International Journal of Computational and Experimental Science and ENgineering (IJCESEN)

Vol. 11-No.4 (2025) pp. 4546-4559
http://www.ijcesen.com

ISSN: 2149-9144

Copyright © IJCESEN

Research Article

Maintenance of historical buildings using modern materials, equipment and technologies for the purpose of reuse

Mohamed Sami Abdelmoatee Abdeen[1]* , Salah Zaki Saied[2] , Abdel Salam A. Soliman[3]

[1]Ph.D., researcher Architecture, Faculty of Engineering, Al-Azhar University, Cairo, Egypt
***Corresponding Author Email** : Eng_mohamed_abdeen@yahoo.com, **ORCID:** 0009-0009-4726-7718

[2]Prof. Department of Architecture, Faculty of Engineering, Al-Azhar University, Cairo
Email: profsalahzaki@gmail.com -**ORCID:** 0009-0002-8452-3142

[3]Architectural Engineering Department, Faculty of Engineering Al-Azhar University Cairo
Email: eng_arch_ab@yahoo.com - **ORCID :** 0009-0008-6105-9002

Article Info:

DOI: 10.22399/ijcesen.5184
Received: 10 June 2025
Revised: 20 August 2025
Accepted: 31 October 2025

Keywords:

Historical buildings
Preservation
Modern tools and devices
project management
organization programs

Abstract:

As a result of the multiplicity of trends in modern architecture, architecture has become more advanced in design, implementation, and direction. Some of these trends can be combined with valuable architectural buildings during their reuse in order to preserve the building while adding a modern function to it, while maintaining its historical, architectural, and artistic value. This facilitates its preservation for a long period. These trends agree on reusing and using these buildings in a modern technological way and with advanced materials. Among these trends are (Green architecture - Smart high technology). These modern trends are characterized by their use of programs, technologies, architectural materials, advanced equipment, and reliance on renewable energy as much as possible. Therefore, the research has focused on this technology and its use in developing and reusing historical buildings.

1. Introduction

The architecture of the period between the late 19th and early 20th centuries left behind a large collection of valuable buildings, including palaces, private residences, and apartment blocks. Some of these were repurposed as administrative and educational buildings, while many others were neglected. In fact, many of these buildings are not registered with any archaeological authority and receive no care or protection from theft, neglect, encroachment, and, often, deliberate demolition.Preservation aims to maintain and perpetuate the historical image created by the community. Methods for preserving valuable buildings are numerous and include restoration, maintenance, renovation, reconstruction, upgrading, revitalization, rehabilitation, and repurposing. Repurposing is considered one of the best methods of preservation, as it facilitates the ongoing maintenance of the building, allowing the heritage to survive for as long as possible and continue to play a role in the life of the surrounding community. Modern technology and clean energy are among the requirements of the modern era, as relying solely on current energy sources such as petroleum and electricity is not sufficient to meet human needs at present. Therefore, the trend towards employing modern technology in our buildings helps to reduce the consumption of depleted energy sources and helps to create a clean environment that relies on natural resources and modern means that have become easy to use in various areas of life..

2. Research objectives:

This research is based on working on repurposing valuable buildings by finding an approach that organizes the exploitation of modern technology means in employing valuable buildings as an advanced approach to repurposing them, which helps to preserve them using modern programs.

3. Research Questions:

This research seeks to find suitable functional and design solutions for utilizing the spaces within valuable buildings, thereby increasing their lifespan and preserving them. This will be achieved by integrating modern technologies into our buildings, which will help reduce energy consumption and contribute to a cleaner environment. These technologies will be used to rehabilitate and repurpose heritage buildings.

The research will answer a set of questions to determine the importance of preserving buildings. These questions will be explained in the following points:

1- What are the reasons behind the preservation process?

2- What are the methods and processes of preservation?

3- Which entities are responsible for and fund preservation?

4- Who are the beneficiaries and stakeholders of preservation?

5- What are the steps for repurposing valuable buildings using modern technologies?

4. Research Hypothesis:

Developing a methodology and steps for repurposing historical buildings that are flexible in implementation and suitable for all cases, using technological programs, materials, and modern restoration methods.

5. Literature Review

1- The Emergence of Smart Architecture:

Since the early 1960s, several attempts began to control buildings, leading to the development of automated systems that remotely controlled electrical systems and switchboards. A significant breakthrough didn't occur until the early 1980s, when research began on mechanical and electronic device management systems to increase building energy efficiency.[1] The term "smart buildings" emerged at the beginning of the 20th century, referring to buildings where environmental systems are integrated, encompassing energy use, temperature and lighting control, sound, workspace, and communication.[2] There is enormous potential for retrofitting older buildings to improve their energy performance. Currently, approximately 1% of these older buildings are being retrofitted annually. With increasing attention to smart building technologies, air quality, greenhouse gas emissions, and ongoing discussions about new government regulations to reduce energy consumption, older buildings are becoming ripe for cost-effective energy upgrades that can improve their energy efficiency.[3] Preserving Heritage Buildings [4]:

The methods used to preserve archaeological sites vary according to the building's historical value, type, archaeological function, and architectural features.

- Levels of Rehabilitation for Heritage Buildings [5]: The levels of rehabilitation for existing heritage buildings vary depending on the size of the building being preserved, as described above, and are based on the size, type, and importance of the buildings.

These can be classified as follows: - Rehabilitation of Heritage Elements: This is usually carried out on heritage pieces and elements after their restoration and treatment using scientific methods that ensure their preservation and safety.

Rehabilitation of a Single Building: This includes restoration and renovation of heritage buildings and their conversion into museums or tourist attractions.

Rehabilitation of a Group of Buildings: In the case of a group of adjacent heritage buildings, they are preserved as a whole, highlighting the heritage value of the group and the importance of each individual unit.

2- Repurposing Heritage Buildings:

To invest in historical buildings, they must be preserved and sustained.[6] The importance of these heritage buildings as venues for cultural and social events has been proven. These buildings represent a significant economic resource in the field of investment. Consequently, it became necessary to find a new approach suitable for the nature and aspirations of the future, adopting a new concept that focuses on utilizing the building and its history for functions that suit its design, spaces, and nature.[7]

3- Conservation Processes:

Conservation in historical areas aims to preserve the cultural character and protect heritage buildings, focusing on archaeological sites and surrounding buildings with distinctive features. This is achieved through studying architectural elements, building materials, restoration, maintenance, building rehabilitation, and repurposing, along with studying economic activities suitable for the location and the needs of the residents. This can be summarized as follows:

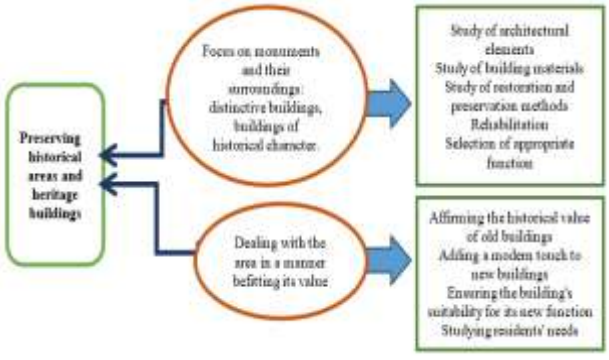


Figure 1 *illustrates the processes of preserving the source researcher*

• **Conservation:** This refers to a set of processes and procedures that help us preserve heritage buildings and areas. It includes (restoration, maintenance, reconstruction, rehabilitation, repurposing, revitalization, and upgrading).

- **Methods of Conservation Processes:** a- Preventive Conservation: Also called indirect conservation, this encompasses all preventive and proactive processes that delay the deterioration and disappearance of a historical building. It also includes indirect activities that do not physically or effectively affect the condition of the structure. Examples include documentation and registration procedures, periodic inspections and surveys of the structure, microclimate control, assessment of the effects of pollution and site vibrations, earthquake-resistant design measures, planning policies to enhance the building's heritage and economic value, and the exchange and management of structural and descriptive information among relevant parties, among others.

B- Maintenance: Maintenance is defined as all activities, whether technical (such as testing and measurements, replacement, adjustment, and repair) or administrative (such as planning, implementation, follow-up, and control during and after implementation). It is carried out at two levels: the first before damage occurs, and the second after. Reasons for carrying out maintenance operations:

Poor selection of materials used.

Poor construction of the building and lack of precision in executing work items.

The building's lifespan, which may have ended or be nearing its end.

Weather conditions, the impact of which varies depending on the building's location.

Misuse of the building, which is related to the degree of cohesion and density within it.

Changing the building's needs and utility due to a change in its original function.

The main objective of carrying out maintenance operations is to provide a safe and sound environment, free from any defects that may occur in buildings, and to ensure that all its structural and service elements operate efficiently.

C- Restoration: The process of reviving and preserving the building as it is, returning it to its original condition as it was when constructed. Or for a specific period prior to that, including, for example, the removal of extraneous elements and the replacement of worn-out pieces with new ones that are distinguished from their old counterparts. It also includes the policy of anastylosis, which is the reconstruction of the ruined structure by reassembling its scattered pieces (especially stone ones) and incorporating new materials only when necessary and based on genuine and credible historical evidence and documents [8].

• **Restoration Methods:**

1- Structural Restoration: This involves restoring the building's load-bearing structural elements, including injection and insulation of foundations, and reinforcement of walls and ceilings to prevent collapse. It also addresses problems arising from seepage and leakage, among other structural issues, ensuring the building's stability and balance. Materials compatible with the original materials should be used to prevent future damage.

2- Architectural Restoration: This focuses on rebuilding collapsed buildings, replacing deteriorated parts with modern materials similar in appearance, nature, and properties. It also involves completing missing elements to strengthen the building and load-bearing components such as ceilings and lintels, highlighting significant architectural features while preserving the original architectural style and ensuring a clear distinction between the old and new elements.

The restoration process should be carefully planned to avoid obscuring or altering the building's style.

3- Fine Restoration: This includes all work related to filling cracks and gaps, injecting fissures, stabilizing surface scales, treating wall reliefs, decorations, and ornaments, cleaning and fixing colors, assembling and strengthening stone blocks, extracting salts, restoring decorations, inscriptions, and paintings, and similar delicate work on buildings.



Figure 2 *illustrates fine restoration, including crack injection and the treatment of inscriptions and decorations.[8]*



Figure 3 *illustrates protection and its associated cleaning and repainting operations.[8]*

T- Protection: This includes all maintenance procedures and minor interventions that contribute to protecting the building and slowing the rate of its

current structural and functional deterioration. Examples include cleaning, repainting, removing vegetation attached to the structure, and controlling rodents and harmful insects.[8]

Th- Reconstruction: The process of rebuilding a historical element or building that has been destroyed or lost due to natural disasters or wars, using modern materials and based on authentic, documented evidence. It also includes the process of reconstructing a historical building and relocating it from its original site to another location to protect it from the dangers and threats posed by the surrounding natural and environmental factors. Currently, this term is used to describe the digital reconstruction of historical sites and heritage buildings through their re-enactment using modeling and 3D software to create virtual reality spaces and environments.Based on the above, the concept of sustainable conservation is no longer limited, as commonly understood, to archaeological sites and individual historical buildings. Rather, various conservation mechanisms are typically employed to protect and maintain all constructed buildings, whether historical, traditional, or modern. This process doesn't begin immediately after the project's completion and the commencement of its use, but rather from the initial planning stages. It involves employing preventative conservation measures, such as using Building Information Modeling (HBIM) and other technologies, and preparing for remedial conservation activities. These include maintenance procedures and periodic inspections to anticipate any future problems and to establish a timeline for necessary maintenance or other remedial interventions. The goal is to extend the physical and functional lifespan of the building. A building doesn't necessarily need to be of historical value to be preserved using the aforementioned methods. The aim is to protect economic resources, the urban fabric environmentally, and the cultural characteristics of the community, which usually necessitates adopting various sustainable conservation policies [9].However, green architecture remains one of the fields constantly vulnerable to being re-engaged in the very system it seeks to resist. Terms like "energy saving," "reuse," and "organic and local materials" dominate the prevailing definition of green buildings. Many contemporary green buildings, equipped with green roofs and greywater recycling systems, host lifestyles and production patterns similar to their non-green counterparts. This is all within the linear understanding of growth imposed by capitalist thinking, which grants the green seal legitimacy to the construction of entire cities and shields them from any accountability regarding the needs of their communities.

4- Reuse:

The objective of reusing a valuable building is to preserve it, ensure its ongoing maintenance, and improve the surrounding urban environment. It is considered the most suitable method for buildings economically, as it is not expensive as a new building, and it ensures the creation of an economic base on which it can rely for maintenance and preservation without conflicting with the historical, heritage and artistic values of the building, achieving both suitability to the visual character of the building, functional suitability and structural suitability[9].

5- Entities Responsible for and Funding the Preservation Process:

This is carried out by multiple entities, varying according to the specific preservation project. The primary responsibility lies with state representatives, acting as a supervisory body and overseeing the funding process, even if they are not the primary funders of the preservation project.

5.1 Beneficiaries and Stakeholders of Preservation Projects:

A building of historical value represents a profitable investment project by all measures, benefiting various stakeholders, a fact that has recently gained attention. This has led to increased interest in the building as an architectural, economic, and cultural asset, and a key resource for the state.

5.2 Types of Utilization of Valuable Buildings:

Valuable buildings are considered one of the most important primary tourism and cultural resources, and a significant economic resource upon which many developed countries rely. From this perspective, the idea of repurposing them as a type of investment has emerged, applicable to specific types of buildings such as castles, palaces, houses, administrative buildings, railway stations, and heritage villages. Some of these uses are outlined below:

a- Utilizing Buildings as Residential Spaces:

This is considered one of the best ways to preserve buildings, whether permanently by their owners or through investment by the private sector, in accordance with residential accommodation standards in hotels and other establishments. This allows for ongoing restoration and maintenance, ensuring the building remains in good condition.

b- Utilizing Buildings as National Museums:

Buildings of historical value are considered among the best museum sites for displaying artifacts or preserving various forms of folk heritage, including maps, coins, handicrafts, and antiquities.



Figure 4 *illustrates the reuse of the railway building for the Musée d'Orsay in France [10]*

C-Utilizing the building as a restaurant serving traditional cuisine:

The investor prepares the building for this function, aiming to offer local, traditional dishes that are compatible with the historical building, while ensuring its continued preservation through ongoing maintenance and conservation.

Utilizing the buildings and site as spaces for practicing traditional crafts: Most artisans working in traditional crafts work near these historical buildings and sites, giving their work and products a historical character that allows them to sell their products in these locations. This creates an integration between the craft and the place where the craft products are made.Utilizing the buildings as studios for visual arts: Many visual artists use these buildings as studios, in addition to using them to hold exhibitions to display their work inside the buildings or in the heritage corridors frequented by art enthusiasts and visitors. 6- Using the HBIM (Historic Building Information Modeling) System

Preparing models of valuable buildings: * This program is considered a modern application in dealing with valuable buildings in many developed countries, and while relatively new in Egypt, we suggest its use in conservation and reuse projects. It was utilized in this research for the following reasons:

The "Historic Building Information Modeling" system serves as an organizational tool that allows for the organization of information about a valuable building. It is structured in a way that contributes to documenting and preserving this information for future use. A range of different programs are used, and the outputs from these programs are organized and translated into an accurate architectural model that matches the original. This model is used to visualize the building's spaces after rehabilitation and reuse, thus reducing errors compared to traditional methods. It also helps in estimating quantities and various requirements for electrical, air conditioning, fire, water, drainage, security, internet, and information networks, as well as architectural materials. The new function serves to conserve energy and reduce carbon emissions.

It also facilitates the relationship between restoration project managers, designers, engineers, and contractors, creating a common language and a comprehensive, equitable collaborative strategy. This goes beyond mere software proficiency. The project is divided into several phases, and its implementation requires a fully integrated project team with expertise in relevant computer programs: (Photogrammetry, Point Clouds, TLS-Terrestrial Laser Scanning, Autodesk Software - Revit, CAD, SketchUp, Navisworks 3D Viewers, Design Builder, etc.)

These programs help in building accurate project models, calculating quantities, developing internal and external design alternatives, and documenting the building's current condition.

The research identified the steps for repurposing valuable buildings using modern technologies, as illustrated in Figure (5).

7. Reichstag, New German Parliament Building Project

The Reichstag building was the former parliament building of the German Reich. Construction began in 1894 and continued until 1933 when it was burned down. It served as the de facto parliament of the Nazi regime (1933-1945). In 1990, its name was changed to the Bundestag.[11]

It is a historical monument in Berlin, dating back to the reign of Kaiser Wilhelm I, who laid the foundation stone on June 9, 1884. It is said that the Kaiser needed three attempts to lay the foundation stone due to the breaking of the machine used. Construction was completed in 1894.

On November 9, 1918, MP Philipp Scheidmann made a statement from a window announcing the establishment of the Republic. On February 27, 1933, under mysterious circumstances that remain unexplained, the Reichstag building burned down, destroying the chamber and the dome. After being destroyed in World War II, the building was rebuilt between 1961 and 1971 in a simpler form, without the dome that had been removed in 1945, according to the plans of Paul Baumgarten. Following German reunification, the current German parliament (Bundestag) decided to use the building as its seat once again.

In June 1991, the German Bundestag decided to relocate the parliament and government to Berlin. To make the Reichstag building its headquarters in Berlin once more, and after launching an international architectural competition, a new parliamentary district was established on the bend formed by the Spree River in Berlin. The landmark became the redesigned Reichstag building, featuring a glass dome through which visitors can walk. Three new parliamentary buildings were constructed around the Reichstag.

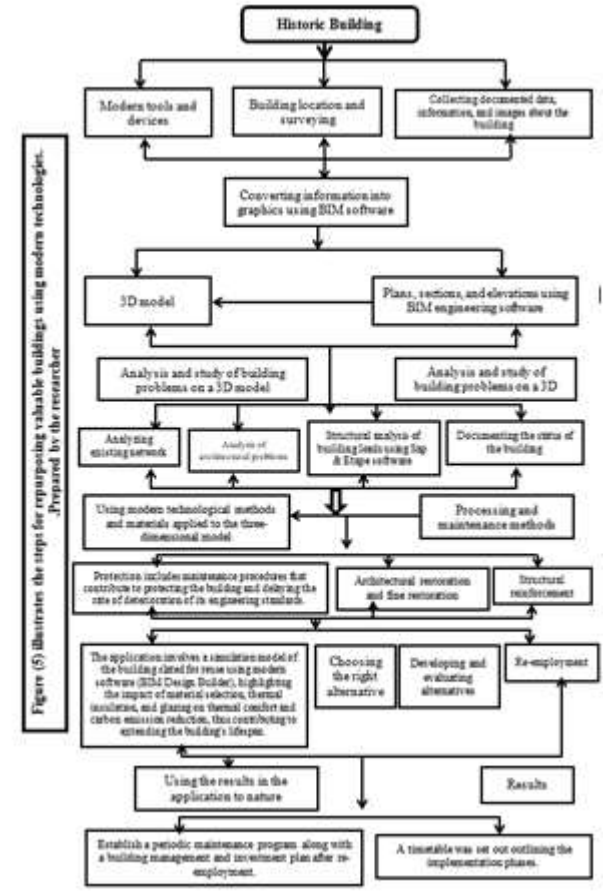




Figure 6 *illustrates the chronological development of the Reichstag building from its construction to its redevelopment.[12]*

7.1 The Objectives and Reasons for Intervention

 (Preserving Value) Preserving the aesthetic and historical values inherent in the building and reviving the symbol of democracy by addressing the causes of deterioration through all repair and restoration work.

 (Diversity in Integrating the Old and the New) in all development and construction work.

 (Sustainability through Green Architecture Principles) Using environmental compatibility and adaptation technologies and making it a model in the field of sustainable design.

 (Reusing the Building) Restoring the building to its original function as a parliament.

 (Community Participation) in the project after rehabilitation and reuse by making it a tourist attraction.

7.2 The Intervention and Treatment Phase

a- Preventing Deterioration: By conducting the necessary studies, including structural studies to determine the structural condition and measure structural safety before intervention, and ensuring its safety after intervention, as well as carrying out architectural surveys.

B- Preservation: This includes repair (reinforcement and restoration).

This is achieved through work to preserve the building's basic structural core, in addition to structural strengthening and the installation of necessary bracing to reinforce the old structure. It also includes necessary treatments to prevent deterioration and ensure the structural integrity of the old structure. Furthermore, periodic maintenance serves as a preventative measure to avoid any cracks or any direct or indirect impacts on the building's structural integrity.[13]

C- Providing Self-Maintenance for the Building and Updating Materials: This is done by maintaining the building's original function while adding new buildings with new materials that serve other functions that complement the original function, creating a comprehensive set of functions.[14]



Figure 7 *illustrates the reinforcement work for the building's safety.[15]*



Figure 8 *illustrates the modern materials used and the new buildings.[16]*

D- Restoration: This includes removing any alterations made to the building and restoring it to its original state.

Preserving the old graffiti on the walls by Soviet soldiers and its impact on the design, transforming it into a living museum of a period in German history.

E- Regeneration: Norman Foster relied more on solar energy in the design, as it generates more heat

than is needed. Electric generators in the building burn cottonseed oil, and heat absorption machines convert the wasted heat into cooling. Unwanted heat is stored in the summer and recovered in the winter as a free heat source. From here it is clear that this process is very effective, as the Restag is no longer a power generation station, but rather the power station for the new building complex. Natural ventilation was given priority in the design, and the roof structure formed an important part of the system. The transparency of the dome allows light to penetrate after it is controlled by a rotating roof that provides natural lighting to the main room without solar heat gain into the room [16].

H- Reuse:

 Reviving the Function with the Same Character: This is achieved by restoring the building's function as a headquarters and parliament, a voice of democracy, and recalling its original purpose in 1894.

Looking at the building's condition, we find that it was damaged by war and inadequate reconstruction attempts. Therefore, the building later incorporated elements of the original structure.

 Adaptation through Reuse

Modifying Spaces and Interior Extensions: The heights were utilized to create different levels, while redistributing interior spaces and preserving the facades and exterior courtyards.



Figure 9 *illustrates the internal corridors, spaces, and heights across different levels.[17]*

Integrated Reuse [17]:

Additions were made to new buildings with functions that complement and integrate with the original structure.

D- Reconstruction and Renovation:

The original character was restored, particularly the newly constructed dome. The old dome was square and Baroque in style, while the modern dome is transparent with a curved, enclosed line. Furthermore, the building presents a positive drama of contemporary German history through the remains of burned walls, as well as inscriptions and signatures left by Russian soldiers during World War II. Thus, history was transformed into a form of realistic decoration.[18]



Figure 10 *illustrates the dome's shape after reconstruction.[19]*

The above details of the intervention plan for the German Parliament building can be further illustrated in the table 1.

Table 1 *illustrates the intervention plan in the German Parliament building.*

Table (1) illustrates the intervention plan in the German Parliament building. Source: Researcher

PREVENTIVE CONSERVATION		INTRUSIVE CONSERVATION											
		CONSERVATION			RESTORATION	REHABILITATION			REUSE			RECONSTRUCTION
		REPAIR										
Prevention of Deterioration	Protection	Deterioration Prevention	Maintenance	Updating Materials	Renewal of building	Complete Restoration	Use of Techniques	Eco-Compatibility, Sustainability, & Green Architecture	Additions & Adaptations	Internal Functional Reorganization	Adaptation	Integrated Reuse	Complete Restoration of Original Character
											Internal Adaptation		
											Internal Extension		

8. Renwick Gallery Restoration Project

This National Historic Landmark was designed by architect James Renwick Jr. in 1858 and was the first building in the United States built specifically to be an art museum.[20]

Commissioned by William Corcoran and designed in 1858 by architect James Renwick Jr. also known for his design of St. Patrick's Cathedral in New York City—the Renwick Gallery, formerly known as the Corcoran Art Gallery, became the first purpose-built art gallery in the United States. Inspired by Napoleon III's renovations of the Louvre in Paris, Renwick incorporated architectural details that would become emblematic of the Second Empire style: pavilions, apse roofs, and double columns.

The gallery opened to the public after the end of the Civil War in 1874, but in 1899 it became the new home of the Federal Court of Claims. By the 1950s, the old Corcoran Gallery building was slated for demolition until First Lady Jacqueline Kennedy intervened in 1962.[21] A few years later, it was handed over to the Smithsonian, which renovated and reopened it in 1972 as the Renwick Gallery, a branch of the Smithsonian Museum of American Art dedicated to crafts and decorative arts, and the only art museum in America named after its architect.[21]



Figure 11 *shows the hall's appearance after the exterior work was completed in 1860.[22]*

8.1 Reasons for Intervention:

 Addressing the root causes of deterioration through replacement and renovation. This involves replacing and upgrading the building's components to achieve LEED-NC Silver rating, a 50% reduction in energy consumption, a 35% reduction in potable water consumption, and achieving an overall 50-year lifecycle before major renovations are required.[23]
 Functional Objective: Upgrading the building's components to support a range of innovative exhibition programs with additional electrical, technological, and structural capabilities. This approach should minimize the need for major alterations over a 50-year lifecycle and includes (a new elevator, replacement of old windows, addition of a new iron staircase in accordance with civil safety requirements, replacement of the ramp for people with disabilities, reconstruction of the main basement, stormwater drainage pipe work, stone restoration, and resurfacing).
• **Preserving the building's value** – an approach compatible with current building codes and energy efficiency standards, without requiring exemptions or altering the building's form, thus integrating the building into a sustainability framework.
• **This highlight other important aspects of the project**: utilizing modern technology to enhance the renovation process and increase building efficiency [23].

8.2 Buildings Analyzed: This phase was conducted through the following:

a. Preventing Deterioration:
Conducting historical impact studies and structural analysis to determine the condition of the foundations. Structural safety was assessed before intervention, and the infrastructure and systems were updated using the latest sustainable and energy-efficient technologies. The renovation also included restoring many of the building's historical details and installing new explosion-proof windows.[23]
The $30 million major renovation of the Renwick Gallery at the Smithsonian American Art Museum preserves and respects the historic character of the National Historic Landmark while modernizing the infrastructure with the latest sustainable and energy-efficient technologies.[23]
B. Protection: By registering it as a monument, its treatment is subject to regulations, laws, and charters to protect its value.
C. Preservation
1. Repair and Reinforcement:
This includes the necessary bracing and preservation of the building to achieve structural safety standards during the execution of the work and the preventive inspection procedures undertaken during construction, which include the following:



Figure 12 *illustrates - the external scaffolding and preventive inspection procedures undertaken during construction.[24]*

2. Material Replacement:

Description of the proposed work for the roofs:
Non-architectural roof areas will be replaced with similar materials to ensure the building envelope's continuous weather resistance. Window Replacement:
Description of Proposed Work: It is proposed to replace a total of 34 existing window units with new, high-performance windows. Aluminum-framed windows with steel reinforcement are selected due to their ability to provide blast protection, along with the required thermal performance, durability, and low maintenance.

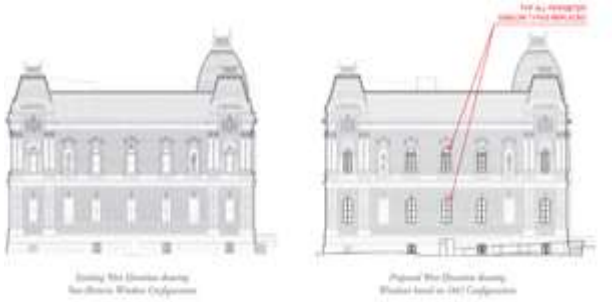


Figure 13 *illustrates the proposed window replacement [25]*

B- Restoration:
This phase was carried out through the following:
1. Restructuring the Original Building [26]:
More than 90 percent of the building's structure was reused, with meticulous pre-construction planning

using a high-resolution Building Information Model (BIM) of the existing structure.



Figure 14 *illustrates the restoration of two vaulted ceilings on the second floor, which were previously covered by flat roofs [26*]

C- Rehabilitation: This phase was carried out through: Revitalizing and Developing Functionality (Repair – Renovation – Additions – Modifications):
1. Repair: The rainwater drainage pipes (Qarqouri) require repair to address problems caused by frequent outages and to ensure proper separation between the sewage and rainwater systems.
2- Additions: This phase was completed through the following:
An elevator was added in a manner that does not detract from the historical character of the building, and an external iron staircase was added in accordance with safety code requirements.



Figure 15 *shows the elevator additions in the floor plan [27].*

Utilization of Advanced Technologies:
Targeted improvements to the window, roof, and lighting systems allowed for a reduction in the size of the HVAC systems.
The costs associated with the performance-enhancing measures (e.g., energy cost recovery and water savings) were analyzed.
Renovation: All pipe casings were color-coded for greater system visibility and maintenance. The air handling unit, comprising a set of six fans, was assembled in place over three weeks.[27]Pre-construction planning was meticulously executed using a high-resolution Building Information Model (BIM) of the existing structure.[26] Environmental Compliance and Green Architecture Principles:
The design team worked closely with enterprise-wide facility managers to install an HVAC condensate extraction system, one of the first such systems implemented across the group. This system enabled a 35 percent reduction in cooling tower water usage and a decrease in chemical water treatment requirements.[28]



Figure 16 *illustrates modern cooling systems that provide a 35 percent reduction in water consumption.[28]*

C- Reconstruction, which includes:

Restoring the original state:
Extensive research was conducted in archival materials to determine the composition of the historical windows. The existing windows, installed in the 1980s, are not historically accurate.

Table 2 *illustrates the intervention plan for the restoration of the Renwick Gallery.*

Table No. (2) illustrates the intervention plan for the restoration of the Renwick Gallery. Source: Researcher

PREVENTIVE CONSERVATION		INTRUSIVE CONSERVATION							
		Conservation		Restoration		Adaptive Reuse			Reconstruction
		Repair							
Prevention of Deterioration	Protection	Deterioration Prevention Maintenance	Maintenance	Removal of building additions	Original character restoration	Usage of modern techniques	Environmental compatibility & green architecture	Additions and adaptations	Complete Restoration

9- The Greater Cairo Library Project in Zamalek:
This palace, on which the library stands, is attributed to its owner, Princess Samiha, daughter of Sultan Hussein Kamel, the first Sultan of Egypt from 1914-1917, and granddaughter of Khedive Ismail.
In 1902, a Jewish grain merchant named Qattan built an elegant palace on the banks of the Nile in Zamalek, one of Cairo's most prestigious neighborhoods. Later, Princess Samiha Kamel, the middle daughter of Sultan Hussein Kamel, who ruled Egypt from 1914 to 1917, purchased it for 300 Egyptian pounds, a considerable sum at the time. She transformed it into a literary and artistic salon [29].Princess Samiha converted the palace into a

cultural salon for hosting seminars, artistic evenings, and musical performances. She lived in the palace until her death in 1984, leaving a will dedicating it to cultural service. The palace was renovated in 1992 and subsequently transformed into the Greater Cairo Library in January 1995. It was registered as an Islamic monument in 2011.

9.1 Reasons for Intervention:

• **Functional Objective:** Reuse of the Building: The Ministry of Culture decided to renovate the palace and convert it into a public library in 1991, adding spaces suitable for its function as a public library (structural review, new hydraulic elevator).

• **Addressing the Root Causes of Deterioration:** Restoring the building to its former glory, including (replacing old windows, restoring the iron staircase, restoring the main building's facades to reflect their history and value, including all decorations and cornices, adding bathrooms, restoring the stones, installing air conditioning, and adding drainage channels for rainwater). Preserving the building's value is an approach consistent with current building codes, recognizing it as a building of architectural and historical significance with numerous inherent values.

Sustainability is key to preserving the building and passing it on to future generations.

9.2 Intervention Plan: This phase involved the following:

a. Preventing Deterioration:

This phase was achieved through the following:

The palace on which this library is located was attributed to its owner, Princess Samiha, daughter of Sultan Hussein Kamel, the first Sultan of Egypt from 1914-1917, and granddaughter of Khedive Ismail. Renovation work on the palace continued from September 1992 until its inauguration on January 24, 1995 [30].

Historical studies of the monument and structural work were conducted to determine the condition of the foundations and assess structural integrity before intervention. The infrastructure and systems were upgraded using the latest sustainable and energy-efficient technologies. The renovation process also included the restoration of many of the building's historical details.

B. Protection:

By registering it as a historical site, its management falls under the regulations, laws, and charters designed to protect its value.

The palace was registered in 2011 as an Islamic monument [31].

C. Preservation:

This stage was achieved through the following:

1. Restoration and Reinforcement:

This involved implementing the necessary bracing and preservation measures for the building to ensure structural safety during the execution of work on the main hall in the basement, as well as injecting the basement walls and the building's foundations [32].



Figure 17 *illustrates the protective reinforcement work undertaken during the construction process. Source: (Salah Marzouk Sayed, master's Thesis, Faculty of Engineering, Department of Architecture, Helwan University, 2017)*

2. Material Replacement:

This stage was carried out through the following:

• Modern furniture elements were used, appropriate to the new function, to introduce a building air conditioning system and improve the efficiency of the spaces.[33]

• All existing facade openings were replaced with new window designs consisting of internal glass shutters and panes that harmonize with the building's architectural style and the exterior whitewash of the facades.

• The floors were treated with sound-absorbing materials, and carpeting was used in the main reading room. Dark blue carpeting was used to absorb any noise from the room. Parquet flooring was used in other rooms, and ceramic tiles in some spaces.[33]

• Modern fire alarm systems were installed.



Figure 18 *illustrates the use of modern fire alarm systems. Source: Researcher*



Figure 19 *shows the shape of the windows before modification. Source: (Salah Marzouk Sayed, master's Thesis, Faculty of Engineering, Department of Architecture, Helwan University, 2017)*



Figure 20 *shows the shape of the windows after modification of external shutters and glass windows that are consistent with the architectural style. Source (Researcher)*

B- Restoration, which included:

• The western ceiling of the exit room and the ceiling of the coloured indexing hall were restored, as well as the interior decorations.



Figure 21 *illustrates the exterior decorations after restoration.*

C- Rehabilitation:

This stage was carried out through the following:

Reviving and developing the function (restructuring the original building - repair - renovation - additions - modifications):

• **Restructuring the original building:** by removing any additions that had been made to the building, specifically the guard's room and the service room, which were built into the building's interior and do not belong to the palace's architectural style.

• Service rooms built into the building's interior and do not belong to the palace's architectural style.



Figure 22 *illustrates the added buildings and those removed to restore the building to its original state (Salah Marzouk Sayed, master's Thesis, Faculty of Engineering, Department of Architecture, Helwan University, 2017).*

Repairs: Repair of all structural roofs that could not bear the required live and dead loads, the main entrance staircase of the palace, and the restoration and repair of the service staircase using steel beams. Additions: An elevator was added in a manner that does not detract from the historical character of the building, and an external iron railing was added in accordance with safety code requirements.

Rainwater pipes were added to the repairs to address problems caused by frequent interruptions and to ensure proper separation between the sewage and rainwater drainage systems. An external pergola was also added to the roof. Utilizing modern, advanced technologies: This involved incorporating electromechanical works, including fire suppression systems, acoustics, surveillance cameras, air conditioning, and rainwater drainage.

H- Reconstruction and Reuse:

This phase was achieved through the following:

Looking at the building's previous condition, we find it was disfigured by time and neglect until the relevant authorities undertook reconstruction and restoration efforts. As a result, the building subsequently regained some of its original features.

Furthermore, haphazard structures on the rear facade were removed and replaced with modern elements that complement the building's architectural style.

I- **Reuse**: This phase was achieved through the following: The spaces within the old palace building

were repurposed, transforming it from a residential to a cultural space after the Ministry of Culture acquired it. This is considered a positive step in rehabilitating the building in terms of its functional value.

Table 3 *illustrates the intervention plan in the Cairo Library. Source: Researcher*

Table No. (3) illustrates the intervention plan in the Cairo Library. Source: Researcher



Table 4*shows a comparison between three intervention plans for the preservation of historical buildings*

Table No. (4) shows a comparison between three intervention plans for the preservation of historical buildings

Elements	Parliament Building	Renwick Museum	Cairo Library
Prevention of Deterioration	%100	%90	%90
Protection	%90	%90	%90
Maintenance	%90	%90	%90
Structural Reinforcement	%90	%90	%90
Analysis and Study of Existing Conditions	%90	%100	%90
Updating Materials	%90	%100	%90
Restoration of Original State	%75	%100	%100
Use of Modern Technology and Equipment	%90	%90	%0
Adjustments, Repairs, and Additions	%80	%90	%70
Environmental Compatibility and Green Building Principles	%100	%90	%0
Restoration of Original Character	%90	%90	%90

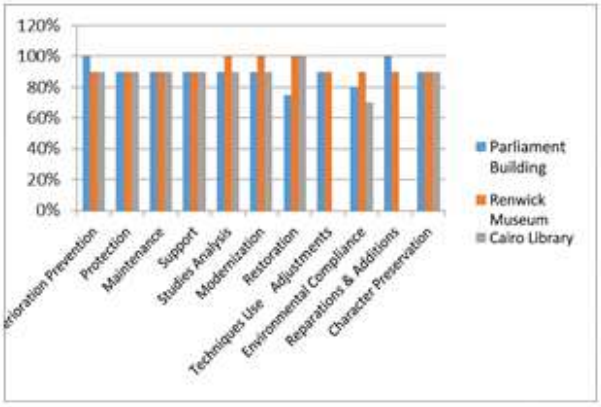


Figure 23 *illustrates the superiority of the second model in the comparison process because of its reliance on modern technologies and devices.*

10- Results:

1- By comparing the architectural treatments of the German Parliament building, the Rheinock Museum, and the Cairo Library, it was found that the German Parliament and the Rheinock Museum relied on modern technology and materials, resulting in a high degree of environmental compatibility with green building principles. This contrasts with the Cairo Library, which relied on primitive materials. This is illustrated in the comparison table (4) and Figure 23.

2- The use of the "Historical Information Modeling System" (HIMMS) as an organizational tool allows for the organization of information about a building of value. This is achieved by constructing a system that contributes to documenting and preserving this information for future use. A range of different software programs are used, and the outputs from these programs are organized, arranged, and translated into an accurate architectural model that matches the original. This model is used to visualize the building's spaces after rehabilitation and repurposing, thus reducing errors compared to traditional methods and aiding in quantity estimation. The various requirements in each of the following are considered: electrical, air conditioning, fire, water, drainage, security systems, internet and information networks, and architectural materials that serve the new function, all of which contribute to energy efficiency and reduced carbon emissions.

3- It is also used to organize the relationship between restoration project managers, designers, engineers, and contractors to create a common language and a comprehensive and equitable collaborative strategy, not just software proficiency. The project work is divided into several phases. Implementing this program requires a fully integrated project team experienced in relevant computer programs:
(Photogrammetry, Point Clouds, TLS-Terrestrial Laser Scanning, Autodesk Software-Revit, CAD, SketchUp, Navisworks 3D viewers, Design Builder, etc.)
These programs help in building accurate project models, calculating quantities, creating internal and external design alternatives, and documenting the building's current condition.

11- Recommendations:

1. Rehabilitating and reusing a heritage building is not just a preventative and maintenance process, but also an affirmation of cultural and historical identity through the preservation of its architectural and aesthetic elements. For the building.
2. Repurposing heritage buildings is one of the strategies for preserving the architectural and urban heritage of Arab cities, thus preserving their cultural identity. Furthermore, rationalizing energy consumption and reducing carbon dioxide emissions extends the lifespan of historical buildings, ensuring their continuity and preservation for future generations.
3. Reusing heritage buildings and reducing the energy required to operate them contributes to their

economic benefit while preserving their status as valuable heritage and historical buildings.

4. The model for linking the old urban fabric with the new one must be sound. This should encompass all physical, social, and economic aspects to ensure that the revitalization and development process is integrated, not partial.

5. Modern programs should be utilized by developing a plan to reduce energy consumption and carbon emissions, thus contributing to the economic benefit of reuse.

Author Statements:

- **Ethical approval:** The conducted research is not related to either human or animal use.
- **Conflict of interest:** The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper
- **Acknowledgement:**. The author extends his sincere thanks and appreciation to Atrium Quality Contractors (Talaat Moustafa Group), being part of this team, for their moral support and constant encouragement."
- **Author contributions:** The authors declare that they have equal right on this paper.
- **Funding information:** The authors declare that there is no funding to be acknowledged.
- **Data availability statement:** The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Reference :

[1] Valerio Travi (2001), Advanced Technologies: Building in the Computer Age (The Information Technology Revolution in Architecture), Brikhauser, Publishers for Architecture, Basel.

[2] Caffrey, R. (1990), Building Performance and Occupant Productivity - Personal Environments - A New Building Focus. Hong Kong: Fourth World Congress - Tell Buildings: 2000 and Beyond.

[3] https://greenfue.com

[4]https://hqassim.com/wirting-blog/historical-buildings-restoration

[5]https://natural-resources.canada.ca/sites/www.nrcan.gc.ca/files/oee/buildings/pdf/RetrofitGuidelines-e.pdf

[6] Abu Leila, Mohamed Mohamed Shawky (2008), Towards a Sustainable Methodology for Documenting Architectural Heritage in Egypt - A Case Study of Mansoura City - Unpublished Doctoral Dissertation - Department Architecture – Faculty of Engineering – Mansoura University – p. 49.

[7] Abu Leila, Mohamed Mohamed Shawky (2018) Intelligence Techniques in Architecture: Towards Investing in Heritage Buildings – The Fourteenth International Al-Azhar Conference on Engineering, Architecture, and Technology, Volume 1, Issue 1.

[8] http://www.bonah.org

[9] Heba Allah Farouk Abu El-Fadl, "Repurposing Old Buildings," Master's Thesis, Department of Architecture, Faculty of Fine Arts, Alexandria University, 1998.

[10] https://en.parisinfo.com/paris-museum-monument

[11] https://ar.wikipedia.org/wiki/%D9%85%D8%A8%D9%86%D9%89_%D8%A7%D9%84%D8%B1%D8%A7%D9%8A%D8%AE%D8%B3%D8%AA%D8%A7%D8%BA

[12] https://hmn.wiki/ar/Reichstag_building

[13] Othman, Sarah Ahmed Mohamed, Experiences in Reusing Buildings of Value in the Arab Republic of Egypt (Documentation and Analysis), Master's Thesis, Department of Architecture, Faculty of Engineering, Cairo University, 2008.

[14] Ahmed, Asamer Zakaria, "Technical Standards for Repurposing Buildings as Museums According to the Concept of Value: A Computer Application," Master's Thesis, Department of Architecture, Faculty of Engineering, Cairo University 2008.

[15]https://areq.net/m/%D9%85%D8%A8%D9%86%D9%89_%D8%A7%D9%84%D8%B1%D8%A7%D9%8A%D8%AE%D8%B3%D8%AA%D8%A7%D8%BA.html

[16]chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.btg-bestellservice.de/pdf/80140700.pdf

[17]chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.btg-bestellservice.de/pdf/80140700.pdf German Bundestag Public Relations Department Berlin

[18] Dr. Fouad Khadra, "Architectural Element or Integrated Project," Tishreen University Journal for Research and Studies, Engineering Sciences Series, Volume 33, Issue 5, 2011.

[19] https://www.syr-res.com/article/9134.html

[20] https://www.si.edu/museums/renwick-gallery

[21] https://savingplaces.org/stories/the-renwick-renewed-inside-the-gallerys-renovation

[22] https://americanart.si.edu/about/history/renwick-architecture

[23] https://www.wbdg.org/additional-resources/case-studies/renwick-gallery

[24]https://www.wbdg.org/additional-resources/case-studies/renwick-gallery

[25]www.ncpc.gov/files/Renwick_Gallery_Renovation_American_Art_Museum_Submission_Materials_7518_Sep2013.pdf

[26]https://www.aia.org/showcases/185096-the-renwick-gallery-of-the-smithsonian-amer

[27]https://www.wbdg.org/additional-resources/case-studies/renwick-gallery
[28]https://www.aia.org/showcases/185096-the-renwick-gallery-of-the-smithsonian-amer
[29] http://egyptian1.com/archives/8562
[30] Shady M. El-Zeiny "Method to Assess Historic Palaces Rehabilitation Projects" INTERNATIONAL JOURNAL OF ARCHITECTURAL ENGINEERING AND URBAN RESEARCH VOLUME 3, ISSUE 1, 2020
[30] http://www.moc.gov.eg/
[31] https://darelhilal.com/News/742456.aspx
[32] Salah Marzouk Sayed "The Intervention Limit Scale as an Approach to Preserving Buildings of Value" Master's Thesis, Faculty of Engineering, Department of Architecture, Helwan University, 2017.
[31] El-Zeiny M. El-Zeiny INTERNATIONAL JOURNAL OF ARCHITECTURAL ENGINEERING AND URBAN RESEARCH VOLUME 3, ISSUE 1 2020