

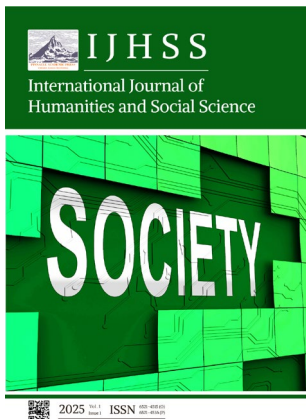
Article **Open Access**

Reuse and Functional Renewal of Historical Buildings in the Context of Cultural Heritage Protection

Jingyuan Huang ^{1,*}

¹ Architecture Studio, Studio Joseph, New York, 10022, United States

* Correspondence: Jingyuan Huang, Architecture Studio, Studio Joseph, New York, 10022, United States



Abstract: With the ongoing urbanization, the reuse and functional renewal of historical buildings have become crucial topics in the protection of cultural heritage. This paper explores the fundamental concepts and significance of historical building reuse, emphasizing the preservation of historical memory and cultural identity, the promotion of sustainable urban development, and the efficient utilization of architectural resources. Building upon this foundation, the study integrates relevant scientific and technological approaches for historical building reuse, including structural reinforcement, energy efficiency and environmental sustainability, intelligent digital technologies, and material conservation techniques. Furthermore, a design methodology for the adaptive reuse of historical buildings is proposed, focusing on functional positioning, adaptive design, spatial optimization, and environmental integration. The goal is to achieve a harmonious balance between historical value and contemporary functional demands.

Keywords: historical buildings; reuse; functional renewal

Received: 01 June 2025

Revised: 11 June 2025

Accepted: 16 July 2025

Published: 21 July 2025



Copyright: © 2025 by the authors. Submitted for possible open access publication under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

Historical buildings are important representatives of cultural heritage, conveying a wealth of historical information and unique aesthetic value. However, due to the rapid expansion of cities, historical buildings are increasingly challenged by the need to balance modernization demands with effective conservation strategies. In the context of cultural heritage protection, the reuse and functional renewal of historical buildings can not only preserve and inherit the historical and cultural heritage, but also promote the long-term development of the city and the rational utilization of resources. Therefore, it is particularly important to integrate modern functions and technologies into historical buildings without compromising their original design and cultural significance. The proper use of this method has become an important way to protect and renew historical buildings.

2. The Core Value of Reuse and Functional Renewal of Historical Buildings

2.1. Cultural Inheritance and Continuation of Historical Memory

Historical buildings carry rich cultural contexts and serve as tangible reminders of past societies. They are not only material witnesses to history but also active transmitters of cultural heritage. Through the reuse and functional renewal of historical buildings, this heritage can be preserved and passed down. These buildings embody historical narratives and cultural symbols, facilitating a connection between the past and present. Preserving historical buildings is not just about maintaining their architectural forms, but also about infusing them with new vitality and functions to ensure their cultural and historical legacy

remains intact. As a result, historical buildings transform from static "cultural relics" into dynamic cultural spaces with modern functions, becoming valuable cultural assets in contemporary society [1].

2.2. Urban Sustainable Development and Resource Conservation

Adaptive reuse of historical buildings helps conserve resources that would otherwise be consumed in constructing new buildings and reduces the waste generated by demolition. This practice aligns with green and economic principles in urban development. By restoring and reusing historical buildings, their lifespan is extended, mitigating the significant energy loss and waste typically associated with demolition and reconstruction. Additionally, architectural features and materials that reflect local characteristics can be harmonized with the surrounding environment, reducing the need for external resources and promoting cultural integration within the community.

3. Reuse and Functional Renewal Technology of Historical Buildings under the Background of Cultural Heritage Protection

3.1. Structural Safety and Reinforcement Technology

After decades or even hundreds of years, factors such as the aging of structural materials, natural disasters, and human-induced damage can significantly degrade the structural integrity of buildings, compromising their load-bearing capacity and stability. Consequently, safeguarding these historically significant buildings and reinforcing their structures to meet modern functional requirements has become a critical scientific and technological challenge. Structural reinforcement involves either partially reconstructing or enhancing the load-bearing capacity of historic buildings to ensure their safety, stability, and preservation of their historical appearance while adapting to contemporary use. In the process of reinforcing such buildings, the original structural materials are often preserved and utilized, ensuring that the historical style and cultural value are maintained to the greatest extent possible (see Table 1).

Table 1. Comparison of structural strengthening techniques of historical buildings.

Reinforcement technique	Peculiarity	Application field	Advantage	Inferior position
Reinforced concrete	Adds layers of steel and concrete to increase load carrying capacity	Suitable for load-bearing structures, such as walls and floors	Improves compressive and bending resistance, enhance the shock resistance	significant impact on the original structure, complicated construction
Carbon fiber reinforcement	High-strength carbon fiber material bonding reinforcement	Suitable for non-load-bearing structures (columns and beams)	Light weight, corrosion-resistant, does not alter appearance	High cost, limited application range
Steel structure reinforcement	Increased structural stability with steel	Suitable for seismic reinforcement of old buildings	High strength, fast construction speed	Potential to damage the building's original appearance

Reinforced concrete and carbon fiber techniques are among the most commonly used methods for strengthening historic buildings. These methods primarily involve adding steel and cement to the original structure to enhance the compressive strength and tensile capacity of walls and floors, as well as improving the building's earthquake resistance and overall load-bearing capacity. Additionally, carbon fiber reinforcement offers advantages such as high toughness, lightweight properties, and excellent corrosion resistance, making

it particularly suitable for the reinforcement of older buildings. In this process, the carbon fiber material is applied to the original structure using adhesives, which effectively increases the tensile strength of the building without altering its external appearance, thus preserving the aesthetic integrity while ensuring structural stability [2].

3.2. Energy Saving and Environmental Protection Technology

Historical buildings generally have low energy efficiency, particularly in areas such as walls, doors, windows, and roofs, where thermal exchange is prevalent. To address this, the installation of external wall insulation can significantly reduce the heat dissipation from the building, help maintain a stable indoor temperature, and decrease the reliance on cooling and heating systems. Additionally, enhancing the roof insulation layer can block thermal radiation, especially during summer months, thus reducing the energy consumption of air conditioning systems. Enhancing window performance is also essential for improving energy efficiency. The use of double or triple-glazed insulating glass, combined with appropriate window frame materials, can further minimize heat loss or gain, improving thermal insulation. Moreover, the installation of effective window seals prevents the leakage of hot or cold air, enhancing the building's overall energy efficiency. These energy-saving and environmental protection methods can substantially improve the functionality of historical buildings during reuse, all while preserving their original architectural appearance and design. This approach aligns with contemporary green development principles, ensuring both the conservation of energy and the continued preservation of the building's cultural heritage [3].

3.3. Intelligent and Digital Technology

Intelligent building management systems leverage sensing devices and data analytics to provide unified monitoring and control of various environmental factors such as temperature, humidity, air quality, lighting, and electricity consumption. This helps conserve resources while also enhancing occupant comfort. For instance, the system can adjust lighting and ventilation automatically, reducing the need for manual intervention and achieving a balance between energy efficiency and comfort (see Table 2).

Table 2. Application of intelligent and digital technology.

Technology type	Application field	Function and advantage	Sustainability and innovation
Intelligent building management system	Building environment control and management	Real-time monitoring of indoor conditions (temperature, humidity, air quality, lighting, etc.); optimizing energy use and enhancing comfort	Automatic adjustments, reduced manual intervention, improved operational efficiency and comfort
3D laser scanning technology	Building status recording and accurate modeling	High-precision recording of building structure, generating 3D models for restoration and renovation	Precise data for targeted restoration and protection execution
Building information modeling (BIM)	Full life cycle Design, Construction, and Management	Real-time updates to building data during design, construction, and operation to optimize decision-making	Enhances building lifecycle management efficiency and reduces resource waste

Digital technology serves as a critical enabler in the design, transformation, and ongoing maintenance of historical buildings. For example, 3D laser scanning technology captures the precise current state of a building and generates highly detailed 3D models.

These models offer precise data for conducting structural analysis, formulating restoration strategies, and managing the construction process. Furthermore, digital information management ensures that building data is continuously updated throughout its life cycle, facilitating effective maintenance and minimizing resource waste during its use and preservation.

3.4. Material Protection and Maintenance Technology

The primary goal of material conservation technology is to prevent further deterioration of raw materials, extend the lifespan of buildings, and preserve their historical and cultural significance. This often involves the maintenance and restoration of traditional materials such as wood, stone, and brick. For example, anti-corrosion treatments and ventilated coatings for wood can extend its service life by 30% to 50%. Non-destructive crack repair and external cleaning of stone and tile have also proven to reduce stone weathering by up to 60% when appropriate repair materials are used.

The compatibility of materials employed in the restoration process is essential to avoid damage caused by incompatible materials. Research has shown that utilizing highly compatible repair materials can prolong the structural service life of historical buildings by approximately 25%. Regarding the protection of coatings on ancient buildings, nano-coatings and breathable coatings have been shown to reduce the impact of environmental factors, delaying the aging process of coatings by over 30%. These coatings also ensure the breathability of the building's surface, preventing excessive moisture buildup and contributing to the building's overall preservation [4].

4. Design Methods of Reuse and Functional Renewal of Historical Buildings in the Context of Cultural Heritage Protection

4.1. Function Positioning and Adaptive Design

The first step in functional positioning is to analyze the original purpose of the building and examine how similar functions are applied in modern contexts, in order to determine the most suitable new use for the building in its contemporary environment. Adaptive design involves selecting modern functions that align with the building's structural characteristics, layout, and historical value, thereby minimizing potential damage to the original structure. For example, the office space can be divided into open office areas, maintaining the original structural framework of the historic building, and while avoiding significant alterations to walls or the addition of unnecessary decorative elements. For some important historical and cultural heritage, such as walls, windows, and window frames, it is necessary to focus on them, use modern scientific and technological means, and choose transparent, lightweight, or removable materials in order to adapt to new functional requirements and avoid irreversible damage to the original structure as far as possible (see Figure 1).

The Grand Central Terminal in New York is one of the most iconic and historically significant buildings in the United States, renowned for its grand architecture and pivotal role in the city's transportation system. Initially facing the threat of demolition in the 1990s, the terminal was preserved through the efforts of historic preservationists, and its restoration became a celebrated example of adaptive reuse. While preserving the building's exterior and key architectural features, such as the celestial dome in the main concourse and the elegant marble floors, the terminal was also updated to meet the demands of modern use. In addition to maintaining its original function as a transportation hub, the building now houses retail spaces, restaurants, and offices, seamlessly integrating modern commercial activities with the historical elements of the terminal. This blend of preservation and modernization has allowed Grand Central to remain a vital part of New York's urban fabric, offering a space that connects both the past and the present while meeting contem-

porary needs for commerce and transportation. Today, it stands as a symbol of how adaptive reuse can protect architectural heritage while simultaneously revitalizing and transforming an iconic structure into a dynamic space for the future.

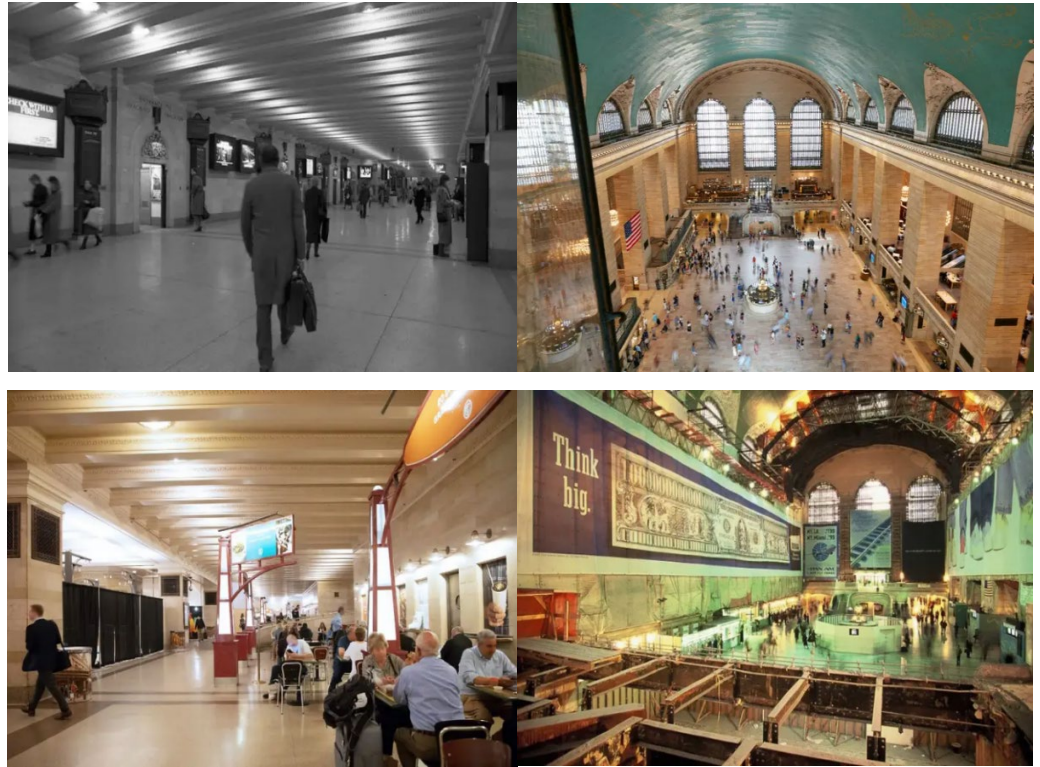


Figure 1. Grand Central Terminal- A Comparison of Its Restoration from 1990s to 2018.

At the same time, adaptive design must also prioritize the sustainability of the building's use. When selecting new functions, it is essential to integrate green building principles, such as incorporating renewable energy sources like solar and geothermal energy. This not only enhances the building's energy efficiency but also ensures it meets modern standards for comfort and sustainability.

4.2. Spatial Layout and Streamline Optimization

Through thoughtful planning of functional zoning and pedestrian flow, the efficiency of the building can be improved while preserving its original architectural style and historical significance. When designing the spatial layout, it is essential to respect the building's historical structure, ensuring that its characteristic spatial forms and architectural elements are preserved to the greatest extent possible. At the same time, modern design concepts should be introduced to accommodate new uses without compromising the building's historical features (see Figure 2).



Figure 2. Spatial layout design structure.

In terms of spatial determination, adjustments should be made based on the building's actual conditions, prioritizing the protection and retention of its original spatial characteristics. Public areas, such as halls, courtyards, and auditoriums, can be adapted to create a fresh and functional experience. Appropriate zoning techniques, like the use of flexible office divisions with removable partitions or lightweight walls, can effectively designate areas for modern offices, cultural activities, or commercial uses. This approach minimizes the impact on the original structure.

Circulation design is another critical factor influencing the building's functionality and user experience. The layout of historical buildings often presents limitations for optimizing pedestrian flow, so it is important to guide traffic efficiently while preserving the building's original style. For instance, maintaining the main entrance and key passageways while adding auxiliary corridors, vertical transportation systems (such as elevators and stairs), and other modifications can optimize movement within the building and improve the flow of people [5].

4.3. Material Selection and Craftsmanship Preservation

Appropriate material selection can enhance the building's usability and durability while preserving its original architectural style. This also facilitates a harmonious integration of historical structures with modern design elements. In the selection of materials, it is possible to maintain the continuity with the previous buildings, especially those with historical and cultural connotations. For cultural relics constructed from wood, the same type of wood is preferred to ensure the maintenance of the entire building, and for the replacement of materials such as stone or brick, materials with similar texture and appearance should be chosen to ensure visual consistency with the original structure. If new materials are to be used, they should also be new materials that can make up for the defects of raw materials, such as glass and steel, which not only enhance the building's modern functionality but also preserve visual harmony. Regarding the inheritance of craftsmanship, in the process of maintaining historical buildings, the craft technology of the original building should be preserved and inherited as much as possible, especially the old building technology, such as woodworking, stone carving, brick carving and other traditional

crafts. For example, in the restoration process of wooden structures, traditional carpentry techniques should be prioritized, with mortise-and-tenon joints replacing modern metal connectors to avoid destroying the exquisite details of the original process.

The Tate Modern, located in London, is an exemplary case of material selection and craftsmanship preservation in the adaptive reuse. Originally constructed as the Bankside Power Station, the building has been transformed into one of the world's leading modern art museums while maintaining its original industrial character. (See Figure 3).



Figure 3. The Power Station: Tate Modern Before Renovation.

The preservation of the steel framework and brick facade ensures that the building's historic character and appearance are preserved. In the interior, modern materials like glass and steel have been introduced to create an expansive, open gallery space that meets the functional demands of a contemporary museum, without disrupting the building's visual continuity. The selection of materials, such as the use of original brick for restoration and the careful integration of modern elements, respects the heritage of the structure, ensuring both its aesthetic integrity and durability. Additionally, craftsmanship preservation is key to the project's success (See Figure 4).



Figure 4. Tate Modern after Restoration and Expansion.

The use of traditional construction techniques, including those for the restoration of masonry and other architectural details, ensures that the building's architectural craftsmanship is preserved and respected. The Tate Modern's transformation highlights how thoughtful material selection and the preservation of craftsmanship can seamlessly blend modern functionality with the historical value of a structure, ensuring that both the building's cultural significance and its functional adaptability are preserved.

4.4. Environmental Integration and Landscape Design

The first step in environmental integration is to consider the relationship between the historical building and its surroundings. During landscape design, it's essential to analyze the location of the building, the surrounding natural landscape, urban patterns, and the architectural style of nearby structures. The landscape design should avoid overly modern elements that could disrupt the original appearance of the historical building, minimizing

contemporary design interventions to ensure the building blends harmoniously with its environment. For example, can soften architectural boundaries and create a buffer zone between the historic building and its urban surroundings. When selecting flooring materials, options like slate or brick can help maintain visual consistency between the building and its natural surroundings.

In landscape design, attention should be given to creating spatial layers and making full use of the open spaces around historical buildings. For instance, incorporating fountains, sculptures, and seating can enhance the artistry and interaction of the area while offering a comfortable seating area for visitors. Additionally, appropriate lighting can enhance the cultural atmosphere of the building at night. Using soft light to highlight architectural features such as windows, roofs, and porches helps to emphasize the building's architectural details and historic character. The ultimate goal of environmental integration and landscape design is to protect the cultural heritage of the historical building while organically integrating it with the modern urban environment and the daily needs of people, thereby enhancing the building's social function and cultural value.

Millennium Park exemplifies the successful fusion of historic building preservation and modern landscape design. Integrating modern design elements such as sculptures, art installations, and green spaces, the park enhances the visual appeal of the space while complementing nearby historic buildings, like the Clark Street Station in Chicago. These elements transform the park into a dynamic urban space, enriching the visitor experience and preserving the historical value of surrounding structures. The park's layout thoughtfully integrates historic buildings into the public space without compromising their integrity, ensuring that modern design enhances rather than disrupts the architecture. The landscape design of Millennium Park effectively uses open areas and greenery to highlight the importance of historic buildings in urban life, with features like water elements, sculptures, and seating bringing vitality to the site. The careful arrangement of spaces emphasizes the buildings' cultural significance while maintaining their relevance in the modern urban context. Millennium Park demonstrates how to balance the preservation of cultural heritage with the needs of a modern city, offering spaces for cultural engagement, recreation, and artistic expression, while maintaining the architectural integrity of heritage structures. This harmonious blend of modern landscape design and historic preservation creates a vibrant environment where cultural heritage and contemporary urban life coexist seamlessly (Figure 5 and Figure 6).



Figure 5. Millennium Park: A Modern Landscape Framed by Chicago's Architectural Legacy.



Figure 6. Reflections of the City: Cloud Gate in Millennium Park.

5. Conclusion

The reuse and functional renewal of historical buildings is a critical component of cultural heritage preservation, as it ensures the continuation of history and culture while promoting sustainable urban development. Through the intelligent use of structural reinforcement, energy conservation, environmental protection, and modern technologies, they can be scientifically redesigned and adapted to meet contemporary functional needs while retaining their cultural significance. This process not only increases the utility of the building but also contributes to optimizing the urban environment and rationally utilizing resources, achieving a balance between the preservation of historical buildings and urban develop.

References

1. F. Gençer, "Assessment Method of Modern Buildings Constructed in a Historical Area; as a Case Study İMC Blocks," *ICONARP Int. J. Archit. Plan.*, vol. 11, no. 2, pp. 807–837, 2023, doi: 10.15320/ICONARP.2023.265.
2. C. S. Tan and K. Fujita, "Building construction of pre-war shophouses in George Town observed through a renovation case study," *J. Asian Archit. Build. Eng.*, vol. 13, no. 1, pp. 195–202, 2014, doi: 10.3130/jaabe.13.195.
3. L. Jiang, E. Lucchi, and D. Del Curto, "Adaptive reuse and energy transition of built heritage and historic gardens: The sustainable conservation of Casa Jelinek in Trieste (Italy)," *Sustain. Cities Soc.*, vol. 97, p. 104767, 2023, doi: 10.1016/j.scs.2023.104767.
4. E. Fregonara, "Building upcycling or building reconstruction? The 'Global Benefit' perspective to support investment decisions for sustainable cities," *Front. Sustain. Cities*, vol. 5, p. 1282748, 2023, doi: 10.3389/frsc.2023.1282748.
5. W. Che, et al., "Renewal and upgrading of a courtyard building in the historic and cultural district of Beijing: Design concept of 'multiple coexistence' and a case study," *Indoor Built Environ.*, vol. 31, no. 2, pp. 522–536, 2022, doi: 10.1177/1420326X211010359.

Disclaimer/Publisher's Note: The views, opinions, and data expressed in all publications are solely those of the individual author(s) and contributor(s) and do not necessarily reflect the views of PAP and/or the editor(s). PAP and/or the editor(s) disclaim any responsibility for any injury to individuals or damage to property arising from the ideas, methods, instructions, or products mentioned in the content.