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Research on Strategies for Promoting the Application of BIM Technology in the Protection of Ancient Buildings

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Abstract: This paper focuses on the selection of technical paths for energy-saving renovation of historic buildings under the low-carbon concept. Supported by theories such as sustainable development, it elaborates on the screening principles for low-carbon and energy-saving technologies applicable to historic buildings, including the principles of conservation, applicability, and economic feasibility. Technical paths are constructed from aspects such as the building envelope system and energy systems, and the renovation effects are evaluated in terms of economic, environmental, and social benefits. The study aims to provide scientific guidance for low-carbon renovation of historic buildings and to promote the coordinated advancement of cultural heritage conservation and low-carbon development.

Keywords: Historic buildings; low-carbon renovation; energy-saving technologies; cultural conservation

Introduction

Against the backdrop of the global low-carbon development trend, energy-saving renovation of historic buildings, as important cultural heritage assets, is of great significance. Such renovation must not only preserve historical context and cultural value but also achieve low-carbon development goals, which poses multiple challenges. Traditional renovation approaches may damage the building fabric and cultural significance while often resulting in high energy consumption. Based on theories such as sustainable development, this paper explores the screening principles of low-carbon and energy-saving technologies suitable for historic buildings, selects appropriate technical paths, and conducts benefit evaluations, thereby providing feasible solutions for the low-carbon renovation of historic buildings.

1. Theoretical Foundations of Low-Carbon Renovation of Historic Buildings

Low-carbon renovation of historic buildings is fundamentally supported by sustainable development theory, circular economy theory, and building life-cycle theory. It aims to achieve the dual objectives of preserving historical context and promoting low-carbon development, representing an important practice in the coordinated advancement of ecological civilization construction and cultural heritage conservation. Sustainable development theory emphasizes meeting present needs without compromising the ability of future generations to meet their own needs. In the context of historic building renovation, this requires balancing cultural conservation and energy efficiency, while avoiding excessive interventions that may damage the building fabric or the surrounding environment. Circular economy theory advocates the principles of "reduction, reuse, and recycling," guiding the optimization of resource allocation during renovation, minimizing construction material waste and carbon emissions, and promoting the recycling and reuse of materials from existing buildings. Building life-cycle theory calls for a holistic approach that encompasses the renovation, operation, and maintenance stages of historic buildings, accounting for carbon emissions at each phase and achieving carbon reduction across the entire life cycle [1]. At the same time, by integrating heritage conservation theory, low-carbon renovation is ensured not to compromise historical appearance, structural integrity, or cultural value. Together, these perspectives form a theoretical framework characterized by "conservation priority, low-carbon adaptation, and long-term operation," providing scientific guidance for subsequent technology screening, path selection, and benefit evaluation.

2. Principles for Screening Low-Carbon and Energy-Saving Technologies Applicable to Historic Buildings

The screening of low-carbon and energy-saving technologies for historic buildings should be grounded in the buildings' historical value, structural characteristics, and functional requirements. Adhering to systematic and comprehensive principles, such screening must balance three core dimensions—conservation, applicability, and economic feasibility—to ensure that technological applications achieve carbon reduction goals without violating the fundamental requirements of historic building preservation.

2.1 Conservation Principle

The conservation principle is the primary prerequisite for selecting low-carbon renovation technologies for historic buildings. Its core objective is that "renovation must not cause damage, and energy saving must not compromise appearance," giving priority to safeguarding structural safety, historical appearance, and cultural value. When screening low-carbon and energy-saving technologies, comprehensive investigations of the building's heritage classification, structural fabric, and architectural features are required. Technologies that may damage the main structure, decorative components, or historical details must be strictly avoided. For example, large-scale demolition or alteration of walls, or replacement of original doors and windows solely for energy efficiency purposes, should be avoided. Instead, technologies with high reversibility and low intervention intensity should be prioritized to ensure that renovation processes are traceable and reversible. In addition, coordination with the surrounding historic environment must be considered to prevent disjunction between the renovated building and its context. Through such an approach, cultural heritage conservation and low-carbon energy efficiency can be organically integrated, allowing low-carbon renovation to support—rather than hinder—the transmission of historical continuity.

2.2 Applicability Principle

The applicability principle requires that the selection of low-carbon and energy-saving technologies be closely aligned with the intrinsic characteristics of historic buildings, including structural type, functional use, and regional environmental conditions, so as to ensure technical feasibility, operability, and long-term effectiveness. Owing to differences in structural forms and construction techniques among historic buildings, low-carbon technologies should be selected in a context-specific manner, avoiding the direct replication of low-carbon renovation models used for ordinary buildings. For example, for historic buildings with timber structures, low-carbon technologies with good fire resistance and moisture-proof performance should be adopted to prevent safety risks caused by improper technical adaptation. For historic buildings located in cold regions, priority should be given to technologies with excellent thermal insulation performance, balancing energy efficiency with indoor comfort [2]. In addition, technological applications must be consistent with the functional positioning of the building. If a historic building is used for cultural relic exhibition, the installation of low-carbon equipment should not interfere with exhibition effects. In this way, technological application can meet carbon reduction requirements without altering the building's core functions, achieving precise adaptation between technology and architecture.

2.3 Economic Principle

The economic principle emphasizes that the screening of low-carbon and energy-saving technologies should take into account renovation costs, operation and maintenance costs, and overall benefits, so as to achieve a balance of "low cost, high energy efficiency, and long-term benefits," and to avoid cost overruns caused by an excessive pursuit of low-carbon performance. Low-carbon renovation of historic buildings often involves cultural heritage protection, resulting in more complex procedures and making cost control particularly critical. Therefore, priority should be given to technologies with high cost-effectiveness and simple maintenance requirements, reducing both initial renovation investment and long-term operation and maintenance costs. At the same time, both short-term costs and long-term benefits should be considered. Some low-carbon technologies require relatively high upfront investment but can significantly reduce long-term energy consumption and carbon emissions, thereby lowering future energy expenditures. Such technologies should be reasonably selected in accordance with the renovation budget. Moreover, the scalability and economic viability of technologies should be considered, avoiding niche, high-cost, and difficult-to-maintain solutions. This ensures that renovation projects can achieve carbon reduction targets while maintaining sustainable economic feasibility and balancing cultural conservation with economic benefits.

3. Selection of Energy-Saving Renovation Technical Paths for Historic Buildings under the Low-Carbon Concept

Under the low-carbon concept, the selection of technical paths for energy-saving renovation of historic buildings should be oriented toward full life-cycle carbon reduction goals. By integrating the intrinsic characteristics of historic buildings with the three screening principles, a "comprehensive, multi-level, and low-intervention" technical system should be established, covering four core aspects: the building envelope system, energy systems, indoor environmental regulation, and construction and operation management.

3.1 Energy Efficiency Optimization of the Building Envelope

The building envelope is the primary source of energy loss in historic buildings, and its energy efficiency optimization constitutes one of the core paths of low-carbon renovation. The key objective is to enhance thermal insulation, heat resistance, windproofing, and waterproofing performance without compromising the architectural appearance. During renovation, priority should be given to technologies with high reversibility and low intervention intensity. For example, environmentally friendly insulation materials can be added to the interior side of walls, and energy-efficient doors and windows consistent with the original architectural style can be selected to replace components with poor airtightness. This approach ensures improved thermal performance while preserving the original appearance of the building. For roof envelope structures, insulation layers and rainwater harvesting systems can be introduced on the premise of retaining the original roof form, thereby integrating energy efficiency improvement with water resource utilization. At the same time, large-scale demolition or alteration of the envelope should be avoided. Damaged original components should be repaired through restorative renovation measures, achieving an organic combination of the principle of "restoring the old as the old" and energy efficiency optimization. Through such measures, energy loss from the envelope system can be effectively reduced, thereby lowering overall building carbon emissions.

3.2 Low-Carbon Upgrading of Energy Systems

Low-carbon upgrading of energy systems is a critical lever for reducing carbon emissions in historic buildings. Its core lies in replacing traditional energy sources with high energy consumption and high emissions, optimizing the energy supply structure, improving energy utilization efficiency, and establishing a clean, low-carbon, and efficient energy system. In the renovation process, traditional high-carbon energy sources such as coal and fuel oil should be gradually phased out, while renewable energy sources—including solar energy, geothermal energy, and biomass energy—should be prioritized and rationally deployed according to regional resource endowments. For instance, small-scale photovoltaic systems can be installed on building roofs to meet part of the electricity and lighting demand, while geothermal energy can be utilized for heating and cooling, thereby reducing reliance on conventional energy sources. In parallel,

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energy transmission and utilization systems should be optimized by replacing high-energy-consumption equipment and installing energy metering devices to enable real-time monitoring of energy use. Through refined energy management, overall energy efficiency can be further enhanced, effectively reducing carbon emissions associated with energy consumption.

3.3 Intelligent Regulation of the Indoor Environment

The technical path of intelligent indoor environmental regulation focuses on optimizing parameters such as indoor temperature, humidity, and lighting through intelligent means while ensuring occupant comfort, thereby reducing energy consumption and achieving a dual improvement in low-carbon performance and user experience. During renovation, intelligent devices compatible with the architectural style should be selected to avoid damage to the building fabric or decorative details. For example, concealed intelligent temperature control systems and sensor-based lighting systems can be installed to realize functions such as automatic lighting shutdown when spaces are unoccupied and adaptive temperature regulation, thereby reducing unnecessary energy consumption [3]. In accordance with the functional use of the building, indoor spatial layouts should be optimized to maximize the use of natural lighting and natural ventilation, reducing reliance on artificial lighting and mechanical ventilation and thus lowering energy demand. Through intelligent monitoring systems, indoor environmental parameters and energy consumption can be tracked in real time, enabling precise control of equipment operation and preventing energy waste. In this way, indoor environmental regulation can be made intelligent and low-carbon while simultaneously meeting comfort and energy-saving objectives.

3.4 Carbon Emission Reduction during the Construction and Operation Stages

As critical components of the full life cycle of low-carbon renovation of historic buildings, the construction and operation stages play a decisive role in carbon emission reduction. The core approach lies in optimizing construction techniques and standardizing operation and maintenance management to reduce energy consumption, material waste, and carbon emissions throughout these stages. During the construction phase, material selection is of paramount importance. Priority should be given to environmentally friendly and low-carbon building materials, which have relatively low environmental impacts during both production and use. At the same time, the reuse potential of recyclable materials from demolished components of existing buildings should be fully explored and reasonably utilized, avoiding excessive extraction and processing of new materials and thereby reducing carbon emissions. Optimization of construction schemes is equally essential. The adoption of green construction techniques—such as precision construction and modular installation—can effectively reduce dust, noise pollution, and energy consumption during construction. Reasonable scheduling and shortening of the construction period can further decrease carbon emissions at this stage. In the operation and maintenance stage, establishing a long-term low-carbon management mechanism is fundamental. Regular inspection and maintenance of energy-saving equipment and envelope structures are required to ensure normal operation and stable energy-saving performance. Energy metering and management should be strengthened to accurately account for carbon emissions during operation, enabling timely optimization of operation and maintenance strategies based on data analysis. In addition, professional training for operation and maintenance personnel should be carried out to enhance their awareness and technical capacity for low-carbon management, ensuring effective implementation of various low-carbon measures and ultimately achieving full-process carbon emission reduction during both construction and operation stages.

4. Benefit Evaluation of Energy-Saving Renovation Technical Paths for Historic Buildings

4.1 Economic Benefit Evaluation

The economic benefit evaluation of technical paths for energy-saving renovation of historic buildings mainly focuses on renovation costs, energy-saving benefits, asset appreciation gains, and reductions in operation and maintenance costs, so as to comprehensively assess the economic feasibility and overall returns of renovation projects. During the evaluation process, initial renovation investments should be accurately calculated, including costs of building materials, construction, and equipment installation. At the same time, long-term benefits after renovation should be assessed. In addition, policy-supported benefits should be taken into account, as some regions provide subsidies, tax incentives, and other supportive policies for low-carbon renovation of historic buildings, which constitute an important component of economic benefits. By comparing renovation costs with comprehensive returns, the investment return rate and economic sustainability of different technical paths can be evaluated. Priority should be given to technical paths with high return on investment and stable long-term benefits, ensuring that renovation projects achieve low-carbon objectives while maintaining sound economic performance.

4.2 Environmental Benefit Evaluation

Environmental benefit evaluation is a core dimension in assessing low-carbon renovation technical paths for historic buildings. It mainly focuses on carbon emission reduction effects, total energy savings, and improvements to the surrounding ecological environment, thereby measuring the contribution of renovation projects to ecological civilization development. In the evaluation process, carbon emissions over the entire life cycle of the building before and after renovation should be calculated, including emissions during the construction, operation, and maintenance stages. Comparative analysis of total and relative carbon reductions after renovation is required to verify the effectiveness of low-carbon technical paths in energy conservation and emission reduction. At the same time, energy-saving benefits should be assessed by calculating total energy consumption after renovation and comparing it with pre-renovation energy use to determine the specific outcomes of energy conservation. In addition, the impacts of renovation projects on the surrounding ecological environment should be evaluated. For example, the use of environmentally friendly building materials can reduce environmental pollution, while the application of rainwater harvesting systems can improve water resource utilization efficiency, promoting positive ecological development. Through such comprehensive analysis, the environmental value of different renovation technical paths can be fully assessed.

4.3 Social Benefit Evaluation

The social benefit evaluation of technical paths for energy-saving renovation of historic buildings mainly focuses on cultural heritage inheritance, improvement of the living environment, enhancement of urban quality, and social demonstration effects, so as to comprehensively assess the social value of renovation projects. First, the cultural heritage benefit should be evaluated by examining whether the selected low-carbon renovation technical paths effectively protect the original architectural appearance and cultural connotations of historic buildings, whether they promote the inheritance and dissemination of historical context, and whether they enhance public awareness of cultural heritage conservation [4]. Second, the benefits related to the improvement of the living environment should be assessed. This includes evaluating whether indoor comfort and safety are enhanced after renovation, whether residents' living conditions are improved, and whether better spaces for cultural exhibition, leisure, and public activities are provided. Finally, the social demonstration effect should be evaluated. As a model for the coordinated advancement of cultural conservation and low-carbon development, low-carbon renovation of historic buildings should be assessed in terms of whether it offers replicable experience for other regions and historic buildings, whether it promotes the diffusion of low-carbon concepts throughout society, and whether it contributes to the enhancement of urban quality, thereby achieving coordinated development of social, cultural, and ecological dimensions.

Conclusion

Energy-saving renovation of historic buildings under the low-carbon concept is of far-reaching significance, as it concerns both cultural heritage preservation and ecological civilization development. Through the scientific screening of technologies, the construction of rational renovation paths, and comprehensive benefit evaluations, a win–win outcome between cultural conservation and low-carbon development can be achieved. In the future, continued exploration of innovative technologies, optimization of renovation models, and enhancement of renovation effectiveness are required to enable historic buildings to gain renewed vitality in the low-carbon era and to contribute more substantially to sustainable development.

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