Literature Review on Sustainable Building Internal Design (SBID) Approaches Combining Vernacular Architecture Design Strategies to Mitigate Thermal Comfort Issues in Urban Villages

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Abstract: This chapter explores the current situation of urban villages and the necessity of sustainable renovation, discussing issues of indoor discomfort in summer. It also examines sustainable building interior design, its impact on thermal comfort, and briefly outlines various design elements for mitigating thermal discomfort. The application of SBID in improving residential thermal comfort is then elaborated. Finally, research gaps and questions are presented.

1. Introduction

This chapter explores the current situation of urban villages and the necessity of sustainable renovation, discussing issues of indoor discomfort in summer. It also examines sustainable building interior design, its impact on thermal comfort, and briefly outlines various design elements for mitigating thermal discomfort. The application of SBID in improving residential thermal comfort is then elaborated. Finally, research gaps and questions are presented.

2. Relevant Concepts

The purpose of this study is to explore the feasibility of sustainable renovation of urban village buildings. To better understand the research content, this section describes some important concepts involved in the study, including urban villages, thermal comfort, sustainable building interior design, and vernacular architecture.

2.1 Urban Villages (UV)

This study examines urban villages from the perspective of renovation, focusing on the phenomenon of urban villages located within bustling city centers. These villages occupy prime geographical locations and are surrounded by modern buildings, creating significant conflicts with urban aesthetics and development. The phenomenon of urban villages can be observed in almost all major cities in China, as well as in small- and medium-sized cities.

Research on the characteristics of urban villages can be summarized as follows:

The first type summarizes the characteristics of urban villages from spatial and landscape perspectives (He Shenjing & Qi Xiaoling, 2014; Hu Weijie & Wang Yiting, 2022). These studies identify urban villages as characterized by crowded buildings, high density, lack of public spaces and facilities, and a distinct non-urban, non-rural spatial landscape. Thus, for the safety and health of residents and the renewal of urban aesthetics, the government should accelerate the renovation of urban villages.

The second type summarizes the characteristics of urban villages from the perspective of economic development (Yin Yuchao & Cai Yinying, 2020; Fu Chuke, 2023). These studies suggest that land in urban villages is often rented out by village collectives to generate income, and villagers rely on rental income to survive. Therefore, the government must consider how to ensure stable income for villagers after losing rental income during the renovation process.

The third type summarizes the demographic characteristics of urban villages (Hou Yu et al., 2018). Urban village populations are highly mobile, with tenants outnumbering original residents, and residents' education levels are generally lower than those of urban populations.
The fourth type discusses the cultural and social characteristics of urban villages (Li Haitao, 2021). These studies focus on the gaps between villagers and migrants and the discord between the historical culture of urban villages and modern development. Recently, scholars have begun advocating for the preservation of urban villages.
In summary, the main characteristics of urban villages include poor architectural environments and public hygiene, complex and mobile populations, and divergence from the civility of modern urban spaces. Retaining elements during urban village renovation can effectively preserve their historical culture and traces of urbanization.

2.2 Thermal Comfort (TC)

This study mainly focuses on the effect of SBID on mitigating indoor overheating in urban village buildings. Therefore, understanding the concept of thermal comfort, factors affecting human thermal comfort, and reviewing previous design strategies for improving thermal comfort can provide theoretical and practical support for exploring solutions to indoor overheating in urban villages.
In ASHRAE Standard 55-2023, thermal comfort is defined as the state of mind in which a person expresses satisfaction with the thermal environment, which corresponds to the general perception of thermal sensation. It refers to the subjective overall sensation of warmth or coldness in a specific environment. Factors affecting human thermal comfort are divided into two categories: the first category includes physical environmental factors, such as air temperature, air humidity, air velocity, and mean radiant temperature. The second category includes human factors, such as metabolic rate and clothing.
A review of previous studies on thermal comfort in the field of architecture shows that most focus on improving human thermal comfort from the perspective of optimizing the physical environment of buildings. Design strategies for altering physical environmental factors can be divided into three categories:
The first category involves optimizing building envelope materials (Olumide Ebenezer Jegede & Ahmad Taki, 2021; Alex Nutkiewicz et al., 2022; Adegun O.B., 2023). These studies mainly focus on insulation materials for exterior walls and roofs.
The second category involves ventilation and shading design for building envelopes (Tianqi Liu & W.L. Lee, 2020; Zhao Yu, 2023). These studies focus on window-to-wall ratios, building orientation, and internal and external shading devices.
The third category involves optimizing the color of building envelopes (Azarnejad & Mahdavi, 2015). Although relatively few, these studies show that light-colored exterior surfaces can reduce peak indoor temperatures.
In summary, the primary factors influencing thermal comfort are physical environmental factors, and the most common methods for improving thermal comfort through architectural design are modifications to building envelopes (materials, shading, ventilation, and color). Therefore, researchers hypothesize that the building envelope is the primary factor in SBID for mitigating indoor overheating in urban villages.

2.3 Sustainable Building Interior Design (SBID)

As a solution to mitigating indoor overheating in urban villages, defining the concept, principles, and thermal comfort-related design factors of SBID can help researchers propose sustainable building interior designs that positively impact the living environment. Additionally, these factors can be used to analyze residential buildings in Wenzhou's urban villages based on SBID principles.
In this study, "internal design" and "interior design" are regarded as synonyms. The term "internal design" is chosen because the scope of this study includes building envelopes and interior layouts, whereas "interior design" is limited to interior layouts and focuses on interior

decoration and aesthetic design. A review of the literature found that "Sustainable Interior Design (SID)" and "Environmental Sustainable Interior Design (ESID)" are the terms closest to the proposed concept of SBID. By organizing a timeline (Table 2.1), the concept of SBID applicable to this study is summarized.

Table 2.1 Sustainable Building Internal Design Concepts Sorts by Time

Year	Author	Definite
2022	Obeidat, S. M., & Obeidat, I. M.	SID is an approach that "focuses on the study of space and the development of solutions to improve the living environment and to make the best use of it according to individual needs".
2022	Rady, M. et al.	SID is concerned with more than a project's impact on the global environment; it also prioritizes the comfort and safety of the building's occupants and the interests of other stakeholders.
2020	Dissanayake, N. et al.	ESID means that all systems and materials are designed with an emphasis on integration as a whole, with the aim of minimizing negative impacts on the environment and occupants and maximizing positive impacts on the environment, the economy and social systems over the life of the project
2020	Obeidat, I. M., & Obeidat, S. M.	"SID is defined as the process of forming and creating interior spaces by treating spaces and their interior components in an environmentally responsible manner, by using renewable and environmentally friendly materials, and by utilizing environmental and design treatments to achieve comfort, luxury, health, safety, and privacy within these architectural spaces, thereby reducing energy consumption and harmful emissions that may jeopardize environmental safety "
2015	Hayles, C.S.	The term "ESID" has been adopted by many scholars and is defined as an approach that "focuses on the intended application of materials, aesthetic qualities, environmental and health impacts, usability, ease of installation and maintenance, and initial and life-cycle costs".
2015	Pilatowicz, G.	"SID is a broader concept that considers not only the impact of design decisions on the global environment, but also the physical and psychological impact on the occupants and everyone involved in the project, while conferring a nourishing and multi-sensory experience that transcends functional and aesthetic needs"
2009	Mihyun Kang & Denise A. Guerin	ESID is an approach that "emphasizes environmental issues and enhances the quality of indoor environments by improving indoor air quality and human comfort and using sustainable interior materials".
2006	Bonda, P., & Sosnowchik, K.	Designed to minimize negative impacts on the environment and energy consumption while improving indoor environmental quality to promote physical and psychological comfort for users

As shown in the table, early researchers equated sustainable interior design with environmental sustainable interior design, focusing on environmental issues in interior design, such as how to save materials, water, and energy, and how to improve the physical quality of the indoor environment (indoor air quality, thermal comfort, lighting, and acoustic environment). Rady, M., Obeidat, I. M., and Obeidat, S. M. believed that sustainable interior design should not only focus on indoor environmental issues and their impact on humans but also consider comfort, health, safety, and privacy from the perspective of indoor spaces.

Researchers summarized the design factors in SBID that can regulate indoor thermal comfort, as shown in Table 2.2.

1.Shading facilities for building envelopes: Regarding this design element, previous studies mainly explored the impact of adding shading facilities to building facades and the exterior of windows on

indoor temperatures. Therefore, researchers believe that adding or modifying shading facilities for building envelopes can reduce direct sunlight and lower indoor temperatures.
2.Proportion of building envelopes: Regarding this design element, previous studies mainly explored the impact of the window-to-wall ratio (window area size) on indoor temperature and lighting. Therefore, researchers believe that an appropriate window-to-wall ratio can effectively control indoor lighting and thermal load, thereby improving energy efficiency and indoor comfort.
3.Orientation of building envelopes: Regarding this design element, previous studies mainly explored the impact of the position of doors and windows and their relative positions on indoor ventilation. Therefore, researchers believe that correctly configuring the positions of doors and windows can promote air circulation between indoor and outdoor spaces, help form effective ventilation paths, improve indoor air quality, and reduce reliance on mechanical ventilation systems, thereby reducing energy consumption.
4.Materials of building envelopes: Regarding this design element, previous studies mainly explored the impact of wall and window materials on indoor temperatures. Therefore, researchers believe that the materials of building envelopes are the most important design factor for achieving thermal insulation.
5.Color of building envelopes: Regarding this design element, previous studies mainly explored the impact of facade colors on indoor temperatures. Therefore, researchers believe that lightening the color of building envelopes can reduce the solar heat absorbed by residences, thereby lowering indoor temperatures.
6.Interior layout: Regarding this design element, previous studies mainly explored the impact of balcony position and depth, bedroom position, furniture position, and functional flexibility on indoor ventilation. Therefore, researchers believe that changing interior layouts (e.g., flexible interior partitions) can improve natural ventilation, increase airflow and fresh air exchange, and alleviate summer discomfort issues.

Table 2.2 Design factors for alleviating indoor thermal comfort in sustainable building internal design

Design Factors	References
Envelope Building Shading Facilities	Emad S. Mushtaha et al., 2005; Bradshaw, 2010; Liu Xiaochun, 2012; Li Junzhi, 2012; Sheng Liu et al., 2018; Zhang Cunde, 2022; Liu et al., 2020
Envelope Building Ratio	Allan Rogers Kibaya 2013; Wu Di, 2014; Alex Nutkiewicz et al., 2018; Sheng Liu et al., 2020; Shima Moolavi Sanzighi et al., 2020; Farzaneh Soflaei et al., 2020; Wang Dandan, 2022
Envelope Building Orientation & Location	Liu Xiaochun, 2012; Wu Di, 2014; Zhang Zaiyi, 2020; Buyankhishig Maisar, 2020; Wang Dandan, 2022
Envelope Building Materials	Emad S. Mushtaha et al., 2005; Liu Xiaochun, 2012; Li Junzhi, 2012; Wang Tianyi, 2017; Alex Nutkiewicz et al., 2018; Shima Moolavi Sanzighi et al., 2020; Farzaneh Soflaei et al., 2020; Kunlun Li, 2021; Paula Fensterseifer et al., 2022; Wang Dandan, 2022; Nik Siti Fatimah Nik Hassin et al., 2023; Mohamed Hssan Hassan Abdelhafez et al., 2023
Envelope Building Color	V. Cheng et al., 2004; María G. Alpuchea et al., 2014;
Internal Layout	Hasim Altan et al., 2015; Wang Tianyi, 2017; Zhang Zaiyi, 2020; Zhang Cunde, 2022; Wang Dandan, 2022

In summary, sustainable building interior design is a design approach that addresses indoor environmental issues while considering the comfort, health, safety, and privacy of indoor spaces in adapting to the physiological and psychological needs of occupants. In this study, it specifically refers to the sustainable renovation design for the indoor spaces of urban village buildings and the transitional spaces between indoors and outdoors. The goal is to alleviate indoor discomfort in urban villages during summer, with renovation outcomes adhering to the principles of energy efficiency, environmental protection, human-centered design, and flexible adaptability.

2.4 Vernacular Architecture (VA)

Understanding the definition of vernacular architecture and its relationship with sustainability provides a clear framework for the subsequent field investigation of vernacular architecture in Wenzhou.

Fatma Kürüm Varolgünes (2019) defined vernacular architecture as buildings designed and constructed according to local climate, topography, and cultural traditions. It typically uses local materials and techniques to adapt to the surrounding environment while providing comfortable living conditions and protecting the environment.

The relationship between vernacular architecture and sustainability requires a dialectical perspective. First, from the perspective of environmental sustainability, the construction philosophy of vernacular architecture aligns with sustainable building practices. One reason is that vernacular architecture uses local materials that are energy-efficient, environmentally friendly, and recyclable (Maria Philokyprou et al., 2021). However, with the rapid increase in modern building scale, adopting the materials and methods of vernacular architecture may lead to excessive exploitation of stones and timber, causing shortages of renewable resources. Additionally, such materials are often bulky and require more frequent transportation compared to modern building materials, which can lead to environmental pollution during transportation (José María Fuentes Pardo, 2023).

Second, the spatial layout of vernacular architecture is designed according to local geographical and climatic conditions (Fatma Kürüm Varolgünes, 2019; Ebru Ergöz Karahan et al., 2021). Vernacular architecture in Wenzhou is primarily designed for summer conditions, featuring deep eaves and raised roofs with double eaves to provide shade and prevent rain. Overhanging eaves also protect mountain slopes from water erosion. The interior layout emphasizes symmetry, with houses, doors, and windows symmetrically arranged to ensure good lighting and ventilation. Open halls and corridors are commonly used for ventilation, dehumidification, and air exchange. However, the application value of these measures in modern high-rise buildings is relatively low.

From the perspective of economic sustainability, vernacular architecture faces issues such as long construction cycles, complex craftsmanship, low-rise structures, and large land use, which contradict sustainable building principles. Additionally, the high maintenance costs of vernacular architecture are one of the reasons for its preservation challenges in China. For example, modular construction, as a representative of sustainable buildings, offers advantages in maintenance costs and processes through modular assembly. From the perspective of energy-saving costs, vernacular architecture does not align with sustainable building principles.

Finally, from the perspective of social sustainability, the design and function of vernacular housing do not always align with modern family structures or comfort requirements. Vernacular architecture often lacks compatibility with modern facilities, and its lighting and design are not suitable for contemporary living needs. The complexity of its construction also makes adapting spaces to modern living requirements challenging. However, as products of resident participation and practical, time-tested design (Yahya Qtaishat et al., 2020), vernacular buildings embody local culture and traditional craftsmanship. Compared to the standardized appearance of modern or sustainable buildings, vernacular architecture has a stronger social sustainability dimension.

In conclusion, vernacular architecture holds significant value in enhancing the environmental sustainability of modern buildings, offering useful experiences and inspiration. Therefore, this study seeks to identify effective solutions to address indoor overheating in urban villages under Wenzhou's hot and humid climate by drawing insights from vernacular architecture in Wenzhou. This exploration aims to develop sustainable building interior designs suitable for urban village buildings in Wenzhou.

3. Application of SBID in the Sustainable Renovation of Urban Villages

Research on SBID in the sustainable renovation of residential buildings in urban villages can be summarized as follows:

The first type involves the renovation of building structures (He Jinghua, 2021). This type of renovation includes upgrading, repairing, and optimizing the basic structure and functional systems of buildings to improve safety, functionality, and comfort, while extending their lifespan.

The second type involves the renovation of public space facilities (Zhou Yi & Li Zhigang, 2021; Wang Yao & Yao Dong, 2023). This type of renovation focuses on providing a safer, more convenient, and comfortable living environment for urban village residents, especially considering the safety and accessibility of elderly residents.

The third type involves the renovation of the physical environment of buildings (Wenjian Pan & Juan Du, 2017; Ahana Sarkar & Ronita Bardhan, 2020). This type of renovation aims to improve the comfort and health of living spaces by measuring and analyzing the thermal environment of urban villages to provide data for optimizing the physical environment of buildings.

Currently, the sustainable renovation of urban village buildings mainly focuses on three aspects: safety, age-friendliness, and comfort. However, attention to the thermal comfort of urban village buildings is minimal, often limited to measuring and analyzing the thermal environment of urban villages, with few proposals or validations of renovation strategies and designs. This may be because the Chinese government initially approached urban village issues with a demolish-and-rebuild mindset, resulting in a lack of attention or even neglect toward the comfort of urban village buildings.

In recent years, as the government has begun advocating for the renovation and preservation of urban village buildings, researchers have started exploring ways to extend the lifespan of these buildings, leading to studies on strengthening and repairing structures. At the same time, attention has shifted from building safety to public spaces, considering how to renovate these spaces to meet residents' safety needs for outdoor activities.

Research on the thermal comfort of urban villages in mainland China has only just begun. Therefore, this study adopts a thermal comfort perspective for the sustainable renovation of urban village interiors and uses DesignBuilder software to simulate and test design strategies. The research results aim to fill the gap in studies on the thermal comfort of residential buildings in urban villages.

4. Application of SBID in Improving Residential Thermal Comfort

This section attempts to explore the application of SBID from the literature on thermal comfort in other existing residential buildings.

Compared to constructing a new sustainable building, sustainably retrofitting existing buildings is more difficult and complex (Smith, P., 2018; Belpoliti, V. et al., 2019). Retrofitting existing buildings requires considering how new technologies and designs can be integrated with existing building structures to meet current sustainability standards. This leads to the fact that not all sustainable design strategies or measures can be applied in retrofitting old buildings. As a result, building renovations mainly focus on improving building envelopes (e.g., external walls, roofs, windows) rather than upgrading entire building structures. For residential retrofitting, many researchers believe that focusing on modifications to building envelopes and interiors can significantly reduce energy consumption and greenhouse gas emissions.

Regarding the practical application of sustainable design in residential building retrofitting, one of the main goals is to alleviate the thermal environment and improve thermal comfort. The methods to achieve this goal can be summarized into two categories:

The first category considers how to improve thermal comfort from the exterior of the residence (Pu Mengmeng, 2020; Liu Zhongyong, 2021; Nutkiewicz A, et al., 2022; Xie Weidong, 2022). These studies mainly evaluate and measure the thermal insulation performance of building envelopes such as external walls, roofs, windows, and shading devices, and explore how to optimize the design of existing residential buildings to meet the needs of rapidly changing future climates.

The second category considers how to improve thermal comfort from the interior of the residence (S. Flores-Larsen et al., 2019 ; Zhang, X. et al., 2022 ; Deng, F., 2023 ; Kai Gao et al., 2024). These studies primarily investigate the factors that affect indoor temperature and humidity and optimize these factors to improve the thermal comfort of residential buildings.

First, most studies suggest that natural ventilation is the most important means to improve indoor temperature and humidity. Particularly, S. Flores-Larsen et al. (2019) analyzed several passive designs for addressing climate change, showing that shading and natural ventilation are the most effective strategies for energy saving and preventing indoor overheating.

Second, lighting power and color also affect indoor temperature and humidity. Especially, Deng Fanle (2023) used experiments and subjective questionnaires to investigate people’s comfort levels in indoor environments with three different temperature, illuminance, and color temperature conditions, concluding that thermal perception is influenced not only by the main effect of temperature but also significantly by illuminance and correlated color temperature.

Finally, residents, as the main participants in indoor activities, have a significant impact on energy consumption through their behavior and habits. At the same time, residents’ thermal perception

determines the indoor thermal comfort. Therefore, studies on factors influencing residents' energy-saving behavior are also important for exploring residential thermal comfort.
In summary, whether from the perspective of interior or exterior retrofitting of residential buildings, single design strategies are not optimal. Only by integrating or combining several design strategies can the performance of existing buildings be improved. Therefore, this study will adopt a combined strategy of interior and exterior retrofitting to reduce indoor overheating in urban villages, reduce building energy consumption, and improve indoor thermal comfort, ultimately achieving the sustainability of urban village buildings.

5. Research Gaps and Research Questions

From the perspective of attention and discussion on urban village residential issues, there has been limited focus on energy-saving and environmentally friendly renovations, and even less from the perspective of indoor environmental problems and renovation design. Although as early as 2011, scholars began addressing thermal comfort and overheating issues in Guangzhou's urban villages, and research findings confirmed the existence of overheating problems, subsequent studies on thermal comfort in urban villages have been rare and limited to Guangzhou and Shenzhen, with no research on Wenzhou's urban villages.
Research on building and residential thermal comfort is a key area of focus in the field of sustainable architecture. However, studies specifically addressing the thermal comfort of urban village buildings remain scarce. From the perspective of environmental sustainability, sustainable building practices are urgent, as overheating significantly impacts urban village residents.
In terms of applying sustainable building interior design methods, the main strategies for addressing residential thermal environment issues are passive design and greening. Passive design includes building orientation and layout design, natural ventilation, shading, and the thermal performance of building envelopes. Studies have shown that these strategies can effectively optimize residential thermal comfort, improve energy efficiency, and achieve sustainable buildings . However, these strategies are rarely applied to urban village renovations, possibly due to the constraints of urban village renovation conditions, such as material selection, building density, and the stability of existing structures. Additionally, the limited awareness of sustainability among urban village residents is another factor. Studies indicate that environmental knowledge and residents' education levels are important factors influencing environmental awareness.
This study applies sustainable building design to renovate urban villages, aiming to explore which design elements can address thermal environmental issues in a way that is energy-efficient and environmentally friendly, while also expanding the scope of sustainable building interior design. Additionally, by conducting interviews and engaging with residents during the research process, the study seeks to enhance urban village residents' awareness and understanding of building sustainability.
In conclusion, a review of the literature reveals that most researchers have overlooked or ignored energy-saving and environmentally friendly renovations in urban villages. Published studies show that only a few researchers have explored the overheating phenomenon in urban village buildings, and computer simulations have confirmed that indoor overheating exists in urban village buildings under subtropical monsoon climates. However, there is a lack of consideration and discussion regarding design solutions to address this phenomenon. Furthermore, sustainable building interior design is rarely used in urban village renovations. Therefore, this study investigates how sustainable building interior design can alleviate summer discomfort in urban village residences. The findings aim to further supplement research on energy-saving and environmentally friendly renovations in urban villages.

6. Conclusion

Firstly, this chapter highlights several key concepts relevant to the study: urban villages, sustainable renovation, thermal comfort, sustainable building interior design, and vernacular architecture. It includes the two major factors affecting thermal comfort: environmental factors (air temperature, humidity, mean radiant temperature, and air velocity) and personal factors (clothing insulation and metabolic rate). Additionally, it discusses the design elements of sustainable building interior design that influence thermal comfort, such as building envelope materials, color, proportion, shading devices, orientation, and interior layout.

Secondly, this chapter emphasizes the application of SBID in the sustainable renovation of urban villages and its role in improving residential thermal comfort. The discussion reveals that most researchers neglect or overlook energy-saving and environmentally friendly aspects of urban village renovations. Moreover, while a small number of studies confirm the existence of indoor overheating in urban village buildings, there is a lack of consideration and discussion regarding design solutions to address this issue. Sustainable building interior design is also rarely applied in urban village renovations. Finally, this chapter summarizes the research gaps and proposes the research questions.

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