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Sustainable development in the renovation of historical buildings: the example of the Panoffs' Mansion in Wuhan

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KEYWORDS

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ABSTRACT

This study examines the energy-efficient transformation of Panoffs' Mansion in Wuhan, integrating sustainability into urban renewal while preserving historical integrity. Through a qualitative methodology, the research employs field observations, literature reviews, and case studies. It explores how adaptive reuse of heritage structures can meet contemporary energy standards and urban demands, balancing preservation with modernization. This approach illuminates the potential of sustainable practices in revitalizing historical buildings, promoting a model for low-carbon urban development.

1. Introduction

In recent discussions on urban planning, the focus is increasingly on urban renewal and sustainable development as strategies to address the rapid pace of global urbanization. According to Roberts (2000), urban renewal is designed to enhance the economic vitality of cities and improve residents' quality of life by redeveloping areas with decaying, outdated, or nonfunctional buildings [1]. Its aim is to revitalize the city, addressing issues such as land, air, and water degradation, infrastructure obsolescence, housing shortages, and income or social segregation. However, traditional approaches to urban renewal have often emphasized physical renovation over broader concerns related to environmentally sustainable, socially inclusive, and economically viable regeneration [2].

Sustainable development, defined in the 1987 Brundtland Report, seeks to meet current needs without compromising the ability of future generations to meet theirs [3]. This approach calls for integrated planning that respects environmental integrity, economic stability, and social equity during urban renewal efforts. This shift in perspective has encouraged urban and transport planning to evolve from a one-dimensional to a multi-dimensional approach that includes green building, low-carbon strategies, public transit improvements, and the creation of vibrant centers to foster sustainable urban environments [4].

The challenges of rapid urbanization, particularly in developing countries, are compounded by environmental concerns, financial constraints, weak infrastructure, and high demographic growth, which make sustainable development even more challenging from an environmental and carbon emissions standpoint [5]. It is crucial for these regions to adopt holistic, low-carbon urban renewal approaches that address the nature of urban expansion, associated environmental challenges, and foster socioeconomic development [6].

China, as the most populous country and the world's second-largest economy, has experienced significant urbanization in recent decades, leading to severe environmental issues such as pollution

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and resource depletion [7]. A pivotal policy shift in 2013 saw the Chinese government incorporate eco-civilization into its national strategy, aiming to balance economic growth with environmental preservation [8]. This led to the aggressive promotion of "Green Building Evaluation Standards" across many cities in China to ensure that urban renewal projects adhere to environmental sustainability standards. These standards focus on energy efficiency, material conservation, and environmental friendliness, thus transforming old residential districts into ecological mixed spaces [9].

This research establishes the connection between urban renewal and sustainable development from multiple perspectives, particularly focusing on historical buildings as elements of energy-efficient renewal. Against this backdrop, the study employs a multi-dimensional methodological framework consisting of literature review, case studies, and empirical data analysis to explore the benefits and challenges of energy-efficient renovation of historical buildings, thereby advancing empirical knowledge of sustainable urban renewal strategies.

2. Literature Review

2.1. Challenges and Practices of Energy-Saving Urban Renewal

Urban renewal refers to the redevelopment and reconstruction of deteriorated, outdated or inefficient urban areas, with the purpose primarily of improving urban functions as well as increasing quality of human life [10]. This process is intended to solve a myriad of problems with urban development in general, such as environmental pollution, deteriorating infrastructure, and housing shortages or social isolation. Thus, the redevelopment of place in traditional urban renewal approaches stresses physical space interventions and frequently overlooks the integrated dimensions of environmental protection, social justice, and economic viability [11]. Building low-carbon cities is now a strategic direction for urban regeneration work. The concept of low-carbon cities is designed to mitigate carbon emissions and improve energy efficiency via utilization of renewable energies while minimizing environmental externalities.

In order to achieve the low carbonization of cities, measures like green buildings and sustainable districts should be developed [12]. Singapore, for example, is considered a global leader in the green building market with its strong architectural heritage and financial incentives such as governmental subsidy which helps it to quickly step-up development of green buildings through anamorphosis building standard [13]. Copenhagen likewise having introduced a highly workable energy-saving building system, has dramatically lowered urban carbon emissions, showing the path to "sustainable cities" on a global scale [14].

Government, in this respect, takes an irreplaceable role by setting up and enforcing related policies and regulations as well the mandatory legal, and financial supports to renew the urban habitats [15]. But the exact problems and hurdles faced in policy implementation differ by country and region. Research focusing on how best to tailor and adapt national policies to local contexts is very necessary with substantial scope for more depth in investigation Green building and low-carbon design should be further integrated with urban renewal in a more systematic way to achieve both environmental improvement and economic profit [16]. Furthermore, this is an important area to examine the implementation of urban renewal policies and sustainable development as well.

The characteristics of low-carbon and sustainable development have been incorporated into the urban renewal process in China in recent years. The Chinese government has facilitated and implemented these initiatives [17]. Beijing is also a city that has been making substantial efforts in urban renewal with low-carbon focus. The government provides subsidies, after all new buildings' standards of energy consumption, and has set strict limits of energy consumption, while for the loss facilities the restrictions were mainly in existing buildings [4].

The last observation indicates disparities in resource distribution and policy implementation across regions are still prevalent. For example, the adoption and enforcement of strict environmental standards is often constrained in smaller cities and economically less developed areas because of their limited financial resources and technological capacities [18].

2.2. Integrating Sustainability and Cultural Heritage: Preservation and Development

The preservation of historic districts represents a complex yet essential endeavor that necessitates a meticulous balance between maintaining cultural heritage, modernizing urban functionality, and meeting the evolving needs of contemporary society [19]. Historic district preservation is based on certain principles to ensure that the originality and cultural significance of a place are retained without compromising the needs for modern urban development. International guidelines, such as the Venice

Charter (1964) and the Prague Charter (1976), underline the preservation of original forms and historical contexts, while accommodating modern uses of structures [20]. This preservation strategy helps not only in protecting the historical memory and cultural heritage of urban context, but also in enhancing the quality of urban life by providing rich cultural experiences.

Preservation of the historic districts depend on building renovation and is one of the vital elements. The buildings can be updated to function better and be safer without losing the aesthetic that comes with maintaining history. The energy-efficient buildings and sustainable designs are now used on modernized urban areas in recent past [21]. The Marais district of Paris offers an example of how these can be carefully exchanged. One in which this district has been able to preserve its history and culture, whilst growing into a lively cultural and commercial center [22], Such projects as the renovation of the Parisian Marais district saw the Parisian government work to maintain a majority of historical buildings and enhance public parks, infrastructure, and environmental quality, thus simultaneously encouraging sustainability and cultural preservation.

Modern technology and materials also have an important part to play in construction- apart from preservation and renovation. Synthetic materials and modern technology can make buildings both safe and functional while retaining their historical integrity [23]. Glass and steel structures when used can add to the strength of a building; however, they also allow for better light and improve natural ventilation [24]. Also, energy can be conserved properly by the use of solar panels, rainwater recharging system and saving devices are installed and make heritage buildings eco-friendlier and more sustainable [25].

China has had the most extensive history of culture for preservation, and its achievements in the preservation of historic districts are a combination of traditional conservation practices and modern sustainable development ideas [26]. These include the preservation work in the ancient city of Suzhou, celebrated for its classical gardens and the creative preservation policies in Beijing's Hutongs which respect historic preservation alongside modern urban needs [27], [28]. These initiatives reflect China's commitment to preserving its cultural heritage while promoting sustainable urban development.

However, the research landscape in China also reveals several challenges. These include an inadequate incorporation of low-carbon, environmentally friendly technology into preservation practices and the lack of a cohesive legal system framework [4]. Researchers call for a more expanded perspective that captures the range of contemporary developments in green technologies [29].

3. Methods

Wuhan, the capital of Hubei Province, is a pivotal city in central China, often dubbed the "Thoroughfare of Nine Provinces" due to its strategic role as a transportation and industrial hub. With a rich history spanning over 3,500 years, Wuhan has long been a significant commercial and industrial center. The city's unique geographic and urban landscape is shaped by the confluence of the Yangtze and Han Rivers [30].

Historically, Wuhan was a locus for foreign concessions, where various Western powers set up enclaves for trade and residency during the late 19th and early 20th centuries [31]. Following the Second Opium War, Hankou became a concession area for Western powers, beginning from Jianghan Road and extending along the river [32].

Panoffs' Mansion stands out in the former concession area of Hankou, boasting a land area of 3,998 square meters and a base area of 2,368 square meters, with a building density of 59.4% and a total building area of approximately 9,423 square meters. During the same era, a typical plot in the Russian Concession measured about 2,000 square meters, with most blocks divided into 5 to 10 plot units, except for industrial estates. Panoffs' Mansion is unique as the only non-industrial building that occupies an entire block [33].

Located at a Y-shaped intersection, Panoffs' Mansion follows a triangular plot layout, a shape uncommon in Chinese cities but frequently seen in Western urban planning, where radial roads and triangular or fan-shaped blocks with acute angles are prevalent, as shown in Figure 1. Western architects often design buildings on acute-angled plots with arcs or truncated corners, a feature reflected in the design of Panoffs' Mansion.

This study aims to explore the transformation of this historic building. It examines how authorities managed to convert a dilapidated residential building into a historic heritage site that meets modern needs and energy efficiency standards following its restoration.

Methodologically, this research employs a qualitative approach, including resource analysis of writings and fieldwork observations. Conducted in 2024, the fieldwork involved two months of non-intrusive observations of the building's exterior and public spaces, alongside content analysis of web-

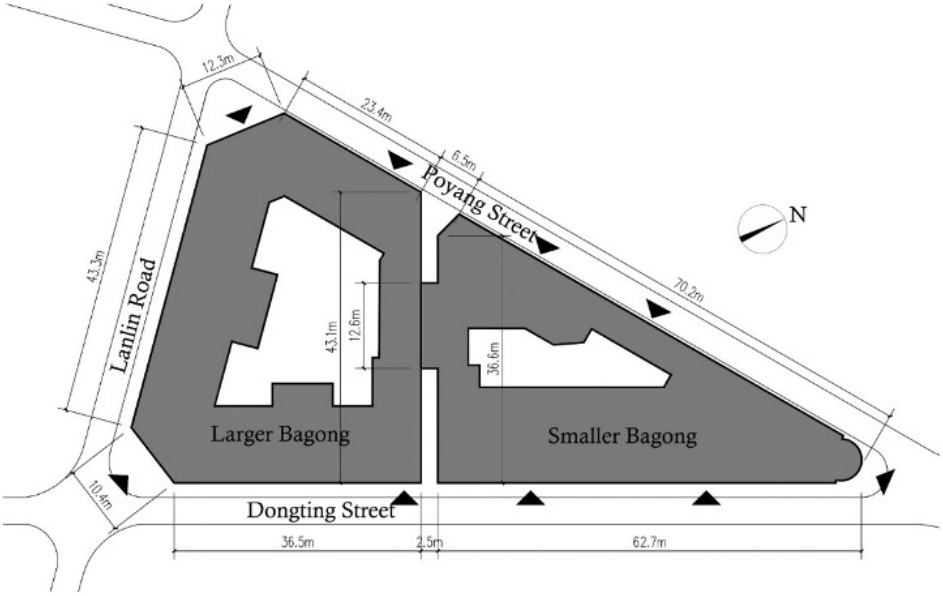

Fig. 1. Plan map of Panoffs' Mansion

based materials and official documents. This blend of methods provides a comprehensive, multidisciplinary perspective on the subject.

4. Results

4.1. Architectural history and characteristics

Panoffs' Mansion, the largest high-grade apartment in Hankou during the late Qing Dynasty and early Republic of China, is a landmark in the former Russian Concession of Jiang'an District, Wuhan, China. This building, a pioneer of apartment living in Wuhan, represents the earliest example of collective residence architecture in Hankou and typifies modern collective living from that era. Since its construction, the building has witnessed the handover of the Hankou concession and the establishment of the People's Republic of China, with numerous changes in its residents [33].

Constructed in 1901 by Russian tea merchant J.K. Panoff, the building is situated at Poyang Street. The actual designer remains unknown, though sources suggest it might be Hemmings & Berkley or a Russian architect. The structure was developed in two phases: the larger section on Lanling Road known as "Larger Bagong" was completed first in 1910, followed by the "Smaller Bagong" on Lihuangpi Road, recognized for its smaller size.

Panoffs' Mansion is built from masonry with a wooden structure, featuring three floors above ground and one below. It combines Russian ethnic characteristics with romantic elements prevalent in the European classical revival style of that period. The building is notably triangular, with a hall on the

Fig. 2. Photo of Panoffs' Mansion in the 1920s

third floor resembling a monk's hat, earning it the nickname "Russian head tip."

This building features a distinctive Russian-style dome at the corner and cantilevered balconies along the street-facing façade, as seen in Figure 2. The architecture primarily exhibits the classical revival style popular in Europe at the time, characterized by the repetition of motifs on the façade, with a strong emphasis on proportion and symmetry. This style also extends to the interior, where the layout strives for symmetry, incorporating classical elements such as columns and arches [34].

Additionally, the building incorporates features of the colonial style, notably exterior porches that serve as balconies or corridors connecting different units. This architectural style originated from colonizers in Southeast Asia, designed to adapt to the region's hot and humid climate. As it spread to the concessions of major Chinese cities, it became one of the first Western architectural styles to influence local designs.

4.2. Lack of maintenance of historic buildings

Due to a shortage of living space, modifications were made over time: interior balconies were enclosed, rooms were subdivided, and mezzanines were added to maximize space. Despite these adaptations, overcrowding was a significant issue even before these changes, as described in a 1947 Yishi Newspaper article that portrayed the dense and cramped conditions, with potentially thousands of residents at one time [33].

Following the founding of the People's Republic of China in 1949, the building was nationalized and allocated to bank employees as public housing. In response to ongoing space shortages, an additional story was added in 1964. The new top floor is three meters high, contrasting with the original floors' heights of 4.3 and 3.8 meters. In the renovation, Smaller Bagong maintained the original red plain brick style, whereas Larger Bagong's addition was covered with cement mortar, creating a stylistic divergence in the building's facade and overall appearance.

The additional storey, while providing some relief, could not adequately accommodate the growing number of inhabitants, resulting in excessive wear and tear on the building's infrastructure (Figure 3). This continuous overuse has exacerbated the deterioration of both its interior and exterior. The hallways and staircases, designed for far fewer occupants, now bear the marks of decades of overcapacity, showing signs of structural fatigue and neglect. Furthermore, the repeated subdivision of rooms compromised the building's original architectural integrity, leaving many areas poorly ventilated and inadequately lit, which diminished the quality of living conditions significantly.

Moreover, the lack of regular maintenance has left the building in a dilapidated state. The facade, once a testament to architectural elegance, now displays a patchwork of mismatched materials and styles, reflecting the piecemeal repairs that have failed to preserve its historical character [34]. Inside, the situation is no better, with cracked plaster, peeling paint, and outdated electrical systems that pose safety risks to the residents. The heritage's historic charm and structural stability have been severely compromised, calling for urgent comprehensive restoration efforts to salvage and restore it to its former glory, both as a protected heritage building and as a useful modern space.

Fig. 3. Panoffs' Mansion in the 2010s with dilapidated infrastructure

4.3. Sustainable design renovation project

Promoting low-carbon living is crucial, particularly through the retrofitting and construction of buildings adhering to green and low-carbon standards. The renovation of Panoffs' Mansion employed energy-saving technologies and sustainable materials to enhance energy efficiency and reduce emissions, while preserving its original appearance. The installation of LED lighting and improvements in thermal insulation were key focuses. By enhancing wall, roof, and window insulation, heat loss in winter and cooling needs in summer were minimized, reducing the overall energy demand for climate control. These enhancements not only saved significant energy but also improved the indoor comfort for both residents and businesses.

The preservation and restoration of this historic building began in 2018. Experts from the China International Trust and Investment Corporation (CITIC) Design & Research Institute conducted comprehensive on-site surveys, data collection, and consultations to accurately restore the building's original form and materials. Structural reinforcements were made to adapt the building to new uses while preserving its architectural integrity. "Determining the original architectural form and dealing with the many later modifications added a layer of complexity to the restoration," experts noted. The

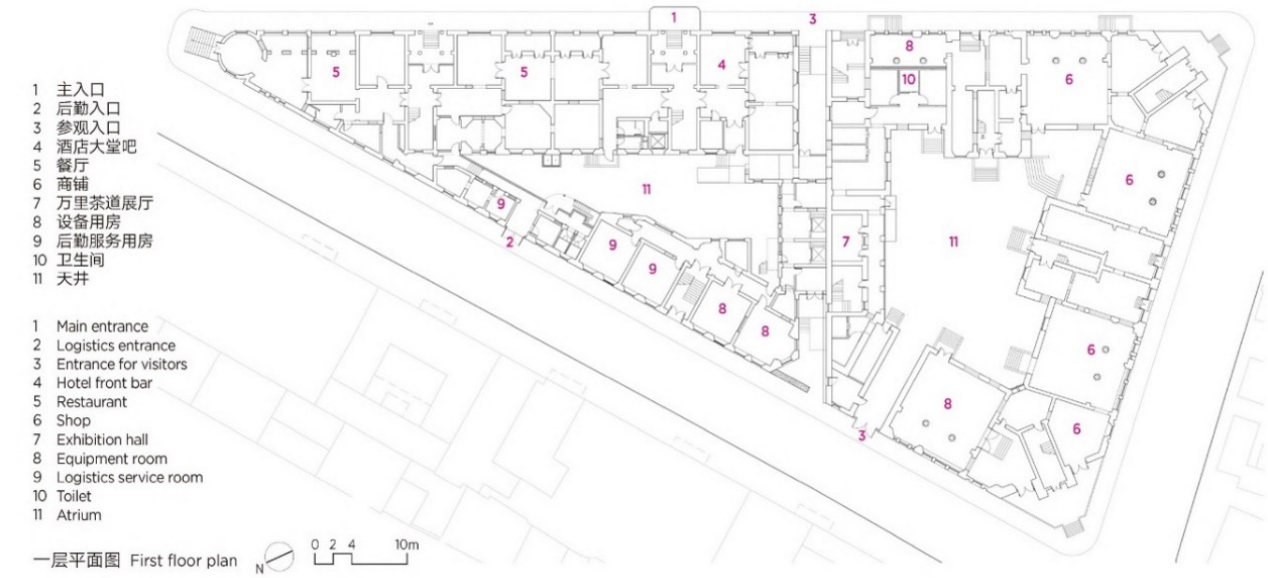

Fig. 4. First floor plan of Panoffs' Mansion after the rehabilitation project

building now serves as a commercial and cultural hub, featuring exhibition spaces that highlight its history, as well as culturally themed restaurants and a hotel. The redesign also transformed two patios into open spaces to facilitate better air circulation and public interaction, as shown in Figure 4.

The project embraced green and sustainable design principles, using integrated solutions for ventilation, sun shading, and thermal insulation, supported by Building Information Modeling (BIM) technology for precise supervision of design and construction. The "3R" principle—recycle, reuse, and renew—guided the selection of materials, favoring those that matched the original in utility while promoting resource sustainability (Figure 5). "Extensive pre-construction trials and discussions ensured the appropriateness of materials and methods." the team explained. This approach not only reduced the project's carbon footprint by limiting energy-intensive production but also extended the lifecycle of materials, supporting a circular economy.

4.4. Interior renovation complying with energy-saving standards

In terms of energy efficiency, particular attention was given to the thermal insulation performance of the building's envelope, crucial in regions with hot summers and cold winters. The project utilized innovative internal insulation techniques and 3R materials to enhance the thermal performance of facades and other key elements without compromising the building's historical façade. The use of double-pane LOW-E insulated windows and strategically placed louvers reduced unnecessary solar heat gain, maintaining the building's aesthetic while enhancing its energy efficiency. Environmental simulations of these materials helped achieve thermal coefficients well within the local energy-saving standards for Wuhan, significantly lowering the building's heating and cooling requirements.

According to simulation calculations Table 1, the thermal coefficients (K-values) for the exterior walls and the roof of the remodeled building envelope were simulated at 0.51 W/(m²·K) and 0.35 W/(m²·K), respectively. When compared with the Wuhan building energy-saving design standards, these values fall within the acceptable ranges. By

Table 1. Simulated thermal coefficient calculation

Building structure	Simulated building Coefficient W/ (m²·K)	Wuhan Municipal Energy Conservation Design Standard Coefficient W/ (m²·K)
Roof	0.35	0.40
Exterior walls	0.51	0.70
Windows	1.80	2.00

Fig. 5. Details of the renovated building facade

incorporating these environmentally friendly materials and technologies, we can significantly reduce the energy required for heating and cooling, thereby decreasing carbon emissions. This approach not only aligns with sustainable building practices but also contributes to broader environmental protection goals.

Additional sustainable features include rainwater harvesting, high-performance air conditioning systems with heat recovery, and rooftop solar panels, which collectively decrease the building's dependence on conventional energy sources and enhance its overall sustainability. Intelligent lighting systems further reduce the building's energy consumption.

Today, Panoffs' Mansion is not only a preserved cultural landmark in Wuhan but also a popular tourist destination, as shown in Figure 6. These renovations have successfully extended the life of this historic building, aligning it with modern environmental and energy standards while maintaining its historic charm. The project's recognition with the Berlin Better Future Award underscores its significance and the growing public and official interest in sustainable restoration practices.

Fig. 6. Historical buildings are now popular tourist destinations

5. Conclusion and Limitations

This research underscores the dynamic interplay between historical preservation and modern sustainability through the renovation of Panoffs' Mansion in Wuhan. The project exemplifies how integrating sustainable design within urban renewal initiatives can effectively enhance energy efficiency and foster environmental stewardship while safe-

guarding cultural heritage. By implementing cutting-edge green technologies and adaptive reuse strategies, the initiative not only preserved the heritage's historical integrity but also transformed it into a beacon of low-carbon living.

The broader impact of this project extends beyond architectural conservation, stimulating local economic growth. The transformation of Panoffs' Mansion into a vibrant, multifunctional space has contributed to the revitalization of the surrounding area, promoting it as a cultural and tourist hub. This has, in turn, bolstered public interest and investment in sustainable urban development, highlighting the potential for heritage sites to lead urban innovation.

Moreover, the project serves as a valuable case study for similar initiatives worldwide, providing insights into the challenges and opportunities of marrying historical preservation with sustainability goals. The successful implementation in Wuhan demonstrates the practicality of such endeavors, encouraging other cities to consider sustainable practices in their urban renewal efforts.

However, the study's findings are tempered by certain limitations. The unique architectural and historical context of Panoffs' Mansion means that the specific strategies employed may not be directly applicable in different settings, where varying cultural, environmental, and regulatory conditions may affect the feasibility of similar interventions. Additionally, the research was primarily qualitative, focusing on observational and case study data which, while rich in detail, might lack the empirical rigor provided by quantitative methods.

Future studies could enhance the robustness of findings through mixed-methods approaches, incorporating statistical analyses to quantify the environmental and economic impacts of renovation projects. This would provide a more comprehensive evidence base to support the scalability of sustainable urban renewal strategies across diverse global contexts.

References

1. P. Roberts, "The evolution, definition and purpose of urban regeneration," *Urban regeneration: A handbook*, vol. 1, pp. 9–36, 2000.
2. H. W. Zheng, G. Q. Shen, and H. Wang, "A review of recent studies on sustainable urban renewal," *Habitat international*, vol. 41, pp. 272–279, 2014.
3. M. Hajian and S. J. Kashani, "Evolution of the concept of sustainability. From Brundtland Report to sustainable development goals," in *Sustainable resource management*, Elsevier, 2021, pp. 1–24.
4. G. W. Hunter, G. Sagoe, D. Vettorato, and D. Jiayu, "Sustainability of low carbon city initiatives in China: A comprehensive literature review," *Sustainability*, vol. 11, no. 16, p. 4342, 2019.
5. A. Aliyu and L. Amadu, "Urbanization, cities, and health: the challenges to Nigeria–a review," *Annals of African medicine*, vol. 16, no. 4, pp. 149–158, 2017.
6. X. He *et al.*, "Implementation plan for low-carbon resilient city towards Sustainable Development Goals: challenges and perspectives," *Aerosol and Air Quality Research*, vol. 20, no. 3, pp. 444–464, 2020.
7. P. Wu and M. Tan, "Challenges for sustainable urbanization: a case study of water shortage and water environment changes in Shandong, China," *Procedia Environmental Sciences*, vol. 13, pp. 919–927, 2012.
8. M. Marinelli, "How to build a 'Beautiful China'in the Anthropocene. The political discourse and the intellectual debate on ecological civilization," *Journal of Chinese Political Science*, vol. 23, no. 3, pp. 365–386, 2018.
9. W. Pan and J. Du, "Towards sustainable urban transition: A critical review of strategies and policies of urban village renewal in Shenzhen, China," *Land Use Policy*, vol. 111, p. 105744, 2021.
10. N. Ezeadichie and C. John-Nsa, "Sustainable urban renewal: planning or people oriented?," *Journal of Environmental Management and Safety*, vol. 12, no. 1, pp. 17–17, 2021.
11. K. Bradley, "Just environments: politicising sustainable urban development," PhD Thesis, KTH, 2009.
12. W. Drożdż, G. Kinelski, M. Czarnecka, M. Wójcik-Jurkiewicz, A. Maroušková, and G. Zych, "Determinants of decarbonization—how to realize sustainable and low carbon cities?," *Energies*, vol. 14, no. 9, p. 2640, 2021.
13. H. Han, "Governance for green urbanisation: Lessons from Singapore's green building certification scheme," *Environment and Planning C: Politics and Space*, vol. 37, no. 1, pp. 137–156, 2019.
14. T. Beatley, Green Cities of Europe-Global Lessons on Green Urbanism. Island press, 2012.
15. M. Priyanta and C. S. A. Zulkarnain, "Urban green open space in developing countries: Indonesia regulations, problems and alternative solutions," *Journal of Property, Planning and Environmental Law*, vol. 16, no. 2, pp. 134–151, 2024.
16. L. Chen *et al.*, "Green construction for low-carbon cities: a review," *Environmental chemistry letters*, vol. 21, no. 3, pp. 1627–1657, 2023.
17. M. Radulescu, J. Cifuentes-Faura, K. Si Mohammed, and H. Alofaysan, "Energy efficiency and environmental regulations for mitigating carbon emissions in Chinese Provinces," *Energy Efficiency*, vol. 17, no. 6, p. 67, 2024.
18. H. Yi and Y. Liu, "Green economy in China: Regional variations and policy drivers," *Global Environmental Change*, vol. 31, pp. 11–19, 2015.
19. Z. Qian, "World Heritage Site inscription and waterfront heritage conservation: evidence from the Grand Canal historic districts in Hangzhou, China," *Journal*

of Heritage Tourism, vol. 16, no. 6, pp. 684–704, 2021, doi: 10.1080/1743873X.2020.1828894.

20. M. Ripp and D. Rodwell, "The geography of urban heritage," *The Historic Environment: Policy & Practice*, vol. 6, no. 3, pp. 240–276, 2015.
21. D. Rodwell, Conservation and sustainability in historic cities. John Wiley & Sons, 2008.
22. T. Freytag and M. Bauder, "Bottom-up touristification and urban transformations in Paris," *Tourism Geographies*, vol. 20, no. 3, pp. 443–460, 2018.
23. C. Kibert, Sustainable construction: green building design and delivery. John Wiley & Sons, 2016.
24. S. Sadineni, S. Madala, and R. Boehm, "Passive building energy savings: A review of building envelope components," *Renewable and sustainable energy reviews*, vol. 15, no. 8, pp. 3617–3631, 2011.
25. P. Ombati, "Evaluating Awareness Levels and Barriers to Green Building Implementation," PhD Thesis, University of Nairobi, 2023.
26. J. Whitehand and K. Gu, "Urban conservation in China: Historical development, current practice and morphological approach," *Town Planning Review*, vol. 78, no. 5, pp. 643–670, 2007.
27. X. Ma and B. Wu, "Cooperation of Protection, Renovation of Historic Streets and Sustainable Development of Tourism: A Case Study of Dazhalan Area in Beijing," *Urban Plan*, vol. 9, pp. 49–54, 2005.
28. M. Orlenko *et al.*, "The specificity of the restoration and monument protective measures for the preservation of historical Chinese Gardens," *International journal of conservation science*, vol. 12, no. 3, pp. 1003–1026, 2021.
29. S. E. Bibri and J. Krogstie, "Smart sustainable cities of the future: An extensive interdisciplinary literature review," *Sustainable cities and society*, vol. 31, pp. 183–212, 2017.
30. S. Han and X. Wu, "Wuhan," *Cities*, vol. 21, no. 4, pp. 349–362, 2004, doi: 10.1016/j.cities.2004.03.007.
31. S. Cheng, Y. Yu, and K. Li, "Historic conservation in rapid urbanization: a case study of the Hankow historic concession area," *Journal of Urban Design*, vol. 22, no. 4, pp. 433–454, Jul. 2017, doi: 10.1080/13574809.2017.1289064.
32. X. Li, "Cultural heritage and modernization: the evolution of Lifen neighborhoods in Wuhan," *Urban, Planning and Transport Research*, vol. 12, no. 1, 2024, doi: 10.1080/21650020.2024.2409683.
33. X. Liu, J. Yang, and Q. Tong, "The forerunner of modern collective residence in Hankou: the study on Panoffs' Mansion," *Journal of Asian Architecture and Building Engineering*, vol. 22, no. 5, pp. 2460–2489, 2023.
34. Z. Zhang, Y. Zou, and W. Xiao, "Exploration of a virtual restoration practice route for architectural heritage based on evidence-based design: a case study of the Bagong House," *Heritage Science*, vol. 11, no. 1, p. 35, 2023.