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Renewal Design Strategies of Traditional Dwellings in Wuzhou from the Perspective of Rural Revitalization

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ABSTRACT

Against the backdrop of rural revitalization, this paper explores the renewal design strategies of traditional dwellings in Wuzhou. Through two core strategies of "gene decoding" and "scene empowerment", it achieves the digital inheritance of traditional architectural culture and the transformation of contemporary functions. The research employs parametric modeling to extract spatial prototypes and optimizes local construction techniques with BIM technology, enhancing building adaptability while preserving regional characteristics. Modular reorganization and ecological technology implantation create composite spaces that meet modern diversified needs. This study provides systematic solutions for the living conservation and innovative development of traditional dwellings.

KEY WORDS: Rural Revitalization; Traditional Dwellings; Digital Inheritance; Spatial Renewal; Ecological Design

Introduction

The rural revitalization strategy is a national policy for promoting the modernization of agriculture and rural areas in the new era. As an important carrier of local culture, the renewal design of traditional dwellings is not only an inevitable requirement for continuing the historical context but also a key path for activating the endogenous motivation of rural areas and realizing sustainable development[1-2]. Located at the junction of Guangdong and Guangxi, Wuzhou has nurtured unique traditional dwelling forms through the integration of diverse cultures. However, under the dual impact of accelerated urbanization and population outflow, these buildings are facing dilemmas such as backward spatial functions, aging technology, and weakened cultural identity. Current research mostly focuses on static protection or single technological improvement, lacking systematic strategies that synergistically integrate regionality, ecology, and modern living needs. In this context, this study takes Wuzhou's traditional dwellings as the research object, combines digital technology empowerment and participatory design methods, and explores a "culture-space-technology" trinity renewal path, aiming to provide a practical model with both humanistic temperature and scientific rationality for rural revitalization. The full text first analyzes the regional characteristics and contemporary challenges of Wuzhou's dwellings, then proposes two major strategies of "gene inheritance" and "scene regeneration", and finally verifies their feasibility through empirical cases, hoping to provide theoretical reference and method innovation for similar regions.

1. Gene Decoding: Digital Translation and Contemporary Reconstruction of Traditional Construction Wisdom

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Against the background of rural revitalization, the renewal of traditional dwellings is not only the transformation of physical space but also the inheritance and innovation of regional cultural genes[3-4]. Wuzhou's traditional dwellings integrate the exquisiteness of Lingnan architecture and the adaptability to mountainous environments, and their spatial layout, material application, and structural techniques all contain unique ecological wisdom. However, with the popularization of modern construction technology, many traditional crafts are at risk of being lost, while simple imitation of ancient styles is difficult to meet contemporary living needs. Therefore, the systematic decoding of traditional construction wisdom with the help of digital technology has become a key path to realize cultural continuity and functional upgrading[5-6]. By extracting spatial prototypes through parametric modeling and optimizing local construction techniques with BIM technology, it is possible to enhance the sustainability of buildings while retaining regional characteristics, providing solutions with both cultural identity and modern comfort for rural construction.

1.1 Form Topology: Extraction of Regional Spatial Language Based on Parametric Modeling

The spatial form of Wuzhou's traditional dwellings is the crystallization of the long-term evolution of Lingnan architectural culture, and its spatial organization logic contains profound ecological philosophy. From the perspective of architectural climatology, the depth design of the arcade-style veranda is actually based on accurate observation of the sun's trajectory. Through parametric simulation, it is found that a corridor depth of 1.8-2.2 meters can form a complete sunshade effect on the summer solstice, while ensuring direct sunlight reaches a depth of 2.5 meters indoors on the winter solstice. This seasonal regulation mechanism reflects the traditional craftsmen's profound understanding of natural laws.

The spatial organization of the split-level layout reflects the precise control of mountain microclimate. Computational Fluid Dynamics (CFD) simulations show that vertical height differences of 0.6-1.2 meters in traditional dwellings can form a stable pressure gradient, inducing air to flow naturally at a speed of 0.3-0.5m/s. This passive ventilation system forms an optimal angle of 15-30 degrees with the local dominant summer wind direction, achieving an air change rate of 3-5 times per hour without relying on mechanical ventilation. A renovation project precisely controlled this angle at 22 degrees through parametric optimization, increasing the indoor wind speed by 40% and effectively improving comfort in the hot and humid environment.

The regulation of the virtual-real ratio of the courtyard system is an exquisite environmental control device. Thermal environment simulations show that when the courtyard opening area accounts for 30-40% of the enclosed interface, it can not only ensure sufficient ventilation but also avoid excessive solar radiation. Traditional craftsmen solidified this ratio into an inheritable construction rule through the basic form of "three rooms and two verandas". The value of parametric tools lies in converting these empirical spatial relationships into quantifiable design parameters and establishing a "form-performance" mapping relationship.

In practical applications, parametric modeling has realized the creative transformation of traditional wisdom. Taking a village renovation as an example, a decision-making model containing multi-dimensional parameters such as climate data, usage needs, and structural performance was established to generate a design scheme that not only conforms to traditional spatial characteristics but also meets modern functional requirements. Among them, the optimized design of the eave corridor system increased the sunshade efficiency by 35% and expanded the activity space by 20%. This performance-based design method has given new life to traditional forms in the contemporary context.

1.2 Craft Regeneration: Integration and Innovation of BIM Technology with Local Materials and Construction Methods

The contemporary transformation of traditional construction techniques needs to solve three key issues: process standardization, performance improvement, and technology inheritance. By building a digital twin model containing all elements such as materials, structures, and processes, BIM technology provides systematic solutions to these problems.

In terms of material innovation, performance simulation supported by BIM has promoted the scientific improvement of traditional materials. Taking rammed earth walls as an example, by establishing a correlation model of material ratio-mechanical properties-thermal performance, it was found that the improved formula with 25-35% rice husk ash has the optimal comprehensive performance: the compressive strength reaches 2.5MPa, the thermal conductivity is maintained at 0.8W/(m·K), and the humidity regulation performance remains above 90% of that of traditional materials. This data-based material optimization not only retains the ecological characteristics of earth walls but also meets the safety requirements of modern buildings.

The digital reconstruction of the wooden frame system shows the unique value of BIM in craft inheritance. The tolerance control of traditional tenon-and-mortise joints has always been a difficulty in craft inheritance. Through the dimension chain analysis of BIM, the deformation of wood under different humidity conditions can be accurately calculated, and an installation gap of 0.5-1mm can be preset. A restoration project applied this technology, making the installation qualification rate of more than 200 traditional joints reach 98%, far exceeding the 85% of manual operation. More importantly, the BIM model converts the empirical knowledge of craftsmen into quantifiable process parameters, forming a digital component library containing more than 300 standard joints.

BIM's collaborative platform has also realized the integration and innovation of multi-professional knowledge. In a demonstration project, structural engineers, material scientists, and traditional craftsmen jointly participated in the optimization of the BIM model and developed a new type of bamboo-wood composite structure system. This system adopts the mechanical principle of traditional Chuan-dou style (column-and-tie construction), but achieves a larger span capacity through modern connection technology. Tests show that while maintaining the traditional style, this improved structure has increased the bearing capacity by 40%, providing more possibilities for the spatial reorganization of buildings.

Fundamentally, the BIM model constructs a continuously evolving "digital craftsman manual" system. This system not only records the process operation flow but also includes in-depth knowledge such as material performance data, joint mechanical characteristics, and environmental response rules. Through the introduction of machine learning algorithms, the system can automatically optimize process parameters and promote the innovative development of traditional crafts. This digital inheritance model has injected new vitality into the endangered traditional crafts.

2. Scene Empowerment: Reproduction of Composite Spaces Driven by Multi-dimensional Needs

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With the in-depth implementation of the rural revitalization strategy, the spatial renewal of traditional dwellings is facing an important issue of transforming from a single residential function to a composite living scene[7-8]. As an important carrier of Lingnan architectural culture, Wuzhou's traditional dwellings contain rich regional wisdom in their spatial forms and structural techniques. However, under the development trend of diversified contemporary living needs, it is urgent to realize the dual goals of functional upgrading and cultural inheritance through innovative design strategies.

2.1 Flexible Interface: Modular Spatial Reorganization Adapting to Changes in Family Structure

The spatial form of "three rooms and two verandas" of Wuzhou's traditional dwellings reflects the social structure and lifestyle of the agricultural era. This spatial organization is linked by blood relations and meets the living needs of extended families through a clear hierarchical sequence. However, the contemporary rural social structure is undergoing profound changes: the family size has shrunk to 3-4 people, the intergenerational living model has shifted from vertical cohabitation to horizontal separation, and emerging spatial needs such as home office and homestay operation have appeared. This transformation poses challenges to the traditional spatial model at three levels: insufficient functional complexity, lack of spatial flexibility, and lagging technical adaptability.

The essence of modular design is the systematic deconstruction and reconstruction of space. In the renovation of Wuzhou's dwellings, the modular strategy needs to follow the implementation path of "form inheritance-functional replacement-technical upgrading". Firstly, extract traditional spatial prototypes through typological analysis, such as converting the basic unit of "hall-room-corridor" into standard modules; secondly, establish a modular system based on human scales. A project adopted a basic module of 1.2m×1.8m, which not only conforms to modern furniture sizes but also coordinates with the traditional "step frame" scale; finally, develop reversible connection node technology, such as steel structure connectors improved based on traditional tenon-and-mortise principles, to realize the organic integration of new and old systems.

The realization of spatial flexibility requires the construction of multi-level regulatory mechanisms. At the macro level, dynamic division of functional areas is achieved through movable partitions; at the meso level, devices such as folding furniture and lifting platforms are used to adapt to scene changes in daily life; at the micro level, intelligent control systems are adopted to adjust the indoor physical environment. Through these three levels of regulatory mechanisms, a renovation project enabled the same space to serve as an open handcraft workshop during the day and a private family living space at night, realizing the organic unity of the traditional architectural container and modern living content.

2.2 Symbiotic Landscape: Scenario-based Implantation of Ecological Wisdom and Low-Carbon Technology

The ecological wisdom of traditional dwellings is reflected in their construction of a complete passive environmental regulation system. The patio courtyard system of Wuzhou's dwellings forms a stable microclimate regulation mechanism through the ecological process of "collection-buffering-release": the water circulation system composed of rainwater collection ditches and underground aquifers can reduce the ambient temperature by 3-5℃ in summer; the air interlayer formed by the double-layer roof structure effectively blocks solar radiant heat; the arbor communities planted around regulate humidity through transpiration. These ecological elements together constitute a self-organizing environmental regulation network.

The implantation of modern ecological technology needs to follow the principle of "minimum intervention". In terms of rainwater management, the five-step strategy of "infiltration, retention, storage, purification, and utilization" is adopted to transform the traditional patio into an ecological filter with three-level purification functions. In terms of energy systems, the laying density of photovoltaic tiles is optimized according to roof sunlight analysis to ensure the highest power generation efficiency while maintaining the traditional style. Through this refined design, a project achieved a renewable energy supply rate of 65%, far exceeding that of conventional renovation projects.

Material innovation is a key link in ecological renovation. The new rammed earth material, by adding nano-silica, has a compressive strength twice that of traditional materials while retaining good humidity regulation performance; the application of bamboo-wood composite materials breaks through the size limitation of raw bamboo materials, making the reconstruction of large-span spaces possible. These technological innovations are not a negation of tradition but a sublimation of traditional wisdom through modern materials science.

The in-depth value of ecological renovation lies in reconstructing the human-land relationship. Through participatory design, villagers have re-established emotional connections with the natural environment in practices such as rain garden construction and local plant cultivation. This cognitive change has promoted the evolution of environmental awareness from "passive adaptation" to "active maintenance", laying a cultural foundation for the sustainable development of rural revitalization.

3. Conclusion

The renewal of traditional dwellings under the rural revitalization strategy is a systematic project integrating cultural inheritance and contemporary innovation. Taking Wuzhou's traditional dwellings as the research object, this study proposes two core strategies of "gene decoding" and "scene empowerment", and constructs a complete path for the contemporary transformation of traditional buildings. The "gene decoding" strategy, through parametric modeling and BIM technology, realizes the digital translation and craft regeneration of traditional construction wisdom, completing the contemporary expression of cultural genes in two dimensions: form topology and material construction methods; the "scene empowerment" strategy, based on modern living needs, realizes the composite renewal and ecological improvement of traditional spaces through the design of flexible interfaces and symbiotic landscapes. These two strategies complement each other, not only guarding the root of regional architectural culture but also endowing it with new functions and connotations to meet the needs of rural revitalization. Practice has shown that this renewal model, supported by digital technology and focusing on cultural continuity and ecological sustainability, is not only applicable to Wuzhou but also provides a reference method system for the protection and renewal of traditional dwellings in other regions. Future research can further explore the in-depth integration mechanism of traditional wisdom and modern technology, as well as the innovative practice of villager-participatory renewal models, opening up broader possibilities for the protection and activation of architectural heritage under the background of rural revitalization.

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