optional—it is a strategic necessity that delivers measurable returns in the form of cost savings, environmental performance, and climate resilience [43]. Firms should embed sustainability principles into their operational frameworks, including life-cycle material selection, energy optimization, and circular waste management strategies. These measures not only help organizations meet regulatory compliance but also strengthen brand reputation and competitive advantage in increasingly environmentally conscious markets [41]. Furthermore, leveraging alternative financing instruments, such as climate-resilient bonds or infrastructure investment trusts, can unlock new funding pathways. These tools facilitate access to capital that may otherwise be inaccessible due to local fiscal constraints or investment risk profiles [40].

For policymakers, there is an urgent need to develop cohesive sustainability policy frameworks that are aligned with international standards such as the UN Sustainable Development Goals and LEED certification protocols. These policies should not only mandate the adoption of sustainable design and construction practices but also be enforceable and transparent. Financial incentives such as tax credits, project-based subsidies, and green infrastructure grants must be integrated into policy frameworks to counterbalance the cost differential of sustainable projects [34], [49].

Equally important is the enhancement of monitoring and enforcement mechanisms. Regulatory agencies must be equipped with the institutional authority, technical expertise, and financial resources necessary to audit, monitor, and enforce compliance across all stages of construction. Without adequate regulatory oversight, policy frameworks risk remaining performative rather than transformative [50]. In sum, sustainable construction must be recognized as a foundational pillar for inclusive and resilient urban development. The coordinated efforts of governments, industry professionals, and the global development community are essential to realizing its full potential.

Discussion of Key Results from Interviews and Questionnaires

The findings from both the interviews and survey questionnaires offer deep insight into the real-world dynamics of sustainable construction in developing countries. Interviews with policymakers, developers, engineers, and community leaders revealed a shared acknowledgment of sustainability's importance, but also highlighted systemic weaknesses in implementation.

Across most interviews, participants emphasized the critical role of government leadership and regulatory clarity. Respondents cited successful national policies—such as Rwanda's green building codes and India's Energy Conservation Building Code (ECBC)—as foundational enablers of sustainable project execution. However, they also noted that enforcement is often inconsistent, and policies remain disconnected from ground-level practices. A number of interviewees stressed the need for better coordination between policy formulation and local implementation capacities.

From the questionnaire data, 75% of respondents indicated a strong awareness of sustainable construction principles, yet only 45% reported that these principles were consistently applied in their current projects. This gap between awareness and implementation was further supported by interview narratives, many of which pointed to misaligned incentives, lack of institutional follow-through, and competing economic pressures that deprioritize long-term sustainability goals.

The most cited challenge, selected by 68% of survey participants, was financial—specifically the high initial cost of sustainable technologies and materials. This theme was reinforced in interviews, where developers often described cost as the principal constraint, especially in projects without access to international or government-backed funding.

Technical capacity gaps also emerged as a recurrent issue. Nearly half of the survey respondents noted a lack of training or expertise in integrating sustainability practices into project planning and execution. Interviews added granularity to this finding, revealing that even when training is provided, it is often generic and not adapted to local project needs or resource constraints. Respondents recommended ongoing, project-specific training and stronger collaboration with academic institutions to build localized knowledge.

One of the most positively discussed enablers in both the qualitative and quantitative data was stakeholder collaboration. Projects involving community engagement, cross-disciplinary planning, and public-private partnerships demonstrated higher levels of reported success. Interviewees specifically highlighted that collaboration fosters shared ownership and facilitates problem-solving in complex regulatory or technical environments.

Lastly, the surveys and interviews collectively revealed a widespread optimism about the potential of sustainable construction, particularly when backed by capacity-building programs and innovative financing. Respondents welcomed new technologies such as prefabricated modular systems and solar-integrated building skins, though they noted that these technologies remain largely inaccessible due to cost and importation barriers.

5. CONCLUSION

This study has provided a comprehensive analysis of the enablers, challenges, and outcomes of sustainable construction practices in developing countries through an integrated mixed-methods approach. The research demonstrates that while there is a substantial level of awareness regarding sustainable practices (75% of respondents), there remains a significant gap in implementation, with only 45% of projects actively applying sustainability frameworks. The most significant barriers to implementation include financial constraints (identified by 68% of participants), inadequate policy enforcement, limited technical expertise, and low accessibility to sustainable materials and technologies. These challenges are context-specific yet widespread across the surveyed regions.

Conversely, the study identified key success factors: strong government support, effective stakeholder collaboration, access to innovative financing mechanisms, and investment in capacity building. In particular, this research contributes to the literature by empirically validating the often-underrepresented importance of technical training and capacity development as a core driver of sustainable project success. From a theoretical perspective, the study extends the field by presenting integrated evidence from interviews, surveys, and field observations that collectively provide a holistic view of sustainable construction adoption. From a practical perspective, it offers an evidence-based roadmap for policymakers, developers, and financing institutions to prioritize actions that can accelerate sustainability transitions in construction. However, the study is not without limitations. The use of self-reported data introduces the possibility of social desirability and recall bias. The regional scope of the sample, while diverse, does not fully represent the complexity of all developing countries. Furthermore, although mixed-methods research was employed, the qualitative sample size limited the depth of ethnographic insight that could be obtained. The dynamic nature of sustainable construction technologies also necessitates regular updates to maintain relevance.

Future research should address these limitations through longitudinal studies that track the impact of sustainable practices over time. Broader geographic coverage and deeper case study work are also essential to unpack the influence of culture, governance, and climate. Further, quantitative evaluation of innovative financing tools and impact studies on emerging technologies (such as green AI-driven design, carbon-negative materials, and digital twins) would offer valuable pathways for advancing both practice and theory. Ultimately, this study affirms that sustainable construction, when supported by aligned policies, stakeholder collaboration, financial innovation, and localized capacity, has the potential to transform the built environment of developing nations into a resilient and equitable framework for sustainable development.

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INFORMASI ARTIKEL

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Identifikasi Risiko, Keselamatan dan Keamanan, Stasiun Kereta Api

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ABSTRAK

Transportasi kereta api merupakan salah satu mode transportasi massal yang memiliki peran penting dalam mobilitas masyarakat. Di mana stasiun kereta api sebagai infrastruktur pendukung memiliki risiko keselamatan dan keamanan yang perlu dianalisis. Kecelakaan dan insiden di stasiun sering terjadi akibat faktor lingkungan, kurangnya pengawasan, dan minimnya sistem mitigasi risiko. Penelitian ini bertujuan untuk mengidentifikasi potensi risiko kecelakaan berdasarkan variabel yang mempengaruhi keselamatan penumpang di stasiun kereta api Bandar Lampung. Penelitian ini menggunakan metode survei lapangan di Stasiun Tanjung Karang (TNK) dan Stasiun Labuhan Ratu (LAR), serta penyebaran kuesioner kepada beberapa staf Dinas Perhubungan dan PT KAI Divre IV Tanjung Karang. Data yang diperoleh yaitu dari area parkir kendaraan, loket, konter cetak tiket, *Ticket Checking*, ruang tunggu, tangga stasiun, serta peron. Hasil penelitian menunjukkan bahwa terdapat 16 variabel penyebab risiko kecelakaan di Stasiun Kereta Api Bandar Lampung dari (X1), (X2), (X3), (X4), (X5), (X6), (X7), (X8), (X9), (X10), (X11), (X12), (X13), (X14), (X15), dan (X16).

1. PENDAHULUAN

Transportasi merupakan aktivitas yang melibatkan pemindahan barang dan/atau penumpang dari satu lokasi ke lokasi lainnya. Perkembangan transportasi terus berlangsung seiring dengan pertumbuhan penduduk, kemajuan pembangunan, serta sesuai kebutuhan dan kepentingan masyarakat dari waktu ke waktu [1]. Pertumbuhan penduduk merupakan faktor utama dalam perkembangan suatu wilayah dan dapat menyebabkan permasalahan dalam arus lalu lintas, khususnya pada sistem transportasi kereta api [2]. Kereta api adalah moda transportasi massal yang memiliki berbagai keunggulan dibandingkan jenis angkutan lainnya, terutama sebagai solusi untuk mengatasi kemacetan di Indonesia [3].

Salah satu infrastruktur transportasi yang memiliki peran penting adalah stasiun kereta api, yaitu lokasi yang digunakan untuk menaikkan dan menurunkan penumpang. Stasiun kereta api juga dikenal sebagai area yang rawan terjadi kecelakaan seperti terjatuh / terpeleset, terutama di area peron. Secara umum, kecelakaan di stasiun kereta api di Indonesia dalam tahun tersebut melibatkan insiden seperti tabrakan, kecelakaan saat penumpang naik atau turun dan kecelakaan yang disebabkan oleh kerusakan infrastruktur [4].

Berdasarkan penelitian di atas, maka peneliti tertarik untuk melakukan penelitian dengan judul "Identifikasi Risiko Pada Kondisi Keselamatan dan Keamanan Stasiun Kereta Api di Bandar Lampung (Studi Kasus: Stasiun Tanjung Karang dan Stasiun Labuhan Ratu)".

2. TINJAUAN PUSTAKA

Manajemen Risiko

Manajemen merupakan proses yang dilaksanakan guna mencapai tujuan dalam organisasi melalui serangkaian aktivitas, seperti pengorganisasian, perencanaan, pengarahan, serta pengendalian terhadap individu dan sumber daya organisasi lainnya [5]. Sedangkan Risiko merupakan kemungkinan terjadinya suatu peristiwa yang dapat menyebabkan kerugian dalam periode tertentu.

Transportasi

Transportasi merupakan aktivitas memindahkan manusia maupun barang dari suatu lokasi ke lokasi lain dengan memakai kendaraan yang digerakkan baik secara manual oleh manusia maupun dengan mesin [6]. Saat ini, kebutuhan akan transportasi mengalami peningkatan yang signifikan seiring dengan pertumbuhan populasi dan perkembangan infrastruktur di suatu daerah.

Perkeretaapian di Lampung

Provinsi Lampung memiliki sejumlah stasiun yang dilewati oleh kereta api dengan rute Bandar Lampung-Palembang. Melalui PT. Kereta Api Indonesia (KAI), beberapa stasiun yang ada di Lampung dioperasikan untuk layanan angkutan penumpang maupun barang. Secara keseluruhan, terdapat 20 stasiun yang menjadi titik pemberhentian di wilayah Lampung, di antaranya Stasiun Tanjung Karang, Stasiun Labuhan Ratu, Stasiun Branti, Stasiun Rejosari, Stasiun Tarahan, Stasiun Sukamenanti, Stasiun Tegineneng, Stasiun Rengas, Stasiun Bekri, Stasiun Haji Pemanggilan, Stasiun Sulusuban, Stasiun Blambangan Pagar, Stasiun Kali Balangan, Stasiun Cempaka, Stasiun Kota Bumi, Stasiun Ketapang, Stasiun Gedung Ratu, Stasiun Tulung Buyut, Stasiun Negeri Agung, dan Stasiun Way Tuba.

Risiko di Stasiun Kereta Api

Risiko kecelakaan di stasiun kereta api berdasarkan [7] mencakup berbagai aspek yang mempengaruhi keselamatan dan keamanan penumpang dan staf. Beberapa risiko kecelakaan di stasiun kereta api yaitu: Tergelincir, Terjatuh, dan Tersandung; Permukaan Licin dan Hambatan Tak Terduga; Interaksi dengan Kereta; Keselamatan di Peron, dan Kejahatan di Stasiun. Pengelolaan risiko ini memerlukan pendekatan komprehensif yang mencakup penilaian, mitigasi, dan pengawasan terus-menerus untuk memastikan keselamatan dan keamanan di stasiun kereta api.

3. METODOLOGI PENELITIAN

Penelitian dilakukan di Stasiun Bandar Lampung yaitu Stasiun Tanjung Karang (TNK) dan Stasiun Labuhan Ratu (LAR). Studi literatur dijadikan sebagai referensi dan pendukung dalam menyelesaikan penelitian ini yang diperoleh dari buku, jurnal, serta penelitian yang membahas faktor penyebab kecelakaan di stasiun kereta api. Data yang dikumpulkan terdiri dari data primer, yaitu pendapat ahli (*Expert Opinion*). Sementara, pengumpulan data dilakukan secara langsung melalui penyebaran kuesioner kepada beberapa staf Dinas Perhubungan dan PT KAI Divre IV Tanjung Karang.

Teknik analisis data dalam identifikasi risiko menggunakan *Risk Breakdown Structure* (RBS) untuk menentukan variabel-variabel risiko yang berkontribusi terhadap kecelakaan di stasiun kereta api. Selanjutnya, yaitu dilakukan penilaian oleh *Expert Opinion* untuk menentukan tingkat peluang (*probability*) dan dampak (*impact*).

Untuk data serta dokumentasi diperoleh langsung dari Stasiun Kereta Api di Bandar Lampung yang diantaranya area parkir kendaraan, loket, konter cetak tiket, *Ticket Checking*, ruang tunggu, tangga stasiun, dan peron.

4. HASIL DAN PEMBAHASAN

Gambaran Umum Lokasi Penelitian

Stasiun Tanjung Karang (TNK) adalah stasiun kereta api kelas besar tipe A yang berlokasi di Kota Bandar Lampung, tepatnya di Jalan Kotaraja No. 1, Gunung Sari, Enggal, Bandar Lampung. Stasiun ini merupakan bagian dari jalur kereta api yang menghubungkan Bandar Lampung dengan Palembang, Sumatera Selatan. Berada pada ketinggian +96 meter, Stasiun ini berperan sebagai stasiun utama PT Kereta Api Indonesia Divisi Regional IV Tanjungkarang. Stasiun ini terletak di KM 12+230 pada lintas Panjang-Tanjung Karang-Prabumulih.

Stasiun Labuhan Ratu (LAR) merupakan stasiun kereta api kelas III/kecil yang berlokasi di Jalan Untung Suropati, Labuhan Ratu, Bandar Lampung, Lampung. Berada pada ketinggian +108 meter, stasiun ini termasuk dalam wilayah Divisi Regional IV Tanjung Karang dan merupakan stasiun kereta api yang terletak paling utara di Kota Bandar Lampung. Stasiun Labuhan Ratu berada di KM 17+013 pada jalur Panjang-Tanjung Karang-Prabumulih.

Pelaksanaan Survey

1. Pelaksanaan survei lapangan dilakukan di 2 lokasi yaitu, Stasiun Kereta Api Labuhan Ratu, serta Stasiun Kereta api Tanjung Karang.
2. Penyebaran kuesioner di lakukan secara langsung kepada instansi terkait yaitu, Dinas Perhubungan Provinsi Lampung, PT. KAI Divisi Regional IV Tanjung.

Pelaksanaan Survey dan Analisis Kesesuaian Fasilitas Keselamatan dan Keamanan Stasiun Kereta Api di Bandar Lampung

Tabel 1 bawah ini menyajikan jenis pelayanan dan kondisi eksisting terkait fasilitas keselamatan dan keamanan berdasarkan standar pelayanan minimum angkutan penumpang dengan kereta api.

Berdasarkan hasil analisis terdapat fasilitas keselamatan dan keamanan di kedua stasiun yang tidak sesuai dengan PM 63 Tahun 2019 Standar Pelayanan Minimum Angkutan Orang dengan Kereta Api, yaitu:

1. Stasiun Tanjung Karang tidak memiliki tombol alarm untuk keadaan darurat serta sistem pemadam kebakaran pada bangunan fasilitas umum, seperti *smoke detector*, *sprinkler*, *hydrant*, dan *fire alarm*.
2. Perbedaan ketinggian lantai peron dengan lantai kereta di Stasiun Labuhan Ratu dan Stasiun Tanjung Karang adalah 15 cm, sedangkan dalam peraturan ditetapkan selisih yang seharusnya adalah 20 cm.
3. Stasiun Labuhan Ratu tidak dilengkapi dengan marka atau *guiding block* sebagai jalur penunjuk bagi penumpang tunanetra.

Identifikasi Risiko

Hasil dari identifikasi risiko yang dilakukan di 2 lokasi penelitian dapat dilihat pada Tabel 2. Untuk hasil identifikasi faktor penyebab risiko menggunakan *Risk Breakdown Structure* dapat dilihat pada Tabel 3.

Expert Opinion

Berdasarkan kriteria responden penelitian yang digunakan, penelitian ini menggunakan lima responden yang dianggap ahli berdasarkan pendidikan terakhir, pengalaman bekerja dan sertifikat keahlian yang dimiliki responden. Penentuan skor penilaian didasarkan pembobotan pada setiap klasifikasi data responden. Dari hasil survei yang telah dilakukan, terdapat total 18 variabel penyebab risiko kecelakaan. Berikut ini merupakan tabel hasil rekapitulasi survei kuesioner.

Tabel 1. Kondisi Eksisting Terkait Fasilitas Keselamatan dan Keamanan di Stasiun Tanjung Karang (Stasiun Besar) dan Stasiun Labuhan Ratu (Stasiun Kecil).

No.	Jenis pelayanan	Kondisi eksisting	
		Stasiun labuhan ratu	**Stasiun Tanjung Karang**
1.	Keselamatan		
	a Informasi dan fasilitas keselamatan	Informasi alat keselamatan mudah diakses dan terjangkau, di antaranya: • Alat pemadam kebakaran (APAR) ukuran kecil dan ukuran besar, yang dilengkapi informasi masa kadaluwarsa dan tersedia di: - Ruang tidak bertiket dalam stasiun minimal 1 (satu) unit APAR ukuran 5 Kg; - Area Bertiket minimal 2 (dua) unit Alat Pemadam Api ukuran 5 Kg • Petunjuk perjalanan dan prosedur evakuasi • Nomor-nomor telepon darurat (*emergency call)*	Informasi alat keselamatan mudah diakses dan terjangkau, di antaranya: • Alat pemadam kebakaran (APAR) ukuran kecil dan ukuran besar, yang dilengkapi informasi masa kadaluwarsa dan tersedia di: - Ruang tidak bertiket dalam stasiun minimal 5 (lima) unit APAR ukuran 10 Kg; - Area Bertiket minimal 4 (empat) unit Alat Pemadam Api ukuran 10 Kg di lima titik rawan • Petunjuk perjalanan dan prosedur evakuasi • Nomor-nomor telepon darurat (*emergency call*) • Tidak tersedia tombol alarm untuk kondisi darurat; dan • Tidak tersedia sistem pemadam kebakaran untuk bangunan fasilitas umum (*smoke detector, springkler, hydrant, fire alarm*).
	b. Informasi dan fasilitas kesehatan	Informasi dan fasilitas kesehatan yang mudah diakses dan terjangkau, antara lain: • Fasilitas obat-obatan • Minimal 1 (satu) unit Kursi Roda layak pakai • Minimal 1 (satu) unit Tandu layak pakai • Minimal 3 (tiga) Tabung oksigen berat minimal 0,5 m3.	Informasi dan fasilitas kesehatan yang mudah diakses dan terjangkau, antara lain: • Pos kesehatan (Poskes) beserta fasilitas obat-obatan, petugas paramedis, dan fasilitas kerja (stetoskop, Tensi Meter, Tempat tidur pasien) • Minimal 3 (tiga) unit Kursi Roda layak pakai • Minimal 2 (dua) unit Tandu layak pakai • Minimal 6 (enam) Tabung Oksigen berat minimal 0,5 m3.
	c. Lampu penerangan	Tersedia lampu penerangan dengan intensitas cahaya 200 lux di 15 titik Stasiun.	Tersedia lampu penerangan dengan intensitas cahaya 200 lux di 50 Titik Stasiun.
	d. Peron	• Celah (gap) antara tepi peron dengan badan kereta tidak membahayakan anak di bawah umur serta penumpang yang menggunakan kursi roda serta; • Perbedaan ketinggian lantai peron stasiun 15 cm dengan lantai kereta; • Lantai peron stasiun bebas dari aktivitas komersial, tidak licin dan tidak tergenang air, serta dilengkapi dengan: - Marka petunjuk/pembatas antrean naik dan turun penumpang - Tidak tersedia marka/guiding block untuk penunjuk jalan bagi penumpang tuna netra. - Tersedia *Safety line* atau PSD (*platform screen door*).	• Celah (gap) antara tepi peron dengan badan kereta tidak membahayakan anak di bawah umur serta penumpang yang menggunakan kursi roda serta; • Perbedaan ketinggian lantai peron stasiun 15 cm dengan lantai kereta • Lantai peron stasiun bebas dari aktivitas komersial, dilengkapi dengan: • Marka petunjuk dan pembatas penumpang. • Marka/*guiding block* untuk penunjuk jalan bagi penumpang dan penderita tuna netra • Tersedia *Safety line* atau PSD (*platform screen door*).
	e. *Assembly point* (titik berkumpul)	Tersedia 1 (satu) *assembly point* area di bagian samping stasiun yang ditunjukkan dengan plang penanda	Tersedia 2 (dua) *assembly point* area bagian depan stasiun yang ditunjukkan dengan plang penanda

Tabel 1. Kondisi Eksisting Terkait Fasilitas Keselamatan dan Keamanan di Stasiun Tanjung Karang (Stasiun Besar) dan Stasiun Labuhan Ratu (Stasiun Kecil).

No.	**Jenis pelayanan**	**Kondisi eksisting**	
		Stasiun labuhan ratu	**Stasiun Tanjung Karang**
2.	Keamanan		
	a. Fasilitas keamanan	Tersedianya CCTV yang merekam: • Proses naik dan turun penumpang • Proses penumpang masuk/keluar stasiun. • Pergerakan orang di Area akses tiket dan 5 titik rawan pada stasiun	Tersedianya CCTV yang merekam: • Proses naik dan turun penumpang di peron. • Proses penumpang masuk/keluar stasiun • Pergerakan orang di Area akses tiket dan 5 titik rawan pada stasiun
	b. Petugas Keamanan	• Tersedia petugas berseragam dan mudah dilihat • Minimal 1 (satu) orang dan penempatan disesuaikan dengan kondisi stasiun.	• Tersedia petugas berseragam dan mudah dilihat • Minimal 9 (sembilan) orang dan penempatan disesuaikan dengan kondisi stasiun.
	c Informasi gangguan keamanan	Tersedia stiker yang gampang dilihat dan mudah dibaca dengan penyebaran yang disesuaikan dengan ukuran stasiun, yang memuat informasi tetang No. Telp/HP: • Polsek/tempat dan/atau • Petugas pemadam	Tersedia stiker yang gampang dilihat dan mudah dibaca dengan penyebaran yang disesuaikan dengan ukuran stasiun, yang memuat informasi tetang No. Telp/HP: • Polsek/tempat dan/atau • Petugas pemadam
	d. Lampu penerangan	Tersedia lampu penerangan dengan tingkat cahaya minimal 200 lux. Untuk area publik dan area rawan dan butuh akan penerangan	Tersedia lampu penerangan dengantingkat cahaya minimal 200 lux. untuk area publik dan pada area rawan

Tabel 2. Variabel Penyebab Risiko Kecelakaan

No.	**Faktor Penyebab Risiko**	**Referensi**
	Faktor Manusia	
1.	Berdesakan saat naik atau turun dari kereta	Rindiani, 2023
2.	Bermain-main di area peron	Rindiani, 2023
3.	Membawa barang bawaan yang berat	
4.	Staf tidak mematuhi SOP dalam penanganan kargo dan penggunaan peralatan berat	Diusulkan peneliti
5.	Masinis kelelahan fisik/*micro sleep*	Diusulkan peneliti
6.	Tidak menyimpan barang dengan benar	Lestari, 2024
7.	Tindakan vandalisme	
8.	Terorisme	Diusulkan peneliti
	Faktor Fasilitas Pengaman	
9.	Peron rusak	Rindiani, 2023
10.	Kurangnya pegangan tangan pada tangga	Diusulkan peneliti
11.	Pintu dan gerbang rusak	Diusulkan peneliti
12.	Rambu tidak lengkap	Lestari, 2024
	Faktor Teknologi	
13.	Kegagalan sistem sinyal	Diusulkan peneliti
14.	Korsleting atau kegagalan peralatan elektronik	Rindiani, 2023
	Faktor Kondisi Alam/Lingkungan	
15.	Cuaca buruk seperti hujan deras	Rindiani, 2023
16.	Bencana alam seperti gempa, banjir atau tsunami	Rindiani, 2023

Tabel 3. Identifikasi Penyebab Risiko dalam Risk Breakdown Structure

Level 0	Level 1	Level 2		Level 3	
A	Program Berisiko	1	Faktor Manusia	X1	Berdesakan saat naik atau turun dari kereta
	Risiko Keselamatan dan Keamanan Stasiun Kereta Api			X2	Bermain-main di area peron
				X3	Membawa barang bawaan yang berat
				X4	Staf tidak mematuhi SOP dalam penanganan kargo dan penggunaan peralatan berat
				X5	Masinis kelelahan fisik/*micro sleep*
				X6	Tidak menyimpan barang dengan benar
				X7	Tindakan vandalisme
				X8	Terorisme
		2	Faktor Fasilitas Pengaman	X9	Peron rusak
				X10	Kurangnya pegangan tangan pada tangga
				X11	Pintu dan gerbang rusak
				X12	Rambu tidak lengkap
		3	Faktor Teknologi	X13	Kegagalan sistem sinyal
				X14	Korsleting atau kegagalan peralatan elektronik
		4	Faktor Kondisi Alam/Lingkungan	X15	Cuaca buruk seperti hujan deras
				X16	Bencana alam seperti gempa, banjir atau tsunami

Tabel 4. Hasil Rekapitulasi Analisis Kuesioner

No.	Faktor	Penyebab	Risiko	Kode	Peluang					Dampak				
					1	2	3	4	5	1	2	3	4	5
1	Faktor Manusia	Berdesakan saat naik atau turun dari kereta	Penumpang terjatuh dari peron ke jalur kereta	X1	3	2					1	4		
		Bermain-main di area peron	Penumpang tertabrak kereta	X2a	1	3		1		1		1		3
			Penumpang terjatuh dari peron ke jalur kereta	X2b	1	2	1	1		1	1	2	1	
		Membawa barang bawaan yang berat	Penumpang terjatuh	X3	1	3	1				3		2	
		Staf tidak mematuhi SOP dalam penanganan kargo dan penggunaan peralatan berat	Staf stasiun mengalami cedera	X4	1	1	3			1	1		2	1
		Masinis kelelahan fisik/*micro sleep*	Kereta menabrak stasiun	X5a	5					3			1	1
			Tabrakan antar kereta	X5b	5					3			1	1
		Tidak menyimpan barang dengan benar	Kehilangan dan kejahatan seperti pencurian	X6	1		2	1	1	2	1	1		1
		Tindakan vandalisme	Penumpang mengalami cedera	X7	2	2	1					2	1	2
		Terorisme	Terjadinya tindakan kekerasan	X8	4		1			1		1		3
2	Faktor fasilitas pengaman	Peron rusak	Penumpang terjatuh dari peron ke jalur kereta	X9	2		3			1	1	2	1	
		Kurangnya pegangan tangan pada tangga	Penumpang terjatuh di tangga	X10	1	2	2			1	1	2	1	

Tabel 4. Hasil Rekapitulasi Analisis Kuesioner

No.	Faktor	Penyebab	Risiko	Kode	Peluang					Dampak				
					1	2	3	4	5	1	2	3	4	5
		Pintu dan gerbang rusak	Penumpang terjebak atau terjatuh	X11	1		1	3		2		2		1
		Rambu tidak lengkap	Penumpang terjebak di jalur yang tidak aman atau area berbahaya	X12		2	1	1	1	1			1	3
3	Faktor teknologi	Kegagalan sistem sinyal	Tabrakan antar kereta	X13		2	2	1					1	4
		Korsleting atau kegagalan peralatan elektronik	Kebakaran	X14	1	1	3			1			1	3
4	Faktor kondisi alam/ lingkungan	Cuaca buruk seperti hujan deras	Penumpang terjatuh atau tergelincir	X15	1		4			1		2		2
		Bencana alam seperti gempa, banjir atau tsunami	Penumpang dan staf mengalami cedera atau kematian	X16	2		3			1			2	2

5. KESIMPULAN

Dari hasil analisis yang telah dilakukan didapatkan kesimpulan bahwasanya hasil dari identifikasi risiko potensi celaka pada penumpang di Stasiun Kereta Api Bandar Lampung didapatkan 16 variabel penyebab risiko. Di antaranya adalah berdesakan saat naik atau turun dari kereta (X1), bermain-main di area peron (X2), membawa barang bawaan yang berat (X3), staf tidak mematuhi SOP dalam penanganan kargo dan penggunaan peralatan berat (X4), masinis kelelahan fisik/*micro sleep* (X5), tidak menyimpan barang dengan benar (X6), tindakan vandalisme (X7), terorisme (X8), peron rusak (X9), kurangnya pegangan tangan pada tangga (X10), pintu dan gerbang rusak (X11), rambu tidak lengkap (X12), kegagalan sistem sinyal (X13), korsleting atau kegagalan peralatan elektronik (X14), cuaca buruk seperti hujan deras (X15), bencana alam seperti gempa, banjir atau tsunami (X16).

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INFORMASI ARTIKEL

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Keterlambatan proyek, manajemen konstruksi, proyek infrastruktur, strategi mitigasi, *systematic literature review*

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ABSTRAK

Keterlambatan proyek infrastruktur merupakan permasalahan yang umum terjadi di sektor konstruksi Indonesia dan berdampak pada peningkatan biaya, penurunan mutu, dan gangguan pelayanan publik. Penelitian ini bertujuan untuk mengidentifikasi faktor-faktor penyebab keterlambatan dan strategi mitigasinya melalui pendekatan *systematic literature review* (SLR). Sebanyak 13 artikel ilmiah terpilih yang diterbitkan antara tahun 2020 – 2025 dianalisis secara tematik. Hasil kajian menunjukkan bahwa terdapat 80 entri faktor penyebab keterlambatan yang dapat diklasifikasikan ke dalam Sembilan kategori utama, dengan tiga kategori paling dominan yaitu faktor teknis (22 kemunculan), manajerial (20 kemunculan), dan kesternal (18 kemunculan). Faktor teknis mencakup kesalahan desain, metode pelaksanaan yang tidak sesuai, dan kondisi lapangan yang tidak terprediksi. Faktor manajerial berkaitan dengan lemahnya perencanaan, koordinasi, serta dokumentasi proyek, sedangkan faktor eksternal meliputi cuaca buruk, pembebasan lahan, dan kebijakan regulasi. Strategi mitigasi yang ditemukan mencakup penggunaan teknologi (BIM), penjadwalan adaptif, pelatihan SDM, penguatan logistic, dan koordinasi lintas instansi. Temuan ini menegaskan pentingnya pendekatan secara menyeluruh dan kolaboratif dalam pengelolaan keterlambatan proyek infrastruktur.

1. PENDAHULUAN

Keterlambatan dalam pelaksanaan proyek infrastruktur menjadi salah satu tantangan utama yang sering dihadapi dalam sektor konstruksi, baik pada proyek skala nasional maupun daerah [1]. Dampak dari keterlambatan ini tidak hanya meliputi peningkatan biaya proyek, namun juga penurunan kualitas hasil konstruksi, gangguan pelayanan publik, serta berkurangnya kepercayaan *stakeholder* terhadap penyelenggara proyek [2]. Di Indonesia, data dari Badan Pemeriksa Keuangan (2022) dan Kementerian PUPR menunjukkan bahwa sejumlah proyek strategis nasional mengalami deviasi waktu signifikan akibat berbagai faktor, baik teknis maupun non-teknis.

Berbagai studi telah mengidentifikasi beragam penyebab keterlambatan proyek, mulai dari perencanaan yang kurang matang [3], permasalahan komunikasi antar pihak yakni owner – kontraktor – pengawas [4], kendala cuaca yang menyebabkan kerusakan material [5], hingga keterbatasan sumber daya manusia [6] dan alat [7]. Namun demikian, belum banyak studi yang secara sistematis mensintesis faktor-faktor tersebut dalam konteks proyek infrastruktur di Indonesia, terutama dalam kurun waktu lima tahun terakhir.

Penelitian ini bertujuan untuk:

- Mengidentifikasi dan mengklasifikasikan faktor penyebab keterlambatan proyek infrastruktur di Indonesia berdasarkan studi literatur tahun 2020 ke atas.
- Merumuskan strategi manajemen yang digunakan atau disarankan untuk mengatasi kendala keterlambatan proyek infrastruktur di Indonesia.
- Menyintesis temuan dari berbagai studi untuk memberikan rekomendasi berbasis literatur dalam manajemen proyek infrastruktur.

Melalui pendekatan *systematic literature review* (SLR), penelitian ini diharapka dapat memberikan kontribusi konseptual dan praktis terhadap pengelolaan proyek konstruksi di Indonesia, serta menjadi dasar pengambilan keputusan bagi pelaku industri dan regulator.

2. TINJAUAN PUSTAKA

Manajemen Proyek Konstruksi

Manajemen proyek konstruksi mencakup proses perencanaan, pelaksanaan, pengawasan, dan pengendalian terhadap elemen-elemen proyek seperti waktu, biaya, mutu, dan risiko [8]. Secara umum, proses pelaksanaan proyek konstruksi harus memperhatikan tiga kendala (*triple constrain*), yaitu (a) kendala kualitas, yaitu sesuai dengan spesifikasi yang ditetapkan; (b) kendala waktu, yaitu sesuai dengan jadwal pelaksanaan yang ditetapkan (*time schedule*); dan (c) kendala biaya, yaitu tidak melebihi biaya yang direncanakan. Ketiga kendala tersebut harus dipenuhi secara bersamaan [9]. Dalam konteks proyek infrastruktur, pengelolaan waktu menjadi aspek krusial mengingat kompleksitas teknis dan keterlibatan banyak pihak dalam pelaksanaan proyek.

Keterlambatan Proyek

Keterlambatan dalam proyek dapat didefinisikan sebagai keterlambatan penyelesaian, baik melebihi tanggal yang ditentukan dalam kontrak maupun tanggal yang ditentukan oleh para stakeholder [10]. Menurut Alaghbari et al (2007), keterlambatan dapat diartikan sebagai pelaksanaan tugas yang berlangsung lebih lambat dari yang diperkirakan atau penyelesaian pekerjaan yang awalnya direncanakan untuk diselesaikan lebih cepat. Di industri konstruksi, keterlambatan dalam bentuk apa pun dapat menimbulkan berbagai dampak dan konsekuensi, yang berpotensi menyebabkan risiko baik yang terlihat maupun yang tidak terlihat. Keterlambatan umumnya diklasifikasikan menjadi dua: delay yang dapat dikendalikan (*controllable*) dan delay yang tidak dapat dikendalikan (*uncontrollable*).

Faktor Penyebab Keterlambatan

Berbagai studi mengungkapkan bahwa keterlambatan proyek dapat disebabkan oleh:

- Faktor teknis, seperti kesalahan desain oleh perencana [12] dan perbaikan pekerjaan tidak sesuai spesifikasi [13].
- Faktor manajerial, seperti kurangnya pengawasan owner dan konsultan, risiko proyek tidak dimitigasi dengan benar [14], ketidakpastian kelanjutan proyek [15], dan penjadwalan yang kurang efektif [16].
- Faktor eksternal, seperti cuaca ekstrem [17] dan keterlambatan penyerahan lahan [18].

Strategi Manajemen Keterlambatan

Upaya mengatasi keterlambatan umumnya dilakukan melalui:

- Meningkatkan efektivitas komunikasi antar pihak [19].
- Penggunaan teknologi digital seperti BIM dan *software* manajemen [20].
- Penjadwalan ulang pekerjaan serta menunda pekerjaan lapangan yang rentan terhadap cuaca buruk dan menggantinya dengan pekerjaan lain [21].

3. METODOLOGI PENELITIAN

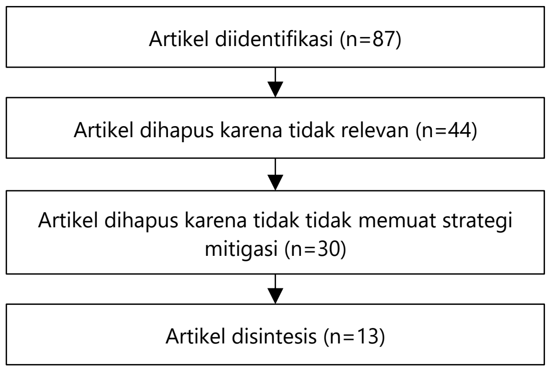
Penelitian ini menggunakan pendekatan *Systematic Literature Review* (SLR) untuk mengidentifikasi dan menganalisis faktor-faktor penyebab keterlambatan proyek infrastruktur di Indonesia serta strategi manajerial yang dapat diterapkan untuk mengatasinya. Pendekatan ini dilakukan secara sistematis dan terstruktur agar hasil yang diperoleh valid.

SLR dilakukan dengan mengacu pada tahapan dari Kitchenham (2004), yang meliputi:

- Formulasi pertanyaan penelitian (*research question*)
  a. Apa saja faktor utama penyebab keterlambatan proyek infrastruktur di Indonesia?
  b. Strategi manajemen apa yang telah terbukti efektif dalam mengatasi keterlambatan proyek infrastruktur?
- Kriteria inklusi dan eksklusi
  a. Inklusi
    1) Artikel jurnal, prosiding, dan laporan ilmiah yang dipublikasikan antara tahun 2020 – 2025
    2) Fokus pada proyek infrastruktur konstruksi (jalan, gedung, jembatan, dan lain-lain) di Indonesia
    3) Studi yang mengidentifikasi faktor penyebab keterlambatan atau strategi manajemen keterlambatan
    4) Publikasi dalam bahasa Indonesia atau Inggris
  b. Eksklusi
    1) Artikel yang tidak dapat diakses secara penuh
    2) Studi kasus tidak dilakukan pada proyek infrastruktur Indonesia
    3) Literatur sebelum tahun 2020
- Sumber literatur
  Literatur dikumpulkan dari berbagai database ilmiah, seperti *Google Scholar, ScienceDirect, Scopus,* dan Garuda.
- Kata kunci pencarian
  Kata kunci yang digunakan dalam pencarian literatur:
  a. *Construction delay*
  b. *Project delay*
  c. Keterlambatan proyek konstruksi
  d. Manajemen konstruksi
  e. Faktor keterlambatan proyek
- Analisis data
  Literatur yang lolos disintesis menggunakan pendekatan deskriptif dan tematik, serta diklasifikasikan ke dalam kelompok faktor keterlambatan dan strategi mitigasinya.

4. HASIL DAN PEMBAHASAN

Seluruh proses pencarian dan pemilihan literatur dalam penelitian ini, termasuk tahap pengumpulan awal, pengecekan relevansi, penghapusan artikel yang tidak memenuhi kriteria inklusi, hingga penentuan artikel akhir yang dianalisis, divisualisasikan dalam diagram PRISMA untuk memperlihatkan alur seleksi yang transparan dan sistematis Gambar 1.



Gambar 1 Seleksi Literatur Diagaram PRISMA

Klasifikasi Faktor Penyebab Keterlambatan

Berdasarkan hasil telaah terhadap 13 artikel terpilih, ditemukan sejumlah faktor penyebab keterlambatan proyek infrastruktur yang dapat diklasifikasikan ke dalam beberapa kategori utama (Tabel 1). Ringkasan klasifikasi dan distribusi masing-masing kategori berdasarkan frekuensi kemunculannya disajikan dalam Lampiran 1.

Tabel 1. Kategori Faktor Keterlambatan Dominan

No	Kategori Faktor	Jumlah Kemunculan	Catatan Klasifikasi Turunan
1.	Teknis	22	Desain, lingkungan, operasional, struktural, perencanaan, proyek
2.	Manajerial	20	Perencanaan, konsultan, komunikasi, organisasi, pengawasan
3.	Eksternal	18	Non-teknis, sosial, alam, ekonomi, lingkungan, politis
4.	SDM (Sumber Daya Manusia)	12	Tenaga kerja, pengorganisasian, internal
5.	Operasional	11	Peralatan, sistem, teknis/operasional
6.	Material/ Logistik	7	Logistik, material, operasional/material
7.	Keuangan	6	Internal, kontraktual, finansial
8.	Regulasi/ Administratif	3	Regulasi, administratif
9.	K3	2	Keselamatan

Pembahasan

Berdasarkan hasil klasifikasi terhadap 80 entri dari 13 artikel yang dianalisis secara sistematis, ditemukan bahwa penyebab keterlambatan proyek infrastruktur di Indonesia dapat dikelompokkan ke dalam 9 kategori utama. Tabel 2 menunjukkan bahwa tiga kategori paling dominan adalah Teknis (22 kemunculan), Manajerial (20 kemunculan), dan Eksternal (18 kemunculan).

Faktor teknis banyak muncul dalam bentuk kesalahan desain, metode pelaksanaan yang tidak tepat, kondisi tanah tak terduga, dan kurangnya pengujian teknis serta kesiapan alat. Kategori ini mencakup sub klasifikasi seperti desain struktural, geoteknik, dan logistik teknis. Sedangkan faktor manajerial mencakup perencanaan yang tidak matang, ketidaksiapan dokumen tender, lemahnya koordinasi, dan keterlambatan dalam proses administrasi proyek. Banyak faktor dalam kategori ini berasal dari kurangnya integrasi antar pihak (*owner*, konsultan, kontraktor), buruknya komunikasi, hingga perubahan desain yang terlambat.

Sementara itu, faktor eksternal sebagian besar berasla dari cuaca buruk, pembebasan lahan yang lambat, kebijakan regulasi pemerintah, serta kondisi lingkungan proyek yang tidak mendukung. Beberapa klasifikasi yang tercatat sebagai non-teknis, sosial, alam, ekonomi, lingkungan, dan politis, telah dikelompokkan dalam kategori ini karena berada di luar kontrol kontraktor langsung.

Faktor SDM (12 kemunculan) juga signifikan, termasuk rendahnya keterampilan tenaga kerja, kurangnya pelatihan, manajemen tim yang tidak efektif, hingga sistem kerja yang kurang adaptif. Kategori ini penting karena kualitas sumber daya manusia sangat menentukan keberhasilan di lapangan. Selain itu, kategori operasional (11 kemunculan) meliputi permasalahan seperti kerusakan alat, produktivitas peralatan yang rendah, serta sistem kerja dan logistik yang belum optimal. Adapun kategori material/logistik (7 kemunculan) menyoroti ketidaktepatan waktu pengadaan, keterbatasan gudang, dan ketergantungan terhadap vendor tertentu.

Kategori keuangan (6 kemunculan) sering dikaitkan dengan keterlambatan pembayaran dari pihak *owner*, kesulitan arus kas kontraktor, dan ketidaksesuaian termin pembayaran dengan progres proyek. Sementara kategori regulasi/administratif dan K3 masing-masing muncul 3 dan 2 kali. Meskipun demikian, kedua kategori tersebut berdampak besar, terutama berkaitan dengan kelengkapan izin, keselamatan kerja, dan risiko hukum.

Secara keseluruhan, hasil ini menunjukkan bahwa keterlambatan dalam proyek infrastruktur tidak disebabkan oleh satu faktor saja, melainkan merupakan hasil dari berbagai aspek yang saling berkaitan. Hal ini menegaskan pentingnya pendekatan yang menyeluruh dan kolaboratif dalam pelaksanaan proyek konstruksi.

Adapun strategi mitigasi yang ditemukan dalam literatur cukup beragam, mulai dari yang bersifat teknis hingga manajerial, seperti:

- Penggunaan *Building Information Modeling* (BIM) dan *software* manajemen proyek untuk sinkronisasi desain dan perencanaan,
- Penjadwalan fleksibel berbasis kurva S dan *buffer* waktu,
- Pelatihan teknis dan manajerial untuk pekerja dan pengawas,
- Penguatan sistem logistik proyek dan manajemen material,
- Koordinasi lintas instansi untuk percepatan perizinan dan pembebasan lahan.

Dengan banyaknya penyebab yang beragam, hasil sintesis ini menunjukkan bahwa keterlambatan proyek infrastruktur di Indonesia tidak dapat diselesaikan hanya dengan satu solusi. Diperlukan pendekatan yang menyeluruh, yang memperhatikan aspek teknis, manajerial, sosial, dan lingkungan untuk mengurangi risiko keterlambatan secara signifikan.

5. KESIMPULAN

Berdasarkan analisis terhadap 13 artikel terpilih yang telah disintesis dan 80 entri yang dianalisis, ditemukan sembilan kategori utama penyebab keterlambatan. Tiga kategori yang paling dominan adalah adalah faktor teknis, manajerial, dan eksternal, yang masing-masing mencakup persoalan desain, metode pelaksanaan, kelemahan koordinasi, serta faktor lingkungan dan regulasi di luar kendali kontraktor. Keterlambatan proyek terbukti bersifat multidimensional yaitu muncul dari berbagai faktor yang saling berkaitan.

Strategi mitigasi yang ditemukan dalam literatur meliputi penggunaan teknologi seperti BIM dan *software* manajemen proyek, penjadwalan adaptif dengan *buffer* waktu, pelatihan SDM, penguatan logistik, serta koordinasi lintas instansi. Hal ini menunjukkan bahwa penanganan keterlambatan proyek tidak dapat diselesaikan dengan cara yang setengah-setengah. Sebaliknya, diperlukan strategi yang komprehensif dan terintegrasi mulai dari tahap perencanaan hingga pelaksanaan proyek.

Untuk meminimalkan keterlambatan proyek infrastruktur, praktisi dan manajer proyek disarankan untuk melakukan evaluasi risiko sejak tahap perencanaan dengan menggunakan teknologi seperti BIM, serta meningkatkan pelatihan tim proyek. Bagi peneliti selanjutnya diharapkan tidak hanya mengidentifikasi faktor keterlambatan, tetapi juga menguji efektivitas strategi mitigasi dalam konteks lokal. Sementara itu, pemerintah perlu mendukung dengan kebijakan yang mendorong adopsi teknologi konstruksi, memperkuat sistem pengadaan, dan menyelaraskan regulasi agar proyek dapat berjalan lebih efisien dan terintegrasi.

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Lampiran 1. Hasil Sintesis Artikel Terpilih

No	Sumber (Penulis, Tahun)	Faktor Penyebab	Klasifikasi Faktor	Lokasi Studi	Strategi Mitigasi
1.	Laksana Putra et al., 2025 [22]	Persetujuan material yang lama	Eksternal	Probolinggo	Persetujuan material minimal H-7 sebelum pelaksanaan; penggunaan *software* manajemen proyek
2.	Laksana Putra et al., 2025 [22]	Perubahan ruang lingkup pekerjaan	Eksternal	Probolinggo	Penggunaan BIM untuk visualisasi dan deteksi dini konflik; rapat koordinasi intensif saat perencanaan
3.	Laksana Putra et al., 2025 [22]	Tambahan pekerjaan yang sering terjadi	Internal	Probolinggo	Evaluasi dampak penambahan pekerjaan pada waktu dan biaya; dokumentasi tambahan pekerjaan
4.	Laksana Putra et al., 2025 [22]	Identifikasi jenis pekerjaan yang tidak lengkap	Internal	Probolinggo	Review mendalam dokumen proyek; simulasi proyek menggunakan *software* konstruksi
5.	Irawan, 2025 [23]	Lahan belum bebas	Non-teknis	Sumatra, Kalimantan, Jawa	Percepatan pembebasan lahan; koordinasi intensif antar instansi
6.	Irawan, 2025 [23]	Perencanaan dan penjadwalan yang tidak tepat	Manajerial/teknis	Sumatra, Kalimantan, Jawa	Review jadwal lebih realistis; masukkan risiko sejak awal dalam perencanaan
7.	Irawan, 2025 [23]	Kekurangan tenaga kerja, alat, dan material	Operasional/teknis	Sumatra, Kalimantan, Jawa	Estimasi kebutuhan lebih akurat; pengadaan material dan SDM secara bertahap
8.	Irawan, 2025 [23]	Perubahan desain dan spesifikasi	Teknis	Sumatra, Kalimantan, Jawa	Koordinasi desain lebih awal; penguncian scope pekerjaan sejak awal kontrak
9.	Irawan, 2025 [23]	Cuaca ekstrem	Eksternal/non teknis	Sumatra, Kalimantan, Jawa	Penjadwalan fleksibel; penambahan buffer waktu dan peralatan proteksi cuaca
10.	Rita et al., 2021 [2]	Kekurangan material	Operasional/ material	Sumatera Barat	Manajemen material yang baik dan pengaturan suplai
11.	Rita et al., 2021 [2]	Lambatnya pembebasan lahan	Non teknis/ eksternal	Sumatera Barat	Koordinasi lintas instansi dan valuasi ganti untung
12.	Rita et al., 2021 [2]	Manajemen lapangan kontraktor yang buruk	Manajerial/internal	Sumatera Barat	Peningkatan kompetensi manajeman proyek lapangan
13.	Rita et al., 2021 [2]	Perencanaan dan penjadwalan tidak efektif	Manajerial/ konsultan	Sumatera Barat	Survei lapangan lebih rinci dan penguncian desain awal
14.	Rita et al., 2021 [2]	Kesulitan keuangan kontraktor	Finansial/ internal	Sumatera Barat	Pengawasan penggunaan uang muka dan termin pembayaran

Lampiran 1. Hasil Sintesis Artikel Terpilih

No	Sumber (Penulis, Tahun)	Faktor Penyebab	Klasifikasi Faktor	Lokasi Studi	Strategi Mitigasi
15.	Rita et al., 2021 [2]	Kesalahan desain	Teknis/konsultan	Sumatera Barat	Survei pendahuluan yang akurat, review desain lebih awal
16.	Rita et al., 2021 [2]	Kurangnya peralatan	Opersional	Sumatera Barat	Manajemen alat yang memadai dan logistik terencana
17.	Rita et al., 2021 [2]	Rendahnya kualitas SDM kontraktor	SDM/internal	Sumatera Barat	Pelatihan teknis dan sistem seleksi pekerja
18.	Rita et al., 2021 [2]	Kondisi lapangan proyek tidak terduga	Teknis/lingkungan	Sumatera Barat	Survei topografi lebih lengkap dan penyesuaian metode
19.	Rita et al., 2021 [2]	Peralatan yang rusak	Operasional/ teknis	Sumatera Barat	Pemeliharaan alat yang rutin dan penggantian alat lama
20.	Ananda et al., 2021 [1]	Metode konstruksi yang tidak tepat	Teknis/internal	Pontianak	Penyesuaian metode konstruksi dengan kondisi proyek; evaluasi teknis awal yang komprehensif
21.	Ananda et al., 2021 [1]	Kualitas tenaga kerja yang buruk	SDM/internal	Pontianak	Seleksi dan pelatihan tenaga kerja; peningkatan kompetensi
22.	Ananda et al., 2021 [1]	Kekurangan material	Operasional/ material	Pontianak	Perencanaan pengadaan material lebih ketat; kontrol logistik proyek
23.	Ananda et al., 2021 [1]	Kekurangan tenaga kerja	SDM/internal	Pontianak	Tambahan pekerja, manajemen SDM padat karya yang lebih efisien
24.	Windi et al., 2024 [24]	Keterlambatan pengadaan material	Operasional/ material	Bekasi	Perencanaan logistik dan pengadaan lebih awal; komunikasi vendor yang lebih intensif
25.	Windi et al., 2024 [24]	Pekerjaan tambahan di luar kontrak (addendum)	Non teknis/ perubahan scope	Bekasi	Koordinasi perubahan scope sejak awal; buffer waktu pada jadwal
26.	Windi et al., 2024 [24]	Perubahan volume pekerjaan	Teknis/ perencanaan	Bekasi	Review dokumen desain dan kuantitas lebih awal
27.	Windi et al., 2024 [24]	Kurangnya efektivitas perencaan proyek awal	Manajerial/ internal	Bekasi	Penjadwalan realistis berbasis kurva S; evaluasi jadwal dan progres rutin
28.	Liespono and Tjendani, 2023 [25]	Upah tenaga kerja tidak kompetitif	SDM/internal	Surabaya	Evaluasi sistem pembayaran; penyesuaian insentif dan bonus
29.	Liespono and Tjendani, 2023 [25]	Kondisi lingkungan kerja tidak optimal	Lingkungan/ eksternal	Surabaya	Penyesuaian jam kerja, penggunaan alat protektif, manajemen waktu adaptif
30.	Liespono and Tjendani, 2023 [25]	Kurangnya pengalaman tenaga kerja	SDM/internal	Surabaya	Pelatihan tenaga kerja, penempatan berdasarkan kompetensi, mentoring onsite

Lampiran 1. Hasil Sintesis Artikel Terpilih

No	Sumber (Penulis, Tahun)	Faktor Penyebab	Klasifikasi Faktor	Lokasi Studi	Strategi Mitigasi
31.	Albar and Johari, 2023 [26]	Gambar kerja tidak memadai	Perencanaan/ teknis	Garut	Perencanaan waktu pembuatan gambar yang lebih baik
32.	Albar and Johari, 2023 [26]	Estimasi biaya tidak sesuai dengan pelaksanaan	Perencanaan/ manajerial	Garut	Survei harga pasar, perhitungan volume yang lebih teliti
33.	Albar and Johari, 2023 [26]	Koordinasi antar penyedia jasa yang lemah	Pengorganisasian/ SDM	Garut	Komunikasi intensif dan penjadwalan koordinasi rutin
34.	Albar and Johari, 2023 [26]	Manajemen tenaga kerja dan peralatan yang buruk	Pelaksanaan/SDM	Garut	Perbaikan sistem kerja dan penggunaan metode alternatif bila perlu
35.	Albar and Johari, 2023 [26]	Pelaksanaan terlambat dari rencana	Pengawasan/ eksternal	Garut	Analisis kendala lapangan dan percepatan progres
36.	Albar and Johari, 2023 [26]	Keterlambatan pembayaran dari owner	Pengawasan/ finansial	Garut	Evaluasi pelaksanaan sesuai anggaran dan termin kontrak
37.	Albar and Johari, 2023 [26]	Mutu beton tidak sesuai spesifikasi	Pelaksanaan/ teknis	Garut	Pengujian mutu beton (*slump test*) dan pengawasan ketat saat pengecoran
38.	Arwadi et al., 2025 [27]	Perencanaan yang tidak memadai	Manajerial/ perencanaan	Indonesia	Konsultasi awal, pelaporan berkala
39.	Arwadi et al., 2025 [27]	Komunikasi stakeholder yang buruk	Manajerial/ komunikasi	Indonesia	Kolaborasi lintas fungsi, pemetaan peran stakeholder
40.	Arwadi et al., 2025 [27]	Estimasi waktu dan biaya yang tidak realistis	Teknis/ perencanaan	Indonesia	Spervisi ketat, validasi estimasi sejak awal
41.	Arwadi et al., 2025 [27]	Sistem pelaksanaan proyek yang tidak memadai	Operasional/ sistem	Indonesia	Penguatan manajemen integrasi dan sistem pengendalian proyek
42.	Arwadi et al., 2025 [27]	Analisis dan desain yang tidak tepat	Teknis/desain	Indonesia	Review desain menyeluruh, integrasi awal antara konsultan dan kontraktor
43.	Sitanggang et al., 2025 [28]	Insolvabilitas pemilik proyek	Finansial/ kontraktual	Indonesia	Sistem jaminan proyek, kontrak dengan klausul penyelamatan
44.	Sitanggang et al., 2025 [28]	Risiko inflasi dan kenaikan biaya tak terduga	Eksternal/ekonomi	Indonesia	Penyesuaian kontrak, eskalasi biaya dalam rencana anggaran
45.	Sitanggang et al., 2025 [28]	Keterlambatan dalam persetujuan administratif	Regulasi/eksternal	Indonesia	Koordinasi lintas instansi sejak awal, izin paralel
46.	Sitanggang et al., 2025 [28]	Risiko subsoil/geoteknik tak teridentifikasi	Teknis/lingkungan	Indonesia	Survei tanah awal mendalam, uji geoteknik komprehensif
47.	Sitanggang et al., 2025 [28]	Ketidaksiapan dokumen tender dan kontrak	Manajerial/ perencanaan	Indonesia	Standarisasi dokumen, audit awal tender

Lampiran 1. Hasil Sintesis Artikel Terpilih

No	Sumber (Penulis, Tahun)	Faktor Penyebab	Klasifikasi Faktor	Lokasi Studi	Strategi Mitigasi
48.	Sitanggang et al., 2025 [28]	Rsiko kelambatan akibat pengelolaan tim buruk	Manajerial/SDM	Indonesia	Pelatihan manajerial proyek, penguatan sistem komunikasi proyek
49.	Vianthi et al., 2024 [29]	Perubahan kebijakan upah minimum	Eksternal/politis	Denpasar	Menambah anggaran item lain-lain
50.	Vianthi et al., 2024 [29]	Kebisingan akibat alat konstruksi	Lingkungan/ eksternal	Denpasar	Pemotongan dalam ruangan
51.	Vianthi et al., 2024 [29]	Ekspektasi owner yang tinggi	Perencanaan/ manajerial	Denpasar	Persetujuan owner sebelum kerja
52.	Vianthi et al., 2024 [29]	Perubahan desain	Perencanaan/ manajerial	Denpasar	Persetujuan desain lebih awal
53.	Vianthi et al., 2024 [29]	Terlambatnya pencairan dana	Keuangan/internal	Denpasar	Komitmen pencairan tertulis
54.	Vianthi et al., 2024 [29]	Cuaca buruk	Alam/eksternal	Denpasar	Maksimalkan kerja saat cuaca baik
55.	Vianthi et al., 2024 [29]	Keterlambatan pekerjaan jalur kritis	Proyek/teknis	Denpasar	Pengendalian ketat terhadap jadwal
56.	Vianthi et al., 2024 [29]	Kesulitan transportasi alat berat	Teknis/ operasional	Denpasar	Pengiriman malam hari
57.	Vianthi et al., 2024 [29]	Kekurangan tempat penyimpanan material	Teknis/logistik	Denpasar	Pengadaan sesuai kebutuhan
58.	Vianthi et al., 2024 [29]	Kekurangan tenaga kerja	SDM/internal	Denpasar	Koordinasi dengan mandor
59.	Vianthi et al., 2024 [29]	Kurangnya pemahaman teknis	SDM/internal	Denpasar	Pelatihan teknis sebelum kerja
60.	Vianthi et al., 2024 [29]	Tidak ada rambu-rambu peringatan	K3/keselamatan	Denpasar	Pemasangan rambu sebelum kerja
61.	Vianthi et al., 2024 [29]	Ketidakpatuhan pekerja terhadap K3	K3/keselamatan	Denpasar	Pelatihan dan pengarahan K3
62.	Sandra Sarkisian et al., 2023 [30]	Kerusakan alat berat	Operasional/ peralatan	Sidoarjo	Pengawasan berkala terhadap alat dan inventaris
63.	Sandra Sarkisian et al., 2023 [30]	Lokasi site sulit (akses terbatas)	Lingkungan/ eksternal	Sidoarjo	Adaptasi jadwal dan pembagian zona/scope kerja
64.	Sandra Sarkisian et al., 2023 [30]	Perubahan kedalaman tiang pancang	Teknis/desain struktural	Sidoarjo	Pengkajian ulang jadwal dan survei lapangan lebih awal
65.	Sandra Sarkisian et al., 2023 [30]	Terlambatnya pengiriman material	Logistik/material	Sidoarjo	Pengawasan penjadwalan material dan fabrikasi
66.	Sandra Sarkisian et al., 2023 [30]	Lamanya proses fabrikasi material	Operasional/ material	Sidoarjo	Penjadwalan ulang dan kontrol pengadaan
67.	Arafat, 2024 [31]	Perubahan desain oleh pemilik	Manajerial/teknis	Riau (Jembatan Perawang)	Perkuat pengendalian desain dan koordinasi awal
68.	Arafat, 2024 [31]	Persetujuan dokumen tertunda	Manajerial/ administratif	Riau	Mempercepat proses birokrasi dan koordinasi dokumen
69.	Arafat, 2024 [31]	Masalah keuangan kontraktor	Keuangan/internal	Riau	Perbaikan sistem pembayaran; alokasi dana cadangan

Lampiran 1. Hasil Sintesis Artikel Terpilih

No	Sumber (Penulis, Tahun)	Faktor Penyebab	Klasifikasi Faktor	Lokasi Studi	Strategi Mitigasi
70.	Arafat, 2024 [31]	Keterlambatan pengadaan material	Material/ operasional	Riau	Penguatan kontrol logistik dan pengadaan material
71.	Arafat, 2024 [31]	Kurangnya tenaga kerja	SDM/internal	Riau	Penyesuaian rencana tenaga kerja dan pelatihan
72.	Arafat, 2024 [31]	Cuaca buruk	Eksternal/ alam	Riau	Rencana kontingensi dan penyesuaian jadwal kerja
73.	Arafat, 2024 [31]	Gangguan keamanan di lapangan	Eksternal/ sosial	Riau	Manajemen keamanan proyek dan perlindungan aset
74.	Arafat, 2024 [31]	Masalah perizinan	Regulasi/ administratif	Riau	Percepat proses perizinan dan monitoring progres izin
75.	Arafat, 2024 [31]	Kesalahan perencanaan proyek	Manajerial/ perencanaan	Riau	Revisi rencana proyek lebih realistis dan terintegrasi
76.	Arafat, 2024 [31]	Produktivitas peralatan rendah	Operasional/ peralatan	Riau	Peremajaan peralatan dan pemeliharaan berkala
77.	Arafat, 2024 [31]	Keterlambatan pembebasan lahan	Eksternal/sosial	RIau	Koordinasi antar instansi, negosiasi percepatan pembebasan
78.	Arafat, 2024 [31]	Kurangnya koordinasi stakeholder	Manajerial/ organisasi	Riau	Komunikasi intensif, forum koordinasi berkala
79.	Bhekti et al., 2023 [32]	Keterlambatan pembayaran dari owner	Keuangan/internal	Indonesia (proyek submarine)	Koordinasi intensif dengan owner diskusi dampak keterlambatan
80.	Bhekti et al., 2023 [32]	Cuaca tidak baik	Eksternal/alam	Indonesia (proyek submarine)	Penjadwalan proyek sesuai tren cuaca dan buffer waktu

Analisis *Time History* terhadap Kinerja Struktur Gedung Baja Bresing Konsentrik (*Inverted-V*)

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INFORMASI ARTIKEL

Kata Kunci:
bresing konsentrik, gedung baja, kinerja struktur, *time history*

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ABSTRAK

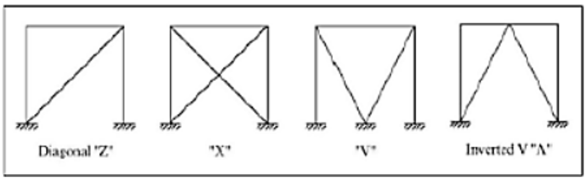
Indonesia adalah negara yang memiliki aktivitas seismik cukup tinggi, sehingga mendorong perkembangan sistem struktur gedung baja tahan gempa. Untuk mendapatkan perilaku struktur yang lebih baik terhadap beban seismik, maka perlu diaplikasikan bresing konsentrik pada struktur gedung baja. Penelitian ini bertujuan untuk membandingkan kinerja struktur gedung baja bresing konsentrik tipe *inverted-v* dengan variasi profil bresing yaitu *equal angle* (model 1) dan *hollow* (model 2), yang memiliki luas penampang hampir sama. Analisis kinerja struktur menggunakan *time history* pada perangkat lunak ETABS. Kinerja struktur yang dibandingkan meliputi berat seismik efektif, gaya geser dasar, simpangan antar lantai, pengaruh P-Δ, rasio kapasitas penampang, dan tingkat kinerja berdasarkan FEMA 356. Setelah dilakukan analisis kinerja struktur secara keseluruhan, baik *equal angle* maupun *hollow*, dapat diaplikasikan sebagai bresing karena berada pada tingkat kinerja yang sama yaitu *Immediate Occupancy* (IO). Namun, dari rasio kapasitas penampang ternyata model 2 lebih unggul dibandingkan dengan model 1, yaitu sebesar 0,993.

1. PENDAHULUAN

Perkembangan ilmu terkait gempa dan bangunan gedung tahan gempa saat ini sudah maju, hal ini didukung karena Indonesia adalah negara yang memiliki aktivitas gempa cukup tinggi. Salah satu struktur bangunan gedung yang memiliki kinerja yang baik untuk digunakan dalam menahan beban gempa adalah bangunan gedung dengan material baja, karena baja memiliki daktilitas yang tinggi [1].

Seiring dengan berjalannya perkembangan terkait sistem struktur tahan gempa maka semakin banyak inovasi pada struktur bangunan gedung di Indonesia. Salah satu inovasi yang berkembang, yaitu dengan penggunaan bresing pada struktur bangunan gedung. Dengan penggunaan bresing pada struktur bangunan gedung baja tahan gempa, maka struktur bangunan gedung diharapkan memiliki kekakuan yang lebih baik dengan deformasi yang dibatasi. Perilaku dan desain sistem rangka bresing ada 2 (dua), yaitu sistem rangka bresing konsentrik (SRBK) [2] [3] [4] dan sistem rangka bresing eksentrik (SRBE).

Penelitian ini dibatasi pada penggunaan bresing secara konsentrik. Umumnya penempatan bresing dilakukan secara menyilang atau diagonal, berfungsi sebagai pengaku suatu portal. Selain itu, penempatan bresing secara diagonal juga menyebabkan bresing akan mampu menahan gaya aksial ketika portal mengalami gaya geser horizontal akibat beban lateral [5]. Bresing konsentrik pada umumnya memiliki 4 tipe bresing, seperti pada Gambar 1.



Gambar 1. Tipe bresing konsentrik [6]

Penggunaan variasi profil bresing pada struktur bangunan gedung juga ternyata memiliki peranan yang cukup signifikan. Berdasarkan penelitian sebelumnya [7], bahwa perbandingan kinerja struktur gedung baja dengan menggunakan profil *hollow* sebagai bresing ternyata memiliki keunggulan yaitu berat struktur yang lebih ringan, sedangkan bresing dengan menggunakan profil *wide flange* (WF) ternyata menghasilkan berat struktur yang lebih berat namun memiliki nilai perpindahan yang lebih rendah.

Struktur bangunan yang diamati adalah struktur naja dengan fungsi hotel yang dibangun di Jakarta. Dengan diasumsikan tanah lunak sedang dengan kategori tanah SD. Berdasarkan Peta gempa terbaru dan SNI 1726:2019 terkait ketahanan gempa untuk bangunan bangunan pada penelitian ini memiliki kategori desain seismik D.

Parameter yang ada di bandingkan pada penelitian ini adalah rasio penampang bresing, deformasi struktur, berat seismik, pengaruh P-Δ, dan penilaian level kinerja dengan menggunakan analisis riwayat waktu berdasarkan FEMA 356. Data gempa yang digunakan untuk analisis riwayat waktu pada penelitian ini adalah El-Centro (California Selatan), Northridge (California), Loma Prieta (California Utara), Denali (Alaska) dan Chi-Chi (Taiwan) yang disesuaikan dengan lokasi gedung yang dimodelkan.

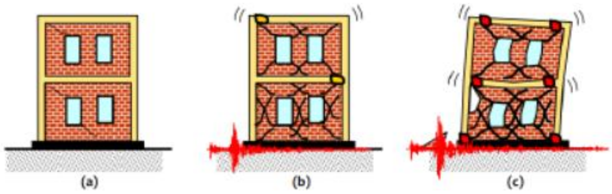
Material baja yang digunakan dalam penelitian ini adalah BJ50 dengan tegangan putus minimum 500 MPa, tegangan leleh 290 MPa dan regangan minimum 16%. Sifat mekanis baja ini telah disesuaikan dengan SNI 03-1729-2020.

2. TINJAUAN PUSTAKA

Bangunan tahan gempa tidak berarti bangunan tidak boleh mengalami kerusakan sama sekali namun struktur tersebut boleh mengalami kerusakan dengan memenuhi syarat yang berlaku yaitu:

a. Pada gempa kecil (gempa yang sering terjadi) yaitu struktur tidak boleh mengalami kerusakan dan masih dapat berfungsi sedangkan kerusakan pada elemen non struktural diizinkan.
b. Pada gempa menengah (jarang terjadi) struktur utama diizinkan rusak namun kerusakan yang dapat diperbaiki dan elemen non struktural diizinkan rusak dan diganti.
c. Pada gempa kuat (jarang terjadi) pada kondisi ini bangunan boleh rusak namun tidak boleh roboh atau runtuh total dengan tujuan untuk mengevakuasi manusia atau penghuni di dalamnya.

Tingkat kerusakan bangunan gedung dapat diilustrasikan seperti pada Gambar 2. (*Earthquake Behaviour of Buildings*, Gurajat State Disaster Management Authority, India)



Gambar 2. Tingkat kerusakan pada bangunan gedung

Untuk menentukan tingkat kinerja struktur dapat menggunakan analisis beban dorong (*pushover analysis*) [5], [8], [9], [10], [11] dan juga analisis riwayat waktu (*time history analysis*). Analisis riwayat waktu adalah suatu metode untuk menentukan riwayat waktu dari respon dinamik struktur bangunan gedung yang berperilaku linier atau non-linier terhadap gerakan tanah akibat gempa (Khoeri, 2019). Analisis ini menggunakan waktu sebagai variabel independen dan perubahan beban yang terjadi sepanjang waktu diambil untuk dipertimbangkan dalam analisis riwayat waktu [12] [11] [13]. Berdasarkan SNI 1726:1019 diisyaratkan minimal tiga gerak tanah yang harus digunakan dengan analisis kondisi, geologi topografi, dan seismotektonik dengan lokasi tempat rekaman gempa berada. Rekaman gempa juga harus dilakukan *matching* ulang dengan respon spektrum sesuai lokasi yang ditinjau.

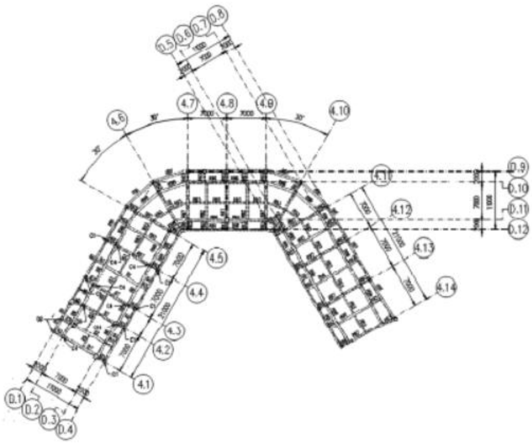
Setelah dianalisis menggunakan analisis riwayat waktu, maka tingkat kinerja struktur diperiksa menggunakan metode FEMA 356/273 untuk *static non linear*. Berdasarkan FEMA 356 terdapat empat level kinerja struktur yaitu:

a. *Operational* (O) merupakan tingkat kinerja struktur yang menunjukkan bangunan gedung tetap dapat beroperasi secara normal setelah terjadi bencana gempa bumi.
b. *Immediate Occupancy* (IO) merupakan tingkat kinerja struktur yang menunjukkan bangunan gedung dapat dihuni kembali setelah terjadinya bencana gempa bumi tanpa kerusakan yang signifikan.
c. *Life Safety* (LS) merupakan tingkat kinerja struktur yang menunjukkan adanya kerusakan pasca gempa bumi yang terjadi signifikan namun bangunan gedung masih memiliki kekuatan untuk mencegah terjadinya kerusakan total atau sebagian, sehingga memungkinkan adanya waktu atau ruang untuk mengevakuasi penghuni di dalamnya. Serta, sebagian struktur bangunan gedung dapat digunakan kembali.
d. *Collapse Prevention* (CP) merupakan kondisi di mana struktur berasa dalam batas kritis keruntuhan dan struktur tidak dapat digunakan kembali karena aktivitas gempa susulan akan menyebabkan keruntuhan total.

Dari studi sebelumnya [6], hasil analisis yang dilakukan mengenai perbandingan kinerja struktur baja SRBKK tipe *Inverted-V* pada gedung bertingkat 12, 16 dan 20 lantai didapat bahwa penggunaan bresing mampu menahan gaya gempa yang bekerja, struktur baja menjadi lebih kaku yang terbukti dengan nilai periode bangunan yang menggunakan bresing lebih kecil dibanding bangunan yang tidak menggunakan bresing. Selanjutnya menurut (Ananda, 2021) Sistem struktur baja dengan bresing *Inverted-V* yang di aplikasikan pada apartemen 12, 16 dan 20 lantai dengan melakukan analisis riwayat waktu menggunakan lima macam percepatan gempa yaitu, Imperial Valley, Kern Country, Kobe, Chi-chi, dan Koceali disimpulkan bahwa struktur berada pada level kinerja *Immediate Ocupancy* (IO). Penelitian ini dilakukan untuk mendapatkan profil bresing paling efisien dan efektif dalam meningkatkan tingkat kinerja struktur.

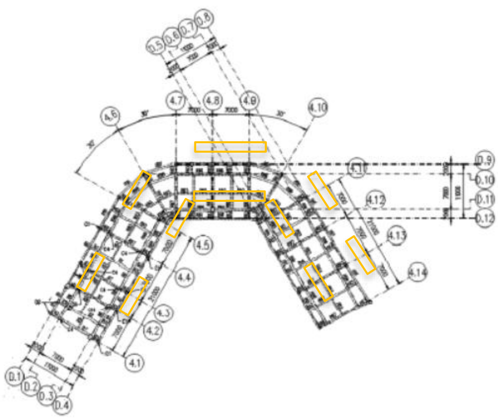
3. METODOLOGI PENELITIAN

Penelitian ini dimulai dengan pengumpulan data terkait denah bangunan (Gambar 3) dan rekaman pergerakan tanah, selanjutnya dilakukan pengolahan data gempa riwayat waktu (Gambar 4 hingga Gambar 8) dengan melakukan *preliminary design* dimensi elemen struktural bangunan gedung seperti balok (Tabel 1), kolom (Tabel 2), serta pelat dari material beton bertulang dengan tebal 120 mm. Bangunan gedung berfungsi sebagai hotel, berlokasi di Jakarta. Setelah langkah tersebut, dilanjutkan dengan pemodelan bangunan gedung struktur rangka bresing konsentrik khusus (SRBK) *Inverted-V* [14] [15] (Gambar 9) menggunakan bantuan perangkat lunak ETABS. Pemodelan bangunan gedung dengan 2 variasi penampang profil bresing, yaitu *equal angle* (L 200x200x32) untuk model 1 dan *hollow* (Tube 250x250x13) untuk model 2. Lalu, semua beban yang mungkin ada dan terjadi seperti beban mati, beban hidup, beban gempa, beban angin di-*input*-kan pada perangkat lunak ETABS. Selanjutnya, dilakukan pemeriksaan hasil analisis struktur terhadap beberapa parameter seperti periode, gaya geser dasar, simpangan antar lantai dan pengaruh P-Δ. Setelah semua dimensi elemen struktural bangunan gedung SRBK terutama balok dan kolom memenuhi persyaratan analisis struktur, kemudian dilakukan pemeriksaan tingkat kinerja struktur dengan menggunakan *time history* terhadap 5 data rekaman gempa berdasarkan FEMA 356.

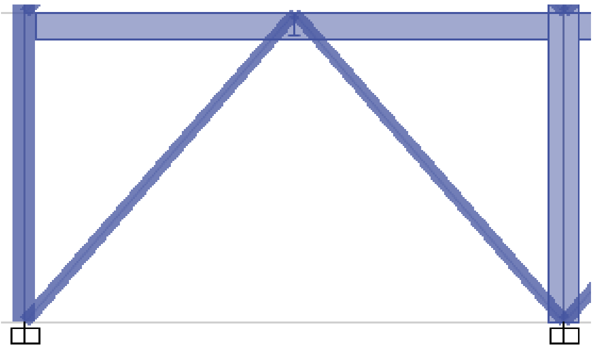


Gambar 3. Denah bangunan gedung

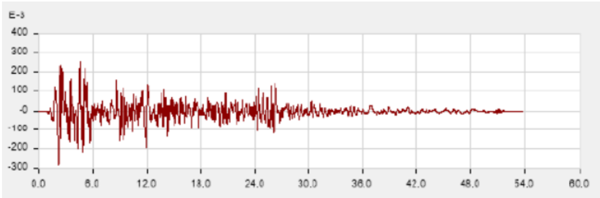
Denah bangunan yang digunakan adalah bangunan yang memiliki ketidak beraturan hal ini juga dilakukan untuk mengetahui efektivitas performa bresing pada bangunan yang tidak beraturan.



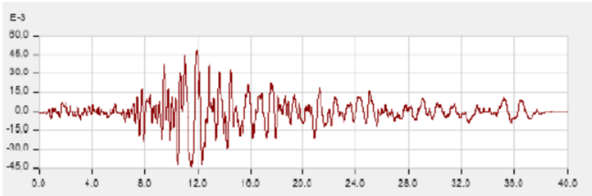
Gambar 4. Posisi bresing pada Model 1 dan 2



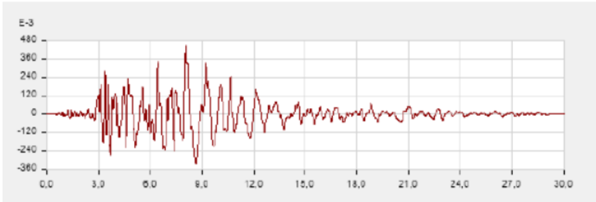
Gambar 4. Konfigurasi bresing pada Model 1 dan 2



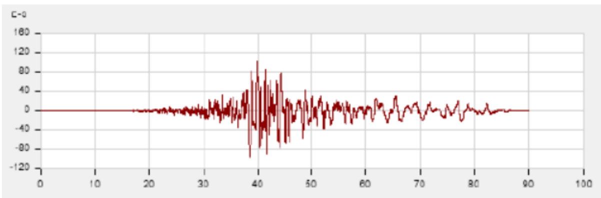
Gambar 5. Gempa El Centro, Amerika Serikat 1940



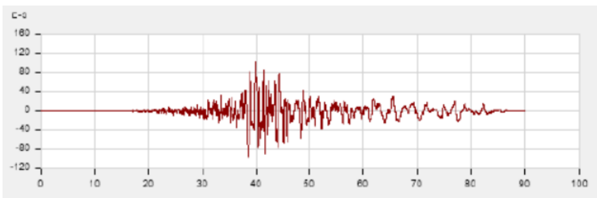
Gambar 6. Gempa Loma Prieta, California 1989



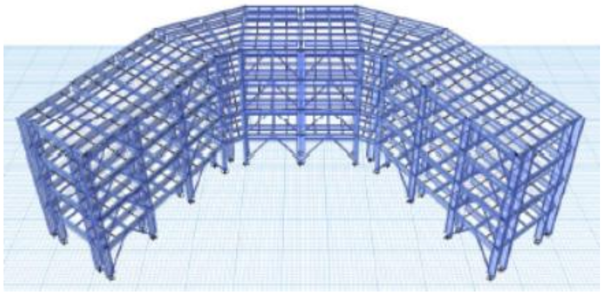
Gambar 7. Gempa Northridge, Amerika Serikat 1994



Gambar 8. Gempa Chi-Chi, Taiwan 1999



Gambar 9. Gempa Denali, Alaska 2002



Gambar 10. Pemodelan 3D bangunan gedung

Tabel 1. Tipe dan Dimensi Balok

No.	Tipe	Profil
1	BI1	IWF 300 x 150 x 6 x 12
2	BI2	IWF 300 x 300 x 12 x 19
3	BI3	IWF 400 x 250 x 12 x 25
4	BI4	IWF 400 x 350 x 12 x 25
5	BI5	IWF 400 x 375 x 12 x 25
6	BA1	IWF 300 x 150 x 6 x 12
7	BA2	IWF 300 x 250 x 9 x 16
8	BA3	IWF 350 x 300 x 12 x 19

Tabel 2. Tipe dan Dimensi Kolom

No.	Tipe	Profil
1	K1	H 400 x 400 x 16 x 25
2	K2	H 500 x 500 x 19 x 32
3	KH1	Tube 400 x 400 x 22
4	KH2	Tube 350 x 350 x 22
5	KH3	Tube 300 x 300 x 13

4. HASIL DAN PEMBAHASAN

Penelitian membahas hasil pemodelan struktur bangunan gedung SRBK tipe *Inverted-V* pada perangkat lunak ETABS mengenai respon strukturnya sesuai SNI 1726:2019 dan tingkat kinerja strukturnya sesuai FEMA 356.

Periode

Periode merupakan rentang waktu yang dimiliki oleh struktur bangunan gedung untuk menerima getaran akibat beban gempa. Nilai periode biasanya dibatasi dan juga diatur pada SNI 1726:2019. Nilai periode yang didapatkan dari perangkat lunak ETABS akan dibandingkan dengan nilai periode struktur maksimum dan periode struktur minimum yang dihitung sesuai dengan SNI 1726:2019. Tabel 3 menunjukkan nilai periode struktur bangunan gedung SRBKK tipe *Inverted*-V yang diteliti.

Tabel 3. Periode

Model Gedung SRBKK	Arah	$T_{a\,min}$ [s]	$T_{a\,max}$ [s]	$T_{a\,ETABS}$ [s]	$T_{a\,use}$ [s]
1	X	0,585	0,819	0,513	0,585
	Y			0,302	0,585
2	X			0,512	0,585
	Y			0,301	0,585

Dari Tabel 3 di atas, maka diperoleh nilai periode struktur bangunan gedung SBKK baik model 1 maupun model 2 sebesar 0,585 detik untuk arah X dan arah Y.

Gaya Geser Dasar

Pada SNI 1726:2019, nilai gaya geser dasar dipengaruhi oleh beberapa faktor antara lain koefisien seismik dan berat seismik efektif. Nilai koefisien seismik didapatkan pada Tabel 4 sedangkan berat seismik efektif untuk model 1 sebesar 2.058.551,41 kN dan untuk model 2 sebesar 2.058.738,19 kN.

Tabel 4. Koefisien Seismik

Model Gedung SRBKK	Arah	$C_{s\,min}$ [g]	$C_{s\,max}$ [g]	$C_{s\,hitung}$ [g]	$C_{s\,use}$ [g]
1	X	0,027	0,139	0,103	0,103
	Y				
2	X				
	Y				

Nilai gaya geser dasar dapat dihitung dari perkalian antara koefisien seismik dan berat seismik efektif, sehingga didapatkan nilai gaya geser dasar arah X dan arah Y untuk model 1 sebesar 2.120,69 kN sedangkan untuk model 2 sebesar 2.120,88 kN.

Simpangan Antar Lantai

Nilai simpangan antar lantai diatur oleh SNI 1726:2019 pasal 7.12.1. Simpangan antar lantai diperiksa untuk semua kondisi beban gempa baik respon spektra maupun riwayat waktu (5 data pergerakan tanah). Nilai simpangan antar lantai maksimal terjadi pada bangunan saat analisis riwayat waktu dengan gempa Northridge. Nilai simpangan antar laintai yang maksimum dapat dilihat pada Tabel 4.

Tabel 4. Simpangan Maksimum Antar Lantai

Model Gedung SRBKK	Arah	Deformasi [mm]	Deformasi Izin [mm]
1	X	19,315	80
	Y	7,035	80
2	X	19,230	80
	Y	7,010	80

Nilai simpangan antar lantai menunjukkan nilai yang hampir sama namun model 2 sedikit lebih baik dengan nilai simpangan yang lebih kecil.

Pengaruh P-Δ

Pengaruh P-Δ pada penelitian ini disesuaikan dengan SNI 1726:2019. Pengaruh P-Δ terdiri dari beberapa faktor antara lain berat seismik efektif, simpangan antar lantai, faktor keutamaan gempa, gaya geser tingkat, ketinggian antar lantai dan faktor perbesaran simpangan. Pengaruh P-Δ tidak perlu diperhitungkan apabila koefisien stabilitas lebih besar dari 0,1. Nilai maksimum pengaruh P-Δ pada model 1 sebesar 0,0028 untuk arah X dan 0,0012 untuk arah Y nilai tersebut masih jauh dari batas nilai maksimum yaitu 0.1 dan untuk bangunan dengan bresing hollow nilai P-Δ hampir mendekati nilai P-Δ dengan bressing siku.

Tingkat Kinerja

Tingkat kinerja struktur dievaluasi menggunakan analisis *time history* sesuai dengan FEMA 356, yang menunjukkan hasil bahwa kedua struktur bangunan gedung baja SRBK baik model 1 maupun model 2 ternyata menghasilkan tingkat kinerja yang sama yaitu *Immediate Occupancy* (IO). Di samping itu, juga dilakukan pengecekan struktur bangunan gedung baja SRBKK terhadap rasio kapasitas penampang dan deformasi maksimal yang terjadi. Pada model 1 nilai rasio kapasitas penampangnya sebesar 0,993 sedangkan model 2 sebesar 0,377. Adapun nilai deformasi pada model 1 yaitu 11,596 mm dan model 2 sebesar 11,552 mm.

5. KESIMPULAN

Dari penelitian yang dilakukan menunjukkan bahwa baik *equal angle* (model 1) maupun *hollow* (model 2) yang diaplikasikan sebagai bresing pada struktur bangunan gedung baja SRBK menghasilkan kekakuan yang lebih baik. Dengan semua parameter yang telah diperiksa sebelumnya, maka struktur bangunan gedung baja SRBK dengan bresing *hollow* (model 2) ternyata memberikan kekakuan tambahan yang lebih baik dibandingkan dengan bresing *equal angle* (model 1). Hal ini ditunjukkan dengan nilai simpangan antar lantai yang lebih kecil, nilai rasio kapasitas penampang yang lebih besar, dan nilai deformasi yang lebih kecil. Dengan nilai luas penampang dan berat baja yang hampir sama profil *hollow* memiliki nilai inersia penampang yang lebih besar memberikan kekakuan yang kebih baik dibandingkan profil siku. Selanjutnya karena profil *hollow* memiliki kemampuan yang lebih baik terhadap kemungkinan *buckling* (tekuk) yang terjadi. Akan tetapi, tidak menutup kemungkinan bahwa struktur bangunan gedung baja SRBK menggunakan bresing *equal angle* (model 2) dapat digunakan dengan catatan selalu dilakukan *maintenance* secara berkala untuk memastikan struktur bangunan gedung masih mampu menahan beban yang terjadi.

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Strategies for Utilizing *Surat Berharga Syariah Negara* in Financing Educational Infrastructure Construction Projects in Indonesia

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ABSTRACT

Indonesia's economic growth drives infrastructure development as outlined in Rencana Pembangunan Jangka Menengah Nasional (RPJMN) 2020–2024. However, a funding gap of USD 164.5 million exists between infrastructure in-vestment needs (USD 391.7 million) and State Budget allocations (USD 144.9 million). To narrow this gap, the government utilizes Surat Berharga Syariah Negara (SBSN) as an alternative financing source for construction projects. This research aims to identify factors influencing SBSN utilization, review its imple-mentation and evaluation, and develop strategies for SBSN utilization. The research was conducted by using mixed-method approach with quantitative analy-sis using Internal Factor Evaluation (IFE), External Factor Evaluation (EFE), and SWOT matrices along with qualitative analysis through the interview with stake-holders involved in one of educational infrastructure construction project at a ma-jor university in Indonesia. SBSN primary strength is the guarantee of fund availability throughout the contract period, which ensures sustained financing during project execution. Conversely, its notable limitation is the funding restriction confined exclusively to asset acquisition expenditures, thereby limiting its applicability for other financial needs. However, the implementation of SBSN faces challenges, such as regulatory ambiguities, ineffective coordination in project monitoring and control, and insufficient understanding among involved hu-man resources. Proposed strategies include enhancing monitoring and evaluation systems, clarifying regulations, and providing training and capacity building for relevant stakeholders to utilize SBSN in construction projects.

1. INTRODUCTION

Infrastructure development and enhancement are considered key drivers for Indonesia in promoting economic growth, as outlined in Rencana Pembangunan Jangka Panjang Nasional (RPJPN, National Long-Term Development Plan) 2005-2025 [1]. The completion of infrastructure projects in Indonesia provides positive impacts on regional economic growth, including improved access to economic centers, which strengthens regional competitiveness, attracts private sector investment, and creates new employment opportunities [2].

Indonesia requires USD 391.6 million for national infrastructure investment as stipulated in RPJMN 2020-2024 [3]. Of this amount, USD 144.9 million or approximately 37% of the total investment needs are allocated from the Anggaran Pendapatan Belanja Negara (APBN/D, State Budget/Regional Budget). However, due to limited funding sources, there is an estimated funding gap of USD 164.5 million or 42% of the total investment needs for infrastructure development in Indonesia [3]. In 2024, the Indonesian government is projected to allocate USD 25.7 billion for infrastructure, as stated by President Joko Widodo in Rencana Anggaran Pendapatan Belanja Negara (RAPBN, State Budget Plan) 2024. This amount represents a 5.8% increase compared to the 2023 infrastructure budget of USD 24.3 billion [3]. Nevertheless, there remains a gap between the required amount and the available government funding.

To reduce this significant funding gap, the government has utilized various alternative funding sources, one of which is the issuance of Surat Berharga Syariah Negara (SBSN). Lembaga Kebijakan Pengadaan Barang/Jasa Pemerintah (LKPP, National Public Procurement Agency) show an increasing trend in SBSN issuance from USD 47.3 million in 2013 to USD 2.1 billion in 2023 [11]. Although SBSN has become one of the alternative financing instruments for construction projects in Indonesia, there remains a disparity between the allocated budget and the actual absorption of SBSN funds based on LKPP data from 2020 to 2023. This indicates issues in the absorption of SBSN as a source of infrastructure project financing.

Therefore, research is necessary to identify factors related to opportunities, threats, strengths, and weaknesses in the utilization of SBSN. Case studies on implementation practices and evaluation of SBSN utilization in Indonesia are expected to provide strategies to optimize the use of SBSN instruments as an alternative financing for construction projects.

This research aims to identify factors influencing the utilization of SBSN as a financing instrument for construction projects, review the implementation and evaluation of SBSN utilization in financing educational infrastructure construction projects, and formulate strategies for utilizing SBSN as a relevant financing instrument for educational infrastructure construction projects based on the implementation and evaluation of SBSN utilization in Indonesia.This research also has several limitations, including the evaluation of SBSN utilization implementation is reviewed based on one educational infrastructure construction project as a case study. Although research respondents include external parties, data collection related to the evaluation and implementation of SBSN utilization is conducted with internal parties executing the educational infrastructure project. Additionally, this research involves experts in the field of project financing as research respondents with the expectation of obtaining in-depth analysis results that can provide insights regarding strategies for utilizing SBSN as a source of construction project financing.

2. LITERATURE REVIEW

Project Financing

Project financing can be defined as the raising of funds on a limited-recourse or non-recourse basis to finance a capital investment project that is economically separable, with fund providers relying on the project's cash flow as the source of funds to service their loans and provide returns on the capital and equity they have invested in the project [6].

Project financing can originate from several sources, both domestic and interna-tional. Although nearly all infrastructure development funds in Indonesia come from the government through the APBN, there are several other types of project financing. According to the Ministry of Public Works and Housing [8], infrastructure financing sources can be divided into five types: government financing, state-owned/regional-owned enterprises, off-balance sheet, strategic financing, and Public-Private Partner-ships (PPP). Within government financing, Surat Utang Negara (SUN, Indonesian Government Bonds) represents one form of bond issuance that can be utilized for infrastructure funding.

Surat Berharga Syariah Negara (SBSN)

The legal foundation for SBSN is outlined in Law No. 19 of 2008 [13], which states that SBSN can be issued to finance the State Budget, including project development. Further provisions are regulated in various Peraturan Menteri Keuangan (PMK, Minis-ter of Finance Regulation), such as PMK No. 220/PMK.08/2015 (procedures for project financing) [14], PMK No. 6/PMK.05/2019 (payment implementation) [15], and PMK No. 120/PMK.08/2016 (monitoring, evaluation, reporting) [16]. Additionally, Peraturan Pemerintah (PP, Government Regulation) No. 16 of 2023 [17] explain the authority, scope, and project requirements, as well as procedures from planning to reporting.

SBSN issuance must comply with specific sharia requirements as outlined in DSN-MUI Fatwa No. 32/DSN-MUI/IX/2002, supported by Quranic principles such as those in QS. Al-Ma'idah [5]:1 and QS. Al-Isra' [17]:34, which emphasize the im-portance of fulfilling contracts and promises. Furthermore, the legal basis for SBSN is strengthened by Al-Qur'an Q.S. Al-Baqarah: 282, which guides financial transactions to properly represent the rights and obligations between transacting parties [28].

Further provisions are regulated in various Peraturan Menteri Keuangan (PMK, Minister of Finance Regulation), such as PMK No. 220/PMK.08/2015 (procedures for project financing) [14], PMK No. 6/PMK.05/2019 (payment implementation) [15], and PMK No. 120/PMK.08/2016 (monitoring, evaluation, reporting) [16]. Additional-ly, Peraturan Pemerintah (PP, Government Regulation) No. 16 of 2023 [17] explain the authority, scope, and project requirements, as well as procedures from planning to reporting.

According to PP No. 56 of 2011 (Article 9) [18], projects that can be financed by SBSN include infrastructure (energy, telecommunications, transportation, agriculture, manufacturing, housing), public services, domestic industry empowerment, and other development in accordance with strategic policies. Projects must meet certain criteria, including ownership by the Central Government, inclusion in RPJM priorities, and compliance with sharia requirements (in accordance with DSN-MUI Fatwa No. 01/DSN-MUI/III/2012) [19] [20]. The relevant ministries or institutions (project initia-tors) are tasked with proposing projects with feasibility study documents and terms of reference.

A fundamental difference between SBSN and conventional bonds is that SBSN must have underlying assets (tangible or intangible) with economic value that comply with sharia principles [29]. These assets must be in good condition, non-military in nature, legally uncontested, and not already used in other SBSN issuances [29]. This asset-backing requirement ensures that the financial instrument represents real economic activity rather than mere financial engineering [29].

The relevant ministries or institutions (project initiators) are tasked with proposing projects with feasibility study documents and terms of reference. SBSN utilizes vari-ous transaction structures based on Islamic contracts, including Ijarah Sale and Lease Back, Ijarah Asset to be Leased, Ijarah Al-Khadamat, and Wakalah [29]. These structures provide alternative financing mechanisms that comply with sharia principles while serving the same economic function as conventional financing.

According to PP No. 56 of 2011 [18], SBSN project financing begins with project proposals by the initiator (ministry/institution), feasibility assessment by the Ministry of Planning, and budget allocation by the Minister of Finance in the State Budget (APBN) or RAPBN. Following SBSN issuance, the project initiator implements activi-ties in accordance with government procurement regulations. Periodic reporting on progress and fund utilization is mandatory, while the Ministry of Finance of the Republic of Indonesia (MOF) and Ministry of National Development Planning of the Republic of Indonesia (Bappenas, National Development Planning Agency) monitor and evaluate projects to ensure accountability.

Several PMK, such as PMK No. 138/PMK.08/2019 [21], govern the procedures for project financing and budgeting. In the initial stage, the Ministry of Finance requests indications of priority projects, while the Directorate General of Budget Financing and Risk Management (DGBFRM) prepares the indicative ceiling for RAPBN. Project implementation can be funded through advanced State Budget financing (Anggaran Pendapatan dan Belanja Negara-APBN), which is subsequently reimbursed after SBSN issuance, or through Rekening Khusus (Reksus). The entire process, from con-tracting and payment to reporting, refers to state financial management regulations and sharia principles. Project initiators submit periodic reports, and if realization does not meet targets, the government may adjust fund allocations or temporarily suspend payments. With this mechanism, SBSN becomes a reliable financing alternative for priority projects, based on transparent governance that complies with sharia provi-sions

3. RESEARCH METHODOLOGY

This research is categorized as mixed methods of research. Creswell explains that mixed methods research design is a procedure for collecting, analyzing, and combining both types of research methods, qualitative and quantitative, in a research study to understand research problems [7]. Data collected for quantitative research was conducted through questionnaires then processed using IFE and EFE matrices. Meanwhile, qualitative research was conducted through data collection in the form of interviews, which were then processed by data reduction and categorization.

This research utilizes both primary and secondary data. The primary data collected includes factors related to SWOT factors in the utilization of SBSN. These factors were obtained through literature review and subsequently compiled in questionnaires to be answered by respondents. The questionnaires were quantitatively measured using a Likert Scale. The actual conditions of implementation and evaluation of SBSN utilization in construction project financing were obtained through a case study of an educational infrastructure construction project in Indonesia. This primary data was obtained through interviews with internal project stakeholders.

Questionnaires and interviews were conducted involving experts and stakeholders engaged in the use of SBSN as a construction project financing instrument and the case study. Research respondents include external parties as regulators, such as MOF and Bappenas, as well as internal parties as project implementers, namely the Ministry of Education, Culture, Research, and Technology (MOECRT) as the Executing Agency, and the Project Implementation Unit (PIU) as the Implementation Body. Below is the list of research respondents involved in the data collection phase of the research, both for questionnaire completion and interviews.

Secondary data serves as a support for this research in designing questionnaires by identifying factors related to opportunities, threats, strengths, and weaknesses in the utilization of SBSN. This can also be observed in the study of several construction projects in Indonesia. The secondary data collection technique used includes literature review.

Sridharan states that the IFE matrices is a strategic tool used to evaluate the internal environment of a company and identify its strengths and weaknesses [8]. Meanwhile, Sridharan also explains that the EFE matrices is a strategic analysis tool used to evaluate the external environment of a company and identify its opportunities and threats [9].

Table 1. List of Research Respondents

No.	Institution	Position Level	Number of Respondents
1	DGBFRM Ministry of Finance	Section Head	6
		Director	1
2	National Development Planning Agency (Bappenas)	Junior Planning Expert	1
		Mid-Level Planning Expert	2
3	Ministry of Education, Culture, Research, and Technology (MOECRT)	Team Leader	1
		Commitment-Making Official	1
		PIU Head	1
4	Project Implementation Unit	Head of Money Division	1
		Head of Contract Control	1
Total Number of Sources			**15**

The IFE and EFE matrices are used as methods to quantify primary data obtained through questionnaires. Internal factors include strengths and weaknesses, while external factors include opportunities and threats. Data processing in the IFE and EFE matrices involves calculating weights, ratings, and weighted scores.

Other methods used to conduct this research is Strengths, Weaknesses, Opportunities, and Threats (SWOT). SWOT analysis is used as a strategic management tool to evaluate internal and external factors that affect an organization or project [22]. The internal dimension includes strengths and weaknesses, while the external dimension includes opportunities and threats. This analysis assists in formulating effective strategies by understanding current conditions and future potential.

4. RESULTS

Factors Influencing SBSN Utilization

The utilization of SBSN as a financing instrument for construction projects in Indonesia is influenced by various internal and external factors. Therefore, the application of the SWOT dimensions, consisting of strengths, weaknesses, opportunities, and threats, is highly relevant as an analytical framework to identify and organize these factors.

The SWOT approach provides clear justification. The Strengths aspect highlights the superior characteristics of SBSN, which according to the Ministry of Finance represent positive features and added value that enhance the competitive advantage of this financing method. On the other hand, the identification of weaknesses helps reveal limitations and negative aspects that potentially impede operational effectiveness and the achievement of financing objectives.

Furthermore, the analysis of opportunities provides insights into external situations or conditions that can be leveraged to promote performance improvement and quality enhancement of projects financed through SBSN. Meanwhile, the recognition of threats is crucial for detecting constraints or problems that may disrupt the smooth implementation of projects. By integrating these four dimensions, SWOT analysis not only maps the factors that influence SBSN as a financing source but also facilitates the formulation of appropriate strategies.

Table 2. SBSN Utilization-Influencing Factors

Code	Factor	Description	Sources
Strength Dimensions			
S.1	Ease of budget submission	Simple and straightforward budget submission procedures	[27]
S.2	Ease of payment and fund disbursement	Simple and straightforward payment/fund disbursement procedures	[27]
S.3	Fund availability assurance	Project funds guaranteed by the government until the end of the fiscal year	[26]
S.4	Financing consistency	SBSN financing is scheduled and annual, following the State Budget cycle	[24]
S.5	Continuity flexibility	Mechanism for multi-year contracts allowing projects not completed within one budget period to continue	[24]
S.6	Financial accountability	Use of special accounts (Reksus) that ensure budget for specific projects will not be cut or diverted for other purposes	[23]
S.7	Output quality control	Quality control of project outputs due to monitoring and evaluation by multiple parties (K/L, Bappenas, and Ministry of Finance)	[23]
S.8	Comprehensiveness	Financing with full costing, covering all project needs for land acquisition, construction services, planning and supervision, including overhead costs	[24]
S.9	Contract flexibility	Flexibility in selecting contract types and procurement methods (EPC and MYC) in accordance with specific project needs	[24]
Weaknesses Dimensions			
W.1	Limitations of fund usage	SBSN financing restricted to capital expenditures that generate assets	[23]
W.2	Inflexibility and lengthy administrative process	Projects using SBSN must undergo a lengthy administrative process and coordination among 3 parties (K/L, Bappenas, and Ministry of Finance)	[23]
W.3	Budget flexibility constraints	Financing through SBSN does not allow for additional budget allocation if issues arise during project implementation	[19]

Table 2. SBSN Utilization-Influencing Factors

Code	Factor	Description	Sources
W.4	Limitations in financing coverage	Financing through SBSN is limited to central K/L projects, not yet covering Regional Governments/SOEs	[19]
W.5	Limitations in cost evaluation	Financing through SBSN does not allow for detailed assessment of cost components (cost fund) of the project	[24]
Opportunities Dimensions			
O.1	Effective inter-institutional communication	Improve and intensify dialogue on SBSN project financing performance	[27]
O.2	Effective communication with project partners	Maximize communication between K/L project initiators and work partners	[19]
O.3	Performance improvement through incentives	Implementation of reward & punishment system based on K/L performance in SBSN projects	[19]
O.4	Optimization of planning	Development of planning corridor utilization for SBSN projects	[24]
O.5	Planning consistency improvement	Transition from operational planning to medium-term planning	[24]
O.6	Standardization of documentation	Standardization of SBSN project submission documents (KAK and DSKP)	[24]
O.7	Independent project evaluation	Panel review of project proposals to be financed through SBSN	[24]
O.8	Technology utilization for monitoring	Utilization of information technology for monitoring SBSN budget planning processes and budget utilization performance	[27]
O.9	Transparency in financial management	Level 1 (one) special account (Reksus) for each SBSN management organization	[23]
O.10	Budget performance evaluation	Setting of SBSN ceiling at the program level (currently at the activity level)	[23]
O.11	Quality improvement	Implementation of project quality audits as a guarantee of construction quality	[24]
O.12	Tender process efficiency	Preparation of tender documents accurately with LKPP assistance	[24]
Threats Dimensions			
T.1	Delays and disruptions in the tender process	Tender process delayed by K/L or failed tenders occur	[20], [24]
T.2	Land readiness issues	Work site not fully ready or not clean & clear	[20], [24]
T.3	Contract changes due to field conditions	Contract changes resulting from discrepancies between actual field conditions during implementation and drawings (designs) and/or technical specifications in the Terms of Reference within the Contract	[24]
T.4	Relocation, reallocation, and scope changes	Occurrence of relocation, reallocation, and/or changes in the scope of work	[24]
T.5	Payment stoppage	Payment stoppage due to inaccurate fund withdrawal plans (RPD) by Ministries/Institutions	[20], [25]
T.6	Technical and administrative archiving issues	Delayed technical and/or administrative archiving	[20], [24]
T.7	Problematic goods/service providers	Goods/service providers experiencing problems and/or performing poorly	[24]
T.8	Project asset damage or loss	Project assets damaged or lost/destroyed due to disasters	[20], [24]

All factors identified above are assessed using IFE and EFE matrices. Table 3 presents the assessment results of weights, ratings, and scores for SWOT factors in the utilization of SBSN based on questionnaire responses from research respondents.

Table 3. Results of IFE and EFE Calculations for Factors Influencing SBSN Utilization

Strengths					Weaknesses				
No	**Code**	**Weight**	**Rating**	**Score**	**No**	**Code**	**Weight**	**Rating**	**Score**
1	S.1	0.10	3.93	0.38	1	W.1	0.24	3.67	0.89
2	S.2	0.11	4.27	0.45	2	W.2	0.20	3.00	0.6
3	S.3	0.12	4.80	0.57	3	W.3	0.20	3.00	0.6
4	S.4	0.11	4.60	0.53	4	W.4	0.19	2.93	0.57
5	S.5	0.11	4.53	0.51	5	W.5	0.16	2.47	0.4
6	S.6	0.11	4.47	0.5	...	...	...	...	...
7	S.7	0.11	4.60	0.53					
8	S.8	0.11	4.53	0.51					
9	S.9	0.11	4.53	0.51	...	...	...	...	...
		Total		**4.49**			**Total**		**3.06**

Opportunities					Threats				
No	**Code**	**Weight**	**Rating**	**Score**	**No**	**Code**	**Weight**	**Rating**	**Score**
1	O.1	0.08	4.00	0.33	1	T.1	0.15	4.27	0.65
2	O.2	0.09	4.27	0.38	2	T.2	0.13	3.73	0.5
3	O.3	0.09	4.27	0.38	3	T.3	0.12	3.33	0.4
4	O.4	0.09	4.40	0.4	4	T.4	0.13	3.6	0.46
5	O.5	0.08	3.67	0.28	5	T.5	0.09	2.6	0.24
6	O.6	0.08	3.67	0.28	6	T.6	0.1	2.73	0.27
7	O.7	0.09	4.13	0.35	7	T.7	0.15	4.2	0.63
8	O.8	0.09	4.33	0.39	8	T.8	0.12	3.47	0.43
9	O.9	0.08	3.67	0.28	...	...	...	...	...
10	O.10	0.07	3.27	0.22					
11	O.11	0.09	4.47	0.41					
12	O.12	0.08	4.00	0.33	...	...	...	...	...
		Total		**4.04**			**Total**		**3.58**

Implementation of SBSN Utilization in Financing Educational Infrastructure Construction Projects

One case study example of SBSN utilization in construction project financing was employed in the funding of an educational infrastructure construction project in Indonesia. The project received funding in three forms consisting of SBSN Single Year Contract (SYC), SBSN Multi Years Contract (MYC), and Loans from Asian Development Bank (ADB). The construction costs for two buildings in this project were sourced from government SBSN funds with MYC. The project construction encompassed two buildings with 12 and 13 floors respectively, while the basements of these buildings are connected with a total of 2 floors. Additionally, other SBSN funds were used for laboratory support equipment in the form of a single-year contract. Funding through SBSN was conducted through the issuance of state securities based on sharia principles to finance construction project activities carried out by the relevant Ministry/Institution, namely the Ministry of Education, Culture, Research, and Technology (MOECRT).

The project's organizational structure involved various agencies with the Directorate General of Higher Education serving as the executive agency. The Ministry of Finance representative handling project financing as a committee in utilizing SBSN is the Directorate of Sharia Financing in DGBFRM. This Directorate was responsible for SBSN project planning, management of SBSN product performance, implementation of SBSN payments, and asset management. The project also involved the Bappenas as a steering committee. Based on the overall project review, Bappenas involved two directorates, the Directorate of Higher Education and Science and Technology, which served as the coordinator in planning higher education funding resources, and the Directorate of Development Funding Allocation, which served as the authority to manage and determine the type of budget scheme and project funding mechanism based on Ministry/Institution proposals. Additionally, the implementing agency in the project is a higher education institution in Indonesia managed by the Project Implementation Unit (PIU). Pejabat Pembuat Komitmen (PPK, Commitment Making Official) of the project is a representative of MOECRT, but originated from within the higher education institution that meeting the project procurement specification requirements.

In determining the type of funding source to be used, several considerations influenced the selection of SBSN. These were conveyed through interview results with representatives from the Directorate of Sharia Financing and Bappenas, including:

1) Ease in Preparation Phase
   Preparation for projects funded using SBSN can be conducted from Q4 T-2 or two quarters before the fourth quarter in the review year. This preparation

includes preparing and conducting assessments for projects funded with SBSN, making the time required in the SBSN funding preparation phase faster compared to other financing instruments.

2) Covering Funding Limitations
The use of SBSN in MOECRT's construction projects was chosen due to limitations in higher education funding, necessitating alternatives beyond project funding using the State Budget.
3) Certainty of Funding Allocation
Project financing using SBSN is full costing, encompassing administration, planning, and construction financing. Additionally, SBSN financing does not have specific value limits that become special boundaries for construction project financing through SBSN. The funding requirements for a construction project through SBSN emphasize the priority side and readiness criteria of the project.
4) Pre-segregated Financing Mechanism
Construction project financing through SBSN can be disbursed through Rekening Khusus. With the use of this special account, the Ministry of Finance can segregate budgets for each Ministry/Institution so that the budgets of each ministry are not mixed. The budget segregation process is conducted from the beginning based on the allocation of each budget. As a case example, the budget needs of the case study project using SBSN will be directly allocated through the budget of the Directorate of Higher Education in MOECRT.

Referring to this case study, SBSN can be utilized in construction project financing due to its ability to cover shortfalls in construction project funding. This alternative financing source also becomes a consideration, especially for government projects that mostly rely on State Budget funding.

Evaluation of SBSN Utilization in Financing Educational Infrastructure Construction Projects

Regarding the implementation of SBSN utilization in construction project financing, several obstacles occurred during the construction project execution. The main problem faced with using SBSN was administrative issues. The educational infrastructure development project that became the case study had gone through three different SBSN budget schemes, resulting in asynchrony between the contract period and project budget period. The contract type that was initially to be used for the project was SBSN SYC. However, after the issuance of Technical Recommendations by the Ministry of Public Works and Housing that the project could run for 26.5 months, the contract type changed to SBSN MYC [10]. The adjustment of the budget type from SYC to MYC caused a delay in project implementation, resulting in the project start time being delayed and impacting the overall project timeline.

Additionally, the project also faced problems with incorrect timing of budget submissions. The budget submission was submitted by the relevant Ministry/Institution in December 2021, the last month of the 2021 budget period. Thus, the MYC contract given to the project team or the project budget period began in the current 2021 budget year. Referring to the PMK No.93/PMK.02/2020 that multi-year contracts are implemented for a maximum of 3 (three) fiscal years, the SBSN MYC contract that started in 2021 would end in 2023. On the other hand, the project contract was signed in July 2022. This emphasizes the difference in calculating the fiscal year period based on the contract period and budget period [10].

Regarding the project organizational structure, the assignment of PPK as representative of MOECRT using representatives from higher education institutions created regulatory ambiguity. Informally, emotionally, and in terms of social responsibility, as a PPK who is part of a higher education institution, a conflict of interest would certainly arise [10]. Thus, there was a lack of clarity in the standing point of the PPK, who should have originated from MOECRT but was a party from the higher education institution. This also impacted on the absence of a binding contract between the PIU and the internal higher education institution because the project owner is MOECRT. The binding contract between consultants and contractors is with PPK, so the PIU feel burdened in driving project implementation due to the absence of legal ties. Additionally, the PIU felt that there was still a lack of clarity in the standards and formats of payment submission documents from Ministries/Institutions because almost every payment submission always went through a revision process and required additional documents, increasing the time needed for administrative processes.

The problem of delayed fund disbursement to the project implementation team also occurred in this project. This was due to the fund disbursement submission being conducted coincident with the turn of the year, necessitating a reallocation of funding and a recomposition of Daftar Isian Pelaksanaan Anggaran (DIPA, Budget Execution Document). This process required a long time, so the payment request submitted at that time could not be fulfilled. Meanwhile, the project implementation conditions in the field were required to continue, making the contractor's financial strength an important factor.

Several other problems were also experienced by the project implementation team related to administrative documents. The educational infrastructure development project that became the case study was a project implemented based on a Detail Engineering Drawing (DED) document created 5 years before the contract signing. This DED document became the basis for the formation of a feasibility study document by the Badan Riset dan Inovasi Nasional (BRIN, National Research and Innovation Agency). Then, the project was transferred from BRIN to the Directorate of Resources and then to the Directorate of Institutions in MOECRT from 2017 to 2021. While there was no clarity on the project, the project budget was blocked so the project implementation team had to wait for project certainty for a period of 5 years. Meanwhile, the project implementation period only began in 2021 and was properly implemented in 2022, so the conditions at the time of DED document creation were far different from the actual conditions before construction. Thus, readjustments were needed regarding field conditions and technical aspects.

Another problem faced is related to project financing supervision and control activities using SBSN. The PIU stated that there is a need for improved coordination between the Ministry Team, PIU, and the internal higher education institution, particularly regarding technical and administrative coordination. The submission of fund disbursement was felt to have been submitted by the project team on time, but payment reception was delayed for the implementation team. Additionally, the internal higher education institution felt that there was a lengthy coordination process with the parties involved in project construction funding. By involving many Ministry parties, there were many approvals that needed to be made before fund disbursement. The project implementation team also stated that there was still a lack of clarity in technical rules, and coordination between parties still required a considerable amount of time.

Based on the results of questionnaire, interview, and evaluation, there are still several problems in implementation of SBSN utilization in project financing, particularly related to unclear regulations, lack of understanding of human resources involved regarding construction project financing using SBSN, and project administration.

Strategies for SBSN Utilization in Construction Projects Financing

Based on the calculation of scores for SBSN SWOT aspects using IFE and EFE matrices, the following SWOT matrices are obtained. Referring to the table above, the appropriate strategy combination for SBSN utilization is the SO strategy. The SO strategy means utilizing the internal strengths of SBSN as one of the financing instruments for construction projects to capitalize opportunities. By employing various combinations of strengths and opportunities, three main strategies with several sub-strategies were identified that could resolve the problems identified in the implementation and evaluation of SBSN utilization. The following are the SO strategies for utilizing SBSN in construction project financing:

1) Enhancement of Monitoring and Evaluation Systems
   a) Development of an Integrated Technology-Based Monitoring System that is Procedural and Specific (S7, S6; O8, O9).
   b) Strengthening Project Quality Audit Mechanisms with Independent Review Panels (S7; O11, O7).
2) Regulatory Strengthening
   a) Harmonization of Contract Period and Budget Regulations (S9, S5; O6).
   b) Refinement of Governance Regulations and Project Implementation Mechanisms (S6, S5; O10).
   c) Clarification of Regulations Regarding Administrative Document Requirements for Budget Disbursement (S1, S2; O2).
   d) Attention to the Correlation Between Contract Type Regulations and Budget Periods (S9; O7).
3) Provision of Training and Capacity Development
   a) Comprehensive Training Programs for SBSN Project Managers (S1, S2; O6, O5).
   b) Development of Medium-Term Planning Capacity (S3; O4, O5).
   c) Strengthening Coordination Among Stakeholders Through Regular Communication Forums (S7, S4; O1, O2).

5. DISCUSSION

SBSN has become a significant alternative financing instrument for construction projects in Indonesia. However, its implementation still faces various challenges, as observed in one of the reviewed educational infrastructure construction projects. Based on the evaluation, a comprehensive strategy needs to be developed to optimize the utilization of SBSN.

Enhancement of monitoring and evaluation systems represents a fundamental dimension in optimizing SBSN utilization through the development of systematic and measurable supervision mechanisms. An integrated technology-based monitoring system that connects supervision from Ministries/Institutions, Bappenas, and the

Table 4. Surat Berharga Syariah Negara (SBSN) SWOT Matrices

SBSN SWOT Matrices		Internal Factor Evaluation (IFE): Strengths (4.49)	Internal Factor Evaluation (IFE): Weaknesses (3.06)
External Factor Evaluation (EFE)	Opportunities (4.04)	Strengths-Opportunities (SO) = 4.49 + 4.04 = 8.53 Selected	Weaknesses-Opportunities (WO) = 3.06 + 4.04 = 7.10
	Threats (3.58)	Strengths-Threats (ST) = 4.49 + 3.58 = 8.07	Weaknesses-Threats (WT) = 3.06 + 3.58 = 6.65

MOF will increase transparency in Special Account management and enable real-time monitoring of financial performance and physical progress of projects. This strategy can be operationalized through the establishment of a comprehensive monitoring and evaluation system, specifically through the development of a web-based automated reporting module. This technological infrastructure would facilitate real-time accessibility and continuous data updates, thereby enabling stakeholders to monitor implementation progress and financial performance metrics with enhanced precision and temporal relevance. Strengthening quality audit mechanisms with independent review panels allocated from the SBSN full costing scheme ensures comprehensive evaluation of technical and administrative aspects of projects, enabling earlier detection of discrepancies between DED and actual conditions, as occurred in one of the reviewed educational infrastructure construction projects.

Regulatory strengthening provides a clear legal foundation and operational framework for SBSN project implementation through harmonization of regulations, governance refinements, clarity of administrative requirements, and synchronization of contract types with budget periods. The practical application of this strategic framework necessitates the formulation of standardized administrative documentation protocols. These protocols would be subject to systematic verification through specialized checklists and Standard Operating Procedures (SOPs), which serve to elucidate the nuances of applicable regulatory frameworks. Additionally, it is imperative to integrate construction project timelines with the budgetary cycles of the Ministry of Finance so that will ensure optimal synchronization between tender processes and fiscal periods which facilitates the submission of requisite documentation at appropriate temporal junctures. Harmonization of contract period and budget regulations for MYC can address asynchronies that cause project delays, while refinement of governance regulations clarifies working relationships between stakeholders. Clarity of procedures and administrative document requirements will facilitate administrative processes and address issues in budget submissions, while attention to the correlation between contract types and budget periods ensures that project submission documents are completed at the appropriate time, optimizing SBSN utilization in supporting national infrastructure development.

Provision of training and capacity development focuses on enhancing the competencies of human resources involved in SBSN project management through comprehensive training programs, medium-term planning capacity development, and strengthened coordination among stakeholders. Furthermore, effective implementation of this strategic approach requires the dissemination of regulatory information pertaining to project funding mechanisms among relevant stakeholders. This would entail the communication of empirical insights derived from pilot initiatives to all project participants, coupled with the orchestration of coordination meetings that incorporate comprehensive representation from both internal organizational entities and external stakeholders. Such collaborative forums would enhance cross functional communication and facilitate the alignment of strategic objectives across diverse stakeholder groups. Comprehensive training programs for project managers regarding SBSN administrative procedures can reduce administrative errors, while medium-term planning capacity development helps Ministries/Institutions integrate SBSN into their development strategies and address document unpreparedness. Strengthening coordination among stakeholders through regular communication forums involving all stakeholders serves as a platform to discuss project progress, constraints, and joint solutions, addressing lengthy and slow coordination problems as observed in one of the reviewed educational infrastructure construction projects.

The strategy for utilizing SBSN as a financing instrument for construction projects in Indonesia needs to focus on three main dimensions: (1) enhancement of monitoring and evaluation systems, (2) regulatory strengthening, and (3) provision of training and capacity development. Comprehensive implementation of these strategies will help address various problems identified in one of the reviewed educational infrastructure construction projects. Additionally, this strategy is expected to have implications for more effective, efficient, and positively impactful utilization of SBSN as a financing instrument for construction projects in Indonesia's national infrastructure development.

6. CONCLUSION

The research results indicate that the SBSN financing instrument has a higher strength value compared to its weakness value from an internal perspective and a higher opportunity value compared to threat value from an external perspective. SBSN utilization can guarantee project fund availability until the end of the contract, thereby increasing funding certainly. However, since SBSN financing is limited to expenditures that generate assets, thorough planning becomes crucial. Additionally, project quality audits open opportunities for construction quality improvement, although potential delays or auction failures could impede implementation. Therefore, proper program development and a deep understanding of funding mechanisms are necessary to optimize SBSN benefits.

Implementation and evaluation of SBSN utilization in educational infrastructure construction project financing still face several obstacles, such as regulatory ambiguity, ineffective coordination in project financing supervision and control, and limited understanding of human resources regarding the SBSN financing instrument. Furthermore, based on the SWOT matrices calculation results, the appropriate strategy for utilizing SBSN as a financing instrument for educational infrastructure construction projects is the SO strategy with the highest score. This strategy encompasses enhancement of monitoring and evaluation systems, regulatory strengthening, and provision of training and capacity development.

On the other hand, this research still has several limitations, namely that the relevance of the strategy for utilizing SBSN as a financing instrument for educational infrastructure construction projects is focused on one case study project review. This research also requires increased diversification so that in the future, more than one case study example can be used.

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