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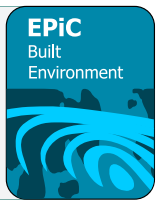

An Innovative Use of Case Models to Manage Stakeholder Interfaces in Energy-Efficient Sustainable Construction

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The stakeholder context in sustainable construction is vital to project success, defining the environment in which stakeholders interact, influence, and are influenced by the project. This paper explores the role of energy efficiency as the primary measure of sustainability in construction projects. This context encompasses roles, interests, relationships, and dynamics, all crucial for managing interactions and achieving positive outcomes. This study is divided into two parts. Part One focuses on developing a conceptual framework during the preparation, planning, and design phases; Part Two introduces a project lifecycle-spanning use case model for the owner, design team, and construction contractor. Focusing on the planning and design phases, this paper emphasizes the importance of early-stage stakeholder management and collaboration to integrate sustainability and energy efficiency objectives from the outset. Early decisions regarding materials, processes, and environmental factors impact long-term project sustainability. Achieving energy-efficient sustainability goals requires cooperation among stakeholders through interface management, balancing economic, social, and environmental considerations. Integrating stakeholder perspectives and fostering partnerships is essential to address complex challenges and promote resilient, sustainable, and equitable built environments. This paper explores stakeholder roles and relationships in sustainable construction, aiming to improve management, reduce conflicts, and enhance project performance and energy efficient sustainability outcomes.

Keywords: Stakeholder Interface Management; Energy Efficiency in Planning and Design Phases; Sustainable Project Management; Built Environments; Construction Project Lifecycle.

Introduction

Achieving sustainability in construction requires an approach that integrates environmental concerns with stakeholder perspectives, emphasizing collaboration, especially in the planning and design phases. Achieving sustainability in construction requires prioritizing energy efficiency as a core objective. Early engagement in these stages is critical to fostering resilient, equitable, and sustainable built environments. The construction industry comprises various stakeholders—clients, owners, contractors, subcontractors, suppliers, consultants, architects, and engineers—whose interactions influence and shape sustainability agendas. The “stakeholder context” encompasses these interactions and reflects the roles, relationships, interests, and priorities each party brings to the project. Collaborative engagement among stakeholders, who may have differing priorities, is essential to embedding sustainability and energy efficiency within planning and design. Understanding stakeholder dynamics in the early stages helps align interests, reduce conflicts, and balance economic,

social, and environmental objectives. This paper explores the roles and relationships of key stakeholders such as owners, contractors, and designers during planning and design phases through a case study. Using a conceptual framework and use case models, it highlights key responsibilities, coordination strategies, and areas for improvement. The findings underscore that effective stakeholder management reduces costs, minimizes delays, and mitigates conflicts, ultimately enhancing sustainability and project performance. The study offers a practical roadmap for industry practitioners and academics. Finally, the paper identifies common barriers to sustainable practices and stresses the importance of understanding stakeholder motivations. It addresses specific challenges and offers actionable recommendations to advance sustainability across the construction industry.

Project Objectives

This study addresses gaps in previous research by presenting a case study focused on stakeholder management within sustainable construction. It focuses on the design-bid-build delivery method, structured according to the Royal Institute of British Architects (RIBA) framework. Part One develops a conceptual framework during the preparation and design phases, applying factors impacting stakeholder interface management. Part Two creates a Use Case Model to analyze relationships among key stakeholders—owner, design team, and contractor—whose collaboration is crucial for project success. Figure 1 outlines areas for enhancing stakeholder engagement in sustainable construction projects. The study's objectives include:

- Establishing a Conceptual Framework: This framework, developed during the preparation and design phases, highlights the importance of stakeholder engagement, particularly in early project stages, to improve energy efficiency through stakeholder interface management in sustainable construction.
- Implementing a Use Case Model: As the first study to apply a use case model in this context, it provides a novel method for analyzing stakeholder interface management in sustainable construction. It offers a unique contribution to the field, aligning roles and interactions with energy efficiency goals.

Literature Review: Stakeholder Theory and Sustainability

Stakeholder theory is now central to management, offering a structured way to understand how diverse individuals and groups either affect or are affected by an organization's goals. This concept was formalized in Freeman's *Strategic Management: A Stakeholder Approach*, where stakeholders are defined as "any group or individual who can affect or is affected by the achievement of the organization's objectives" (Freeman, 1984). Building on this, Mitchell, Agle, and Wood (2016) classified stakeholders as either "claimants" who seek benefits, or "influencers" who hold the power to alter project outcomes. Kaler proposed a hybrid perspective that blends ethical and strategic views, asserting that both claimants and influencers are key to stakeholder management (Kaler, 2002). In the construction sector, stakeholders are further categorized into "internal" participants directly involved in project execution and "external" entities indirectly affected by the project's results (Olander, 2007). The success of construction projects is closely tied to effective stakeholder engagement. Absence of stakeholder input has led to failure of numerous public-private infrastructure projects. Private-sector involvement in stakeholder management often prioritizes market competitiveness, while public-sector projects tend to take a democratic approach to stakeholder engagement. Stakeholders in construction assess project value from diverse perspectives, underscoring the need for robust management strategies to address varied needs (Olander, 2007). Engaging stakeholders ensures their inputs are integrated into project development, enhancing overall project alignment (Olander, 2007). Stakeholder management is essential for sustainable project delivery. Construction stakeholders,

defined by Li et al. (2016) as those influencing project processes, include clients, developers, consultants, engineers, designers, contractors, suppliers, and local authorities, all requiring effective collaboration. Stakeholder dynamics evolve throughout project phases, adding complexity. Sustainability, framed as a technical aim, ethical stance, or "dialogue of values" (Ratner, 2004), relies on governance to align economic, environmental, and social pillars (Sierra et al., 2016; Li et al., 2018). Sustainable projects balance these pillars to reduce costs, lower emissions, and enhance well-being (Jafari et al., 2019). This study focuses on the design team's role during planning and design to optimize outcomes and align with sustainability. Energy efficiency, central to sustainable construction, requires stakeholder collaboration to prioritize energy-efficient materials, designs, and technologies. Bal et al. (2013) highlight the importance of aligning stakeholder agendas with measurable energy performance metrics for sustainable outcomes.

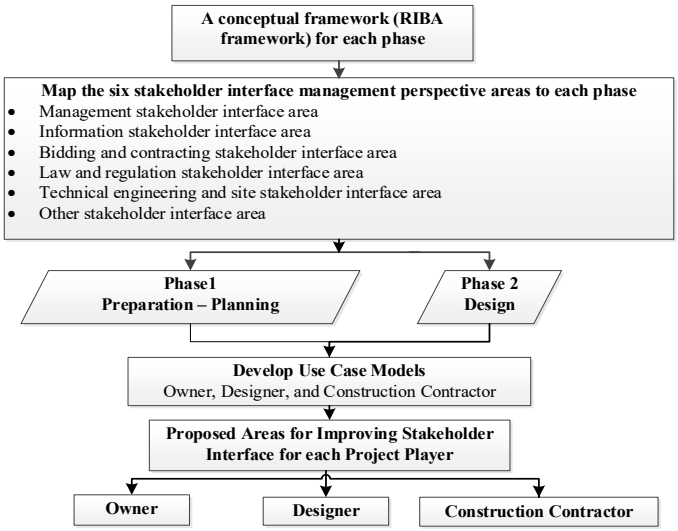

Figure 1. Proposed areas to improve stakeholder interface engagement within sustainable construction projects (authors' concept)

Strategies for Effective Stakeholder Engagement in Sustainable Construction

Effective stakeholder engagement in sustainable construction is essential yet challenging due to conflicting priorities, communication gaps, and resource constraints. Differing economic, environmental, and social objectives often complicate alignment on sustainability and energy efficiency goals. To overcome these challenges, To address these challenges, strategies must focus on energy performance, including prioritizing influential stakeholders, conducting stakeholder analysis, and fostering collaborative planning. Transparent decision-making processes build trust, while regular interactions address evolving priorities. Seeking perspectives on energy efficiency ensures diverse viewpoints are considered, aligning engagement efforts with environmental and energy-efficient outcomes (Nahyan et al., 2019). Bal et al. (2013) propose a six-step process for stakeholder engagement: (i) identifying stakeholders, (ii) aligning stakeholders with sustainability-related targets, (iii) prioritizing stakeholders, (iv) managing interactions, (v) measuring performance, and (vi) implementing targets. Their findings highlight the importance of understanding stakeholders' sustainability agendas and utilizing key performance indicators to achieve sustainability objectives.

Integrated Project Delivery (IPD) enhances engagement by involving stakeholders early on, fostering collaboration, promoting diverse perspectives, and improving sustainability-related decisions (Nahyan et al., 2019). Transparent communication builds trust and reduces conflict, ensuring effective information sharing about energy-efficient practices. Incentive-based mechanisms like financial rewards for adopting energy-saving technologies or meeting benchmarks encourage sustainable behaviors (Agrawal et al., 2023). Community engagement programs address local needs, foster social acceptance, and reduce opposition to sustainability initiatives (Nahyan et al., 2019). These strategies enable projects to overcome barriers, achieve collaborative engagement, and deliver sustainable, energy-efficient outcomes.

Methodology

Following Chouksey and Karmarkar's (2019) recommendation, this study combines qualitative and quantitative methods to enhance result validity and reliability. Surveys, as highlighted by Chouksey and Karmarkar (2019), boost confidence in the generalizability of findings. This research presents an integrated framework to improve stakeholder interface management, emphasizing energy efficiency and sustainability. By combining use case modeling and regression analysis, it offers practical tools and insights to enhance communication, collaboration in construction projects. Six key factors impacting stakeholder engagement, decision-making, and sustainability—management, information, bidding and contracting, law and regulation, technical engineering, and other interface challenges—were analyzed during project preparation, planning, and design phases. (Figure 1). A mixed-methods approach, including a literature review, pilot studies, and a web-based survey, ensured comprehensive data collection and analysis. The literature review identified 31 stakeholder interface problems, with pilot studies uncovering 16 more, resulting in 47 critical issues for further investigation. Web-Based Survey: A web-based survey with Alberta's construction industry stakeholders evaluated identified interface problems. Participants assessed each issue's probability, impact on interface management systems, and importance for project performance metrics such as quality, schedule, cost, scope, safety, and teamwork. They also provided recommendations for improvement. Structured Interviews: Structured face-to-face interviews complemented the survey. As Kajornboon (2005) explains, structured interviews maintain consistency by asking all respondents the same questions in the same wording and sequence. This approach ensured a standardized understanding of participants' perspectives. Participants included members of associations including the Project Management Focus Group (PMFG), Consulting Engineers of Alberta (CEA), Consulting Architects of Alberta (CAA), and the Alberta Construction Association (ACA). Respondents represented various roles, including project managers, engineers, architects, and quality control personnel, across multiple sectors such as commercial buildings, infrastructure, oil and gas, and transportation. Of the 135 valid questionnaires, most responses came from architects and project control groups, followed by structural, mechanical, and electrical engineers. Regression analysis examined correlations between stakeholder management factors and respondent profiles (e.g., company type, role, experience), identifying critical interface management issues and actionable insights. The integrated model developed in this study is based on 12 regression analyses, offering practical strategies to address stakeholder interface problems and enhance sustainability (Weshah et al., 2013, 2014). Use Case Model: this research is the first to apply the use case model to analyze stakeholder interface management in construction. Pender (2003) describes a use case model as a graphical tool that represents interactions between the system and "actors" (individuals, systems, organizations, and other entities interacting with the system). A use case model, consisting of actors, use cases (functional system interactions), and relationships like «include» (mandatory) and «extend» (optional), enables companies to document stakeholder interactions, improve collaboration, and address interface challenges, making it a practical tool for managing stakeholder interfaces in sustainable construction (Pender, 2003).

A Conceptual Framework for Preparation and the Design Phases

Insights from industry experts and analysis results were used to map critical Stakeholder Interface areas for the preparation, planning, and design phases, as shown in Figures 2 and 3. Three main problem areas were identified regarding: management, information, and law and regulation interfaces, with additional focus on technical and other interface challenges. The bidding and contracting factor will be addressed in future work for pre-construction and construction phases. Within the Management Stakeholder Interface for Sustainability, the design phase includes three key stages (see Figure 3): outline proposal, scheme design, and detailed design. The project team must prioritize sustainability assessments, familiarize themselves with local laws, codes, and regulations, and ensure effective information sharing among team members to support final design and cost considerations. Addressing technical engineering and site issues is also critical to meeting sustainability goals in the detailed design phase.

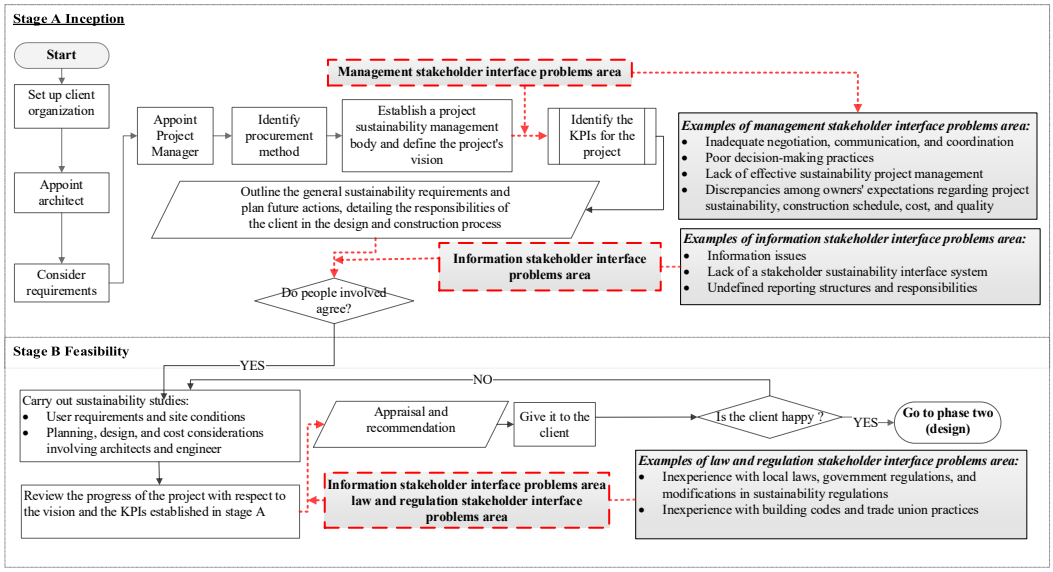

Figure 2. A conceptual framework for Phase One (Preparation – Planning), incorporating management stakeholder interface areas of sustainability in construction (authors' concept)

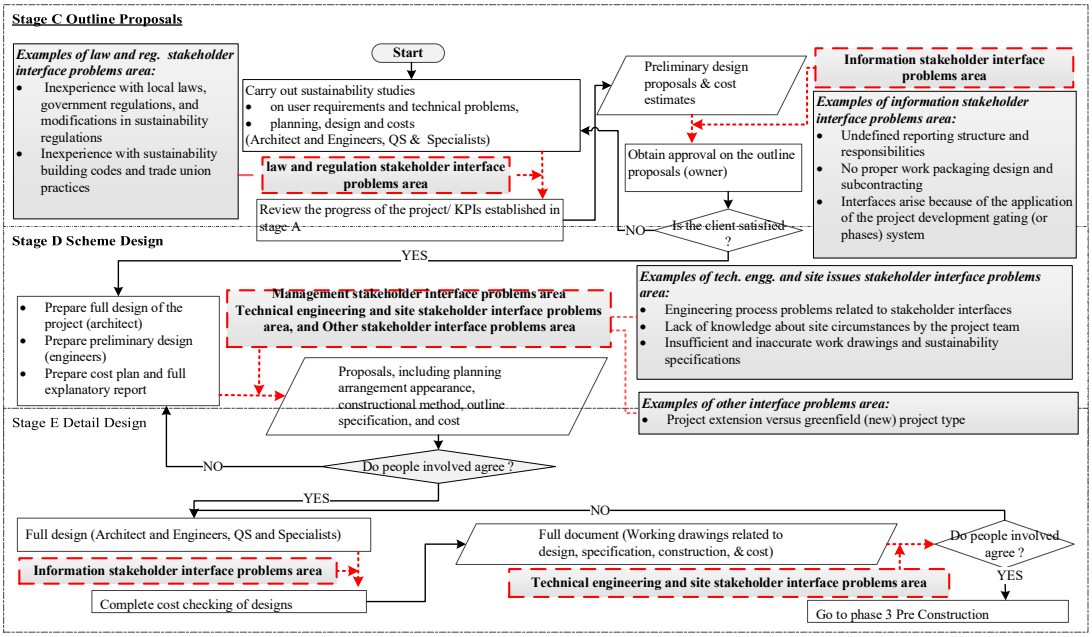

Figure 3. A conceptual framework of Phase Two (Design), incorporating management stakeholder interface areas of sustainability in construction (authors' concept)

Use Case Modeling for Stakeholder Interface Management Between Owner, Designer, and Contractor in Sustainable Construction Projects

Recent studies highlight the value of use case models for managing stakeholder relationships in sustainable construction projects. The versatile, structured framework clearly captures system requirements and workflows. However, it may oversimplify complex scenarios and often requires complementary methods to address non-functional requirements or evolving dynamics. A use case model includes actors (entities interacting with the system), use cases (functional processes), and relationships such as «include» (mandatory) and «extend» (optional) (Ribu, K., 2001). Complex actors (e.g., design team, owner, contractor) have decision-making roles; average actors (e.g., subcontractors) have moderate responsibilities; simple actors (e.g., regulatory agencies) have minimal interactions. Here, weighting factors were excluded to avoid oversimplifying stakeholder roles, focusing instead on core objectives and qualitatively exploring interactions and workflows in sustainable construction. Model development begins by identifying stakeholders and project goals, with each use case defining specific workflows. Unified Modeling Language (UML) diagrams visually represent relationships between owners, designers, and contractors across project phases, distinguishing between "soft" actions (e.g., discussions, informal engagement) and "hard" actions (e.g., formal documentation, regulatory compliance).

Improvement areas are categorized as 70% hard actions and 30% soft actions. Figure 4 illustrates UML use case model relationships. Figure 5 shows relationships across project phases. Figure 6 outlines the design team's tasks and reiterates the distinction between soft and hard actions. It connects use cases with dashed lines and actors with solid lines. The «include» relationship allows us to include the steps from one use case into another. Together, these diagrams provide a practical framework for coordinating stakeholder interactions throughout the project lifecycle, from design to construction, with a strong emphasis on sustainability. This research proposes an innovative use of the use case model to manage stakeholder interfaces in sustainable construction. Departing from previous

studies, it uses the model's visual structure to map interactions between actors and the project, clearly defining stakeholder roles throughout phases (Pender, 2003). In the traditional delivery approach, three core steps—Design Assignment, Competitive Bidding, and Construction Contract—form two main contracts: one between the owner and designer, and another between the owner and contractor. This practical framework coordinates stakeholder interactions from design to construction, focusing on sustainability objectives.

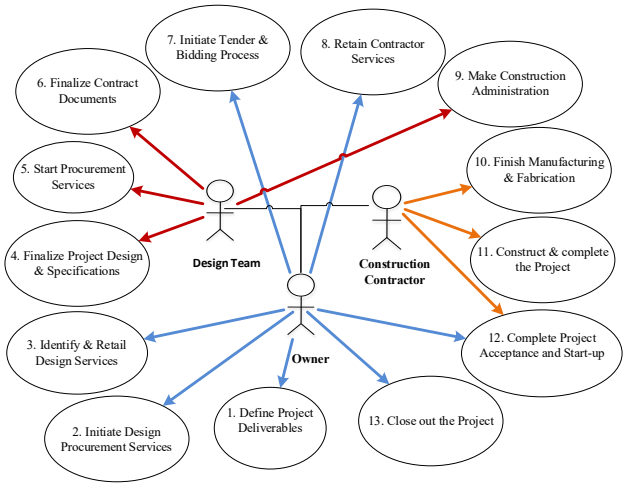

Figure 4. UML use case model of the current relationships among different stakeholders of sustainability in construction: owner, designer, and contractor; adapted from the American Institute of Architects and the Associated General Contractors of America (2011) (authors' concept)

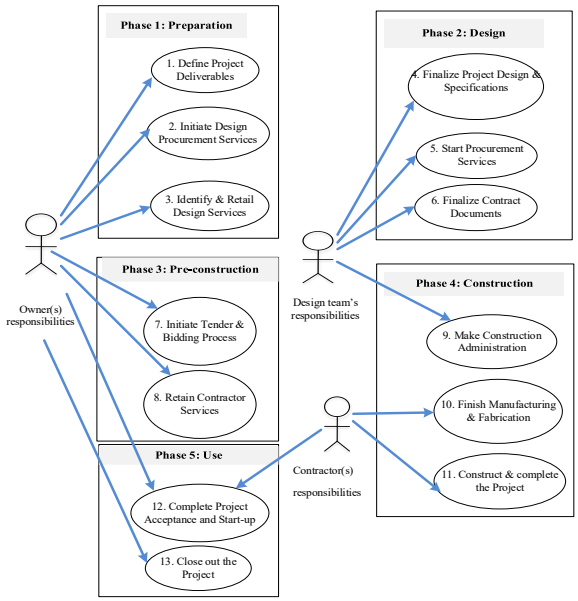

Figure 5. UML use case model packages of relationships between owner, designer, and contractor across project phases (authors' concept)

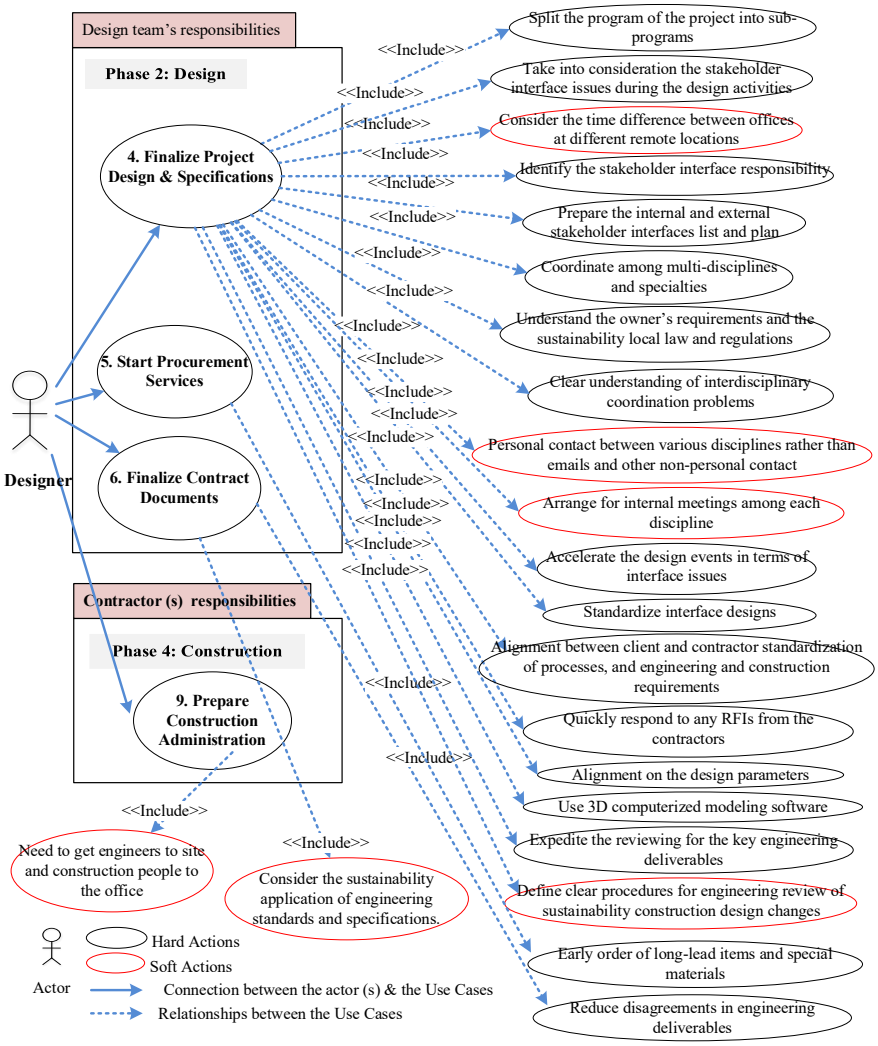

Figure 6. Proposed use case model package for design team's responsibilities and actions

Summary, Benefits of the Research, and Recommendations

This research provides a comprehensive framework for stakeholder management within sustainable construction, particularly regarding sustainability and energy efficiency, benefitting projects by reducing conflicts and improving project outcomes through early and clear definition of roles and interfaces. Structured methodologies, like the RIBA approach and use case models, guide stakeholders in identifying potential interface issues from the outset, allowing for timely interventions and smoother project execution. By adopting a holistic view of stakeholder roles, motivations, and expectations, the research aligns project objectives with broader sustainability goals, enhancing overall project performance and energy efficiency. For effective implementation, the study recommends viewing stakeholders as collaborative partners whose input is essential to the sustainability of construction projects. Ultimately, commitment to proactive stakeholder engagement,

innovative methodologies, and adaptive strategies will help the construction industry develop more sustainable, efficient, and harmonious project environments.

Benefits of the Research

This research presents a UML-based framework to analyze and manage stakeholder relationships in sustainable construction. By employing this structured approach, companies can enhance interactions among owners, contractors, designers, and other stakeholders, promoting sustainability and collaboration throughout the project lifecycle. Findings provide actionable insights for project managers, architects, and engineers to refine tools and methods early on, improving performance and sustainability outcomes. Proactively identifying potential issues helps minimize conflicts, streamline communication, and reduce delays. This approach supports stakeholder alignment, reduces costs, and enhances sustainability goals, with use case models facilitating better coordination.

Future Research Directions

Future research should further refine stakeholder engagement and explore innovative sustainability trends like advanced technologies, circular economy principles, and social impact assessments to enhance collaboration and accountability. Applying this study's framework across project phases like pre-construction, contracting, construction, and maintenance, will deepen understanding of stakeholder impact on sustainable construction outcomes.

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