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Decision-Making Dynamics of Engineers in Selecting Environmentally Friendly Materials for Medium-Scale Construction Projects

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A B S T R A C T

This study examines the decision-making dynamics behind the selection of environmentally friendly materials in medium-scale construction projects in Balikpapan, East Kalimantan. Using a qualitative case study approach, in-depth interviews were conducted with eight key informants, including engineers, project managers, and a quantity surveyor. Thematic analysis reveals that material selection decisions are shaped by dynamic negotiations among technical performance, cost efficiency, schedule constraints, and risk perceptions, with project managers and quantity surveyors playing decisive roles. The study highlights that in medium-scale projects, the adoption of environmentally friendly materials depends more on cross-role decision-making mechanisms than on individual environmental awareness. These findings contribute to practical insights on sustainable material selection and provide an empirical basis for developing more contextual green construction strategies at the project level.

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INTRODUCTION

The issue of sustainability in the construction industry is getting more attention as the environmental impact of development activities globally increases. The construction industry contributes to large amounts of carbon emissions and consumption of natural resources through the use of materials throughout the building life cycle, making material selection a crucial aspect in modern civil engineering practice. According to Akadiri et al., (2020), construction materials have a strategic role in determining the level of sustainability of a project because they are directly related to embodied energy and construction waste. Therefore, efforts to encourage the use of environmentally friendly materials are an important part of the transformation towards sustainable construction.

Globally, various studies show that the adoption of eco-friendly materials is influenced by a combination of interacting technical, economic, and environmental factors. Darko et al., (2020) affirm that although awareness of sustainability is increasing, cost and technical risk considerations are still the main obstacles in its implementation. In many projects, material decisions are often driven more by short-term efficiency than long-term environmental benefits. This condition shows that material selection is not solely a technical issue, but part of the dynamics of professional decision-making.

In academic and professional practice, sustainable material selection is generally analyzed using quantitative approaches such as multi-criteria decision making, which emphasizes the process of weighting and ranking alternative materials. This approach is considered to be able to accommodate various criteria systematically, as explained by Zavadskas et al., (2021). However, such approaches tend to view decision-making as a rational process that is linear and independent of the context of the project's organization. As a result, the interaction between actors and the negotiation process that takes place on the ground is often not adequately revealed.

In the context of developing countries, the dynamics of material decision-making have become more complex due to limited resources and pressure to complete projects. In Indonesia, especially in Balikpapan City as one of the development centers in East Kalimantan, medium-scale construction projects are growing rapidly as the need for infrastructure and building buildings increases. Hjelmbrekke et al., (2021) stated that in projects with limited budgets, technical decisions are often influenced by the organizational structure and control mechanisms of the project. However, empirical studies that specifically discuss how engineers in Balikpapan make decisions on the selection of environmentally friendly materials are still very limited.

The research gap in this study is also seen from the lack of studies that describe the role of each professional actor in the material decision-making process. Project engineers, structural engineers, project managers, and quantity surveyors have different responsibilities and interests, influencing the way they assess the feasibility of environmentally friendly materials. Loosemore & Lim (2022) emphasize that decisions in construction projects are the result of social and organizational interactions, not individual decisions. However, most

previous studies have not explicitly examined these cross-role dynamics in the context of material selection.

Based on these conditions, this study aims to analyze the dynamics of engineers' decision-making in choosing environmentally friendly materials in medium-scale construction projects in Balikpapan City. The focus of the research is directed at how technical, financial, and managerial considerations interact with each other in shaping the final decision. To achieve this goal, this study uses a qualitative approach with a case study method through in-depth interviews with key project actors. This approach was chosen because it is able to explore the decision-making process contextually and in-depth (Yin, 2022).

Theoretically, this research is expected to enrich the study of civil engineering and construction management by viewing sustainable material selection as a dynamic and contextual decision-making process. The findings of this study can broaden our understanding of the relationship between the organizational structure of the project and the resulting technical decisions. Practically, the results of the study are expected to be a reference for contractors and planners in designing more realistic and applicable environmentally friendly material selection strategies, as emphasized by Ozorhon & Oral (2023). Thus, this research contributes to the development of science as well as practical problem solving in the construction sector.

THEORETICAL REVIEW

Eco-Friendly Materials in Sustainable Construction

Environmentally friendly materials are a key component in efforts to reduce the ecological impact of the construction sector on the environment. The use of materials with low carbon emissions, high energy efficiency, and good recycling potential has been proven to contribute to the reduction of the environmental footprint of construction projects (Cabeza et al., 2020). In the civil engineering discipline, sustainable materials are judged not only from environmental aspects, but also from structural resilience and availability in the local market. Therefore, the selection of eco-friendly materials must consider the balance between sustainability and technical feasibility.

Complexity of Decision Making in Material Selection

Material selection decisions in construction projects are a complex process and involve many interrelated considerations. According to Hosseini et al., (2021), material decisions are often influenced by cost pressures, implementation times, and the level of uncertainty of new material performance. In medium-scale projects, limited resources make the decision-making process more pragmatic. This condition causes material decisions not always to reflect the most theoretically sustainable choices.

Limitations of Rational Approaches and Technical Models

Most previous studies viewed material selection as a rational process that could be optimized through technical and analytical models. A numerical evaluation-based approach is considered to be able to help objectively compare

alternative materials (Ding et al., 2020). However, this approach often ignores non-technical factors such as professional experience, organizational preferences, and communication dynamics between project actors. As a result, actual decisions in the field often differ from the results of the model's analysis.

The Role of Engineering Professionals in Construction Projects

In construction projects, engineers and project managers have a strategic role in determining the direction of technical decisions. Structural engineers focus on structural safety and performance aspects, while project engineers assess technical implementation in the field (Zuo et al., 2022). On the other hand, the quantity surveyor assesses the cost impact of each material alternative, while the project manager plays the role of an integrative decision-maker. These interactions between roles form a collective decision-making process.

Influence of Organization and Project Management

The decision to select materials is inseparable from the project management system and the applicable organizational structure. According to Turner & Müller (2021), project control mechanisms and leadership styles affect the innovation space in material selection. In projects with tight budget controls, decisions tend to avoid the risk of using new materials. This shows that organizational factors can be an obstacle or driver for the adoption of environmentally friendly materials.

Context of Medium-Scale Projects in Developing Countries

Medium-scale construction projects in developing countries face different challenges compared to large projects or projects in developed countries. Limited supply of environmentally friendly materials and lack of policy incentives are the main obstacles (Nguyen et al., 2023). In rapidly growing urban areas, material decisions are often more influenced by short-term cost efficiencies. Therefore, the local context is an important factor in understanding the dynamics of material decisions.

METHODOLOGY

Types and Approaches to Research

This research uses a qualitative approach with a case study design, as it aims to understand in depth the dynamics of engineer decision-making in the context of real construction projects. Qualitative approaches are considered the most appropriate to examine social processes, inter-stakeholder interactions, and contextual considerations that cannot be reduced to numerical variables (Creswell & Poth, 2023). The case study design was chosen to allow an in-depth exploration of the phenomenon of eco-friendly material decision-making in medium-scale construction projects in Balikpapan City. By this design, research focuses on understanding processes, not on statistical generalizations.

Population and Sampling Techniques

The research population includes all professional actors involved in material decision-making on medium-scale construction projects in Balikpapan.

The sampling technique used is non-probability sampling with the purposive sampling method, because informants are selected based on their strategic role and direct experience in the material decision process. The number of participants was eight key informants, consisting of three project engineers, two structural engineers, two project managers, and one quantity surveyor. This composition was chosen to represent a variety of technical, financial, and managerial perspectives in project decision-making (Guest et al., 2020).

Data Collection Techniques and Instruments

Data collection was carried out through semi-structured in-depth interviews, which allowed researchers to explore experiences, considerations, and interactions between actors in a flexible but still directed manner. The interview guide was compiled based on a synthesis of the literature on sustainable material decision-making and adapted to the context of medium-scale construction projects. This interview technique was chosen because it was effective in uncovering the subjective meaning and logic of professional decisions (Kallio et al., 2020). In addition to interviews, supporting data is obtained through project documentation to reinforce the empirical context.

Data Validity and Credibility

The validity of the data is guaranteed through the implementation of source triangulation and member checking, namely by comparing answers between informants and confirming the results of interpretation to participants. This approach aims to improve the credibility, consistency, and reliability of research findings. In qualitative research, validity is not measured statistically, but through the accuracy of interpretation and traceability of the analysis process (Nowell et al., 2021). Thus, the results of the study are expected to accurately reflect the reality of decision-making.

Research Implementation Procedure

The research procedure was carried out gradually and systematically, starting from identifying problems and determining the research location, preparing interview instruments, to collecting field data. The next stage includes transcription of the interview, data encoding, and the extraction of key themes. The entire process is carried out iteratively to ensure the depth of analysis and consistency of the findings. This phased approach is in line with qualitative research practices that emphasize continuous reflection during the research process (Tracy, 2020).

Data Analysis Techniques

Data analysis is carried out using thematic analysis, which aims to identify patterns, themes, and relationships between concepts in qualitative data. The analysis process follows the stages of data recognition, initial coding, theme development, and interpretation of findings. To support the regularity and transparency of the analysis, this study uses NVivo software as a qualitative data management tool. Thematic analysis was chosen because it is able to reveal the

dynamics of cross-role decision-making in a systematic and contextual manner (Braun & Clarke, 2021).

RESEARCH RESULTS

Material Selection as a Dynamic Negotiation Process Across Considerations

The results of the study show that the decision to select environmentally friendly materials in medium-scale construction projects does not take place linearly or based on one specific technical criterion. Decisions are formed through a dynamic negotiation process that involves an exchange of arguments between material technical performance, cost efficiency, schedule pressures, and execution risk perceptions. This process takes place gradually and often undergoes revisions as project conditions change and the results of the team's internal evaluation.

In practice, project engineers and structural engineers generally start discussions by proposing alternative materials that are considered to meet technical specifications and have sustainability value. However, the proposal was not immediately accepted, but became a negotiation material with other actors in the project. A project engineer said that material decisions are rarely final from the start. "*Usually we submit it first from the technical side, but later we will definitely discuss again about cost and time. It was not immediately decided,*" (PE-01, interview October 12, 2025).

A similar view is expressed by structural engineers who emphasize that material decisions develop through collective discussion. "*There is never one person who decides. Everything is discussed, especially if the material is new or not yet common,*" (SE-01, interview October 18, 2025). The project manager also emphasizes that decisions are dynamic and contextual. "*The decision is the result of a tug-of-war between many interests, not just technical,*" (PM-01, interview October 15, 2025). This is reinforced by quantity surveyors who see negotiation as an inherent part of the project process. "*Environmentally friendly materials are always negotiated, safe points are sought,*" (QS-01, interview October 21, 2025).

Cost Efficiency as the Main Axis in the Final Decision

The findings of the study indicate that cost efficiency is the main axis that directs the negotiation process for the selection of environmentally friendly materials. In medium-scale projects, budget constraints mean that any material alternative must go through a rigorous cost evaluation before it can be approved. Materials that have a high sustainability value still have the potential to be rejected if they are considered to pose a significant cost burden to the project.

The quantity surveyor plays a central role in this stage by assessing the financial impact of each material option. "*We see whether the material is still within the budget limit or not. If it's too far, it's usually difficult to agree,*" (QS-01, interview October 21, 2025). The project manager added that the final decision is greatly influenced by the results of the cost analysis. "*No matter how good the material is, if it's not realistic in terms of cost, the project can be problematic,*" (PM-02, October 23, 2025 interview).

From a technical perspective, project engineers realize that cost efficiency is often a limiting factor. "*We sometimes have to adjust technical recommendations to*

stay within budget," (PE-02, interview October 14, 2025). The structural engineer also confirmed that the cost aspect cannot be ignored. "*The safety of the structure is important, but it must still be in line with the financial capabilities of the project,*" (SE-02, interview October 19, 2025). These findings suggest that eco-friendly material decisions rely heavily on a compromise between technical ideals and budget realities.

Schedule Pressure and Risk Perception as Controlling Factors

In addition to cost, schedule pressures and the perception of technical risks are strong controlling factors in material selection. Eco-friendly materials that are not commonly used are often perceived as having risks to the smooth implementation, both in terms of availability, installation methods, and workforce readiness. In medium-scale projects, time constraints make project actors more likely to avoid options that are considered high-risk.

A project engineer expressed concern about the impact of the schedule. "*If the material is not used normally, we are worried that the implementation will be slow,*" (PE-03, interview October 16, 2025). The structural engineer added that technical risks are a serious consideration. "*We have to make sure the material is completely safe and doesn't cause problems in the field,*" (SE-01, interview October 18, 2025). The project manager assessed that the delay in implementation could have a systemic impact on the project. "*If the schedule is disrupted, it will have an impact on the cost and reputation of the project,*" (PM-01, interview October 15, 2025). Quantity surveyors also look at risk as part of decision calculation. "*Technical risks usually lead to additional costs, that's what is avoided,*" (QS-01, interview October 21, 2025). These findings suggest that schedule pressures and risk perceptions serve as controlling mechanisms in material negotiations.

The Role of Project Manager and Quantity Surveyor Determinants in the Final Decision

The results of the study consistently show that project managers and quantity surveyors have a determinant role in the final decision on the selection of environmentally friendly materials. Although the process is initiated by technical considerations from the engineer, the final decision rests with the actor who has managerial authority and cost control. This role makes the project manager and quantity surveyor the determinant of the direction of cross-role negotiations.

The project manager sees himself as an integrator of various interests. "*I have to look at all aspects, technical, cost, and time, before I can decide,*" (PM-02, October 23, 2025 interview). The quantity surveyor emphasizes the function of financial validation in decisions. "*The final decision is usually waiting for the green light in terms of cost,*" (QS-01, interview October 21, 2025). Project engineers are aware of the limits of their role in decision structures. "*We give recommendations, but the decision is in the management,*" (PE-01, interview October 12, 2025). Structural engineers also emphasize the collective yet hierarchical nature of decisions. "*Discussion together, but there are still parties who decide,*" (SE-02, interview October

19, 2025). This shows that the adoption of eco-friendly materials is strongly influenced by cross-role decision-making mechanisms.

Individual Environmental Awareness Is Not the Main Determinant of Material Adoption

Another important finding suggests that the environmental awareness of individual engineers is not a major determining factor in the adoption of eco-friendly materials. All informants stated that they had an understanding of the importance of sustainability, but this awareness did not directly translate into material decisions. Implementation remains dependent on the collective process and structural constraints of the project.

A project engineer said that environmental awareness often clashes with the reality of the project. "*We understand the environment, but decisions can't be based on that alone.*" (PE-02, interview October 14, 2025). The project manager added that the project system is more decisive than personal values. "*Individual awareness is important, but what runs is the decision system,*" (PM-01, interview October 15, 2025). Structural engineers also consider that decisions are structural. "*It's not a matter of whether you want to or not, it's about whether you can or can't.*" (SE-01, interview October 18, 2025). The quantity surveyor confirmed the same thing. "*During a decision mechanism like this, personal awareness is not strong enough,*" (QS-01, interview October 21, 2025). These findings confirm the novelty of the research that in medium-scale projects, the adoption of environmentally friendly materials is more determined by cross-role decision-making mechanisms than by the environmental awareness of individual engineers.

DISCUSSION

The results of this study confirm that the selection of environmentally friendly materials in medium-scale construction projects is a dynamic, negotiable, and contextual decision-making process. Decisions are not formed through a linear rational flow based on a single technical criterion, but rather through a process of cross-role argument exchange that continues to evolve as project conditions change. These findings reinforce the view that sustainable construction practices should be understood as a socio-organizational process, not merely as a material technical issue (Flyvbjerg, 2021; Lycett et al., 2022). Thus, sustainability in construction is determined not only by the quality of the materials, but also by the dynamics of the interaction of the project actors involved.

The dynamic negotiation process found in this study shows that technical recommendations from project engineers and structural engineers serve as starting points for discussion, not as final decisions. This is in line with previous research findings that technical decisions in construction projects develop through collective discussion and repeated revisions, especially when they involve innovations or materials that are not yet commonly used (Söderlund & Geraldi, 2021). Theoretically, these findings support an interactive decision-making approach that emphasizes that project decisions are formed through deliberative processes between actors with different interests and authorities.

This research consistently shows that cost efficiency is the main axis that directs the final outcome of the negotiation of the selection of environmentally friendly materials. In medium-scale projects, budget constraints create narrow decision-making space so that materials with high sustainability value still have the potential to be rejected if they are not aligned with the project's financial capacity. These findings are in line with international studies that confirm that cost pressures are a major barrier to sustainable material adoption, particularly in non-iconic and non-government projects (Hwang & Ng, 2021; Nguyen et al., 2023). Conceptually, this suggests a structural tension between long-term sustainability goals and short-term economic rationality in construction practices.

In addition to cost, schedule pressures and the perception of technical risks serve as significant controlling mechanisms in the decision-making process. Eco-friendly materials that are not commonly used are perceived as risky to the smooth implementation of the project, both in terms of availability, construction methods, and workforce readiness. These findings are consistent with risk-averse behavior theory in project management which states that project actors tend to avoid innovation when under conditions of time pressure and operational uncertainty (Too & Weaver, 2021). As such, material sustainability is often compromised in order to maintain schedule stability and minimize potential project failure.

This study also reveals the role of determinants of project managers and quantity surveyors as final decision-makers in the selection of environmentally friendly materials. Although engineers play an important role in providing technical recommendations, strategic decisions remain with actors who have managerial authority and cost control. These findings reinforce a project governance theory that places authority structures and resource control as key factors in decision-making (Turner & Müller, 2021). Empirically, these results expand the understanding of construction sustainability by showing that the adoption of environmentally friendly materials is strongly influenced by the configuration of power in project organization.

Another important finding suggests that the environmental awareness of individual engineers is not a major determinant in the adoption of eco-friendly materials. Although all informants showed a positive understanding and attitude towards sustainability issues, this awareness did not directly translate into material decisions. These results are contrary to the individualized behavior approach that places personal attitudes and intentions as dominant factors in sustainable behavior (Ajzen, 2020). In contrast, this study shows that material decisions in medium-scale projects are more determined by collective mechanisms and structural constraints of the project, so that individual consciousness only serves as a normative background.

In terms of theoretical contribution, this study fills a gap in the literature by presenting empirical evidence based on a qualitative approach on the dynamics of eco-friendly material decision-making in medium-scale construction projects in developing countries. Most previous research has focused on optimization models or quantitative assessments of materials,

without delving into the negotiation processes and power relations that shape actual decisions on the ground. Using NVivo-assisted thematic analysis, this study provides a deeper understanding of how technical considerations, costs, risks, and organizational structures interact with each other in practice.

Practically, the findings of this study imply that efforts to encourage the use of environmentally friendly materials need to be directed at reformulating project decision-making mechanisms, not just on increasing the awareness of individual engineers. Strengthening the capacity of project managers and quantity surveyors in understanding the long-term value of sustainable materials is crucial. The limitations of this study lie in the limited scope of the project and the region, so the findings are contextual. Follow-up research is recommended to involve more cross-regional projects and combine qualitative and quantitative approaches to broaden the generalization of findings.

CONCLUSION AND RECOMMENDATION

This study concludes that the selection of environmentally friendly materials in medium-scale construction projects is a dynamic, collective, and contextual decision-making process, not a linear technical decision or based on individual awareness. Decisions are formed through ongoing negotiations between considerations of technical performance, cost efficiency, schedule pressures, and risk perception, which take place within the project's organizational structure with a clear division of roles and authority. In the context of medium-scale projects in Balikpapan City, project managers and quantity surveyors have a determinant role in the final decision due to managerial authority and control over financial resources, while the role of engineers is more recommendative. These findings confirm that the adoption of eco-friendly materials at the project level is more influenced by cross-role decision-making mechanisms and project structural constraints than by the level of individual environmental awareness of engineers. Thus, efforts to encourage sustainable construction need to be directed at strengthening governance and project decision mechanisms that are more adaptive to sustainability, so that environmental values can be realistically integrated in medium-scale construction practices.

FURTHER STUDY

Future research is recommended to explore more deeply the organizational, institutional, and behavioral factors that shape material selection decisions in medium-scale construction projects. Further studies could examine how procurement policies, contractual arrangements, and incentive structures influence the adoption of environmentally friendly materials. Comparative research across different cities, project scales, or regulatory environments may also provide broader insights into contextual variations in sustainability-oriented decision-making. In addition, longitudinal studies are needed to assess how changes in governance mechanisms, stakeholder collaboration, and sustainability regulations affect the consistency and effectiveness of eco-friendly material adoption in construction practices.

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