Smart Architecture as an approach to Enhancing Efficiency of Heritage Buildings

Sherif Nagy Mohamed Abd-Elaziz [a] — *Assistant Teacher at Architectural Engineering Department, Higher technological Institute*

Fatma Mostafa El-Nekhely [b] — *Associate Professor at Architectural Engineering Department, Faculty of Engineering, Helwan university*

Mohamed Ahmed Reyad [c] — *Associate Professor at Architectural Engineering Department, Faculty of Engineering, Helwan university*

ABSTRACT

The key issue of this current study is related to heritage buildings, highlighting the significance of reuse and upgrading their historical buildings through applications of smart technologies to enhance the efficiency of historical buildings. This aims to draw attention to their cultural and historical values and promote cultural awareness among future generations. Additionally, to achieve the maximum use and saving energy as Challenges facing the world in general and Egypt in particular. As Egypt contains many heritage buildings that must be preserved due to their cultural, civilizational, and historical value, which is a national wealth, treasure and an important economic resource for Egypt.

The paper aims to establish a comprehensive vision and strategy for the development of heritage buildings using smart architecture tools and mechanisms. It emphasizes the importance and concept of smart architecture in achieving economic and environmental efficiency, as well as increasing energy efficiency in heritage buildings. The paper also discusses methods of reducing non-renewable energy consumption through adaptive technology compatible with smart architecture.

Keywords: Heritage Buildings; Smart Architecture; Smart Heritage Building

1 Introduction

With current technology breakthroughs, smart technologies have become an unavoidable issue. The application of these technologies in architecture, particularly in heritage buildings, is critical for maintaining them while increasing energy efficiency. This is especially crucial for Egypt, which has numerous culturally and historically significant buildings that are national treasures and economic assets.

The research focuses on a proposal for the concept of preserving heritage and historical buildings using smart architecture, as well as their impact on increasing the efficiency of these buildings, as a way of drawing attention to those heritage, cultural, and historical values, and as an encouragement to spread culture and awareness among a large base of future generations about the history and significance of these heritage buildings. And, to increase the efficiency of these buildings so that they perform optimally in their functional capacities.

2 CONTEXTUAL FRAMEWORK

3.1 Problem and research context

Inadequate use of technical and technological capabilities in the preservation of heritage buildings by repurposing them to fit their place through the incorporation of smart architectural, a modern technology feature that is both environmentally and architecturally appropriate.

3.2 Research hypothesis

The implementation of smart architecture applications has a significant and positive impact on making the building more liveable and effective, contributing to economic and environmental efficiency. This is a procedure of protecting heritage buildings.

The research anticipates that taking this matter into account contributes to the optimal exploitation of the building economically and environmentally, through the re-use of its elements and spaces in a way that maximizes benefit, provided that the capabilities and techniques of intelligence in architecture are achieved with the building's environmental and architectural conditions.

3.3 Research objectives.

A general and comprehensive vision and plan by creating a thorough theoretical foundation for the advancement of historic structures using the instruments and processes of smart architecture.

The research also deals with trying to find the following sub-goals.

- Recognizing smart architecture's impact on building efficiency, both economically and environmentally.
- Improving energy efficiency in heritage buildings and decreasing non-renewable energy usage with adaptive technology compatible with smart architecture.

3.4 Methodology

The research methodology used in this study employs both inductive and analytical approaches to investigate the principles and techniques for dealing with heritage buildings, as well as the criteria that influence the use of smart architectural tools and mechanisms, and their impact on improving the efficiency of heritage buildings.

3 HERITAGE BUILDINGS

4.1. Definition of heritage and valuable buildings

It is buildings that contain many aesthetic values, homogeneous visual formations, architectural expression, and achieve communication and integration between their components and substructures, giving them a distinct architectural character; however, they have not yet been recorded or documented, making them vulnerable to many problems that may lead to demolition and removal.

They can also be defined as buildings of cultural and historical significance, endowed with a set of heritage lexicon, visual and moral features, symbolism, and civilizational and religious traditions.

The Egyptian law defines it as registered buildings under Law No. 117 of 1983, which are subject to rigorous protection under international laws and treaties. They frequently pique the world's curiosity and are among the top tourist attractions.[1]

The worth of buildings can be interpreted through two main sources: the first deals with the tangible source (the building), which may provide a direct source of income, and the second, which is intangible and symbolizes the cultural and civilizational dimensions.

[1] Hawass, Suheir Zaki - **Urban preservation and revival of heritage areas in Egypt, as an application of the Aga Khan Foundation project in Al-Darb Al-Ahmar** - Cairo - August 2013

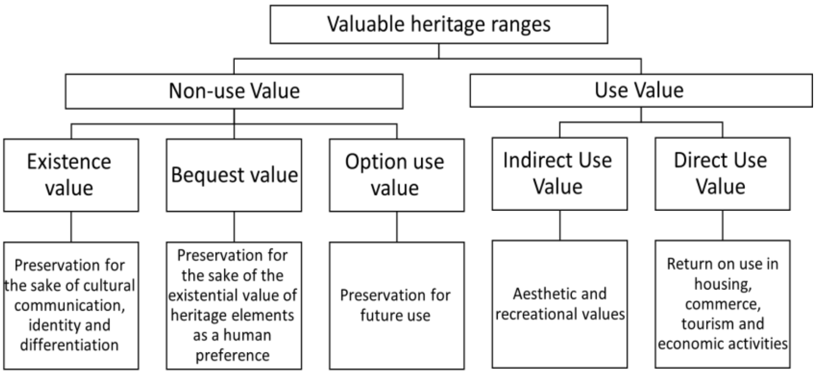

Figure 1. Classification of values derived from heritage sites
Reference: Researcher

4.2. Policies for the Development of Heritage Buildings

Historical and heritage buildings are those that have historical significance, as well as distinct architectural and urban characteristics. They are registered under Egyptian Law No. 119 of 2008, which requires that they be safeguarded, preserved, and their urban identity be maintained. Additionally, efforts should be made to redevelop them if they are in bad condition.

Historical and heritage buildings are frequently viewed as antiquated, archaic, and unfit for the modern period. Many current tasks and needs are thought to be beyond their capabilities. They also face various challenges, including the coexistence of old and priceless structures with new ones, as well as uncontrolled urban expansion and informal housing. Furthermore, they are prone to the degrading impacts of social, economic, and population changes, resulting in urban deterioration in general.

And there have been several ideas and approaches to improving the efficiency of heritage structures. These policies can be split into three categories:

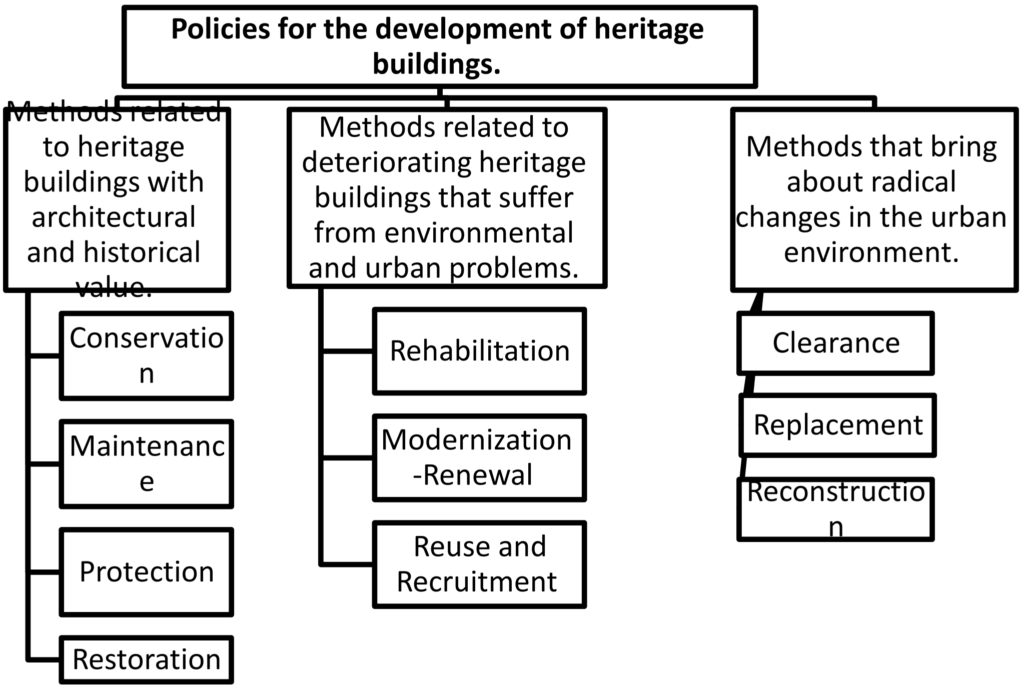

Figure 3. Policies for the development of heritage buildings
Reference: Researcher

4.2.1. Methods related to heritage buildings with architectural and historical value

- Conservation refers to the least amount of intervention needed to limit structural change and alteration. It can be preventative or corrective.
- Maintenance aims to extend the structural and architectural lifespan of buildings by preventative, corrective, and emergency maintenance.[2]
- Protection involves preserving historical or valuable places and preventing structural damage.
- Restoration is a specialist procedure that preserves and showcases the aesthetic value of ancient structures while respecting original materials and records.

4.2.2. Methods related to deteriorated heritage buildings.

- Rehabilitation is a scientific approach that restores the functionality of decrepit buildings and regions, allowing society to profit from their value. This is done via the best usage of existing resources, with the objective of elevating and preserving their cultural identity.[3]
- Upgrading and renovations are specialized operations for old buildings to improve efficiency and align with functional performance levels. Heritage buildings may require comprehensive changes and redesign of interior spaces.
- Reuse and repurposing entails bringing important structures into use, either with the same original purpose but with additions and renovations tailored to the times, or altogether changing their use. It is classified as reuse, adapted reuse, integrated reuse, and conversion and transformation efforts.[4]

4.2.3. Methods for bringing about drastic changes in the urban environment.

- Removal refers to places that are not worth repairing or remodeling due to their deteriorating state and safety risks.
- Replacement is a moderate removal program that minimizes damage to the area's social and economic fabric.
- Reconstruction: The process of restructuring and rebuilding architectural work after disintegration. This happens during wars and natural catastrophes, when valuable elements of a structure fall and need to be rebuilt.

4 SMART ARCHITECTURE

4-1 Smart buildings classification

The historical progression of smart architecture from its beginnings in the 1980s to the present may be split into three time periods as follows:

Automated Buildings 1981-1985	Responsive Buildings 1986-1991	Effective Buildings 1992 till now
• Building management relies on pre-programmed mechanical systems and controls. • Smart control systems like lighting, heating, and air	• Effectively adjust to changing environmental conditions and user demands.	• Automated systems provide dynamic reactivity and use AI and analytics to improve performance.

[2] Hawass, Suheir Zaki - **Urban preservation and revival of heritage areas in Egypt: An application to the Aga Khan Foundation's project in Al-Darb Al-Ahmar** - book - Aga Khan Cultural Services Company - 2013 - p. 40

[3] Nabil, Mohamed Ahmed - **The effect of intervention patterns on the imprint of time - antique marks - and its role in the interaction between the archaeological object and the user** - Master's thesis - Faculty of Engineering - Cairo University - 2015

[4] Mısırlısoy, Damla - Günçe, Kağan - **ADAPTIVE REUSE STRATEGIES FOR HERITAGE BUILDINGS: A HOLISTIC APPROACH** - Sustainable Cities and Society - journal- Vol 26 - Elsevier Science- Amsterdam-Netherlands - OCT 2016

conditioning improve efficiency. • Limited ability to adapt to changing conditions and user requirements.	• Respond dynamically to user and environmental demands. • Enhance flexibility in building systems management.	• Improved sustainability by reducing energy and natural resource usage. • Promotes recycling and sustainable construction practices.

Table (1) Historical division of smart architecture since its emergence in the 1980s
Reference :Himanen,M- The Intelligence of Intelligent Building – VTT Publications - 2003

4-2 Design Requirements in the smart building

A smart building is one that can make choices or adapt to changes for its users, as well as one that delivers current and environmentally friendly technological systems (lighting, air conditioning, heating, security, fire alarm, etc.)[5]

Smart building may be regarded as a system consisting of a number of subsystems that communicate with one another utilizing various components, and information and communication technology provides an assistance for interactions between various subsystems.[6]

Where smart technology advancement and its application methods touch all parts of life, and this impact is evident in the field of architecture through building materials, management and operation systems, smart building elements arose, depicted in

- Smart systems building management.
- Smart materials and their characteristics
- Smart envelopes that represent the link between the world outside and the interior space of the building

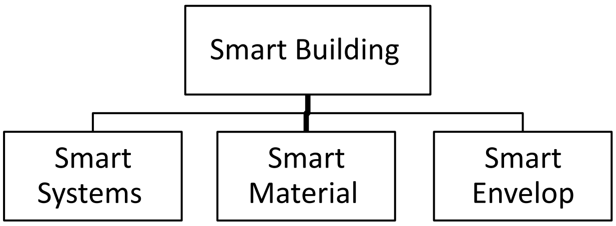

Figure 4. Smart building components
Reference: Researcher

4−2−1 Smart Systems

The processing that occurs in smart buildings requires smart systems to form a system capable of achieving the building's performance requirements, and systems are defined as "the physical part represented by control buttons and communication channels such as wires and input means, among others, which play an important role in building economics and how it interacts with them."

[5] Rafiq, Alaa Salem - **Mechanisms for applying smart architecture requirements to administrative buildings, the Palestinian Retirement Authority building - a case study** - Master's thesis - Department of Architecture - Faculty of Engineering - Islamic University of Gaza - 2017

[6] Smart Building Functional Architecture – Finseny deliverable 4.3 report – v10 – 2013 p10

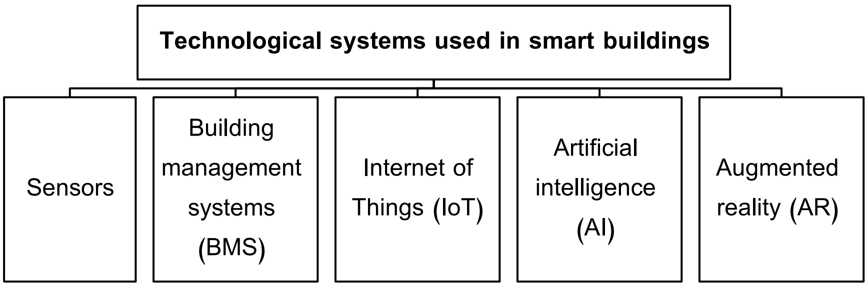

Figure 5. Technological systems used in smart buildings.
Reference: Researcher

Sensors may be used to monitor a wide range of building variables, including temperature, humidity, air quality, and occupancy. This data may be utilized to optimize building system efficiency and guarantee occupant safety.

Building management systems (BMS) gather and analyze sensor data, which is then used to regulate and monitor HVAC, lighting, and other systems. They may be used to automate things like shutting off lights in vacant rooms or regulating the thermostat in response to occupancy and weather conditions.

The Internet of Things (IoT) is a network of physical devices connected to the Internet. These devices may gather and communicate information about a building's surroundings and functions. This information may be utilized to increase the efficiency of building systems and get insight into their functioning.

Artificial intelligence (AI) may be used to evaluate data from sensors and BMS systems in order to detect trends and patterns. AI may also be used to automate repetitive operations like maintenance scheduling and security alarm response.

Augmented Reality (AR) is a technology that superimposes a computer-generated image over a user's perspective of the actual world, resulting in a composite vision. Augmented reality can be used to smart buildings. Augmented reality may be used to guide users around a structure, particularly in big or complicated buildings.

4–2–2 Smart Materials

Materials can perceive and respond to their environment in a needed and specified manner, allowing them to instantly change their physical qualities (such as form, color, and density). In reaction to either natural or artificial stimuli. In certain circumstances, they take corrective steps and attain their aim through the integration of many aspects. Sensors, processors, and computers.[7]

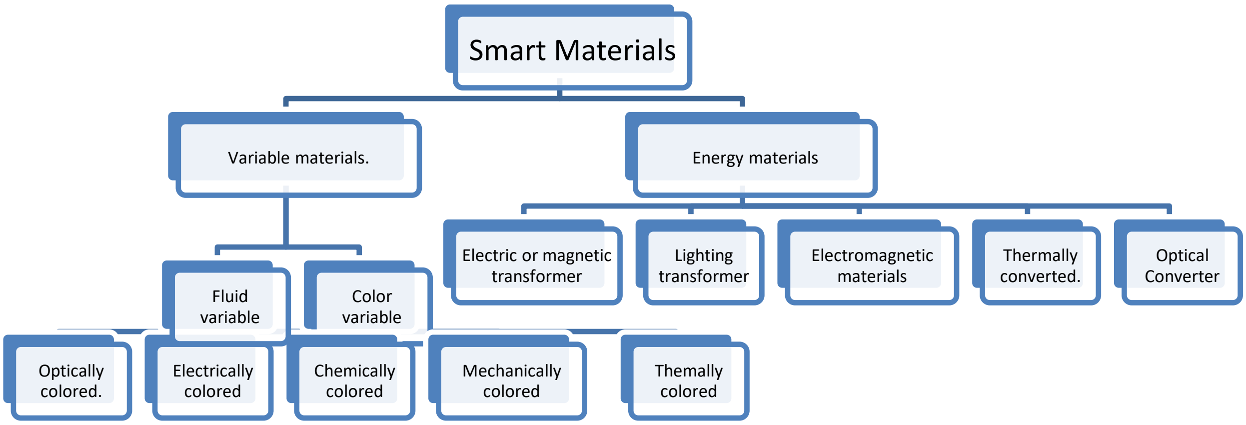

Figure 6. Types of Smart Materials.
Reference: Addington, M & Schodeck, D. -" Smart Materials and Technologies for the architecture and design professions

[7] Addington, M & Schodeck, D. -" Smart Materials and Technologies for the architecture and design professions "- Architecture Press- an imprint of Elsevier- Linacre House- Jordan Hill- Oxford- UK-2004

4−2−3 Smart Envelope

Is a collection of construction features that work together to protect the structure from external weather conditions. It conducts actions that may be changed individually or cumulatively to adapt to predicted environmental changes and maintain comfort while using minimum energy. The envelope elements can also adapt automatically by self-regulating modifications to their own configuration.[8]

The smart envelope varies from the standard façade in that it incorporates changeable devices that provide control over the adaptation of the building envelope to operate as a climate mediator in this manner.

The smart envelope is the building's exterior envelope that employs sensors, motors, and software to monitor and regulate its ambient conditions. This helps to increase energy efficiency, sustainability, and comfort in buildings.

The intelligence scale is assessed by measuring the amount of self-control, since the building envelope has two levels of adaptive behavior: micro and macro.

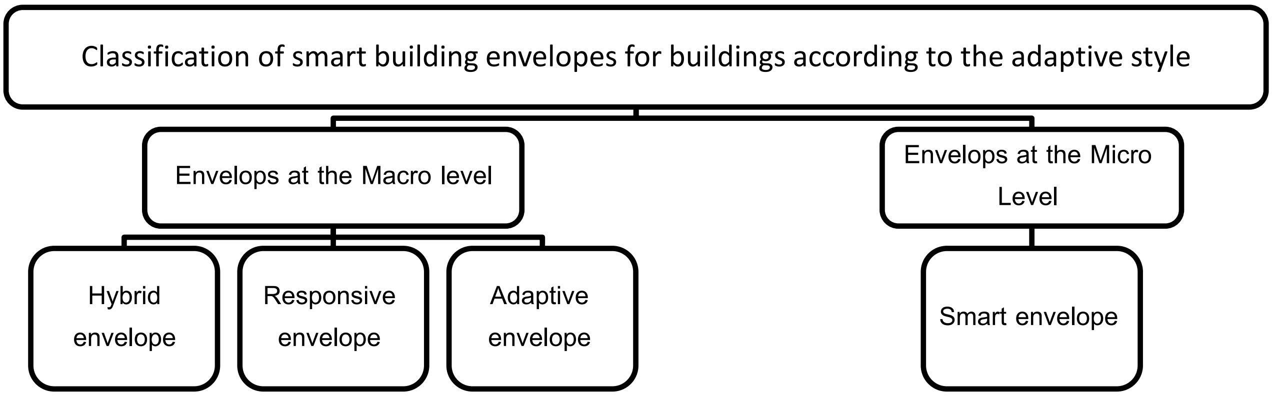

Figure 7. Classification of smart building envelopes for buildings according to the adaptive style.

Reference: Loonen, R, C, G, M, et, al, Climate adaptive building shells: state-of-the-art and future challenges

5 ANALYTICAL APPROACH

5-1 Renwick Gallery of the Smithsonian American Art Museum

5−1−1 Historical Overview

The project was included in the National Register of Historic Places in 1961 and received LEED Silver certification in 2017. The building is located in Washington near the White House and was built in 1859 by architect James Renwick. Restoration of the building began in 1967-1972, and the building was reopened as the Renwick Gallery in 1972. The building suffered damage during the earthquake that occurred in Washington in 2011, leading to the closure of the exhibition. Fundraising for renovation began with significant support in 2013, and the architectural renovation was carried out by Westlake Reed Leskosky and it was reopened in 2015.[9]

Figure 13. Renwick Gallery of the Smithsonian American Art Museum
Reference: www.si.edu
Accessed Apr 2023

[8] Wigginton,Michael, et al., Intelligent skins, First Edition, Reed Educational and Professional Publishing Ltd, USA, (2002)

[9] Echols, Tucker "David Rubenstein Gives $5.4M for Renwick Gallery Renovation". Washington Business Journal. June, 2014.

5−1−2 Architectural Description

It consists of a basement, ground floor, and first floor where the lower floor has been renovated to improve employee offices and workshops, providing a separate entrance and clear separation of features from non-public employee areas and mechanical spaces. The first floor includes temporary exhibitions, and the second floor includes the most famous salon in Washington.[10]

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5−1−3 Smart Techniques used in the Museum.

Smart Security System: Renwick Art Gallery utilizes an advanced set of security and surveillance systems to safeguard high-value artworks, including:

- **High-Quality security Cameras**: HD Security cameras and high-quality CCTV cameras cover every corner of the museum.
- **Motion Sensor System**: Motion and vibration sensors monitor any suspicious activity around the art pieces.
- **Face recognition**: To identify any suspicious individuals.
- **Self-locking doors**: Security doors with self-locking mechanisms and a central locking system that operates in emergencies.
- **Monitoring rooms**: The building is equipped with security control rooms equipped with surveillance screens and alarm systems.

Smart Lighting: The exhibition utilizes smart lighting systems to enhance and magnificence of the art pieces, including the following:

- **LED lighting systems**: Energy-efficient with color temperature and brightness suitable for accurate color display.
- **The Zumtobel Lighting system** is a computer controlled by sensors, and based on the information sent by these sensors, the appropriate lighting system is determined.
- **Lighting control systems**: Ability to control lighting and adjust brightness and contrast levels for each panel.
- **Light sensors**: To measure the level of light falling on the panels and adjust it automatically.
- **Smart dimming systems**: For windows to reduce the impact of external lighting on the visibility of the panels.

Figure 15. LED Lighting System
Reference: *www.aiaohio.secure−platform.com*
Accessed Apr 2023

These systems have reduced the building's lighting energy consumption by 70% even with an increase in the number of visitors.

[10] Yardley, William. " Renwick Gallery of the Smithsonian American Art Museum" Washington Post. 2013

Building Management System (BMS)

The project team utilized various measures to reduce risks by employing Building Information Modeling (BIM) and laser scanning to create a 2D model of all building systems for precise coordination. The building is equipped with a Building Management System (BMS) located in the basement. It controls and monitors building systems efficiently using Neural Networks, capable of creating a network of artificial cells that mimic the functions and biological processes of human brain cells. The building management system relies on information through the Nervous System, consisting of two networks of cables connected to a set of sensors. The building is enhanced with numerous BMS monitors that read inputs and send outputs to control various building systems, including this system.[11]

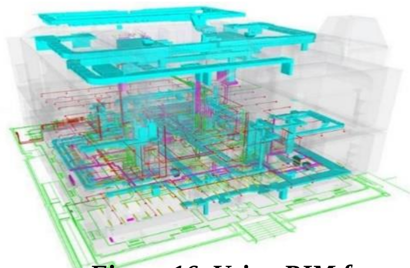

Figure 16. Using BIM for coordination
Reference: www.wbdg.org
Accessed Apr 2023

- **Sensors**: measure and monitor temperature, humidity, and light levels.
- **Ventilation and air conditioning systems**: Maintain optimal preservation standards for oil paintings.
- **Smart lighting systems**: Programmable and remotely controllable
- **Motion and vibration sensors**: Alert in case of any unusual activity.
- **Office Automation**: The building features a Local Operating Network (LON) and a European Installation Bus (ELB) for electrical installations.[12]
- **Response to changes in internal and external environments**: The building has limited responsiveness through all building control systems (lighting, ventilation, heating, cooling) and their integration, responding according to programmed functions.[13]
- **Occupants' control**: Building occupants are provided with control panels on computer screens, allowing them to control heating, cooling, and lighting in designated areas.[14]

Figure 16. Exhibition halls before and after renovation
Reference: www.wbdg.org
Accessed Apr 2023

Visitor Interaction Techniques: Renwick Gallery has implemented a variety of innovative interactive techniques to engage visitors and enhance their experience, including:

- **Virtual Enhancement**: Building systems have been enhanced to support a range of innovative museum display programs, utilizing interactive technologies such as augmented reality and virtual reality to provide visitors with a great experience by creating simulations of different cultures and integrating them into the real environment.[15]
- **Interactive Touch Screens**: Interactive touch screens have been placed in front of the paintings, allowing visitors to access additional information about the artist and

[11] Renwick Gallery Of The Smithsonian American Art Museum Retrieved from https://www.wbdg.org/additional-resources/case-studies/renwick-gallery
[12] Echols, Tucker "David Rubenstein Gives $5.4M for Renwick Gallery Renovation". Washington Business Journal. June, 2014.
[13] Boyle, Katherine. "Renwick modeled it after the Louvre's Tuileries addition". Washington Post. 2013
[14] Boyle, Katherine. "Renwick modeled it after the Louvre's Tuileries addition". Washington Post. 2013
[15] Renwick Gallery Of The Smithsonian American Art Museum Retrieved from https://www.wbdg.org/additional-resources/case-studies/renwick-gallery

the painting.

- `**Smart Tablets**: Visitors carry these tablets to receive detailed information about each painting in multiple languages.

Figure 17. Virtual Reality Techniques
Reference: www.washingtonian.com
Accessed Apr 2023

Environmental Compliance and Sustainability:

Environmental Compatibility and Sustainability: Environmental efficiency is achieved through the integration of natural and artificial lighting, where exhibition lighting has been renewed with energy-saving LED bulbs, utilizing the Zumtobel Lighting system. Thermal environmental efficiency is ensured by enhancing the building with many sensors to measure temperature, relative humidity, pressure differentials, and carbon monoxide levels in the air. The project team has documented all low-emission material credits within the framework of the LEED For New Construction program and utilized ASHRAE Standard as a reference for assessing thermal comfort in the indoor environment.[16]

The use of renewable energy sources relies on solar energy to provide natural lighting for the building and to conserve energy by using a responsive industrial lighting system.

The implementation of smart technologies in the building led to achieving LEED Silver certification. The building operates according to the EUI standard, with an approximate consumption of 100 kilobytes per year, representing a 50% reduction compared to its state in 2012. This was achieved by reusing over 90% of the building structure, reducing lighting energy for display areas by 80%, and decreasing HVAC consumption by 35%.

5−1−4 Analysis of intelligent systems used in buildings.

	sensors	Building management systems (BMS)	Internet of Things (IoT)	Artificial intelligence (AI)	Augmented reality (AR)
Renwick Gallery of the Smithsonian American Art Museum	• sensors for wind speed and direction • sensors for monitor external and internal temperature and humidity • sensors for building occupancy • sensors for lighting intensity	• Building Management System (BMS) controls and monitors building systems efficiently.	• (Local Operating Network - LON) • (European Intstallation Bus ELB) • Wireless communication systems	• Limited response from all building control systems (lighting, ventilation, heating, cooling) where it automatically makes decisions based on information from sensors	• Using Building Information Modeling (BIM) and laser scanning to create a two-dimensional model of all building systems for accurate coordination of building systems. • Using Augmented Reality and Virtual Reality technology to provide visitors with a good experience by creating simulations of

[16] Boyle, Katherine. "Renwick modeled it after the Louvre's Tuileries addition". Washington Post. 2013

	sensors	Building management systems (BMS)	Internet of Things (IoT)	Artificial intelligenc e (AI)	Augmented reality (AR)
	and density				different cultures and integrating them into the real environment.

Table (2) Analysis of intelligent systems used in buildings
Reference: Researcher

6 Practical Approach

The analytical descriptive approach was used, in which the study subject is described, its data analyzed, and the relationship between its components and the opinions expressed about it are examined.

The analytical descriptive approach is defined as "the approach that seeks to describe contemporary or current phenomena or events. It is a form of organized analysis and interpretation to describe a phenomenon or problem, and it provides data about specific characteristics. It requires knowledge of the study participants, the phenomena we study, and the times we use to collect the data." Two main sources of information were used:

- Primary sources: To address the analytical aspects of the study subject, the researcher collected primary data through a questionnaire as the main tool for the study, specifically designed for this purpose, with individuals closely related to the study subject.
- Secondary sources: To process the theoretical framework of the study, the researcher turned to secondary data sources, including relevant Arabic and foreign books and references, as well as journals, articles, reports, previous research, and studies that addressed the study subject, along with research and reading.

6-1 Study Community and sample.

Based on the study problem and its objectives, the target community consists of all architectural and urban engineers in Egypt. The researcher used a survey method, distributing 105 surveys randomly to architectural and urban engineers in Egypt, obtaining 100 surveys with a retrieval rate of 95.2% to determine the importance and impact of each element of smart architecture, which was inferred from the analytical study of the methods of dealing with and enhancing the efficiency of heritage buildings within the tools and mechanisms of smart architecture.

6-2 Statistical processors used in the study.

The questionnaire was transcribed and analyzed using the Statistical Package for the Social Sciences (SPSS). The study involved:

- Calculating frequencies and percentages to describe the study sample.

- Calculating the meaning and relative mean.
- Cronbach's Alpha test to assess the questionnaire item consistency.
- T-Test on a single sample to determine if the response average reached a moderate level of agreement.

6-3 Analysis of survey results

T-Test for item "importance of using smart technologies in heritage buildings in Egypt"

No.	Mean	Average	Standard Deviation	T-Value	Significance Level	Agreement
1	Building management systems	4.31	0.631	20.768	0.00	Very high
2	Visitor interaction technologies (augmented/virtual reality)	4.27	0.930	13.649	0.00	Very high
3	Security and surveillance systems	4.25	0.702	17.813	0.00	Very high
4	Smart lighting systems	3.98	0.876	11.188	0.00	high
average		4.202	0.462	25.978	0.000	Very high

Table (3) T-Test for using smart technologies in heritage buildings in Egypt

Reference: Author from SPSS outputs

The mean is (4.20), and the relative mean is (84.4%). The test value is (15.85), and the probability value (.Sig) is (0.00). Therefore, the dimension "Assessment of the importance of using both smart technologies in heritage buildings in Egypt" is statistically significant.

T-Test for item "strategies to improve security and surveillance systems in heritage buildings in Egypt."

No.	Mean	Average	Standard Deviation	T-Value	Significance Level	Agreement
1	Fire alarm system	4.46	0.658	22.195	0.00	Very high
2	Risk management system	4.25	0.702	17.813	0.00	Very high
3	advanced surveillance cameras	4.25	0.744	16.809	0.00	Very high
4	Security control rooms	4.01	0.785	12.868	0.00	high
5	motion and vibration sensors	3.81	0.720	11.243	0.00	high
6	Smart data analysis	3.74	0.939	7.883	0.00	high
7	Self-locking security doors	3.69	0.940	7.344	0.00	high
8	Smart facial recognition technologies	3.33	0.877	3.764	0.00	high

average	3.9425	0.7956 2	12.48 9	0.00	high

Table (4) T-Test strategies for security and surveillance systems in heritage buildings
Reference: Author from SPSS outputs

The mean is (3.94), and the relative mean is (78.85%). The test value is (17.06), and the probability value (.Sig) is (0.00). Therefore, the dimension "Assessment of the most effective strategies to improve security and surveillance systems for heritage buildings in Egypt" is statistically significant.

T-Test for item "strategies to improve smart lighting in heritage buildings in Egypt."

No.	Mean	Average	Standard Deviation	T-Value	Significance Level	Agreement
1	Lighting direction	4.28	0.668	19.16 5	0.00	Very high
2	Energy-efficient LED lighting systems	3.98	0.876	11.18 8	0.00	high
3	Optical sensors	3.89	0.815	10.91 8	0.00	high
4	Centralized lighting control	3.89	0.852	10.45 1	0.00	high
5	Smart dimming systems for windows	3.56	1.057	5.297	0.00	high
average		3.9200	0.8536	11.40 3	0.00	high

Table (5) T-Test strategies for smart lighting in heritage buildings
Reference: Author from SPSS outputs

The mean is (3.92), and the relative mean is (78.40%). The test value is (13.927), and the probability value (.Sig) is (0.00). Therefore, the dimension "Assessment of the most effective strategies to improve smart lighting systems for heritage buildings in Egypt" is statistically significant.

T-Test for item "strategies to improve BMS in heritage buildings in Egypt."

No.	Mean	Average	Standard Deviation	T-Value	Significance Level	Agreement
1	Building Management System (BMS)	4.25	0.744	16.80 9	0.00	Very high
2	Environmental monitoring	4.13	0.849	13.31 4	0.00	high
3	temperature and humidity Sensors	4.01	0.959	10.53 5	0.00	high
4	Energy management	4.01	0.785	12.86 8	0.00	high
5	Structural monitoring	3.98	1.005	9.753	0.00	high
6	lighting sensors	3.80	0.921	8.685	0.00	high
7	Load management	3.74	1.031	7.177	0.00	high

8	Data monitoring and analysis	3.74	0.799	9.259	0.00	high
9	Heating and cooling control system	3.62	1.023	6.062	0.00	high
10	Motion and vibration sensors	3.52	0.822	6.323	0.00	high
average		3.8800	0.63341	13.893	0.00	high

Table (6) T-Test strategies for using BMS in heritage buildings
Reference: Author from SPSS outputs

The mean is (3.88), and the relative mean is (77.60%). The test value is (13.89), and the probability value (.Sig) is (0.00). Therefore, the dimension "Assessment of the most effective strategies to improve building management systems for heritage buildings in Egypt" is statistically significant.

T-Test for item "strategies to improve Visitor interaction technologies in heritage buildings in Egypt."

No.	Mean	Average	Standard Deviation	T-Value	Significance Level	Agreement
1	Interactive screens	4.16	0.896	12.950	0.00	high
2	Quick Response (QR Code)	4.10	0.759	14.497	0.00	high
3	Digital and virtual tours	4.07	0.782	13.686	0.00	high
4	Mobile applications	4.07	0.700	15.286	0.00	high
5	Augmented reality	4.07	0.820	13.054	0.00	high
6	Interactive presentations	4.01	0.823	12.278	0.00	high
7	Audio guidance	3.99	0.804	12.192	0.00	high
8	Virtual reality	3.98	0.943	10.397	0.00	high
average		4.0550	0.8158	13.0425	0.00	high

Table (7) T-Test strategies for Visitor interaction technologies in heritage buildings
Reference: Author from SPSS outputs

The mean is (4.05), and the relative mean is (81.10%). The test value is (15.905), and the probability value (.Sig) is (0.00). Therefore, the dimension "Assessment of the most effective strategies to improve visitor interaction technologies for heritage buildings in Egypt" is statistically significant at a significance.

T-Test for item "strategies to improve Sustainability and Energy Efficiency in heritage buildings in Egypt."

No.	Mean	Average	Standard	T-Value	Significance Level	Agreement

			Deviation			
1	Eco-friendly materials	4.28	0.866	14.789	0.00	high
2	insulating materials	4.07	1.018	10.515	0.00	high
3	solar energy	4.01	0.823	12.278	0.00	high
4	Installation of high-efficiency windows	3.80	1.101	7.266	0.00	high
5	Improving heating/cooling systems	3.65	0.857	7.583	0.00	high
6	Use of recyclable materials	3.59	1.055	5.592	0.00	high
average		3.9000	0.9533	9.6705	0.00	high

Table (8) T-Test strategies for Sustainability and Energy Efficiency in heritage buildings
Reference: Author from SPSS outputs

The mean is (3.90), and the relative mean is (78%). The test value is (11.966), and the probability value (.Sig) is (0.00). Therefore, the dimension "Assessment of the most effective strategies to improve sustainability and energy efficiency for heritage buildings in Egypt" is statistically significant.

T-Test for item " evaluation of community cooperation and participation in heritage buildings in Egypt."

No.	Mean	Average	Standard Deviation	T-Value	Significance Level	Agreement
1	importance of achieving cooperation between architects, technology experts, and historians in projects aimed at enhancing the efficiency of heritage buildings	4.49	0.559	26.631	0.00	high
2	importance of involving the local community in the processes of enhancing the efficiency of heritage buildings	4.04	0.764	13.606	0.00	high
3	enhancing the efficiency of heritage buildings by introducing smart architecture will affect changing the function of the heritage building	3.31	0.971	3.192	0.00	high
4	involving investors in funding the enhancement	3.37	0.950	3.896	0.00	high

	of heritage buildings will impact changing the function of the heritage building					
average		**3.8025**	**0.53924**	**14.882**	**0.00**	**high**

Table (8) T-Test for the evaluation of community cooperation and participation in heritage buildings in Egypt

Reference: Author from SPSS outputs

The mean is (3.80), and the relative mean is (76.05%). The test value is (14.88), and the probability value (.Sig) is (0.00). Therefore, the dimension "evaluation of community cooperation and participation in heritage buildings in Egypt" is statistically significant.

7 Conclusion:

In the previous study, the research yielded various results regarding the application of artificial intelligence in architecture to enhance the efficiency of heritage buildings. The research paper provided an overview of heritage buildings, including concepts, definitions, value, classification, and the strategies to develop. Additionally, it explored the utilization of smart technologies in architecture, analyzing smart systems, smart materials, and smart envelopes. The study also examined regional and global experiences in using intelligent building technologies to improve the efficiency of heritage buildings. It proposed the establishment of scientific foundations to effectively implement intelligent technologies and achieve economic and environmental benefits, specifically in heritage preservation processes.

The research identified the following:

- Smart technologies have become indispensable due to significant technological advancements in the latter half of the 21st century.
- Using smart technologies in buildings enables easy control and management, leading to energy savings, optimized building utilization, and resource conservation.
- Smart technologies and smartphone utilization present opportunities for increased investment in heritage buildings.
- Numerous methods can be devised, customized, and put into practice when incorporating smart technologies in both the broader realm of architecture and the specific area of heritage conservation.
- The adoption of smart technologies has minimized the disparities among countries in their utilization, as it merely hinges on having the necessary information infrastructure. Access to a plethora of applications for diverse technologies is facilitated through smartphones.

8 Recommendations:

The research offers the following recommendations:

- Enhancing interest in the application of smart technologies in Egypt, particularly in the field of architecture.
- Developing codes that relate to enhancing the efficiency of heritage buildings through smart architectural tools and mechanisms.
- Facilitating collaboration and support from the Egyptian Ministry of Communication,

specialized technology agencies, and relevant organizations involved in heritage preservation to establish a comprehensive support system for enhancing the efficiency of heritage buildings and maximizing its benefits.

- Promoting awareness about smart studies as a new design tool in architecture.
- Leveraging the expertise of foreign technology companies and organizations, particularly in advanced countries, to build upon existing progress.
- Creating informative websites to promote the concept of enhancing the efficiency of heritage buildings within the framework of smart architecture.
- Involving research centers and specialists from various fields to gather opinions and conduct specialized studies aimed at improving the efficiency of heritage buildings.

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