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Systems integration in heritage buildings and site for higher energy efficiency

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ABSTRACT

This paper explores the challenges that lead to the abandonment of heritage buildings in many countries, such as lack of maintenance, limited funding, and the absence of a clear plan for their reuse. It highlights the importance of adaptive reuse as a practical and sustainable solution to protect these buildings from deterioration and bring them back to life in a way that respects their historical and cultural value.

The main goal of the study is to examine how modern systems—like energy-efficient lighting, ventilation, and insulation—can be integrated into historic buildings without damaging their original character. It also looks at how the relationship between the building's surrounding landscape, its original materials, and interior spaces can be strengthened to create a more comfortable and functional environment for users. This kind of thoughtful integration helps ensure that heritage buildings remain in use and are not left to decay.

The research uses a qualitative approach, analyzing selected case studies from around the world where adaptive reuse projects have successfully combined modern systems with historic architecture. These examples offer insights into how to strike a balance between preserving the past and meeting today's needs.

The expected outcome is to show that with the right design strategies, adaptive reuse can improve both the performance and usability of heritage buildings. More importantly, it encourages people to reconnect with these spaces, giving them new life and purpose while keeping their stories alive.

1. INTRODUCTION

Heritage buildings reflect the cultural and social identity of societies across generations. Yet many of these buildings are increasingly at risk of abandonment due to deterioration, lack of funding, and the absence of effective reuse strategies. When historic structures are demolished or left unused, cities not only lose valuable cultural assets but also generate significant environmental waste (Jiang et al., 2023). Adaptive reuse presents a sustainable alternative, offering a way to retain heritage value while introducing new functions. However, successful adaptation requires careful balance between conservation, user comfort, energy efficiency, and economic feasibility.

Many existing studies have focused on either material conservation techniques or modern design interventions that preserve historic aesthetics (Hoffman, 2017; Ragheb, 2021). Others have addressed the challenges of replacing traditional materials with compatible alternatives in renovation processes (Abdelsabour, 2018). Yet, an integrated design approach that simultaneously considers the historic landscape, the building envelope, and the interior space remains underdeveloped—especially one that supports both sustainability and user experience. This research aims to fill that gap by proposing a framework that links the surrounding heritage landscape, the original material envelope, and interior functions to prevent building abandonment and improve energy performance.

The study adopts a qualitative methodology involving literature review and analysis of selected international case studies that have successfully integrated modern systems within heritage contexts. Insights from these cases will inform the development of a practical design framework.

This framework will then be applied to a local case study: the Palace of Aziza Fahmy in Alexandria, Egypt. Once a prominent villa overlooking the Mediterranean in the Gleem district, the palace is currently in a state of neglect—its garden abandoned and its façade severely deteriorated. Although there is currently a trial to restore the façade, the overall revival strategy for the site remains unclear and has not been publicly communicated. It is still unknown whether the building will be reused or how it will serve the community. This makes the project an unresolved and incomplete attempt at heritage preservation, and thus an ideal case to explore how a more integrated, sustainable approach could be applied.

2-THE VALUABLE ELEMENTS OF HISTORICAL BUILDINGS

Historic buildings are made up of many valuable layers that together reflect their identity, cultural meaning, and architectural uniqueness. These layers go beyond just the external appearance; they include the building's materials, spatial organization, construction techniques, and its connection to the surrounding environment. Some of the key elements commonly found in heritage buildings are:

- The building envelope (including façades, walls, roofs, windows, and finishes)
- The interior spaces and layout
- The heritage landscape or the setting around the building
- The materials and construction systems used
- The symbolic, social, or historical associations of the site

In this research, the focus is placed on three main elements: the building envelope, the interior functions, and the heritage landscape. These are treated as interconnected layers that hold the potential to support the building's reuse in a way that balances preservation with sustainability and comfort.

2.1. Heritage landscape

Heritage doesn't exist only in physical form—it also lives in people's memories and emotional connections to places (Capelo et al., 2011). While the heritage landscape is not part of the building itself, it plays a major role in defining the character and identity of the site. The landscape surrounding heritage buildings—such as gardens, courtyards, and open areas—often tells a story about the building's social and historical background. Together, they give the place a sense of meaning and context that shouldn't be lost.

Urban authorities often classify heritage buildings and their associated landscapes based on their age and value, using criteria that help protect them for future generations. According to Abdelsabour (2018), heritage landscapes can be divided into four types:

a. Cultural Landscapes: These are landscapes of historical or cultural importance that have been molded by human activities. They show how humans have interacted with their surroundings over time. Historic gardens, agricultural landscapes, sacred sites, and urban historic districts are some examples.

b. Natural Landscapes: Outstanding natural features, ecological significance, or biodiversity are characteristics of natural landscapes. They frequently consist of national parks, protected places, and environments with unusual geological formations or uncommon fauna.

c. Historic Urban Landscapes: Including whole cities or urban regions that are significant historically, culturally, or socially. They cover the maintenance and preservation of historic structures as well as streetscapes, public areas, and urban design components.

d. Industrial Heritage Landscapes: These are regions where industrial activities have shaped the physical and cultural environment. These consist of former factories, mine sites, or transit systems that were important to a region's industrial history.

2.2. Building envelope of historical buildings

The building envelope is more than just the façade or roof—it includes all the components that separate the indoor and outdoor environments. This includes walls, windows, doors, ceilings, floors, insulation layers, and exterior finishes. The envelope is often the most visually expressive part of a heritage building and plays a key role in defining its architectural identity. It also influences the building's environmental performance, acting as a barrier for air, light, heat, and sound. Preserving the envelope is essential, not only to protect the structure from damage, but also to maintain the original craftsmanship, materials, and architectural character. Many historical buildings were constructed using traditional materials and techniques that differ from modern standards, which makes the renovation process more delicate. In some cases, the original materials are no longer available and must either be specially reproduced or replaced with modern alternatives that closely match the original. The following sections outline the key aspects of the building envelope in relation to both preservation and sustainability.

2.2.1. Building Envelope Functions and Components

The building envelope provides thermal performance, acoustic insulation, weatherproofing, and structural integrity, among other benefits. Walls, ceilings, flooring, windows, doors, insulation, vapor and air barriers, and external finishes are some of its constituent parts (Arnold C., 2016).

2.2.2. Energy Efficiency and the Building Envelope

By minimizing air leakage and heat transfer, the building envelope is essential to energy efficiency. A building's energy performance can be greatly increased with the help of high-efficiency windows and doors, air sealing, and proper insulation (Yi & Bing, 2017).

2.2.3. Moisture Control and Durability

The building envelope aids in preventing condensation and moisture infiltration, which can cause decay, the growth of mold, and structural damage. Using the right materials and moisture control techniques is essential to keeping a strong and healthy building envelope (epa, 2013).

2.2.4. Building Envelope Testing and Performance

To examine how well the building envelope is performed, a number of tests and evaluations are carried out, such as moisture, thermal, and air leakage examinations. These evaluations assist in spotting areas in need of development and guarantee that the envelope satisfies performance requirements (Atlantic Testing Services, 2023).

2.2.5. Sustainable Design and Building Envelope

One essential element of sustainable design is the building envelope. It includes utilizing eco-friendly materials, maximizing energy efficiency, and incorporating renewable energy sources. Sustainable building envelopes help to foster resilience and lessen their negative impact on the environment.

3-SYSTEMS INTEGRATION FOR A BETTER HERITAGE CONSERVATION OF HISTORICAL BUILDINGS

According to the academic dictionaries the word conservation is defined as the preservation of a physical quantity during transformation or reactions. So, the expression of heritage conservation means preserving, protecting, and conserving the cultural and historical value of a building, object, landscape, or other artifacts of historic or heritage significance. It embraces all acts that prolong the life of a nation's cultural and natural heritage. It also includes the maintenance, the preservation and adaptation. Which may be combined depending on the needs of the user or occupier. It is important to note that preservation does not always mean maintaining a place in its original state; rather, it refers to managing changes while preserving the place's cultural significance. By heritage conservation the buildings and gardens are given a second life by being reconnected with the community and society. This meant that rather than preserving the building exactly as it was, efforts were made to add value while preserving its original architectural features and physical form. This investment in the current community benefits their residents current and leaves a priceless legacy for future generations (Abdelsabour. A, 2018).

Integration system means the process of merging and connecting two or more systems. The integration systems are commonly used in architecture to reach the design goal of energy efficiency and sustainability. This goal is reached in historical buildings by 3 methods which are: Envelope retrofitting, adaptation and reuse, heritage landscape preservation. By integrating these 3 methods a preservation from demolition and abandonment will be achieved. Moreover, systems integration refers to the combination of passive and environmental systems, with some support from active systems where necessary, to enhance the performance and usability of heritage buildings while preserving their identity. This process will take place by focusing on each term as its own. Adapting and enhancing each system will create the integration system desired. Connecting the landscape elements with the building envelope and its design features will help in enhancing the building energy efficiency. The landscape elements comprise historical trees and plants, which are subject to renovation and augmentation through the introduction of new species. This includes the consideration of water features, whether they are already present and deemed historical features in the surroundings or have the potential for addition. Concurrently, there is a focus on the renovation and adaptation of the building envelope material and design features, aiming to enhance energy efficiency. Furthermore, there is an emphasis on connecting the systems through the reuse and adaptation of interior spaces. This integration is designed not only to enhance user comfort but also to deter the abandonment of buildings.

3.1. Envelope retrofitting methods

The envelope retrofitting strategies rely mainly on passive and environmental systems, aiming to enhance energy efficiency through natural means without altering the building's historical form. To retrofit or restore the building envelope of an existing heritage building or any building, it could be by installing new roofing, replacing windows, seal air leaks, and adding insulation. Building envelope design and retrofitting can be complicated methods. Thus, various methodologies and factors will need to be considered depending on the building type, its location, and the objectives of the project. It is recommended to collaborate with architects, engineers, and construction specialists who have experience with envelope design and retrofitting to establish customized solutions for every project. According to (Energy, 2023), there are several methods that should be considered to deal with envelope retrofitting, such as:

3.1.1. High-performance Windows

Thermal performance can be greatly enhanced by upgrading windows to high-performance models with low U-values and low-emissivity (low-E) coatings. This lessens condensation problems, enhances occupant comfort, and decreases heat gain or loss (Moghaddam et al., 2021). These upgrades fall under both passive systems (by reducing heat transfer) and active systems when integrated with smart glazing technologies

3.1.2. Natural lighting Strategies

Incorporating daylighting strategies can enhance energy efficiency and occupant well-being. This can involve optimizing window placement, using light shelves or light redirecting devices, and choosing glazing with appropriate shading coefficients to control solar heat gain (Energy, 2023).

3.1.3. Exterior Shading Systems

During warm seasons, installing outside shading devices like awnings, louvers, or overhangs can assist block solar heat gain while letting in natural light. These shading systems can be made to minimize glare and overheating while optimizing sun direction as it's a purely passive method that has a successful results. (Energy, 2023).

3.1.4. Ventilation and Air Exchange

Enhancing energy efficiency and indoor air quality can be achieved through better ventilation systems and air exchange rates. Upgrades to mechanical ventilation systems, the addition of energy recovery ventilation (ERV) or heat recovery ventilation (HRV) systems, or the addition of movable windows to allow for natural ventilation are examples of retrofitting measures (Energy, 2023).

3.1.5. Green Roofs and Living Walls

Green roofs and living walls can be retrofitted onto rooftops or other vertical surfaces to improve biodiversity, minimize stormwater runoff, reduce the effects of urban heat islands, and offer extra insulation. Additionally, these solutions can enhance the building's overall environmental performance and attractiveness (Filipeboni, 2023).

3.1.6. Continuous Insulation

By adding continuous insulation to the whole building envelope, thermal bridging may be avoided and energy efficiency can be increased as it's a passive method to enhance the efficiency. Ensuring a continuous thermal barrier involves installing insulation continuously to the walls, roofs, and floors (Energy, 2023).

3.1.7. Building Management Systems

These are active control systems that manage building performance through smart technologies. Energy efficiency, occupant comfort, and building envelope maintenance can all be maximized by integrating modern building management systems (BMS) or building automation systems (BAS). Better control and monitoring of the building's lighting, Heating, Ventilation, and Air Conditioning (HVAC), and other systems are made possible by these systems.

3.1.8. Retrofitting with Sustainable Materials

By using environmentally friendly and sustainable materials, envelope retrofitting projects can lessen their negative impact on the environment. This can involve the use of low volatile organic compound (VOC) products, recyclable or recycled materials, or materials with a smaller carbon impact (Energy, 2023).

3.1.9. Monitoring and Performance Assessment

In order to make sure that the targeted levels of comfort and energy efficiency are met, it is crucial to monitor and assess the building envelope's performance following retrofitting. To find any possible problems or places that still need improvement, this may entail regular inspections, assessments of indoor air quality, and continuous energy monitoring.

3.2. Adaptation and reuse of heritage buildings

Adaptive reuse acts as a form of **functional system integration**, combining architectural identity with new functional programs to suit modern needs while maintaining the building’s soul. The phrase "to re-use a building or structure for the purpose of giving it new life through a new function" sums up adaptive reuse simply (Vafaie et al., 2023). However, heritage building adaptive reuse is a multifaceted process that tries to preserve the buildings' historical identity while transforming them for present and future generations’ use. According to (Arfa et al., 2022) there are 8 strategies of adaptive reuse planning for historical building as shown in Figure 1.

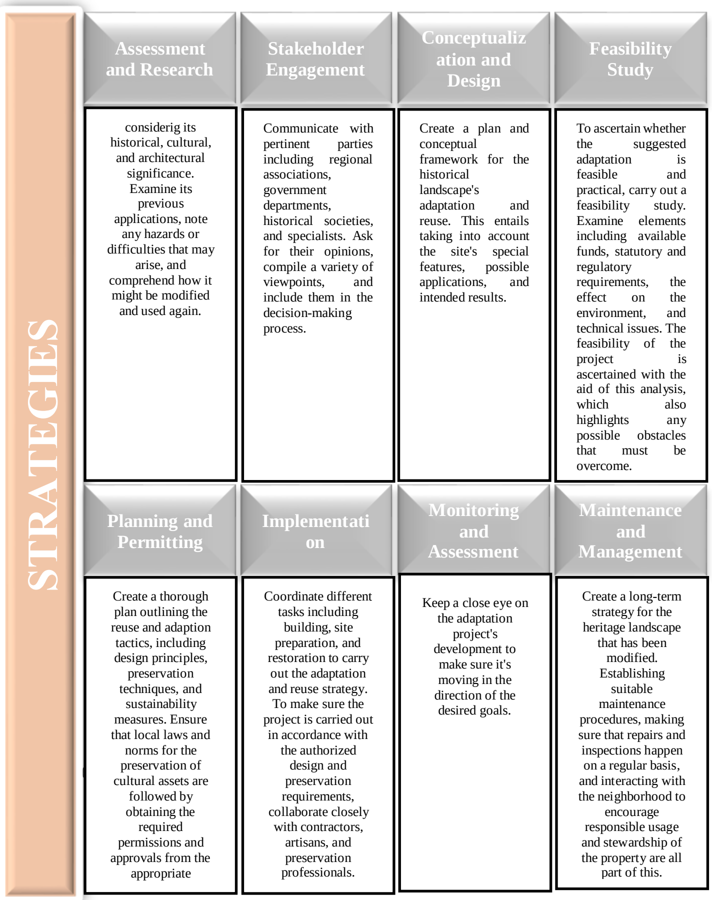

Figure 1. shows the 8 strategies of adaptive reuse planning for historical buildings.

Source: by the authors.

3.3. Heritage Landscape preservation

The process of preservation natural and cultural landscapes in order to preserve their integrity, aesthetic appeal, and ecological significance is known as landscape preservation. It involves making attempts to preserve a certain landscape’s physical attributes, biodiversity, historical relevance, and cultural traditions. according to (UNESCO) there are 6 strategies of heritage landscape preservation planning as shown in Figure 2.

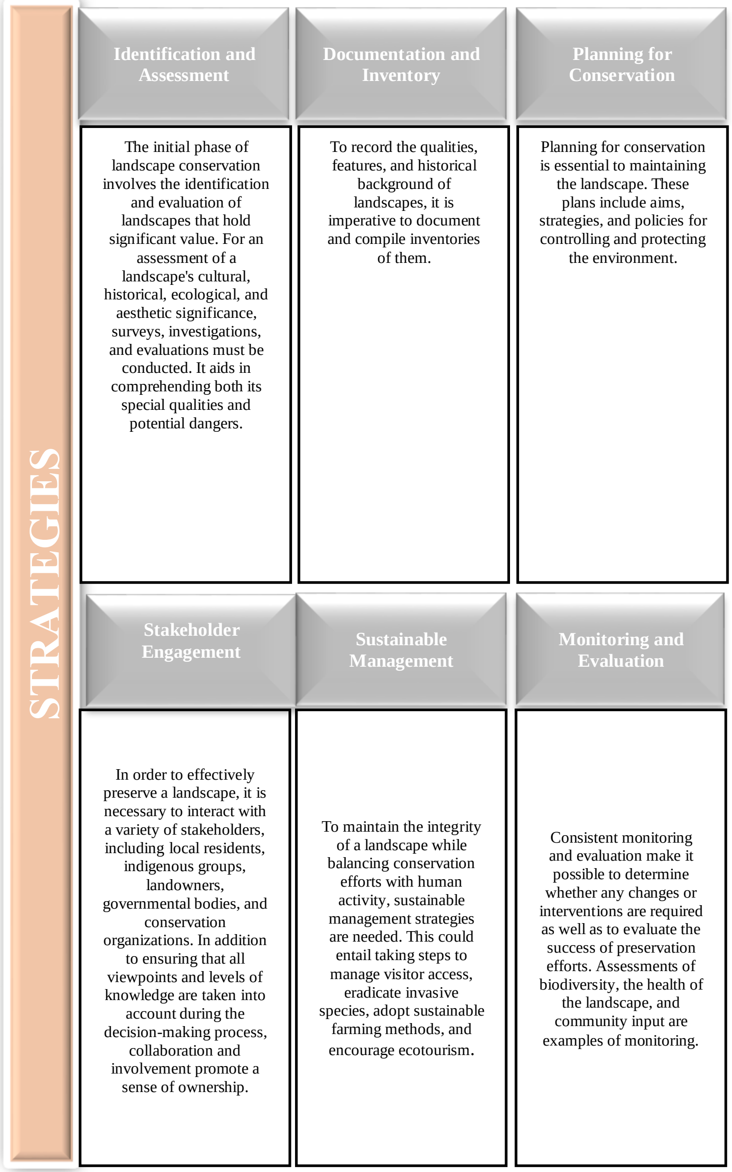

Figure 2 .shows the 6 strategies of heritage landscape preservation planning.

Source: by the authors.

4. ANALYTICAL STUDY OF HERITAGE BUILDING AND LANDSCAPE RETROFITTING METHODS

There are countless numbers of heritage buildings all over the world that represent the culture of their countries and their history. All governments aim to protects these heritage buildings and site. The research has chosen 2 examples of heritage building and one for heritage site to be analyzed according to the discussed strategies of adaptive reuse planning for historical buildings. The analysis aimed to highlight how did the adopted strategies in each case helped in enhancing the energy efficiency of the heritage building or site.

4.1. San Martino Castle in Parella, Italy

The San Martino Castle in Parella (Turin, Italy) was chosen for analyzing its retrofitting methodology, as Italy is similar to Egypt's culture and climate conditions. The analysis aspects were made according to building envelope retrofitting, interior space adaptive reuse and heritage landscape preservation. The San Martino Castle in Parella is a historical building with its landscape, as it was built in the XIII Century (see Figure 3). The original use was a "shelter" or "casa forte" an old farmhouse, then several extensions has been added over the centuries. Although, its historical value, the building has been abandoned for an estimated period of 10-15 years**.**

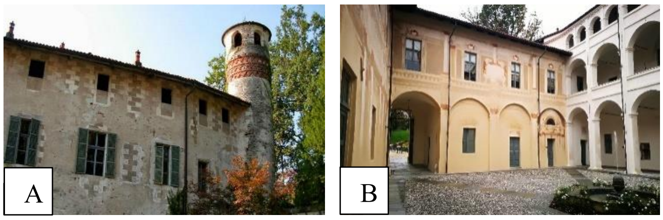

Figure 3. A) shows the exterior of the San Martino castle , B) shows one of the courts in San Martino castle. Source: A) (Serraino & Lucchi, 2017) , B (https://fondoambiente.it/luoghi/castello-di-parella?ldc)

The property has undergone recent revitalization under the ownership of Manitalidea. The renewal includes the incorporation of sophisticated amenities such as a hotel, a convention center, a refined restaurant, a café, a wine bar, a spa, and various retail outlets dedicated to showcasing locally curated products. Additionally, the building site was formerly home to the "Canavesani" gardens established by Adriano Olivetti. It has an agricultural park and a vineyard (Erbaluce). The development of this heritage castle aligns with a commitment to the principles centered on environmental preservation, reverence for the local landscape, and the promotion of regional product. The main goal of the castle renovation and adaptive reuse, was bringing back the building historical identity and architectural features, while, adding new activities and features with the intention of preserving its value. This design proposal is an integral component of a larger tourism accommodation effort that encompasses the approximately 60,000 m2 historical park located near the estate (Serrainoa, Lucchi, 2017). The renovation and development process took three different approaches which are: the interior adaptive reuse, building skin retrofitting and site preservation.

4.1.1. Interior approach strategy (Adaptive reuse of heritage building)

Each space was carefully designed to host the appropriate use. The activities that require several structural adjustments such as: hotel and the bar has been located in areas with either fewer or no decorative and architectural features. Mechanical systems integration with floor system were made in the rooms which have frescoed vaults aiming at preserving the architectural values of the historical vaults. To achieve a good interior environment worth fresh air, radiant panels were integrated with the underfloor channels. Whereas, the conference center and public reception have been positioned to support activities that require less structural changes. Service facilities, such as kitchens and restrooms, have been housed in areas lacking architectural or historical significance (Serrainoa, Lucchi, 2017).

4.1.2. Building Skin approach strategies (enhancing and retrofitting the envelope)

In addition to achieving high energy efficiency levels, the energy retrofit seeks to maintain and respect the building's original features and heritage values. A dynamic energy model of the building was also included in the project to determine the best course of action from an energy perspective. The current energy performance of the building was modeled with the aid of EnergyPlus 7.2 software in order to benefit from the original building envelope's energy behavior. The original skin has high-thickness walls which guarantees good thermal insulation. However, the skin and all of its treatments needed a lot of refurbishments. The real challenge was enhancing the energy with a strategy that doesn't affect the building value. Works were restricted by the frescoes of chambers and courts walls. The original walls have intricate pattern of mixed masonry which is made up of uneven ashlar and a core made of raw and mixed materials including gneous rocks, mortar, bricks, and wood. It measures about 0.6 meters thick and is mostly covered in frescoes, wall paintings, and old lime plaster on both sides. Typically, a U-value for walls is 1.7 W/m2K (Serrainoa, Lucchi, 2017)(See Figure 4).

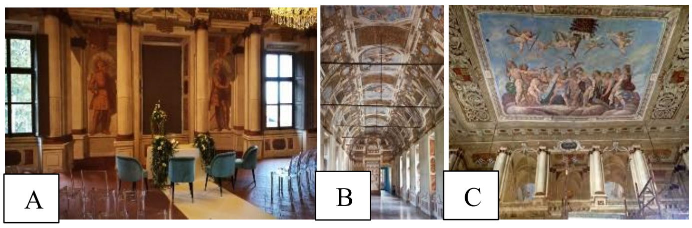

Figure 4.(A, B, C) Shows the frescoes and architectural features of the interior walls and roof. Source: https://www.turismotorino.org/en/castello-di-parella

Because of the architectural features and the frescoes in the interior of rooms, it was difficult to add any interior wall or ceiling insulation. However, the original roof was unsafe from a static perspective, so it has been entirely renovated with an insulated roof. The roof's new layer consists of 0.15 meters of rock wool insulation with a U-value of 0.22 W/m2K. The original walls were injected with allow pressure binders, to increase the wall strengthen and enhance its quality. The windows were made of single glass and wooden frames with a U-value of 5.0 W/m2K. So, small number of windows were replaced with a double glass and a low coating for wooden frames were added to enhance the thermal comfort and the air leakage (Serrainoa, Lucchi,2017).

4.1.3. site approach strategies (enhancing and preserving the landscape)

Before the restorations, the building had a modest heating system and a minimal electrical plant that was only used in a few rooms. To enhance the building performance, a large variety of plant species have been created to satisfy different needs regarding thermal comfort. To support the building mechanically, a new underground building was built adjacent to the "Corte Rustica" to house the mechanical and electrical plant, without compromising the architectural integrity of the heritage site (Serrainoa, Lucchi, 2017).

4.2. Reichstag, New German Parliament

The Reichstag new parliament example was chosen for analyzing its heritage conservation strategy, as it has great historic values. The strategy was challenging 4 main aspects which had to be taken into consideration: the importance of the Bundestag as a democratic forum, historical awareness, accessibility, and a strong environmental agenda (Foster + Partners, n.d. 2024). It was the German Architect Paul Wallot who started the work on the project in 1884 after winning in a competitiom. Wallot's neoclassical architecture underwent numerous modifications, frequently dictated by the whims of the three Kaisers who ruled until the structure was ultimately finished in 1894. The most famous feature of Wallot's architecture, the phrase "Dem Deutsche Volke" (or "To the German People") on the building's main pediment, was added in 1916 as a patriotic emblem during World War I (Douglass-Jaimes, 2023) (see Figure 5). The competiotion was opened again for some architects that has been invited to from all over the world. Norman foster was one of them and after several phases and complications in the competition, finally his design was approved. Foster's design vesion may seem simple enough, but the Reichstag has a lengthy, complicated, and controversial history.

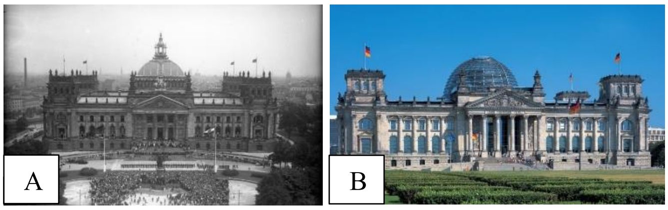

Figure 5. A) shows the Reichstag German parliament 1932, B)shows the Reichstag German parliament nowadays in 2024. Source:A)https://www.archdaily.com/775601/ad-classics-new-german-parliament-reichstag-foster-plus-partners?ad_medium=gallery,B)https://www.archdaily.com/775601/ad-classics-new-german-parliament-reichstag-foster-plus-partners?ad_medium=gallery

The inspiration for this retrofit project came from the original fabric; layers of history were removed to reveal remarkable remnants of the past, such as Russian graffiti and stonemason's marks, which have been conserved as a "living museum." However, it is a dramatic departure in other ways as well; its operations are visible via its translucent and light exterior (Foster + Partners, n.d. 2024). The renovation and development process took two different approaches which are: the interior adaptive reuse and building skin retrofitting.

4.2.1. Interior approach strategy (heritage building reuse)

The building was neglected and abandoned for many years. At the early of 1990s the government decided to use the building for housing the German parliament as a new refresh beginning for the German people. Renowned British architect Norman Foster renovated the old structure to honor German heritage and represent the populace's demands for genuine democracy, civil disobedience, and open government. The Reichstag's innovative design solutions are regarded as sources of sustainability for both the environment and culture. Though most of the inner structure was altered to accommodate a number of new uses, the outside of the original building and some portions of its interior are still intact, demonstrating the concept of historic preservation. To make the Reichstag interior more flexible and adaptable for the additional functions, a variety of steel structures were installed into the building to create new areas on various levels. The new development represents equality by allowing politicians and guests to enter through the same door. The visitors are shown to various public areas within the building, while members of parliament proceed to their offices and the legislative hall upon entering. The building was turned into a museum where guests can view the portions of the ancient building's remains that have been preserved. The stone construction remains in its original form, and the writing of Soviet soldiers in certain areas has been retained (Amartya, 2020)(See Figure 6).

Figure 6. shows the preserved structure
Source:https://issuu.com/amartyakabiraj/docs/the_reichstag_amartya_520216017

The building's roof, the terrace restaurant, and the new designed dome are examples of the public space. Ramps lead to an observation platform there, where people can ascend symbolically above the heads of their representatives in the chamber. The architect used the glass as a main material inside the building to separate the zones with it. The light weight of glass helps in preserving the original structure as well as emphasizing the design concept of transparency and democracy era (Amartya,2020) (see Figure 7).

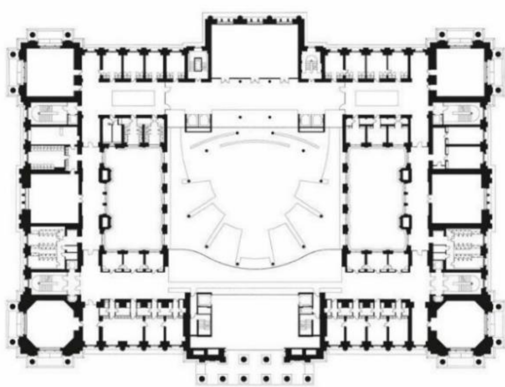

Figure 7. shows the building architectural plan of the Reichstag new parliament with the addition of the internal glass walls.
Source:https://issuu.com/amartyakabiraj/docs/the_reichstag_amartya_520216017

The integration of different mechanical systems within the building interior spaces is considered as great example of sustainability. The building uses the refined vegetable oil, a sustainable biofuel, in a cogenerate of electricity, which is a much cleaner method than using fossil fuels. As a result, carbon dioxide emissions are reduced by 94%. An aquifer located far below the surface stores excess heat as hot water, which can be pumped up to heat a building or power an absorption cooling system to provide chilled water. Remarkably, the building's energy needs are low enough to enable it to function as a micro power plant in the new government quarter and to generate more energy than it uses (*Foster + Partners*, n.d. 2024).

4.2.2. Building Skin approach strategies (enhancing and retrofitting the envelope)

Foster designed several proposals for the cupola as a main addition to the building skin. The one with a domed glass was chosen to provide more lighting and natural ventilation (See Figure 8). Its central component is a "light sculptor," which reflects horizon light into the chamber, while, a sunshield follows the sun's course to prevent glare and solar gain (see Figure 9). The added cupola is considered a well-known landmark in Berlin(Foster + Partners, n.d. 2024).

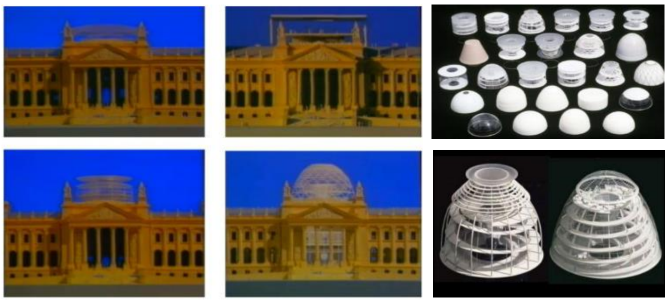

Figure 8. shows the cupola different design proposals Source:https://issuu.com/amartyakabiraj/docs/the_reichstag_amartya_520216017

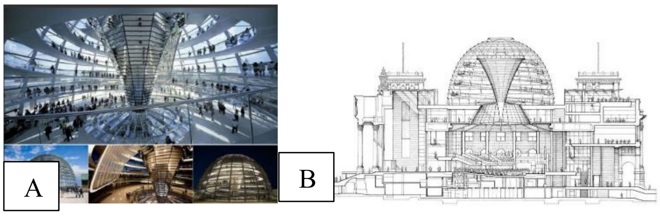

Figure 9. shows the "light sculptor" of the new added cupola design in the Reichstag new parliament. Source:A) https://issuu.com/amartyakabiraj/docs/the_reichstag_amartya_520216017; B) https://www.archdaily.com/775601/ad-classics-new-german-parliament-reichstag-foster-plus-partners?ad_medium=gallery

4.3. The Angkor Wat temple complex in Cambodia

The Angkor Wat temple complex in Cambodia has been chosen to be studied, as it is considered one of the world heritage sites that has suffered from several damages over the decades. It was also chosen for its great importance to the community. The UNESCO has observed its conservation and retrofitting plan by the collaboration with other authorities. The King Suryavarman II constructed the Angkor Wat temple complex in the 12th century, close to Siğmréab, Cambodia (reigned 1113–c. 1150). The Angkor Wat, is a massive religious complex with over a thousand buildings. Angkor Wat is the largest religious building in the world and the pinnacle of Khmer design. The five major towers represent the peaks of Mount Meru, the gods' home according to Hindu mythology. Access to the location is provided by a 188-meter bridge. There are three galleries leading up to the temple, with paved walkways separating them. High-quality bas-relief sculptures depicting Hindu gods, scenes from the Mahabharata and Ramayana, and scenes from ancient Khmer culture fill the walls of the temple (Britannica, 2023). Angkor has faced a lot of problems over the decades such as war damage. The outside world believed that the war events had seriously destroyed the temple complexes based on the different stories that were disseminated through the media. Thankfully, the structures have sustained relatively little damage. Observable, gunfire was chiefly the blame for the damage, which was primarily zaesthetic. In addition to the problems faced the site like drainage problem, effect of age, Hurricane damage and other several problems (Reap, S., 1992). The aim of the project was to preserve the site history and identity while conserving and retrofitting the site to bring back its historical and touristic value to be safe for users to be visited again (See Figure 10).

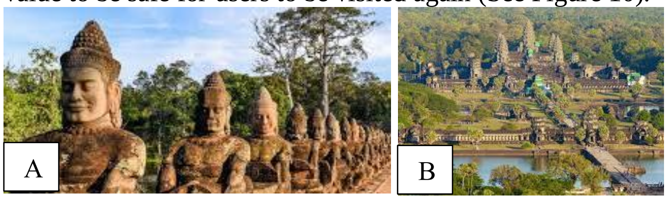

Figure 10. A) shows deteriorated sculptures; B) shows Angkor full site
Source:A) https://www.lonelyplanet.com/cambodia/temples-of-angkor/attractions/angkor-wat/a/poi-sig/500516/1002179; B) https://www.livescience.com/23841-angkor-wat.html

4.3.1. Site approach strategies (Conserving and preserving the landscape)

The Cambodian temple complex known as Angkor Wat is a magnificent example of environmentally responsible preservation. Sustainable practices have been effectively applied at this UNESCO World Heritage site without sacrificing its historical integrity. Angkor Wat has established sustainable tourist methods that boost the local economy and safeguard the monument by collaborating with the community. Lighting systems are now powered by solar panels, which lessens the need for non-renewable energy sources. Eco-friendly materials have been used in an attempt to preserve and restore the delicate structures and beautiful sculptures. The benefits of incorporating sustainability into historical sites are demonstrated by the sustained appeal of Angkor Wat as a tourist destination, which is a direct outcome of these sustainable preservation techniques (Energy, 2023).
Angkor wat heritage site conservation, the project adopted the sustainable strategy and the use of eco friendly materials to bring back historical value of the place.

4.4. Analysis of the selected three examples

The methodology adopted in The San Martino Castle in Parella adaptive reuse were the adaptation of the interior and adding new functions without distorting the historical value as the main focal strategy. Also, using a strategy for skin retrofitting and adapting the landscape for energy efficiency. As a result, the building has kept its historical and architectural character while incorporating new uses and improving its energy efficiency to prevent it from being abandoned (Serrainoa M., Lucchi E., 2017). The strategy adopted in the Reichstag, New German Parliament renovation and adaptive reuse was the idea of integrating the interior with the building envelope and mechanical systems together to enhance the building performance and the energy efficiency. This strategy has increased users' comfort and preserved the history of the building. The strategy adopted in The Angkor wat heritage site conservation was the sustainable site strategy and the use of eco friendly materials to bring back historical value of the place. The following table shows the methodologies of each example according to the theoretical points mentioned previously (See table 1).

Application	Interior (adaptive reuse) check points	skin retrofitting check points	Site (Landscape preservation) check points
The San Martino Castle in Parella (Turin, Italy)	✓ Assessment and Research ✓ Stakeholder Engagement ✓ Conceptualization and Design ▪ Feasibility Study ▪ Planning and Permitting ✓ Implementation ▪ Monitoring and Assessment ○ Maintenance and Management	✓ High-performance Windows ○ Natural lighting Strategies ○ Exterior Shading Systems ✓ Ventilation and Air Exchange ○ Green Roofs and Living Walls ✓ Continuous Insulation ✓ Building Management Systems ○ Retrofitting with Sustainable Materials ✓ Monitoring and Performance Assessment	▪ Identification and Assessment ▪ Documentation and Inventory ✓ Planning for Conservation ▪ Stakeholder Engagement ▪ sustainable management ▪ monitoring and maintenance
Reichstag, New German Parliament (Berlin, Germany)	✓ Assessment and Research ▪ Stakeholder Engagement ✓ Conceptualization and Design ✓ Feasibility Study ✓ Planning and Permitting ✓ Implementation ▪ Monitoring and Assessment ✓ Maintenance and Management	✓ High-performance Windows ✓ Natural lighting Strategies ▪ Exterior Shading Systems ✓ Ventilation and Air Exchange ○ Green Roofs and Living Walls ✓ Continuous Insulation ✓ Building Management Systems ✓ Retrofitting with Sustainable Materials ✓ Monitoring and Performance Assessment	▪ Identification and Assessment ▪ Documentation and Inventory ▪ Planning for Conservation ▪ Stakeholder Engagement ▪ sustainable management ▪ monitoring and maintenance
Angkor wat heritage site (Cambodia, Southeast Asia)	○ Assessment and Research ○ Stakeholder Engagement ○ Conceptualization and Design ○ Feasibility Study ○ Planning and Permitting ○ Implementation ○ Monitoring and Assessment ○ Maintenance and Management Note: the project strategy didn't include the adaptive reuse as it's a historical religious site.	○ High-performance Windows ○ Natural lighting Strategies ○ Exterior Shading Systems ○ Ventilation and Air Exchange ○ Green Roofs and Living Walls ✓ Continuous Insulation ○ Building Management Systems ✓ Retrofitting with Sustainable Materials ✓ Monitoring and Performance Assessment	✓ Identification and Assessment ✓ Documentation and Inventory ✓ Planning for Conservation ✓ Stakeholder Engagement ✓ sustainable management monitoring and maintenance

- ✓ This step has been achieved.
- ▪ Not mentioned if it's done or not.
- ○ This step has been skipped.

5. CASE STUDY OF AZIZA FAHMI PALACE, ALEXANDRIA, EGYPT

The case study chosen for this research is Aziza Fahmy Palace, a heritage landmark located on Corniche Road in Alexandria, Egypt. Built in 1907 by the renowned Italian architect Antonio Lasciac, the palace was commissioned by Ali Fahmy Pasha, a prominent military leader during the reign of King Fuad I (1922–1936). He named the residence after his daughter, Princess Aziza Fahmy. The palace sits atop a level hill approximately 5 meters above sea level, overlooking the Mediterranean Sea (see Figure 11). It consists of two floors and a basement, each containing four main rooms, and is richly adorned with architectural motifs and decorative elements that reflect the craftsmanship and aesthetic of the period (Princess Aziza Fahmy's Palace | Alexandria Egypt, 2023).

Although the palace holds high historical and architectural value, it has faced neglect and deterioration over the years. Currently, there is a visible effort to renovate the building's façade; however, the overall strategy for its revival remains unclear, and public information is limited regarding whether the building will be reused or simply maintained as a static landmark. This uncertainty reflects the need for a clear, integrated conservation approach that not only restores the physical condition of the palace but also reintegrates it into contemporary cultural and social life. The research presents a conceptual framework that addresses these challenges by integrating envelope retrofitting, landscape conservation, and interior adaptation—with the ultimate aim of reviving the palace sustainably while preserving its identity and reconnecting it with the community.

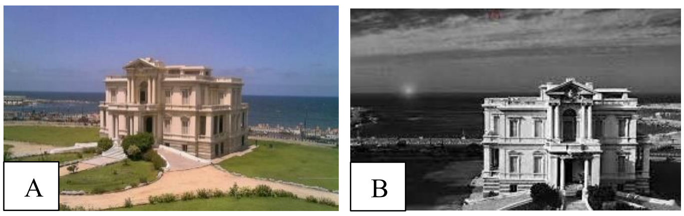

Figure 11.shows the exterior of the palace.
Source: https://enterprise.press/stories/2017/11/28/aziza-palace-case-concludes-after-54-years/

In the 1990s, during a dispute between the inheritors' and the government's ownership of the palace, the building sustained several intentional damages. Although, the great historical value of the place, it has been abundant for several years up until today. It is, currently, facing several problems such as: poor landscape condition which may affect the thermal comfort, as well as, the excessive noise because of the overcrowded Cornish street and no insultation treatments for the building envelop (Princess Aziza Fahmy's Palace | Alexandria Egypt, 2023). (see Figure 12).

Figure 12.shows the poor condition of the landscape in the current situation.
Source:https://www.google.com/maps/uv?pb=!1s0x14f5c5260df98527%3A0x804851abf1c21a9d!3m1!7e164!15sCgIgAQ&hl=en&viewerState=ga&imagekey=!1e10!2sAF1QipM4PRHZIf8oDsoxzHwFecEu6kC_9BIVoP2c_pId

After studying the theoretical aspects of heritage conservation and different methods of retrofitting as well as analyzing three examples, a strategical plan has been deduced to be followed in the following development proposal. Firstly, analyzing all the features, urban context and the problems facing the historical building. Secondly, starting the documentation phase to collect all the data and information needed. Finally, the paper suggests a conceptual integration plan between the landscape renovation, retrofitting of the envelope and the reuse of the palace to be a museum. The research aims to achieve better human comfort within the internal spaces in order to avoid the abandonment of the building. It is suggested to replace the old windows with aluminum double glazing for thermal insulation. When retrofitted into existing window frames, Ener Glaze Low-E-Plus2TM can achieve thermal efficiencies in a double-glazed unit that are 70% better than ordinary double-glazing as it has a U-value of 2.6w/m^2 k compared to the single glass U-value which is 5.2 w/m^2 k. Also, a rock wool material with U-value 0.038 /m^2 k is suggested to be applied to the interior walls and refinished for sound insulation (see Figure 13)

Figure 13. shows the retrofitting and enhancements to the palace facades without changing in its heritage form and aesthetics features. Source: by the author using Revit software.

It is suggested to enhance and replant the surrounding landscape to achieve the thermal and sustainable treatment needed. The proposal also aimed at achieving the heritage landscape conservation by bringing back its original design while adding some modification according to the climatic analysis. The palace and its site had been modeled using Revit software. The original site was traced form google earth (see Figure14).

Figure 13.A)Shows the original design of the landscape lots B) shows landscape and palace model using Revit software.
Source:A)https://from-egypt-with-love.blogspot.com/2016/04/aziza-fahmy-palace-in-alexandria.html#google_vignette
B) by the authors

For the adaptive reuse stage, the palace need to be renovated with the intention of bringing back its identity and preserving its heritage value. The mechanical and activities that need several structural changes is assumed to be placed in the spaces that has no ornaments and features as in the basement. The exhibition space will be placed in the rooms that has architectural features and motifs to get benefit of the beautiful ornaments (see Figure 14).

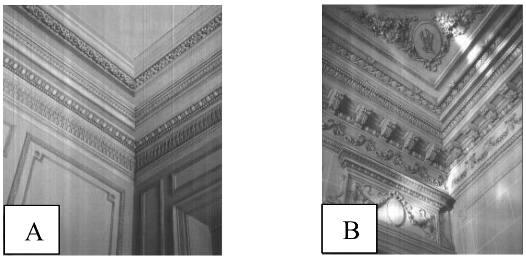

Figure 14. Shows the interior classic motifs in the palace and these rooms were reused for the exhibition spaces
Source: https://from-egypt-with-love.blogspot.com/2016/04/aziza-fahmy-palace-in-alexandria.html#google_vignette
B) by the authors

To level up the energy efficiency of the building, a photovoltaic panel will be placed on the roof facing the south and south-east directions for better sun detection. A 20% efficient solar panel can turn 20% of the sun's energy into useful energy. For best development results and analysis, the integration with the software has easier the work. Forma Autodesk Software has been used for the analysis of energy efficiency in the building after the development and retrofitting methodology (see Figure 15).

Figure 15. shows the solar panels added to the roof in the direction of south and southeast direction to enhance the energy efficiency of the building. Source: By authors using Revit software.

The program has study the wind direction, sun intensity, and the noise analysis by using Revit and Autodesk Forma software's

5.1. Analytical studies of energy efficiency

As its shown in the sun intensity analysis on the site, almost all the facades of the palace and all site direction are heavily exposed to the sun for 9 hours per day specially the south and east facades which has the higher sun intensity. So by adding more trees, heat insulation to the envelope and changing the old windows to a double aluminum glazed ones with more efficient sealant material as previously mentioned, the sun intensity as has been decreased on the south and east facades to be intense for almost 5 to 6 hours per day. For enhancing the building energy efficiency, the roof was used to carry photovoltaic panels directed to the south direction to get benefit of the sun intensity see Figure 16.

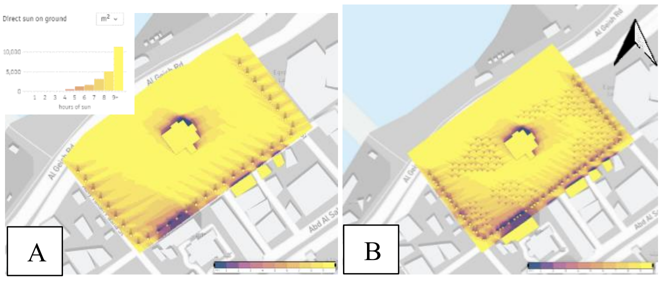

Figure 16. A) shows sun intensity analysis on the different spots of site in the current situation. B) shows sun intensity analysis on the different spots of site after development Source: A&B) by the author using Revit & Autodesk Forma software's

By the use of rock wall material and adding more trees surrounding the building and site the noise affecting the site has be decreased within10% compared to current situation see Figure 17.

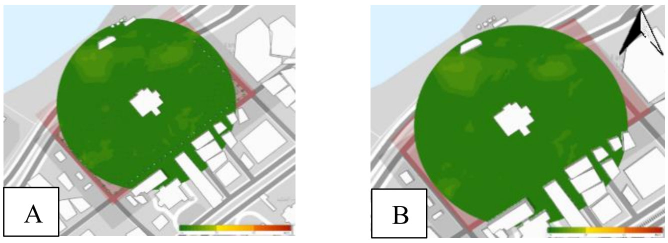

Figure 17. A) shows the percentage of the noise in the current situation which is within 100% B) shows the percentage of the noise in the development which is within 90% Source: A&B) by the author using Revit & Autodesk Forma software's

For achieving better quality of wind comfort the green areas has been re-planted. Trees, shrubs and different species of plants and flowers were added. The locally accelerates wind flows and turbulences resulting from the interaction between building and the actual wind flow as the percentage of the wind comfort increased from 46% in the current use to 49% after development. see Figure 18.

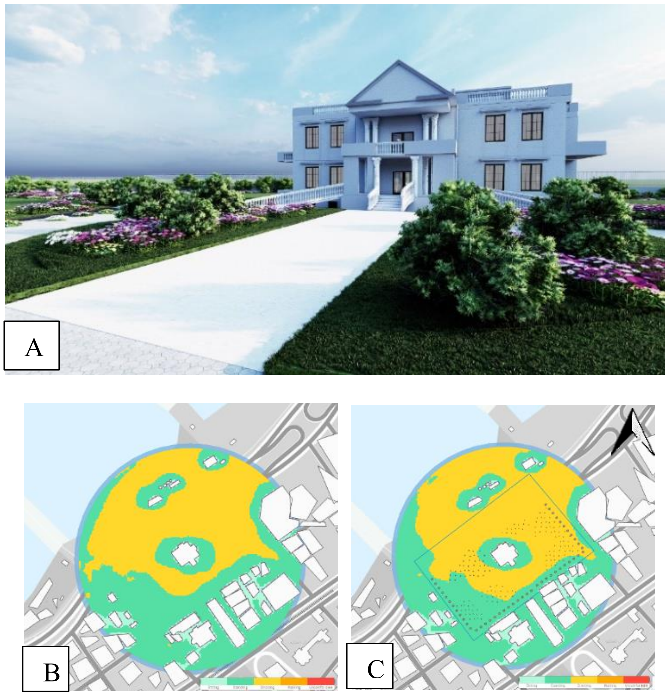

Figure 18. A) shows the developed landscape and palace model. B) shows the wind comfort in the current situation which is within 46% C) shows the wind comfort in the development which is within 49%
Source: (A,B&C) by the author using Revit & Autodesk Forma software's

6. CONCLUSIONS

In conclusion, integrating the different systems of heritage buildings—such as the envelope, interior spaces, and surrounding landscape—plays a vital role in enhancing energy performance and bringing new life to abandoned or under-used heritage sites. This integration supports both the physical conservation of the building and the emotional connection people have with these spaces, making them functional again without losing their identity. Figure 19 visualizes the four-phase framework developed in this study—Analysis, Documentation, Design, and Implementation—showing how an initial understanding of a site's history and condition flows into careful record-keeping, sensitive design decisions, and, finally, on-site actions such as envelope retrofitting, interior adaptation, and landscape restoration**.** By following this loop, the building's systems reconnect with one another and with the community around them, laying the groundwork for long-term stewardship.
Based on the case-study findings, several practical recommendations emerge:

- **Assess first**: Each heritage building should be examined carefully before any intervention, so that reuse strategies and materials are chosen to suit its condition and context.
- **Favour passive solutions**: Upgrades such as added insulation or well-placed shading devices should take

priority, because they boost efficiency without disturbing original architecture.

- **Work in multidisciplinary teams**: Architects, conservation experts, landscape designers, engineers, and local authorities all bring essential perspectives that help reuse plans satisfy both regulatory standards and community needs.
- **Keep the public involved**: When local people feel connected to a place, the risk of future neglect or abandonment drops dramatically.

Looking ahead, future research could develop better tools for measuring the environmental and social impact of reuse projects and could test how digital design technologies—such as simulations or heritage BIM—can help plan conservation strategies before work starts on site.

The methodology set out here, and summarized in **Figure 19**, is intended as a flexible foundation that other designers and researchers can build on, honoring the past while supporting the needs of the present and the future.

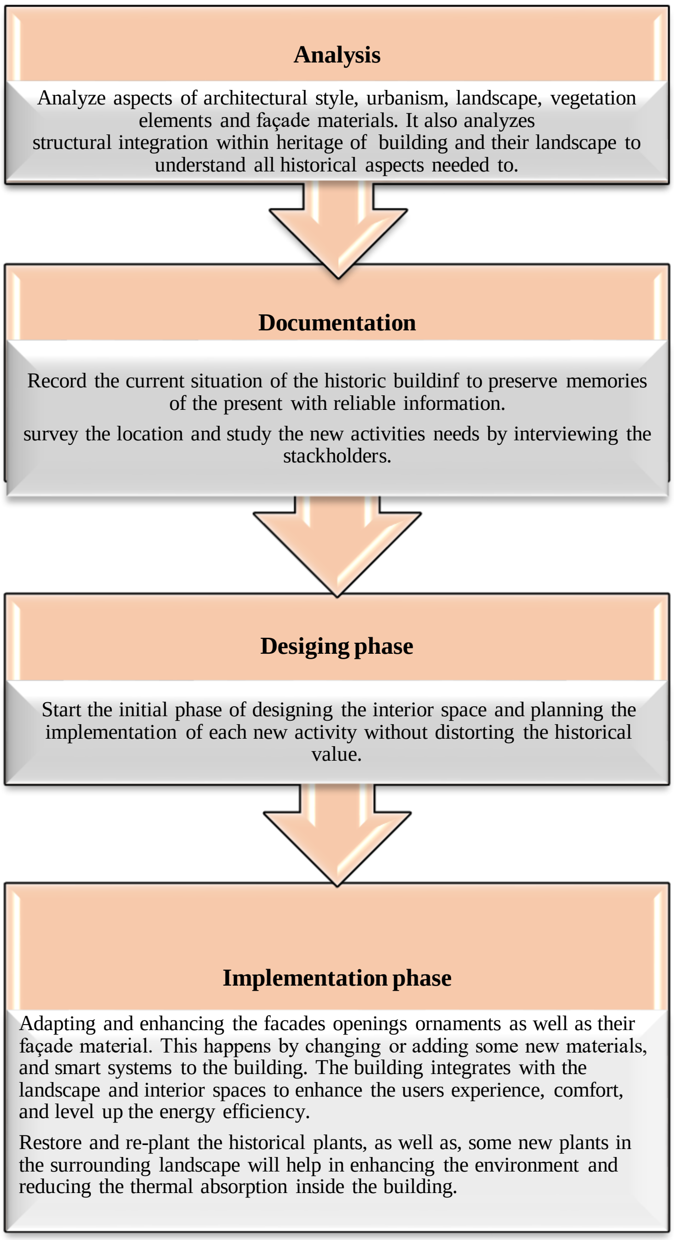

Figure 19: shows the methodology of integration systems to achieve the heritage building conservation and its environment. Source: by the authors

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