Research on energy-saving renovation strategies for traditional residential buildings in Qingduizi Ancient Town based on BIM technology

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Key words: HBIM; BEM ; Traditional residential architecture; Energy saving renovation

Introduction

In the context of the global energy crisis, low-energy buildings have become a focal point of attention. Traditional residential heritage buildings are widely distributed worldwide, with a vast existing stock and substantial demand for renovation and reuse, presenting enormous potential for reducing carbon emissions. Addressing how to preserve cultural value while achieving energy efficiency and emissions reduction goals is a topic of significant research importance.

This study focuses on a typical traditional residential building in Qingduizi Ancient Town, Zhuanghe City, Liaoning Province, Northeast China. Qingduizi Ancient Town has over 600 years of social change history. The residential buildings selected in this article are located in the central area of historic towns and are representative of traditional residential architecture in the region.(Chenglong, 2017)

The methodology of this study involves using gathered survey data to construct HBIM models of traditional residential buildings. These models then provide data for Building Energy Models (BEM) to calculate carbon emissions from traditional residential buildings. This process requires an interoperable workflow(Costa, Cuperschmid and Neves, 2024), specifically using plugins that serve as intermediaries between different software. In this study, Revit software is employed to convert HBIM model data into the widely used green building format, gbXML, facilitating further simulation and computation of building carbon emissions in BEM.Finally, through analysis of the computational results, strategies and recommendations for low-carbon renovation of traditional residential buildings are proposed.

Figure 1 The location of the residence in the ancient town（left）；On site photos of traditional residential buildings（right）

Data acquisition

The data required for model construction includes the geometric shape of the building, maintenance of structural components, material and thermal property information, as well as energy consumption status. In this study, the method used for constructing HBIM models is the CAD-to-BIM approach, which leverages primary CAD drawings to establish the initial HBIM model. Additional data is gathered through on-site surveys and literature review methods.(Farajalah and Töre, 2023)

Modeling analysis

(1) HBIM model construction and data input: Properly categorize and catalogue elements with specific architectural significance(CHNT-ICOMOS, 2024), focusing primarily on distinctive decorations and roof tile hanging of the residence. Input relevant data such as thermal performance of materials or envelope structural components, laying the foundation for building energy consumption simulation.

（2）Using gbXML for data exchange: This paper employs gbXML for data exchange from Revit to GBS, facilitating interoperability between HBIM and BEM data.

（3）Building energy modeling: Importing models with attribute information into the Green Building Studio (GBS) energy simulation tool allows for energy consumption analysis. During the analysis process, inputting corresponding geographical location, climate data, building parameters, and their attributes enables efficient generation of energy consumption analysis results for the entire building.

（4）Calculation of carbon emissions: Based on established carbon emission factors, the carbon emissions during the operational phase of the building are calculated using a carbon emission calculation model.(Guangyu, 2023)

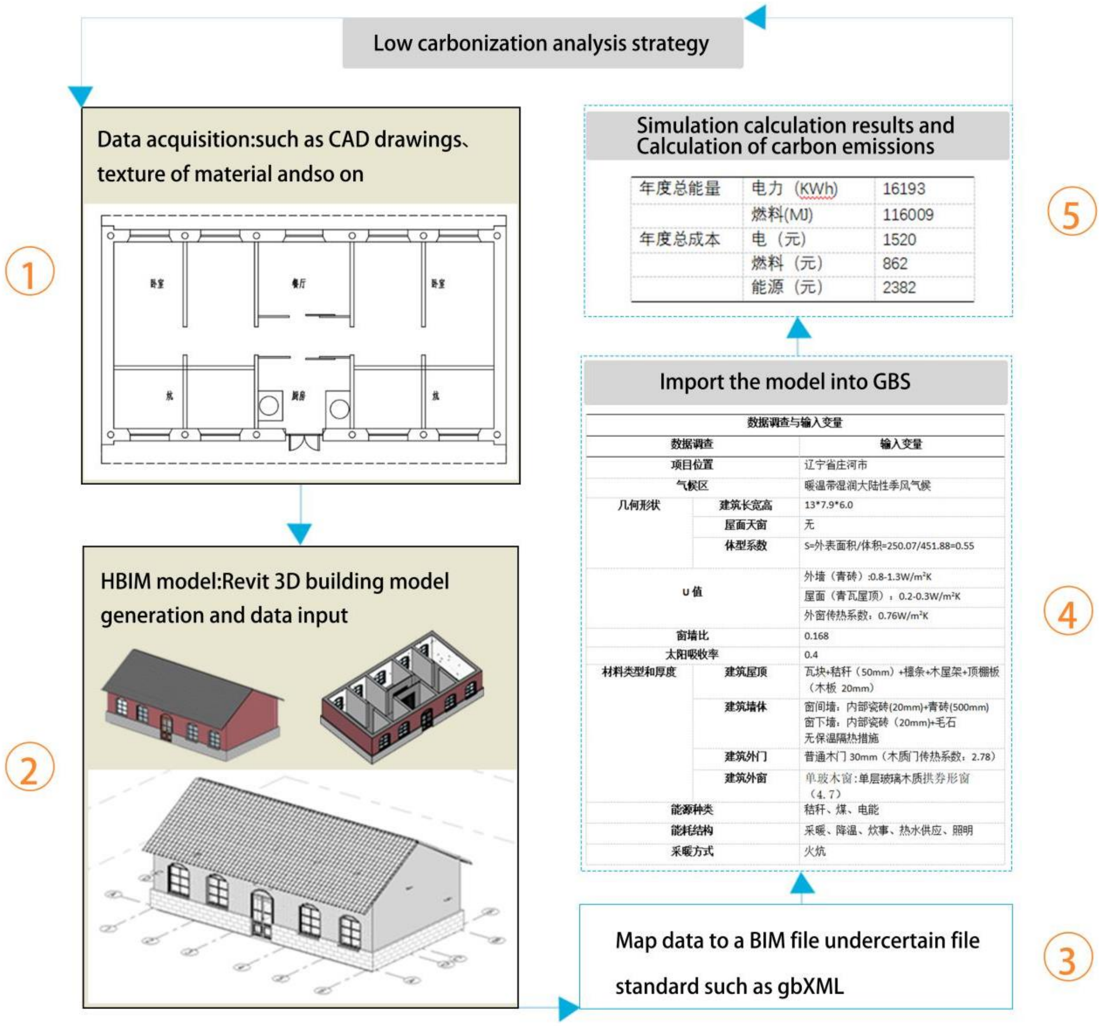

Figure 2 Technical roadmap

Countermeasures and suggestions

Based on energy consumption simulation, important factors affecting carbon emissions from traditional residential buildings are identified from aspects such as building envelope structure, energy utilization, and site ecological landscape. With the aim of enhancing residential quality, strategies for low-carbon transformation of these traditional residential buildings are explored. Specific recommendations are as follows:(1)Building envelope structure materials: To ensure reversibility of the transformation without compromising the authenticity of architectural heritage, an insulated cavity wall can be added to the existing walls. This feature includes characteristics such as detachability, lightweight, and minimal damage to the original wall surface. Energy consumption simulations can calculate the potential reduction in carbon emissions.(2)Optimization of doors and windows systems: Doors and windows in Qingduizi Ancient Town exhibit distinct regional characteristics and can only be partially modified. For instance, using sealing materials like weather stripping to seal gaps improves air tightness. Additionally, specially treated wooden doors and windows or modern insulation materials with wood-like textures can be considered. Simulations can analyze modern insulation materials.(3)Optimization of site ecological landscape: Emphasis on sunshade and sun protection, combined with landscape greening, creates a favorable indoor and outdoor thermal environment.(4)Energy utilization: Adjusting residents' energy consumption patterns to reduce reliance on traditional energy sources.

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