

Research on Green Building Design Concepts and Spatial Optimization in Improving the Human Living Environment

Jun LIU

Zongyang County Natural Resources and Planning Bureau, Tongling, Anhui, 246700, China

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Abstract: With the accelerating pace of urbanization, issues concerning the quality of the human living environment have become increasingly prominent. How to meet people's housing needs while achieving ecological conservation and sustainable development has become a crucial challenge in architectural design. As an effective approach to improving the human living environment, green building emphasizes the organic integration of resource conservation, environmental friendliness, and health and comfort. Its design philosophy not only focuses on the energy efficiency and environmental protection of the building itself but also prioritizes the harmony between humans and nature, as well as between space and function. This paper explores the role and pathways of spatial optimization in enhancing living environments from the perspective of green building design principles. Through analysis of functional space optimization, ecological integration, and intelligent technology applications, combined with case studies, it summarizes the value and significance of green buildings in elevating residential quality, improving ecological environments, and advancing sustainable urban development. The integration of green building principles with spatial optimization represents a core direction for future living environment improvement, offering important reference value for achieving urban development goals that prioritize livability, ecology, and intelligence.

1. Introduction

With rapid urbanization and socioeconomic development, the quality of human living environments has increasingly become a focal point for both the public and academia. Issues such as population density, intensified resource consumption, and environmental pollution not only impact urban sustainability but also directly affect residents' quality of life. Green building, as a key pathway to improving living environments, has gained growing attention. Green buildings emphasize the organic integration of energy efficiency, environmental protection, and comfort. They aim to reduce adverse impacts on the natural environment through rational design and construction methods while creating healthy, livable spaces for people. As a vital component of green building philosophy, spatial optimization focuses on the scientific allocation and rational utilization of internal and external spaces. This approach not only enhances residential comfort and functionality but also effectively boosts environmental ecological value and resource utilization efficiency. Both domestically and internationally, substantial research findings and practical experience have been accumulated in green building and spatial optimization, demonstrating this field's significant role in advancing sustainable urban development. In the specific design and application process, how to integrate regional characteristics with resident needs to further explore pathways for merging green building design concepts with spatial optimization strategies remains an important topic requiring in-depth research. This paper centers on green building design principles, focusing on their value in improving human habitats. It explores implementation methods and practical pathways through the lens of spatial optimization, aiming to provide reference and insights for future urban development and residential environment enhancement.

2. The Essence and Development Trends of Green Building Design Principles

Green building represents a development model centered on energy efficiency, environmental protection, and comfort. Its essence manifests primarily in efficient resource utilization, reduced environmental burden, and improved living environments. Compared to traditional buildings, green architecture not only focuses on functional performance but also emphasizes environmental benefits throughout the entire life cycle. By integrating energy-saving technologies, eco-friendly materials, and renewable energy sources during design, construction, and operation, it achieves efficient energy utilization and minimizes environmental pollution. Its fundamental goal is to create livable spaces where humans and nature coexist harmoniously, thereby advancing sustainable social development. Building Energy Balance

$$E_{\text{total}} = E_{\text{heating}} + E_{\text{cooling}} + E_{\text{lighting}} + E_{\text{appliances}} \quad (1)$$

As sustainable development concepts gain widespread acceptance, green building has evolved to encompass broader implications. It has expanded beyond mere energy conservation and emissions reduction to encompass comprehensive environmental enhancement, including the greening of building materials, rational spatial layout, and integration with the ecological environment. Green building represents not only technological innovation but also a value orientation emphasizing human-centered design and ecological priority. In this process, comfort and health have become key design metrics, with features like natural lighting, air circulation, and temperature/humidity regulation demonstrating the comprehensive benefits of green buildings in improving the human living environment.

Internationally, the development of green building concepts has established relatively mature evaluation systems and implementation standards, such as the U.S. LEED certification, the UK's BREEAM system, and China's Green Building Evaluation Standard. These frameworks not only promote standardized green building practices but also facilitate mutual learning and integration of concepts and practices across regions. The evolution of international standards further underscores that green building has become a critical global focus for the construction industry, exhibiting increasingly systematic and diversified trends.

The future of green building will emphasize deeper integration with intelligent technologies, ecological conservation, and urban sustainability. Emerging technologies like IoT, big data, and AI will enable more precise energy monitoring and environmental control. The carbon neutrality goal injects new momentum, empowering green buildings to play a more active role in combating climate change and advancing low-carbon societies. As green building concepts continue to evolve and expand, they will become a vital force in enhancing human habitats and promoting sustainable development.

3. Pathways to Spatial Optimization in Human Environment Improvement

In the process of enhancing human living environments, spatial optimization serves as a pivotal bridge between theory and practice within the green building philosophy. Scientific and rational spatial organization not only enhances the functionality and comfort of living spaces but also strengthens environmental sustainability and natural affinity through the utilization and integration of ecological resources. With the continuous advancement of intelligent technologies, spatial optimization is no longer confined to physical layout adjustments but is progressively evolving toward smart, dynamic, and personalized approaches. This optimization unfolds across three dimensions: First, prioritizing the rational allocation of functional spaces and human-centered design to ensure the organic integration of residential and public needs. Second, emphasizing the incorporation of natural environments and the creation of ecological spaces to foster harmonious coexistence between humans and nature. Third, introducing intelligent technological means to achieve efficient and refined spatial utilization. These three dimensions collectively form the core pathways for spatial optimization in green buildings, providing robust support for comprehensively enhancing the quality of the human living environment. Daylight Factor (DF)

$$DF = \frac{E_{\text{in}}}{E_{\text{out}}} \times 100\% \quad (2)$$

4. Functional Space Optimization and Human-Centered Design

Functional space optimization is the most fundamental and core element in improving the human living environment, with its primary goal being to achieve efficient utilization and diverse adaptability of space. As residential needs continue to diversify, single-purpose zoning struggles to accommodate residents' lifestyles and usage habits. Therefore, the design process must prioritize spatial flexibility and adaptability, enabling buildings to adjust reasonably according to varying family structures, living scenarios, and usage frequencies. This approach prevents waste of spatial resources and enhances the overall efficiency of the living environment.

Human-centered design emerges as a key element in optimizing functional spaces. Human-centered design prioritizes residents, addressing the physiological, psychological, and behavioral needs of diverse users. Children's activity spaces must integrate safety features, elderly living areas require barrier-free design, while younger residents may value openness and social connectivity. Through thoughtful spatial planning and scale control, comfort is enhanced while fostering inclusivity and adaptability, showed, in Figure 1 :

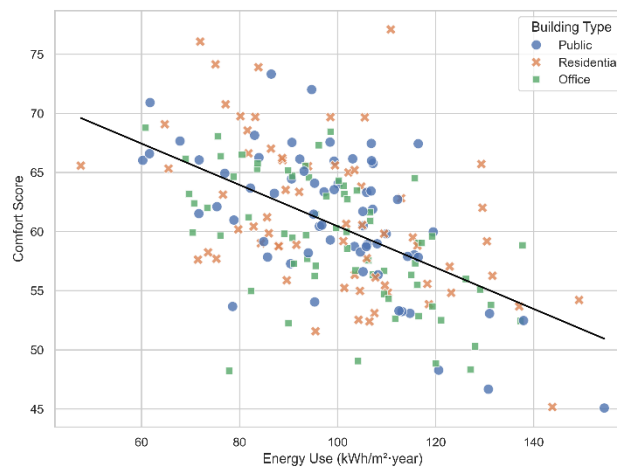


Figure 1 Energy consumption vs comfort score

Functional space optimization must also emphasize seamless integration between residential and public services. Modern living environments extend beyond individual households, forming an integrated whole with community public spaces. Incorporating shared spaces, communal interaction zones, and multifunctional facilities into architectural design fosters neighborhood interaction and promotes harmonious social relationships. This integration of domestic and community spaces not only optimizes the functional structure of the living environment but also embodies the “people-centered” value orientation inherent in green building principles. Ventilation Airflow Rate

$$Q = V \times n \quad (3)$$

The combination of functional space optimization and human-centered design must also align with ecological and energy-saving concepts. During layout planning, scientifically organizing active and passive zones, rationally configuring daylighting and ventilation pathways, and leveraging natural conditions to improve indoor environments can enhance comfort while effectively reducing energy consumption. Functional space optimization is not merely a spatial arrangement issue but a comprehensive design process involving humanistic care, social interaction, and environmental benefits—a crucial pathway for integrating green building with improved living environments.

5. Integration of Natural Environments and Ecological Space Layout

In green building design, integrating natural environments transcends aesthetic considerations to become a vital means of enhancing human habitats. Thoughtful ecological spatial planning fosters harmonious coexistence between architecture and nature, endowing living spaces with greater environmental adaptability and sustainability. Incorporating natural elements into architectural design

improves microclimate conditions both indoors and outdoors while psychologically enhancing residents' sense of connection and comfort, thereby creating healthy, livable environments.

The organic integration of landscape and architecture is central to ecological spatial planning. Design processes must prioritize not only green space ratios and vegetation coverage but also the interaction between natural landscapes and built environments. Strategically placing greenery on rooftops, balconies, and facades enhances environmental aesthetics while contributing to thermal insulation and air purification. Strategically allocating public green spaces, water features, and ecological corridors improves regional ecosystem integrity while providing residents with venues for recreation, social interaction, and nature engagement. Thermal Comfort (Predicted Mean Vote, PMV simplified)

$$PMV = (0.303e^{-0.036M} + 0.028)(M - W) \quad (4)$$

Natural lighting and ventilation systems represent critical technical approaches in ecological space design. By rationally arranging building orientation, window placement, and spatial dimensions, natural light and airflow can be effectively harnessed, reducing energy consumption for artificial lighting and mechanical ventilation. Designing sunshade facilities or ventilation corridors tailored to local climate characteristics not only enhances indoor thermal comfort but also effectively reduces energy consumption, achieving the green building goal of “low energy consumption and high comfort.” This design approach embodies the principle of ecological priority while demonstrating green buildings' efficient utilization of environmental resources.

Ecological space planning focuses not only on integrating natural elements but also emphasizes the systemic coherence and coordination of the entire area. At the urban level, ecological spaces should integrate with surrounding environments, transportation systems, and public service facilities to form a holistic pattern, achieving dual optimization of ecology and functionality. At the community level, spatial design prioritizes creating microenvironments, enabling residents to tangibly experience the comfort and convenience of green surroundings in daily life. Thus, integrating natural environments and ecological spatial planning not only represents a vital pathway for green buildings to enhance human habitats but also serves as a key pillar for achieving sustainable urban development and ecological civilization.

6. The Application of Intelligent Technologies in Space Optimization

With the rapid advancement of information technology, intelligent solutions are increasingly applied in architectural design and spatial optimization, emerging as a key driver for enhancing human living environments. Intelligent technologies not only improve spatial utilization efficiency but also achieve dual objectives of comfort and energy savings through dynamic regulation. Guided by green building principles, the integration of intelligence infuses living spaces with greater flexibility and foresight, transforming them from static physical environments into perceptible, interactive, and optimizable smart spaces. Sustainability Index (SI)

$$SI = \frac{E_{saved} + W_{recycled}}{E_{used} + W_{consumed}} \quad (5)$$

Smart home systems exemplify this optimization directly. By intelligently controlling lighting, heating, ventilation, security, and appliances, they automatically adapt to residents' habits and environmental changes. Lighting and temperature adjust autonomously with time and seasons, enhancing comfort while reducing energy waste. The programmability and remote control capabilities of these systems enable flexible space utilization, catering to diverse personalized needs.

At the building level, intelligent technologies achieve efficient space operation through energy consumption monitoring and environmental management systems. Leveraging sensors, IoT, and big data technologies, real-time monitoring and dynamic regulation of a building's energy consumption, water usage, and indoor air quality are enabled, thereby optimizing the spatial environment. This data-driven approach to space management not only enhances resource utilization efficiency but also provides scientific basis for the operation and maintenance of green buildings, showed in Figure 2 :

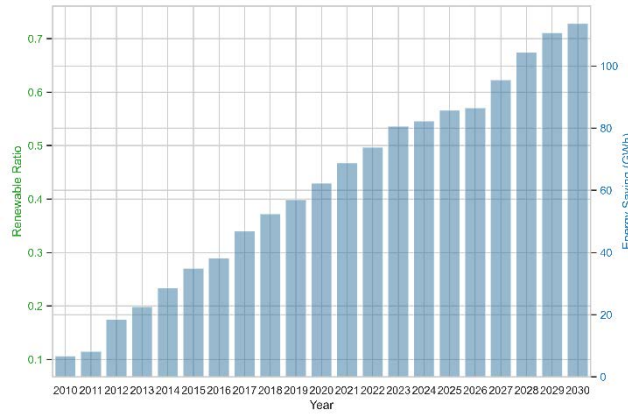


Figure 2 Renewable ratio vs year trend

The deep integration of artificial intelligence and big data will further advance the intelligent evolution of spatial optimization. By analyzing resident behavior patterns and environmental trends through smart algorithms, building spaces will gain active learning and self-adjusting capabilities, shifting from “people adapting to space” to “space proactively adapting to people.” This trend represents the cutting edge of integrating green buildings with smart technologies while pioneering new pathways for enhancing human habitats, elevating comfort, energy efficiency, and sustainability to higher levels.

7. Case Studies and Practical Exploration

In the practice of green building and spatial optimization, a number of representative case studies have emerged both domestically and internationally. These examples not only demonstrate the effectiveness of green design concepts in actual projects but also provide valuable lessons for enhancing the human living environment. The Seattle Green Building in the United States achieved significant energy savings through efficient systems and natural daylighting while maintaining indoor comfort. Meanwhile, the BedZED Zero Carbon Community in the UK centered its approach on holistic community planning, leveraging renewable energy and green transportation to create a model of harmonious coexistence between humans and nature.

Domestically, China's green building initiatives have also yielded remarkable outcomes. The Beijing Olympic Village extensively incorporated solar photovoltaic systems and rainwater harvesting technology, demonstrating the integration of green energy with spatial optimization. Shenzhen's “Vanke Center” achieved a harmonious balance of functionality and ecology for office and residential environments through modular spatial design and ecological landscape integration. These examples illustrate that green buildings and spatial optimization not only enhance living comfort but also play a positive role in energy conservation, emissions reduction, and ecological protection.

Practical experience reveals that successful green building projects typically share three common characteristics: First, they fully leverage natural conditions and regional features to achieve site-specific design solutions. Second, they emphasize the integration of technology and human-centered design, prioritizing both intelligent and energy-saving technical approaches while also valuing spatial comfort and human needs. Third, they establish robust operation and maintenance mechanisms, ensuring sustained green benefits throughout the building's lifecycle through data monitoring and dynamic management. These characteristics not only propel the advancement of green buildings but also provide practical foundations for enhancing future human habitats.

$$\min Z = \alpha \cdot C_{\text{energy}} + \beta \cdot C_{\text{comfort}} + \gamma \cdot C_{\text{cost}} \quad (6)$$

Case analyses reveal that green building and spatial optimization still face challenges during implementation, such as higher construction costs, insufficient technological adoption, and uneven policy support. Future development requires strengthened policy guidance and technological innovation,

alongside heightened public awareness and the establishment of multi-stakeholder collaboration mechanisms. By continuously summarizing and disseminating practical experience, green building and spatial optimization will undoubtedly provide a viable pathway for improving the human living environment on a broader scale.

8. Conclusion

This paper systematically explores the value of green building design concepts in enhancing the human living environment, focusing on functional space optimization, human-centered design, integration with natural surroundings, ecological spatial layout, and intelligent technology applications. Research indicates that green buildings not only enhance ecological quality through energy conservation, emission reduction, and environmental protection but also elevate residential comfort and functionality via scientific spatial optimization, thereby playing a vital role in advancing sustainable urban development. Case studies further demonstrate that green buildings possess strong exemplary effects in practical applications, offering feasible pathways and practical experience for improving human habitat quality.

The promotion of green buildings and spatial optimization still faces challenges such as elevated construction costs, insufficient technological adoption, significant regional disparities, and imperfect operation and maintenance mechanisms. These issues constrain broader implementation while setting higher standards for future research and practice.

Future green building development will emphasize deeper integration with intelligent technologies, low-carbon principles, and ecological civilization construction. Emerging technologies like artificial intelligence, the Internet of Things, and big data will provide more precise support for energy consumption management and spatial optimization in green buildings. The introduction of carbon peak and carbon neutrality goals will also inject new momentum into green building development. Through the combined efforts of policy guidance, technological innovation, and public participation, green buildings will undoubtedly play an increasingly vital role in improving the human living environment, promoting urban green transformation, and achieving sustainable development.

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