

A Study on Sustainable Development Strategies in Engineering Management under the Context of Green Buildings

Meng Li*

Nanchang Institute of Science and Technology, Nanchang, 330108, China

*Corresponding author: 15773022019@163.com

Abstract: Against the backdrop of global energy shortages and increasing ecological pressures, green buildings have become an important direction for the development of the construction industry. As a core link in construction activities, engineering management plays a crucial supporting role in promoting sustainable development. Based on the core concepts and evaluation system of green buildings, this paper analyzes the connotations and development trends of engineering management in terms of resource utilization, environmental optimization, and informatization application, and further explores the logic of integration between the two in concepts, methods, and objectives. On this basis, the study examines the key elements of sustainable development in engineering management, including resource utilization efficiency and life-cycle management, environmentally friendly construction technologies and material selection, as well as intelligent monitoring and informatized collaborative management. Finally, the paper proposes optimization strategies for engineering management oriented toward sustainable development, emphasizing the reconstruction of organizational models through systems thinking, dynamic control of quality and risk throughout the entire process, and innovation-driven continuous improvement under multidimensional collaboration, in order to promote the efficient and sustainable operation of green building projects in complex environments. The research results provide theoretical support and methodological reference for the deep integration of green buildings and engineering management.

Keywords: green buildings; engineering management; sustainable development; life cycle; intelligent management

Introduction

With the acceleration of economic development and urbanization, the construction industry, while meeting social demands, has brought about problems of high energy consumption and high emissions. How to reduce resource consumption and environmental burdens while ensuring construction quality has become an urgent issue to be addressed. As a construction concept that takes energy conservation, emission reduction, and environmental friendliness as its core objectives, green building is leading the structural transformation of the construction industry. Engineering management in this context not only undertakes the functions of organization and control but also requires the coordination and optimization of multiple objectives with the support of systematization, informatization, and intelligentization. Therefore, studying sustainable development strategies of engineering management under the background of green buildings is not only conducive to enhancing the overall efficiency of construction projects but also provides both theoretical foundations and practical approaches for achieving long-term sustainable development in the construction industry. This research holds significant importance and necessity for promoting efficient resource utilization, improving the quality of the living environment, and advancing the high-level development of the construction industry.

1. Theoretical Foundations of Green Buildings and Engineering Management

1.1 Core Concepts and Evaluation System of Green Buildings

The concept of green buildings originates from the construction industry's deep concern for environmental protection and efficient resource utilization, and its connotation is embodied in a people-oriented and environmentally centered comprehensive construction mindset. Green buildings

not only require the reduction of burdens in terms of energy consumption, carbon emissions, and waste treatment but also emphasize improving the health and comfort of building use through rational planning and technical measures. The sustainable goals of the entire building life cycle constitute the essential characteristic of green buildings. From site selection and design to construction management, operation and maintenance, and finally demolition and recycling, all stages must reflect the principles of resource conservation and environmental friendliness. This concept regards construction activities as part of the ecosystem and stresses the positive interaction between building practices and the natural environment.

In the process of achieving the goals of green buildings, a scientific evaluation system serves as an important tool to promote the implementation of these concepts. The evaluation system not only provides quantitative standards but also offers operable pathways for design and construction. At present, internationally recognized systems such as LEED and BREEAM, as well as the widely applied domestic Green Building Evaluation Standard, set clear indicators in areas such as energy consumption, water resource management, material utilization efficiency, indoor environmental quality, and ecological protection. With the diversified development of green buildings, evaluation systems are showing trends of multidimensionality, dynamism, and regional adaptability, increasingly integrating building information modeling and life-cycle assessment tools to enable real-time monitoring and optimization of building performance at different stages. This process not only enhances the scientific nature of green buildings but also provides quantitative references for engineering management ^[1].

1.2 Connotations and Development Trends of Engineering Management

The core of engineering management lies in the systematic and scientific regulation of construction projects as a whole, covering multiple aspects such as project objective setting, resource allocation, schedule control, cost management, and quality assurance. Traditional engineering management has largely emphasized efficiency and economic benefits, whereas under the background of green buildings, its connotations have been further expanded to encompass environmental benefits and social values. Engineering management needs to coordinate multiple resources and factors, ensuring on-time project delivery while simultaneously achieving objectives such as energy utilization optimization, sustainable material selection, and mitigation of environmental impacts. This multi-objective parallel management requires higher levels of professional competence from engineers and poses challenges for the innovativeness and adaptability of management models.

With the development of emerging technologies, engineering management is showing a transformation toward digitalization, intelligentization, and visualization. The introduction of Building Information Modeling, Internet of Things sensor technology, big data analytics, and artificial intelligence tools enables construction projects to achieve life-cycle information integration and dynamic regulation. BIM not only allows for clash detection and energy efficiency simulation during the design stage but also facilitates rational resource allocation and real-time monitoring of energy consumption during construction and operation phases. Big data and artificial intelligence provide predictive analysis and intelligent decision-making support for engineering management, thereby improving management efficiency under the complex variables of green buildings. In the future, engineering management will continue to evolve toward greater collaboration and sustainability, gradually forming an integrated management model characterized by multi-party participation and interdisciplinary convergence.

1.3 The Logic of Integration between Green Buildings and Engineering Management

The relationship between green buildings and engineering management is not a simple superposition but rather a deeply interwoven and mutually supportive logical connection. At the conceptual level, both share the goals of resource conservation and environmental optimization, while further extending their focus to social benefits and residential experience. At the methodological level, engineering management transforms the abstract concepts of green buildings into operable pathways through systematic organizational and control measures, ensuring that the objectives of energy conservation, emission reduction, and environmental protection are implemented across all stages of the project. At the goal level, the sustainable development pursued by green buildings requires engineering management to provide dynamic monitoring and adjustment mechanisms, so as to ensure consistency with environmental coordination objectives from design to construction and subsequently to operation and maintenance ^[2].

The logic of integration is further reflected in the demand for engineering management to achieve a dynamic balance among the fourfold constraints of time, cost, quality, and environment under the complexity of green buildings. Innovations in material selection, energy technologies, and construction processes in green buildings have driven engineering management to shift from traditional linear process control to a nonlinear, dynamically regulated system. This integration not only fosters innovation in management models but also promotes cross-disciplinary collaboration, providing a solid foundation for the application of green buildings in diverse contexts. Through this integrative logic, green buildings are no longer an isolated design concept but rather an overall objective embedded within the engineering management system, while engineering management, through the introduction of green concepts, acquires a stronger orientation toward sustainable development.

2. Key Elements of Sustainable Development in Engineering Management

2.1 Resource Utilization Efficiency and Life-Cycle Management

In the context of green buildings, resource utilization efficiency is not only a direct objective of energy and material conservation but also a core variable for achieving sustainability in engineering management. Construction projects involve multidimensional elements such as energy, water resources, land, materials, and human resources throughout the stages of design, construction, and operation, and the focus of management lies in achieving coordinated allocation under multiple objectives. Refined design and high-precision construction can significantly reduce material waste and energy redundancy. For example, digital modeling technology can accurately simulate resource consumption pathways during the design stage, thereby reducing waste caused by errors; modular construction and prefabricated building methods help optimize material utilization, thereby improving resource efficiency at the source. Under this logic, engineering management is gradually evolving into an integrated management model oriented toward system integration and dynamic regulation.

Life-cycle management further deepens the strategic significance of resource efficiency. It not only emphasizes control over a single stage of a building but also focuses on systematic management across the entire process of design, construction, operation, and demolition. By introducing tools such as life-cycle cost analysis, carbon footprint assessment, and energy simulation, managers are able to comprehensively grasp the dynamic balance between resource input and benefit output. For instance, during the operation stage, energy consumption monitoring data can be fed back into design optimization, providing parameter references for new projects; during the demolition stage, the recycling and reuse of waste materials can reduce environmental burdens and achieve resource recovery. Life-cycle thinking reveals the potential environmental impacts of buildings at different stages, making resource allocation no longer a static economic consideration but rather a dynamic decision for sustainable development. Through this cross-stage management model, green buildings are able to realize the integration of resource conservation and environmental friendliness at a holistic level.

2.2 Environmentally Friendly Construction Technologies and Material Selection

The construction stage is the phase of a building project that exerts the most significant impact on the environment, and environmentally friendly construction technologies therefore serve as a core lever in the engineering management of green buildings. Such technologies, through the optimization of construction processes and the adoption of cleaner production methods, can effectively reduce adverse effects on the surrounding environment. For example, the application of low-emission construction equipment and energy-efficient machinery can reduce energy consumption and carbon emissions; noise suppression and dust control technologies can improve air quality and residential comfort both on-site and in surrounding areas; and the classification, collection, and reuse of construction waste can substantially increase resource recycling rates. Environmentally friendly construction not only helps reduce environmental costs during the project construction stage but also creates conditions for efficient operation of buildings in later phases by reducing energy consumption and waste emissions^[3].

Material selection represents another key dimension for achieving the sustainability goals of green buildings. The thermal performance, durability, and environmental attributes of materials directly affect building energy consumption and carbon emission levels. In recent years, low-carbon building materials, renewable materials, and composite materials with high recyclability have gradually become focal points in the industry. Engineering managers need to evaluate materials' environmental

performance from a life-cycle perspective, considering not only their direct economic costs but also their overall energy consumption and carbon emissions during production, transportation, usage, and disposal. For instance, the use of bamboo and recycled concrete can significantly reduce environmental burdens while ensuring structural performance; photocatalytic concrete and high-performance insulation materials can enhance building performance while also promoting environmental friendliness. Through scientific selection and rational allocation, green buildings are able to achieve dual improvements in environmental benefits and functional value, thereby laying a solid foundation for the sustainable development of engineering projects.

2.3 Intelligent Monitoring and Informatized Collaborative Management

Intelligent monitoring serves as the technological support for enhancing the sustainability of engineering management. The introduction of sensing technology, the Internet of Things, and real-time monitoring platforms enables dynamic collection and analysis of parameters such as energy consumption, environmental quality, and structural safety. This data-driven management approach overcomes the limitations of traditional static management, allowing for instant warnings of abnormal conditions and providing scientific evidence for subsequent decision-making. Intelligent monitoring not only improves management efficiency but also offers quantifiable support for the achievement of green building objectives ^[4].

Informatized collaborative management emphasizes efficient interaction and data sharing among multiple parties. Building Information Modeling plays a central role in this process by integrating information from design, construction, and operation and maintenance, thereby enabling interdisciplinary and cross-stage collaboration. By leveraging informatized platforms, engineering management can effectively reduce loss and distortion in information transfer, while improving the accuracy of resource scheduling and plan execution. This form of collaboration not only shortens the decision-making chain but also enhances system flexibility and adaptability, ensuring that green building projects maintain a high level of controllability and sustainability in complex and dynamic environments.

3. Engineering Management Optimization Strategies under the Orientation of Sustainable Development

3.1 Reconstruction of Project Organization Models Based on Systems Thinking

Green building projects typically span the entire life cycle of design, construction, and operation and maintenance, involving multiple disciplines such as energy systems, structural design, environmental simulation, materials science, and information management. Their complexity and multidimensional characteristics make it difficult for traditional linear management approaches to address the challenges of dynamic change. Systems thinking provides a holistic perspective, viewing construction projects as complex systems composed of interacting elements and emphasizing the optimization of local processes within an overall framework. By identifying the coupling relationships and feedback effects between different stages, it becomes possible to achieve efficient resource allocation and dynamic adjustment of organizational structures, thereby avoiding the problem of overall inefficiency caused by local optimization. A systematic organizational model not only alleviates distortion and redundancy in information transfer but also enhances adaptability and flexibility through multi-path feedback mechanisms, enabling projects to better cope with the complex external environment under the background of green buildings ^[5].

In practical application, the reconstruction of organizational models based on systems thinking emphasizes deep interdisciplinary integration and cross-phase collaborative coordination. Project organization needs to incorporate energy-saving simulations in architectural design, environmental control during the construction process, and energy consumption management in the operation and maintenance stage into a unified management framework, while achieving organic connections between different stages through multi-level objective decomposition. Engineering managers can utilize tools such as system dynamics modeling, network diagram analysis, and scenario simulation to identify key paths and system bottlenecks and to construct optimization schemes oriented toward the whole system. This organizational model not only improves project execution and coordination but also provides organizational assurance for sustainable development of green buildings at the strategic level, gradually transforming construction projects into dynamic management processes oriented toward

system coupling and cyclical optimization.

3.2 Dynamic Control Path for Whole-Process Quality and Risk

Green buildings introduce numerous innovative elements in technical selection, construction processes, and operation and maintenance, which increase the uncertainty and complexity of project management. Whole-process quality management emphasizes controlling the entire project life cycle in a dynamic and closed-loop manner, from validating the rationality of design schemes, to real-time monitoring during construction, and performance tracking during the operation and maintenance stage, all requiring the establishment of high-frequency data collection and feedback mechanisms. The application of digital inspection and intelligent evaluation tools enables quality control to move beyond mere outcome verification, achieving proactive intervention through process monitoring and trend analysis. This mechanism ensures that green buildings maintain consistency with energy-saving, emission reduction, and environmental friendliness objectives at all stages, thereby enhancing overall quality reliability and sustainability.

In terms of risk control, the complexity of green building projects necessitates a multidimensional dynamic management system covering environmental, technical, and economic risks. The dynamic control path relies not only on real-time monitoring and data analysis but also on forward-looking regulation based on probabilistic modeling and big data forecasting. Through early warning and resilient management of potential risks, engineering management can design redundancy schemes and adjustment strategies before unexpected events occur, reducing the impact of risks on project sustainability. For instance, in material application, the uncertain performance of new green building materials must be considered, and reliability curves established through experimental data and long-term monitoring; in construction organization, multi-scenario risk response mechanisms should be developed in conjunction with environmental factors. The dynamic control path for whole-process quality and risk not only safeguards building performance but also lays a stable foundation for the full life-cycle operation of green buildings ^[6].

3.3 Innovation-Driven and Continuous Improvement Mechanism under Multidimensional Collaboration

The diversified objectives of green buildings necessitate that project management break through the traditional single-entity model and establish a multidimensional collaboration mechanism across disciplines and industries. Collaboration is reflected not only in the vertical alignment between design, construction, and operation and maintenance but also in the horizontal interaction among material suppliers, technology research institutions, energy service providers, and end users. By establishing a collaborative platform for information sharing and data interoperability, knowledge and resources can flow effectively throughout the entire life cycle, thereby reducing redundant work and resource waste, and enhancing overall project flexibility and responsiveness. The establishment of multidimensional collaboration enables all participants to create shared value driven by common objectives, providing stable and efficient support for complex green building projects.

Within this collaborative framework, innovation-driven and continuous improvement mechanisms constitute key pathways for the long-term optimization of engineering management. Innovation encompasses not only the application of green building materials, intelligent construction, and energy-saving technologies but also the reform of management methods and the restructuring of process systems. By establishing improvement mechanisms based on performance evaluation and dynamic feedback, project management can develop the capability for continuous iteration and self-optimization. For example, energy consumption monitoring results from the operation and maintenance stage can be fed back to optimize parameters during the design stage, enabling cross-phase cyclical improvement; big data analytics and AI-assisted decision-making tools can also drive the transition of management models from experience-driven to data-driven. The introduction of continuous improvement mechanisms allows green building projects to maintain evolutionary capacity during operation, enhancing their sustainability over the long term. Consequently, engineering management of green buildings can not only address challenges in complex and dynamic environments but also achieve self-renewal and value enhancement through the dual drivers of technology and management.

Conclusion

The integration of green buildings and engineering management provides new ideas and methods for the sustainable development of the construction industry. By introducing systems thinking to reconstruct project organization models, engineering management can better adapt to the complexity and diversity of green buildings; through dynamic control of whole-process quality and risk, project operational stability and reliability are enhanced; through multidimensional collaboration, innovation-driven approaches, and continuous improvement, green building engineering management can establish mechanisms for self-iteration and optimization. Future research can further explore the in-depth application of digitalization and intelligent technologies in life-cycle management, investigate efficient decision-making mechanisms under multi-stakeholder collaboration, and focus on the coupling pathways between green buildings and social value, thereby providing theoretical and methodological support for the construction industry to play a greater role in the global sustainable development process.

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