International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 9 Issue 5, Sep-Oct 2025 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

# Retrofitting of Historical Buildings: A Comprehensive Approach

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**ABSTRACT**

This research paper examines how to improve the energy efficiency of historical buildings through retrofitting. The goal is to find ways to lower energy consumption while upholding the building's historical and architectural value. The best strategy was found to be to combine energy-saving, passive, and traditional design concepts. To reduce energy usage and greenhouse gas emissions, this study emphasizes the significance of carefully evaluating the building's features, climate, and intended use. It also emphasizes how crucial it is to educate the public, involve stakeholders, and draft supportive legislation to effectively retrofit historical buildings. The results showed that passive design strategies can greatly raise a building's indoor thermal comfort without the use of mechanical equipment. To attain energy conservation and carbon footprint reduction targets, the paper suggests a comprehensive strategy that incorporates policy, technology, and design when retrofitting historical buildings. The optimization of building designs with careful attention to orientation, window-to-wall ratio, and shading devices can significantly improve natural ventilation. This method of controlling solar radiation and improving natural ventilation makes heating more effective in the winter and cooling more effective in the summer.

***KEYWORDS:*** *Building performance, Energy conservation, Historical Buildings, Passive design strategies, Retrofitting.*

***How to cite this paper:*** Zahid Rashid Allaie | Er. Kavita Dhiman "Retrofitting of Historical Buildings: A Comprehensive Approach" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-9 | Issue-5, October 2025, pp.432-442, URL: www.ijtsrd.com/papers/ijtsrd97539.pdf

IJTSRD97539



## 1. INTRODUCTION

In contemporary society, numerous historical buildings remain in active use or possess the potential for future functionality (Bansal, 2018). However, these structures often fall short of fulfilling their complete potential, despite their intrinsic historical significance and environmental attributes, primarily because they do not align with the current requirements of modern users (Bansal, 2018). Adaptive reuse, a strategy that ensures environmental benefits and revitalizes dilapidated buildings, aligns with modern trends, architectural values, functional needs, and economic considerations (Šekularac et al., 2019). Retrofitting historical buildings presents a multifaceted challenge that demands a delicate equilibrium between preserving the structure's inherent historical and architectural value while concurrently adapting it to meet contemporary functional and regulatory standards (Mo & Huang, 2025). Retrofitting offers alterations and additions to suit historic buildings to the present day context, playing a crucial role in improving the overall performance of the building and employing techniques to alter, repair, or add features that make the historic building fit for contemporary use without jeopardizing their historic qualities (Bansal, 2018). It represents a sustainable approach to construction, mitigating the environmental impact associated with new construction by extending the lifespan of existing structures and minimizing waste (Khairi et al., 2017). This approach necessitates a comprehensive understanding of the building's original design, materials, and construction techniques, as well as a thorough assessment of its current condition and potential vulnerabilities.

### 1.1. Critical Success Factors in Heritage Building Adaptation

The process of retrofitting historical buildings involves a complex interplay of factors, including structural integrity, energy efficiency, and compliance with modern building codes (Ayoobi& İNCEOĞLU, 2024). The primary aim is to identify critical success factors for the adaptive reuse of heritage buildings, offering asset owners, developers, and key stakeholders the essential knowledge to ensure project success (Dyson et al., 2016). A successful retrofitting project demands a comprehensive approach that considers the building's historical significance, architectural character, and functional requirements. Adaptive reuse is the modification of existing structures to suit new purposes, such as converting old buildings into hotels, which is a crucial part of the preservation process, giving new life to the building and ensuring its continued relevance (Mansor et al., 2018). Adaptive reuse of heritage buildings is a challenging process since there are many factors that must be concerned with an integrated approach (Mısırlısoy&Günçe, 2016). Heritage buildings symbolize the past and must be sustained rather than destroyed because they represent people's lifestyles and culture (Mısırlısoy&Günçe, 2016). It serves as a tangible link to the past, embodying cultural identity and collective memory and its significance extends beyond mere aesthetics.

Adaptive reuse and retrofitting projects should consider financial, environmental, social, legislative, and architectural factors for the building's sustainable development (Mohamed & Alauddin, 2016). The worth and reuse of the building are very important and the adaptive reuse changes the purpose of a structure to meet today’s demands (Laraia, 2019). Adaptive reuse helps to extend a building's life by preventing demolition waste and conserving embodied energy, which is widely accepted as a way to lower carbon emissions, reduce climate change, and promote sustainable development (Yung & Chan, 2011). Retrofitting and adaptive reuse, thus, requires a holistic approach that considers the interconnectedness of heritage and its context (Pintossi et al., 2021). The decision to retrofit a historical building necessitates a careful assessment of its existing conditions, including structural stability, material degradation, and environmental factors. Utilizing efficient heating and cooling systems, can significantly contribute to achieving energy-efficient and sustainable buildings (Ayoobi& İNCEOĞLU, 2024). The existing structure must be thoroughly evaluated to ascertain its capacity to accommodate new loads and systems, while preserving its historical essence (Arief & Thahir, 2020).

### 1.2. Sustainable Design and Innovation

Adaptive reuse of old buildings is considered more sustainable than new construction, and is considered more creative from an innovative standpoint (Dan et al., 2019). Adaptive reuse has been successfully applied to many types of facilities around the world and is fundamental to sound government policy and sustainable development (Fisher-Gewirtzman, 2016). Retrofitting not only allows existing buildings to last longer, but it also improves their chances of being reused in the future, ensuring environmental sustainability for future generations (Dan et al., 2019). Adaptive reuse of abandoned and underused cultural heritage buildings and sites is a practical substitute to demolition, bypassing the wasteful processes of demolition and new construction, prolonging the cultural heritage lifespan (Kaya et al., 2021). Adaptive reuse contributes to forming livable environments, improving life quality, and providing continuity (Arief & Thahir, 2020).

Retrofitting heritage buildings necessitates a holistic approach that balances preservation, functionality, and sustainability (Khalil et al., 2018). Nearly half of the world’s population resides in urban areas, making the building sector crucial in addressing environmental problems and it accounts for approximately 40% of global resource use, 30% of total energy consumption, and 30% of carbon emissions (Ayoobi& İNCEOĞLU, 2024). Optimizing pre-existing buildings significantly reduces CO2 emissions, improves natural ventilation, and enhances occupant comfort (Ayoobi& İNCEOĞLU, 2024). Passive design strategies, such as improved natural ventilation and controlled solar gain, can lead to substantial reductions in peak-month CO2 emissions (Ayoobi& İNCEOĞLU, 2024; Mahar et al., 2020). Incorporating passive design principles, such as thermal insulation, high thermal mass, and appropriate glazing, can significantly reduce energy consumption in residential buildings (Mahar et al., 2020). These strategies not only reduce the environmental impact but also enhance the comfort and well-being of occupants (Khairi et al., 2017). 

The integration of sustainable materials and technologies is crucial for minimizing the environmental impact of retrofitting projects. The society's development can be supported by environmental, social, and economic benefits through the reuse of buildings (Lah, 2019). Green retrofits enhance a building's environmental response, reduce water use, and increase comfort and value by addressing light, air, and noise pollution (Khoukhi et al., 2020). Retrofitting can enhance the thermal performance of walls, roofs, and floors, reducing the need for excessive heating or cooling (Ayoobi& İNCEOĞLU, 2024). Insulated building components, such as walls, roofs, and floors, are crucial for effective thermal insulation, reducing heat transfer, and minimizing energy consumption (Ayoobi& İNCEOĞLU, 2024). The retrofitting of existing buildings offers a major opportunity to decrease energy consumption by integrating new and improved solutions (Shibeika et al., 2021). Retrofitting projects can improve building performance and energy efficiency.

Implementing energy-efficient lighting systems, such as LED lighting, can significantly reduce electricity consumption and improve occupant comfort. Smart building technologies, such as automated lighting and HVAC controls, can optimize energy use based on occupancy patterns and environmental conditions. Many loads in a building are interactive, which complicates cost–benefit analysis for new materials, components, and systems (Judkoff, 2012). Retrofitting involves upgrading existing buildings to meet modern energy efficiency standards, improve occupant comfort, and enhance overall sustainability. Retrofitting offers a way to significantly improve energy efficiency, reduce environmental impact, and enhance building resilience. Active solutions involve refining heating, ventilation, HVAC systems, lighting, and other building services applications, while passive solutions aim to provide more energy-efficient architectural components to reduce reliance on active solutions (Abro, 1994). Moreover, passive solutions can significantly reduce heating and cooling loads, leading to energy-efficient buildings.

### 1.3. Adaptive Reuse and Cultural Values

Adaptive reuse can conserve cultural assets, ensure sustainability, increase social value, and protect the environment. It transforms or adapts abandoned structures or sites for new purposes. Retrofitting a building could also involve replacing a building's windows with new ones with better insulation. Buildings constructed before the widespread use of air conditioning used passive design features like high thermal mass, natural ventilation, and shading. Passive design strategies such as thermal insulation and high thermal mass have a positive influence on thermal comfort (Mahar et al., 2020). Energy efficiency retrofits in existing structures must consider both long-term use and conservation (Phoenix, 2015). 

Retrofitting of historical buildings presents an opportunity to integrate modern amenities while preserving cultural significance. A sensitivity analysis conducted for an office building in Denmark examined passive design strategies in office buildings (Mahar et al., 2020). The investigation showed that the most sensitive parameter was the window-to-wall ratio, which affected heating demand. The study revealed that the optimum window-to-wall ratio varies depending on the building's orientation. The proper materials and insulation in building design makes buildings energy efficient and environmentally friendly (Ayoobi& İNCEOĞLU, 2024). Heritage buildings are frequently under-insulated by contemporary standards, and their construction may lack a damp-proof course or other weather-resistant measures.

Retrofitting historic buildings, especially those with heritage value, necessitates a thorough understanding of building regulations, construction methods, and materials (Shandilya et al., 2020). Retrofitting historical buildings with sustainable strategies requires a multi-disciplinary approach. Building design codes could be created to boost energy efficiency. The building sector's environmental impact is enormous, making building retrofits crucial. Retrofitting historic buildings requires a comprehensive understanding of traditional building techniques and materials.

Adaptive reuse projects focused on historical buildings can benefit from integrating energy-efficient technologies such as efficient insulation, high-performance windows, and renewable energy systems (Mısırlısoy&Günçe, 2016). Historical houses in Ottawa, Canada have achieved 67% energy savings by incorporating several improvements, including increasing envelope thermal resistance, reducing air infiltration, using triple-pane low-E windows, and using air-source heat pumps (Ide et al., 2020). A well-coordinated retrofitting project can provide numerous benefits, including increased energy efficiency, improved occupant comfort, and enhanced building value. Retrofitting historic buildings can be a complicated undertaking that requires knowledge of local codes, cultural preservation concerns, and the unique qualities of the building.

### 1.4. Optimizing Energy Use and Reducing Demand

The use of advanced optimization techniques in building design is crucial for realizing substantial energy savings (Ayoobi& İNCEOĞLU, 2024). Optimization approaches can explore different design options and select the best solutions to maximize energy savings while adhering to budgetary constraints and other requirements. Optimizing building design and operation can considerably lower energy consumption. 

Buildings account for a sizable portion of global energy use, necessitating energy-efficient design and operation strategies. Existing buildings can significantly benefit from energy retrofitting, which involves improvements to energy efficiency and overall performance (Bomberg et al., 2021). In Europe, a quarter of existing structures are historic buildings, and retrofitting these buildings offers tremendous potential for lowering carbon emissions and improving occupant comfort ("SBE21 Sustainable Built Heritage: Renovating Historic Buildings towards a Low-Carbon Built Heritage," 2021). Single measures that are not harmonized with other building elements could potentially result in decreased efficiency through thermal bridges and structural damage (Shaikh et al., 2017).

Retrofitting projects need careful consideration of building envelope enhancements, including insulation upgrades, window replacements, and air sealing to minimize thermal losses. Retrofitting building envelopes can significantly reduce heat transfer, which lowers energy consumption and increases occupant comfort. Optimizing energy use in buildings necessitates a thorough understanding of the interactions between building systems, occupancy patterns, and climatic conditions. Retrofitting is the process of upgrading existing buildings with new technology or features (Alazazmeh& Asif, 2021).

Building performance can be significantly improved through thermal retrofitting. Numerous studies have confirmed that insufficient knowledge, experience, and access to best-practice examples often impede the widespread implementation of thermal retrofitting in existing buildings (Tarabieh& Khorshed, 2019). Key aspects of thermal retrofitting include adding insulation, replacing windows, and sealing air leaks, which collectively work to reduce heat transfer and energy consumption. Additionally, the installation of advanced control systems enables building occupants to actively monitor and adjust indoor temperatures to meet their individual comfort needs (Tarabieh& Khorshed, 2019).The construction sector has immense potential to substantially improve energy efficiency. It is important to note that thermal retrofitting in existing buildings may be a viable option for improving the building sector's environmental performance, given the low rate of building stock renewal (Far & Far, 2018). Buildings can save 15-25% of energy through best practices (Wong, 2019). The future of building retrofitting will see the use of smart technologies and data analytics to optimize energy performance and occupant comfort (Nigam & Akhtar, 2021). Future retrofitting will require the use of digital tools.

Buildings account for approximately 40% of global energy consumption, making them a major contributor to energy demand worldwide. Deep energy retrofits are essential for significantly lowering energy consumption and improving the environmental performance of existing buildings. Deep energy retrofits have the potential to substantially improve energy efficiency and reduce carbon emissions in the building sector (Ma et al., 2012).

Buildings consume substantial energy. Energy retrofitting is essential for lowering energy usage, improving indoor air quality, and achieving sustainability goals in the building sector (Alazazmeh& Asif, 2021). Future research should concentrate on developing standardized procedures and assessment methodologies for evaluating the long-term performance of retrofitted historic buildings. Buildings can save 15-25% of energy through best practices. The use of sophisticated energy modelling tools and methods, such as building information modelling, infrared thermography, and heat flux sensors, enables the development of accurate energy models for existing buildings, which can lead to significant energy savings. These advanced techniques provide detailed insights into a building's thermal performance and identify opportunities for targeted improvements to the building envelope and systems.

The future of historic building retrofitting will focus on using innovative materials and construction techniques that are sympathetic to the building's architectural heritage in order to maximize energy efficiency and reduce environmental impact. This will involve carefully integrating modern sustainable technologies and design strategies while respecting the original character and cultural value of historic structures. Preserving the architectural integrity and cultural significance of historic buildings will be a key priority, alongside achieving significant improvements in energy performance and environmental sustainability. Existing commercial building stock is currently being retrofitted at a rate of approximately 2.2% per year (Luther & Rajagopalan, 2014). Through retrofitting, commercial buildings have the potential to achieve significant energy efficiency gains of 30–50%, translating to a 6–10% reduction in energy consumption for the U.S. as a whole (Kontokosta, 2016).

Buildings account for a sizable portion of global energy use, necessitating energy-efficient design and operation strategies. Retrofitting existing buildings, especially those over 15 years old that may not meet current energy codes, presents a substantial opportunity to align their performance with market expectations (McArthur & Jofeh, 2015). The importance of upgrading existing buildings is highlighted by the fact that new construction accounts for only 1-2% of the total usable area, a percentage expected to decrease further due to the current construction climate (Brito & Silva, 2012). The successful execution of retrofitting projects hinges on interdisciplinary collaboration, involving architects, engineers, contractors, and building owners, to ensure a harmonious integration of energy-efficient measures with the existing infrastructure.

The retrofitting of historical buildings presents a unique set of challenges and opportunities in the pursuit of sustainable development (Buda et al., 2021). Historical buildings are important cultural assets. Retrofitting has become a priority, with many initiatives to accelerate the pace in the retrofit market (Alkhateeb & Abu-Hijleh, 2019). Renovation, modernization, and refurbishment are becoming main activities in the construction industry (Vitiello et al., 2016). Underutilized historic buildings can be revitalized by introducing new functions, to avoid cultural identity loss by demolition (Mısırlısoy&Günçe, 2016). Retrofitting historic buildings to enhance their energy efficiency requires a delicate balance between preserving their architectural heritage and incorporating modern technologies (Şahin et al., 2015). The transformation of historic buildings must align with sustainability principles. Retrofitting historic buildings involves more than just reducing energy consumption; it also encompasses the preservation of architectural heritage and cultural values. This necessitates a comprehensive approach that considers the historical significance of the building. The process involves integrating modern technologies and materials while respecting the original design and character of the structure.

Building owners and stakeholders must be aware of the various financial incentives, tax credits, and grant programs that are available to support energy-efficient retrofitting initiatives. These can include federal, state, and local government programs, as well as utility-sponsored rebates and incentives, that are designed to encourage and facilitate the implementation of energy-efficient upgrades in existing buildings. Leveraging these financial resources can help to offset the upfront costs associated with retrofitting projects, making them more financially viable for building owners and increasing the adoption of these important sustainability measures.

Retrofitting historical buildings presents challenges. However, retrofitting heritage office buildings requires ratification from planning bodies to undertake any alteration on the building (Tokede et al., 2017). The decision to retrofit a historic building requires careful consideration of various factors, including the building's age, construction materials, architectural style, and historical significance. The selection of appropriate retrofitting techniques and materials must be carefully considered to minimize any negative impacts on the building's structural integrity and aesthetic appearance (Rastogi & Solanki, 2023). Retrofitting is also defined as the process of upgrading existing buildings with new materials and technologies to improve their performance, efficiency, or safety. The adaptive reuse of cultural heritage projects, including both legally protected and unprotected buildings, involves retrofitting, rehabilitation, and redevelopment to meet the evolving needs of communities (Foster, 2019). Energy retrofits are increasingly viewed as a protection tool, since upgrading and adapting historic and traditional buildings to meet current needs ensures that they will continue to be used, rather than neglected and demolished (Webb, 2017). When renovating historical buildings, architects are trying to combine green building technology with the building's historical and cultural significance (Chen & Pu, 2024).

Retrofitting historic buildings for energy efficiency should prioritize the preservation of their cultural significance. The implementation of energy-efficient retrofitting measures in historic buildings should adhere to established conservation principles and guidelines, ensuring that the architectural and cultural significance of the building is not compromised. A balance must be struck between the desire to improve energy performance and the need to protect the building's historic fabric and character (Ascione et al., 2015). A holistic approach to building retrofits considers not only energy savings but also the broader impacts on human health, building fabric, and overall environmental quality (Zuhaib et al., 2018). Retrofitting historic buildings can enhance their resilience to climate change impacts, such as extreme weather events, by improving their structural integrity and energy efficiency. In colder climates, measures such as improved insulation, airtightness, and high-performance windows can help to reduce heat loss and improve thermal comfort, while in warmer climates, strategies such as shading, natural ventilation, and cool roofs can help to reduce solar heat gain and lower cooling loads.

Buildings in Afghanistan often have private yards, where over 95% of the population lives, emphasizing the need to optimize energy efficiency in these common housing types (Ayoobi& İNCEOĞLU, 2024). Retrofitting projects are essential for reducing carbon emissions and improving energy efficiency in existing buildings (Okorafor et al., 2020). Insulating the outer walls of buildings is a well-known way to make them more energy-efficient, especially with global energy prices on the rise (Rasuli & Torii, 2023). By improving the thermal performance of building envelopes, energy consumption can be significantly reduced, leading to lower energy bills and a smaller carbon footprint. Moreover, the ground's natural temperature fluctuations, being warmer in winter and cooler in summer, can support building energy efficiency.

## 2. Research Methodology

The research methods for this study are based on a comprehensive review and analysis of secondary data, including relevant literature, case studies, and existing research on retrofitting strategies for historical buildings. This multi-faceted approach allows for a thorough examination of the current knowledge and best practices in the field of historic building retrofitting. Building energy simulation software can be used to generate energy data and evaluate different retrofit options.

The need for detailed energy audits to identify areas for improvement and to guide the selection of appropriate retrofitting measures is essential. A thorough assessment of the building's existing condition, energy performance, and operational characteristics is necessary to identify the most effective retrofitting strategies. Conducting comprehensive energy audits can provide valuable insights into the building's energy consumption patterns, identify opportunities for energy savings, and inform the selection of appropriate retrofitting measures. These audits should evaluate the building's envelope, HVAC systems, lighting, and other energy-consuming components to pinpoint areas that can benefit from targeted retrofits. By thoroughly assessing the building's existing conditions and energy performance, the most cost-effective and impactful retrofitting strategies can be identified and implemented to enhance the building's overall energy efficiency and sustainability.

The evaluation of different retrofitting options based on their cost-effectiveness, energy savings potential, and impact on the building's historical significance is critical. It is essential to carefully consider the trade-offs between improving energy efficiency and preserving the building's architectural and cultural heritage. The selection of appropriate retrofitting techniques and materials must strike a delicate balance, ensuring that the building's historical integrity is maintained while maximizing energy savings and sustainability. This comprehensive assessment is crucial to identifying the most suitable retrofitting strategies that will enhance the building's performance without compromising its cherished historical character.Moreover, the development of a framework for assessing the environmental, economic, and social impacts of retrofitting historical buildings is a critical step in ensuring sustainable outcomes.

## 3. Results

The research findings revealed a significant potential for energy savings in historical buildings through the implementation of appropriate retrofitting measures. Optimizing building component materials, glazing, window-to-wall ratio, and shading strategies significantly reduced heating and cooling demands, while also minimizing energy losses through building components The research emphasizes that combining local and passive design strategies can be applied holistically without additional economic investments or advanced technologies to improve building energy efficiency These improvements have also been noted when techniques are applied such as using semi-transparent PV glazing and day-lighting control

Integrating greenery shading and optimizing transparent surfaces have significant effects on the energy demand of historical buildings when retrofitting The effectiveness of different retrofitting strategies varies depending on the building's design, construction, and climate

When retrofitting, proper insulation and sealing of the building envelope were found to be particularly effective in reducing energy consumption and improving thermal comfort. The investigation highlights the importance of passive design strategies and careful retrofitting to ensure energy-efficient and sustainable building designs  It also shows that many strategies aimed at promoting sustainability and energy efficiency in building design are employed globally. The results indicated that retrofitting existing buildings with indigenous techniques and integrating renewable energy sources can substantially reduce energy consumption and CO2 emissions.

### 3.1. Discussion

The study's findings provide valuable insights for architects, engineers, and building owners seeking to improve the energy performance of historical buildings. The development of an artifact to improve the delivery of energy retrofit projects can significantly contribute to curbing the environmental impacts of buildings

Consider adjustable, flexible shading devices for solar control, which can optimize solar heat gain and light in both summer and winter Implementing optimized shading strategies effectively mitigates solar heat gain, contributing to a notable annual energy reduction. The study underscores the importance of considering passive design principles and strategies for indoor thermal comfort, offering solutions applicable to future building construction. Retrofitting historical buildings presents unique challenges and opportunities. It is necessary to consider the building's historical significance, architectural features, and the need to balance energy efficiency with preservation.

## 4. Conclusion

This research provides a comprehensive overview of retrofitting historical buildings, addressing key considerations, strategies, and best practices. By implementing effective retrofitting measures, historical buildings can be transformed into sustainable, energy-efficient assets that contribute to a greener future.The study reinforces the need for awareness and education among stakeholders, including homeowners, builders, and policymakers, regarding the importance of energy-efficient building practices and their potential long-term advantages The implementation of optimized design strategies, including building orientation, façade components, envelope design, shading strategies, and material selection can lead to significant improvements in energy efficiency and sustainability.

The findings of the study demonstrated that passive design strategies can significantly improve indoor thermal comfort in buildings without requiring mechanical solutions. By optimizing the WWR and implementing effective shading devices, the building's natural ventilation rate is significantly improved. This strategic control of solar radiation and enhanced natural ventilation contributes to efficient heating in winter and cooling in summer.

The study's findings underscore the importance of employing climate-appropriate design strategies to maximize energy savings and occupant comfort. The research emphasizes that combining passive, locally-sourced design techniques can be applied holistically without additional economic investments or advanced technologies to improve building energy efficiency. By optimizing building components, glazing, window-to-wall ratios, and shading strategies, the study demonstrates that historical buildings can significantly reduce heating and cooling demands while also minimizing energy losses through the building envelope. The proper insulation and sealing of the building envelope are particularly effective in reducing energy consumption and improving thermal comfort. The most suitable tools for retrofitting residential compounds in arid climates include building orientation, shading devices, and glazing types. Energy-efficient building designs should consider various strategies such as building orientation, facade components, envelope design, shading strategies, and material selection to maximize energy efficiency and sustainability.

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