

Original Paper

The Critical Implications of Establishing and Refining the Green Construction Evaluation System

Jiekun Zhu^{1*}

¹ Department of Railway Engineering, Sichuan College of Architectural Technology, Deyang, Sichuan 618000, China

* Jiekun Zhu, Department of Railway Engineering, Sichuan College of Architectural Technology, Deyang, Sichuan 618000, China

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Abstract

With the intensification of global environmental challenges and the universal adoption of sustainable development goals, green construction practices have emerged as a critical pathway for industrial transformation within the building sector, garnering substantial scholarly attention. To facilitate the effective implementation of environmentally conscious construction methodologies, the establishment and refinement of a comprehensive green construction evaluation system is becoming imperative. This paper examines the multidimensional significance of perfecting such evaluation frameworks, aiming to establish a theoretical foundation that advances sustainable development paradigms in construction engineering and informs policy formulation through systematic performance assessment mechanisms.

Keywords

Green construction, Sustainable development, Green construction evaluation system

1. Introduction

Earth's material resources constitute the fundamental basis for human survival and civilizational development. The rapid ascendance of China's construction sector, coupled with accelerating industrialization of building practices and urbanization processes, has precipitated a marked escalation in energy and natural resource consumption. Should this trajectory of unrestrained exploitation of material reserves persist, it would inevitably catalyze irreversible ecological degradation and critical resource depletion, thereby engendering existential threats to future generations.

Achieving sustainable societal development necessitates urgent scholarly and practical resolutions to the dual imperatives of resource consumption mitigation and rational natural capital utilization.

Contemporary research identifies three synergistic pathways: 1) Large-scale deployment of green building technologies (GBTs) incorporating energy-positive designs and smart material applications; 2) Systemic implementation of circular economy principles through industrialized construction waste valorization; 3) Strengthening of policy frameworks enforcing life-cycle assessment (LCA) protocols and material passport systems. This tripartite approach aligns with SDG 12 (Responsible Consumption and Production) requirements while addressing China's unique urbanization challenges through localized sustainable construction paradigms.

2. Research Context and Current Status: Domestic and International Perspectives

2.1 Research Context

The dawn of the 21st century has witnessed unprecedented global economic expansion, paradoxically accompanied by escalating environmental degradation and critical resource depletion. As an energy-intensive industry accounting for 39% of global carbon emissions (UNEP, 2022), the construction sector now faces dual imperatives: reconciling developmental demands with ecological preservation while pioneering decarbonization pathways (Gao, 2024).

During the initial phases of economic take-off, environmental considerations were systematically relegated to a subordinate position within China's developmental calculus. However, the triadic interplay between economic expansion, resource depletion (9.2% annual growth in construction material consumption, 2000-2020), and ecological degradation (23% loss of arable land to urbanization since 1990) has crystallized into defining constraints on sustainable growth. This critical juncture precipitated a fundamental policy reorientation (Pan, 2024).

As an innovative low-carbon architectural paradigm, green building achieves optimized utilization of energy resources and synergistic advancement of ecological systems through the integration of three critical components: a holistic design framework, rigorously selected eco-conscious construction materials, and intelligent energy management systems. This comprehensive architecture not only systematically enhances resource efficiency while mitigating environmental impacts, but also aligns with the evolutionary trajectory of contemporary societal demands for enhanced living standards through the establishment of health-oriented, sustainable habitats.

China has established a robust legislative framework and standardized technical specifications to systematically propel green building development. Through a dual-focused approach combining innovation-driven strategies, the nation concurrently advances breakthroughs in core technologies and large-scale industrial implementation, thereby sustaining momentum for ecological modernization within the construction sector. This strategic integration of policy instrumentation and technological innovation establishes a replicable model for sustainable urbanization in developing economies.

Under the macro-background of synergistic advancement between ecological civilization construction and new-type urbanization, green building has evolved into a strategic pivot for industrial transformation in the construction sector and a critical vehicle for achieving carbon peaking and

neutrality targets. As the core phase accounting for 62% of environmental impact weighting throughout building lifecycles, the environmental governance efficacy during construction stages directly determines the practical outcomes of green building initiatives. This necessitates the industry to establish a tri-dimensional objective framework encompassing intensive resource utilization, precision pollution prevention, and enhanced ecological conservation efficiency. Notably, the recently issued Technical Guidelines for Green Construction (MOHURD) has formulated a trinity policy architecture of "standard leadership-technological innovation-market propulsion," systematically constructing an evaluation index system for green construction. Through whole-process quantitative assessment and dynamic optimization mechanisms, this framework effectively addresses the negative environmental externalities inherent in conventional construction practices while injecting new momentum into high-quality sectoral development. Given the relatively recent conceptualization of green construction in China and the prevalent inexperience among construction enterprises, it becomes imperative to strengthen management protocols and establish robust performance evaluation systems to bridge implementation gaps (Nan, 2017).

2.2 Current Research Status

In China, green building evaluation standards primarily include the Green Building Evaluation Standard GB/T 50378-2019, which covers aspects such as site selection, planning, design, construction, and operation. These standards emphasize the environmental impact throughout the building lifecycle, particularly specifying requirements in energy efficiency, water conservation, material savings, and indoor environmental quality. Through the implementation of these standards, many construction projects have actively adopted green technologies and materials during the design and construction phases, achieving significant economic and environmental benefits.

Globally, evaluation systems such as LEED (Leadership in Energy and Environmental Design, USGBC) and BREEAM (Building Research Establishment Environmental Assessment Method) have gained widespread adoption (Omran, 2016). These frameworks extend beyond assessing the environmental performance of buildings themselves, emphasizing ecological preservation of surrounding environments and sustainable community development. International green building assessment standards provide actionable guidelines for the construction industry through systematic evaluation of building materials, construction methodologies, energy consumption patterns, and multi-dimensional sustainability criteria.

Green construction evaluation standards primarily focus on resource conservation, environmental protection, and occupational health during the construction process. Scholars globally have deepened research on green construction, proposing concepts such as "green construction management" and "ecological construction," which emphasize minimizing environmental impacts during the construction phase through scientific management and technological interventions. For instance, China's Green Construction Evaluation Standard (GB/T 51140-2010) delineates fundamental principles of green construction, covering aspects such as on-site management, selection of construction techniques, and

material utilization. This standard aims to guide construction enterprises in achieving efficient resource utilization and environmental preservation while ensuring project quality and safety.

Green building methodologies and their corresponding assessment standards establish a crucial theoretical foundation and practical framework for sustainable construction practices, while the effective implementation of green construction techniques ensures the materialization of eco-architecture principles. With advancing technologies and policy-driven initiatives, research in green building systems and construction methodologies will progressively deepen, ultimately contributing to the realization of advanced sustainable development objectives.

3. Research Content

This study systematically examines extant research on sustainable construction practices to propose that developing a comprehensive green construction assessment framework holds critical significance for advancing ecological building methodologies within the contemporary sustainable development context. The investigative agenda encompasses:

- (1) In-depth analysis of green building concepts and conceptual dimensions, with precise delineation of green construction definitions and distinctive characteristics;
- (2) Critical synthesis of theoretical foundations underlying green construction evaluation systems to identify their core value propositions in architectural projects;
- (3) Systematic formulation of methodological guidelines for structuring green construction evaluation metrics, ensuring alignment with sustainability-driven construction paradigms.

4. Green Building Systems: Definition and Conceptual Dimensions

Green Building refers to the practice of optimizing resource utilization and minimizing environmental impacts throughout the building lifecycle phases of design, construction, operation, and maintenance, while simultaneously enhancing occupant health, comfort, and operational efficiency. Its foundational philosophy aligns with sustainable development principles, aiming to achieve symbiotic coexistence between human activities and natural ecosystems. This paper systematically examines the definition, core principles, technological applications, and the current developmental trajectory of green building practices within the Chinese context.

4.1 Definition of Green Building

The conceptualization of green building exhibits regional variations globally, primarily attributable to divergent climatic conditions, geographical resources, sociocultural contexts, and developmental priorities across nations. While sharing the unified core principle of environmental stewardship, energy efficiency, and sustainable development throughout building processes, specific implementation standards and methodologies demonstrate localized adaptations. Individual countries typically formulate tailored green building criteria and regulations aligned with their unique environmental constraints and societal demands. This diversity fosters a fertile ground for innovative practices and

technological advancements.

Green building transcends simplistic environmental architecture, representing a comprehensive systematic engineering endeavor. As stipulated in China's Green Building Evaluation Standard (GB/T 50378-2019), green buildings must satisfy three foundational requirements:

- (1) Resource Conservation: Rational utilization of land, energy, water, and materials through optimized design and technological integration.
- (2) Environmental Protection: Minimization of ecological disturbances and pollution emissions during construction and operational phases.
- (3) Occupant Well-being: Enhancement of indoor environmental quality (IEQ) through improved thermal comfort, air quality, and safety protocols.

4.2 Conceptual Dimensions of Green Building

Green architecture adheres to the following core operational tenets:

- (1) Energy consumption minimization through deployment of energy-efficient materials and building technologies;
- (2) Water resource depletion reduction via installation of high-efficiency water fixtures and greywater recycling systems;
- (3) Environmental resource conservation achieved by prioritizing renewable/recyclable construction materials;
- (4) Indoor environmental quality enhancement through optimization of natural daylight utilization and passive ventilation strategies;
- (5) Ecological preservation mandates maintaining regional biodiversity and ecosystem integrity throughout design and construction phases..

5. Theoretical Foundations of Green Construction Evaluation Systems

The green construction evaluation system serves as a critical tool for assessing environmental and sustainability practices during building construction. Its theoretical underpinnings derive from an interdisciplinary integration of sustainable development theory, ecological principles, building science, and environmental management. Below is a detailed exploration of these foundational theories.

5.1 Sustainable Development Theory

Sustainable development theory constitutes the foundational pillar of green construction evaluation systems. This paradigm advocates for meeting contemporary societal needs while safeguarding intergenerational equity in resource accessibility. Its operationalization in green construction manifests through three key dimensions:

(1) Resource Efficiency Optimization

Implementation of advanced construction methodologies and strategic material utilization protocols to achieve maximal resource conservation.

(2) Environmental Impact Mitigation

Systematic reduction of adverse ecological consequences during construction activities, including but not limited to acoustic pollution control and construction waste minimization strategies.

(3) Lifecycle Management Integration

Green construction emphasizes holistic lifecycle stewardship spanning architectural design, construction execution, and operational maintenance phases. This approach employs construction process optimization and energy-efficient technologies to extend structural service life while reducing long-term energy demand. A practical exemplification is China State Construction Eighth Engineering Division's integration of photovoltaic modules in railway infrastructure projects, demonstrating lifecycle low-carbon principles through projected annual CO₂ emission reduction of 112.3 metric tons..

5.2 Ecological Principles

Ecology provides significant theoretical support for green construction. The impact of construction activities on the ecological environment is a key focus of the evaluation system.

(1) Ecological Balance: Protecting and restoring ecosystem balance during the planning and implementation of construction projects.

(2) Biodiversity: Minimizing the impact of construction on biodiversity by protecting local flora and fauna through design and construction methods.

(3) Ecological Restoration and Compensation Mechanisms: Green construction emphasizes ecological restoration of areas damaged by construction activities. Examples include using vegetation restoration techniques to rebuild damaged ecosystems, applying ecological engineering methods to control soil and water erosion, and implementing soil remediation through the planting of fast-growing or cold-resistant grass species. The Tema Port project in Ghana achieved a balance between construction activities and ecological compensation by establishing a "Sea Turtle Conservation Center" and artificial intervention to protect endangered species habitats.

(4) Material Cycling and Resource Regeneration: Based on the material cycling theory of ecosystems, green construction promotes the resource utilization of construction waste. Construction sites transform waste into roadbed materials or recycled concrete aggregates through classified recycling and recycled material production, reducing the exploitation of natural resources. For instance, China MCC17 Group adopted prefabricated component technology in a Xi'an project, achieving a construction waste recycling rate exceeding 50%..

5.3 Architectural Science

Architectural science provides a technological foundation for green construction, integrating interdisciplinary knowledge from material engineering, structural mechanics, and built environment studies.

(1) Eco-Materials and Advanced Technology Integration

The adoption of innovative eco-friendly materials and cutting-edge construction techniques enhances both quality and efficiency in sustainable practices. A representative case involves recycled concrete composites formed by integrating ultra-high performance concrete (UHPC), demonstrating 150%

compressive strength compared to conventional concrete while achieving 30% carbon emission reduction.

(2) Energy Consumption Optimization

Scientifically optimized design and construction strategies systematically reduce energy consumption across building lifecycles. Implementation of 300mm graphite-expanded polystyrene insulation layers combined with triple-glazed Low-E coated units with double air cavities, complemented by thermal bridge-free nodal treatments, elevates overall thermal performance by >40%. Building Information Modeling (BIM)-driven simulations for solar orientation optimization and form factor adjustment, coupled with window-to-wall ratio optimization within the 0.3-0.4 range, demonstrate 28-35% cooling load reduction potential.

5.4 Environmental Management

Environmental management theory provides methodological and instrumental frameworks for green construction.

(1) Environmental Impact Assessment (EIA): Conducting comprehensive analysis of potential environmental impacts prior to construction and integrating assessment outcomes into construction planning.

(2) Construction Management: Implementing environmental management frameworks (e.g., ISO 14001) during the construction phase to effectively control and mitigate environmental impacts.

(3) SOR Theoretical Model (Li H.L.,2024): Based on the "stimulus-organism-response (SOR)" framework, this model analyzes the incentive pathways through which environmental regulations drive green construction practices in enterprises. Policy instruments (e.g., market incentives, public participation) promote practical implementation. Specifically, command-and-control environmental regulations, market-incentive environmental regulations, public-participation environmental regulations, and corporate environmental responsibility collectively demonstrate significant influences on green construction behaviors. Environmental regulations can activate the mediating effect of corporate environmental responsibility, thereby incentivizing enterprises to adopt green construction practices.

5.5 Implementation Challenges

Despite the robust theoretical framework underpinning green construction, practical implementation continues to encounter systemic challenges. The adoption of innovative technologies and materials necessitates overcoming dual techno-economic barriers, while collaborative policy formulation and standardization efforts require coordinated governmental and industrial action. Crucially, enhancing environmental consciousness among construction industry practitioners and the general populace emerges as a pivotal driver for sustainable transformation. These multifaceted challenges constitute critical focal points for advancing widespread adoption of green construction paradigms.

6. Challenges in China's Green Assessment System

Despite marked progress in advancing sustainable construction practices through China's green assessment frameworks, systemic challenges persist that demand immediate resolution. A detailed analysis of these issues follows

6.1 Fragmented Standardization Framework

The current system exhibits regional disparities in green building evaluation criteria, undermining nationwide consistency and hindering cross-jurisdictional comparability. Furthermore, existing standards often lack sufficient adaptability to address heterogeneous climatic and geographical requirements, leading to suboptimal technical specifications for localized architectural solutions.

6.2 Insufficient Enforcement Intensity

In some regions, inadequate implementation and supervision of green evaluations have resulted in certain construction projects failing to meet expected green standards. The lack of effective compliance inspection mechanisms may hinder the genuine achievement of green building objectives.

6.3 Limited Market Awareness

Public understanding and awareness of green buildings and evaluation systems remain limited, negatively impacting market demand for green construction. Some developers may prioritize short-term profits over long-term environmental and social benefits, leading to insufficient investment in green building practices.

6.4 Technological and Cost Challenges

Despite the availability of numerous green technologies, their applicability and effectiveness in practical applications are sometimes underutilized. The higher initial investments required for green buildings have caused many developers and owners to adopt a wait-and-see attitude toward their economic returns, thereby impeding large-scale adoption.

6.5 Shortage of Skilled Professionals

There is a scarcity of specialized talent in the green building sector, with existing designers and construction personnel requiring further improvement in green building-related skills and knowledge. Enhanced vocational training and educational programs are necessary to elevate professional competencies and meet the developmental demands of green construction.

While China's green assessment system has served as a critical catalyst for sustainable development in the construction sector, five primary challenges require strategic intervention: standardization inconsistencies, implementation gaps, market perception barriers, techno-economic constraints, and professional workforce deficiencies.

Addressing these challenges necessitates a multi-pronged approach:

- (1) Policy Enhancement: Institutional reinforcement through legal framework optimization and enhanced regulatory oversight mechanisms.
- (2) Stakeholder Engagement: Systematic public awareness campaigns coupled with market incentive structures.

- (3) Technological Advancement: Targeted R&D investment in cost-effective sustainable technologies.
- (4) Capacity Building: Comprehensive professional training programs aligned with international best practices.

These synergistic strategies collectively promise to transform the green assessment framework into a more robust driver for China's low-carbon built environment transition.

7. Future Development Trajectories of Green Assessment Systems

The evolution of green evaluation frameworks will be shaped by emerging technological and regulatory paradigms, presenting transformative opportunities for sustainable construction advancement. Key developmental trends are systematically analyzed below.

7.1 Harmonization and Global Integration

Future initiatives will prioritize the establishment of unified national evaluation metrics to ensure cross-regional benchmarking validity. Concurrently, strategic alignment with internationally recognized certification systems (e.g., LEED, BREEAM) will be pursued through phased adoption of best practices from global sustainability protocols. This dual approach aims to reconcile domestic standardization needs with transnational climate governance imperatives.

7.2 Technology-Driven Optimization

The application of advanced technologies such as the Internet of Things, Big Data, and Artificial Intelligence can effectively promote the overall improvement of green building design, construction, and management. The research, development, and application of novel environmentally friendly materials and construction techniques will further reduce the environmental impact and energy consumption of buildings.

7.3 Policy Support and Incentives

The government will continue to strengthen policy support for green buildings, including tax incentives and financial subsidies. Market-oriented mechanisms such as green finance and carbon trading will be employed to incentivize enterprises and developers to actively participate in green building promotion.

7.4 Public Awareness and Participation

Enhance public education and awareness campaigns on green buildings to improve societal recognition of their importance. Encourage active participation from the public and relevant stakeholders in the planning and implementation of green buildings, thereby increasing the transparency and acceptability of policy execution.

7.5 Whole Life Cycle Management

(1) Comprehensive Life Cycle Evaluation: Future green evaluation systems will prioritize sustainability across the entire building life cycle, from site selection, design, and construction to operation and maintenance.

(2) Operational Management: Strengthen the management and assessment of energy consumption, resource utilization, and environmental impacts during the building use phase to ensure green

performance throughout its life cycle.

7.6 Regional and Climatic Adaptability

Develop adaptive green evaluation standards tailored to the climatic conditions and resource characteristics of different regions. Emphasize addressing climate change challenges in green building design to enhance building resilience and adaptive capacity.

8. Conclusions

The future development of green evaluation systems will increasingly emphasize standardization, technological innovation, policy support, public participation, whole-lifecycle management, and regional adaptability. These trends will further advance sustainable development in the construction industry, establishing green buildings as crucial tools for addressing challenges related to resource conservation, environmental protection, and climate change.

With technological advancements, green building standards will become more stringent, driving continuous industrial innovation. Holistic green management throughout the entire process—from design and construction to operation—will emerge as a prevailing trend. Green buildings will play a significant role in urban renewal and old city renovation projects.

The green construction evaluation system represents an interdisciplinary systematic project, underpinned by theoretical foundations encompassing sustainable development, ecology, architectural science, and environmental management. Guided by these theories, the system effectively assists construction enterprises in achieving resource efficiency, minimizing environmental impacts, and enhancing operational productivity.

Looking ahead, progressive technological advancements and policy refinement will lead to the gradual maturation of green construction evaluation systems, thereby providing robust support for the sustainable transformation of the construction industry.

The improvement of green construction evaluation systems serves as a critical mechanism for promoting sustainable development in the construction sector, holding significant implications for ecological preservation, economic growth, technological progress, social responsibility fulfillment, and public health. Through optimized evaluation criteria, strengthened policy frameworks, and technological innovation, these systems will amplify their role in steering the industry toward greater environmental compatibility and operational efficiency.

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