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Methodology for Raising Efficiency of Heritage Buildings Through of Smart Architecture

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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

Smart technologies have become an unavoidable issue given the current technological advancements. The use of these technologies in architecture, especially in heritage buildings, is crucial for preserving them and maximizing energy efficiency. This is particularly important for Egypt, which is home to numerous culturally and historically significant buildings that are a national treasure and economic asset.

The research deals with a proposal for the concept of preserving heritage and historical buildings using intelligence techniques in architecture and their impact on raising the efficiency of these buildings, and as a kind 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 importance of these heritage buildings. And, to reach to raise the efficiency of these buildings so that they are highly efficient in their functional performance.

2 CONTEXTUAL FRAMEWORK

2.1 Problem and research context

Shortcoming in leveraging technical and technological capabilities in the preservation of heritage buildings by repurposing them to suit their space through the integration of smart architectural, a modern technological element that is environmentally and architecturally compatible.

2.2 Research hypothesis

The use of smart architecture applications has an important and positive impact on making the building live and effective, thus contributing to achieving efficiency in terms of the economic and environmental dimension. This is in the processes of preserving heritage buildings.

The research expects that taking into consideration this matter contributes to the optimal exploitation of the building economically and environmentally, through the re-use of its elements and spaces in a way that achieves maximum benefit from it, provided that the capabilities and techniques of intelligence in architecture are achieved with the environmental and architectural conditions of the building.

2.3 Research objectives

A general and comprehensive vision and strategy by developing a comprehensive theoretical framework for the development of heritage buildings within the tools and mechanisms of smart architecture.

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

- Realizing the importance and concept of smart architecture and its role in achieving the economic and environmental efficiency of buildings
- Increasing energy efficiency in heritage buildings and methods of reducing non-renewable energy consumption through adaptive technology compatible with smart architecture.

2.4 Methodology

The research methodology adopted for this study relies on both inductive and analytical approaches to explore the principles and techniques of dealing with heritage buildings, as well as the criteria that influence the utilization of smart architectural tools and mechanisms, and their impact on enhancing the efficiency of heritage buildings.

3 HERITAGE BUILDINGS

3.1. 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, but they have not been recorded or documented yet, which makes them vulnerable to many problems that may reach the point of demolition and removal.[1]

They can be defined in another way as buildings with cultural and historical value, enriched with a set of heritage vocabulary, visual and moral features, symbolism, and civilizational and religious cultures.

The Egyptian law defines it as registered buildings according to Law No. 117 of 1983, which enjoy strict protection as stipulated by international laws and treaties. They are often of interest to the world and are among the most important tourist attractions.[2]

The value of buildings can be understood through two main sources: the first deals with the tangible source (the building) which may be a direct source of income, in addition to the second source which is intangible and represents the cultural and civilizational dimensions.

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[1] Mohi El-Din, Ismail, Suleiman, Asaad Ali - **Geographic Information Systems (GIS) technology as an effective tool for preserving and developing historical and valuable areas. Case study: Cairo City** - Eleventh Al-Azhar International Engineering Conference - December 22-23, 2010

[2] 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

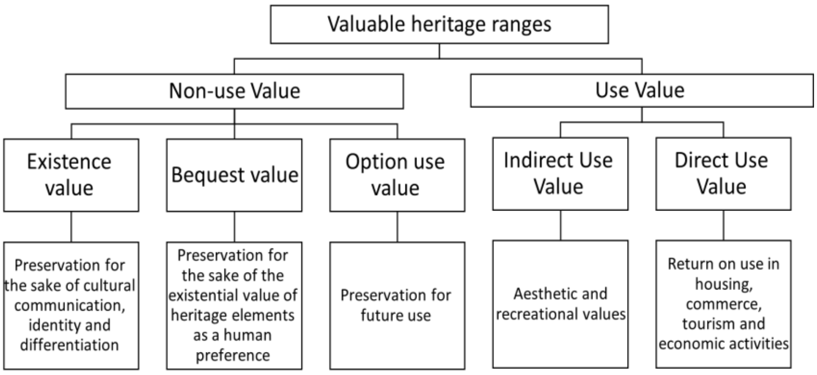

Figure 1. Classification of values derived from heritage sites

Reference: Researcher

3.2. Heritage Buildings Classification

There have been many attempts to classify and define the different values of heritage buildings, and through these attempts, there has been a significant evolution in defining and classifying different values. These values include antiquity, rarity, and distinguished art. The criteria for determining the value of these areas varied from one place to another. The following are some of the approaches used to determine the value of buildings and areas.

Gorden Cullen classification[3]:

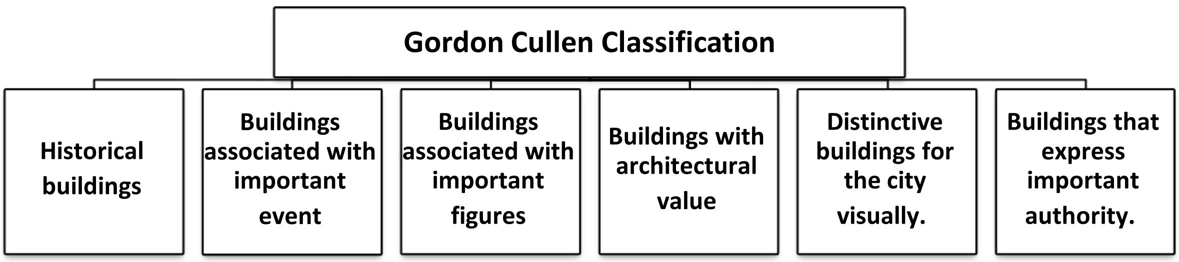

Figure 2. Classification of Gordon Cullen for heritage buildings

Reference: Gordon Cullen - The concise townscape

Historical buildings

They are represented by ancient buildings from past eras, which are considered a historical record of a society, and they are rich in a range of heritage vocabulary, characteristics, visual and symbolic meanings, cultural civilizations, and the heritage of human and religious experience.

[3] Cullen, Gordon - **The concise townscape**- Van Nostrand Reihnold Company- New York-1961

Buildings associated with important events.

These are the buildings that are associated with a certain event that left its impact on society, either at the level of the urban environment of the building or at the national level, and the value of these buildings increases with the increasing importance of the event they are associated with.

Buildings associated with important figures.

These are the buildings that were occupied by public figures in society, whether in the past or still occupied by them in the present, and the value of these buildings increases with the increasing importance of the figures associated with them, such as the house of Nahas Pasha, Baron's Palace, Ahmed Shawqi's house in Giza, and the house of the late President Anwar Sadat in Giza.[4]

Buildings with architectural value

It is the value that is represented in the physical entity contained in those buildings, whether they are architecturally distinguished, aesthetic, or structural, and it is represented in the external form of the buildings that were designed by a famous architect. This value can be perceived through the buildings undergoing architectural analysis to perceive the hidden aesthetic and design dimensions within them.

Distinctive buildings for the city visually.

They include buildings that are distinguished by color, size, architectural design, or their location in the surrounding urban fabric as a visual focal point. These are buildings that are easily distinguishable within the city and through them, a visual image with a unique character can be formed. Such as the distinctive dome of Cairo University.

Buildings that express important authority.

These are buildings whose value and importance are related to their function and their importance increases with the importance of the authority they hold, such as the legislative, executive, or judicial authority. The fundamental value of these buildings is symbolic and increases with the increase in the power of the vacant authority, such as the Supreme Court building.[5]

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[4] The National Organization for Urban Coordination - **Foundations and standards for cultural coordination of buildings and areas of heritage and of distinguished value** - approved by the Supreme Council for Urban Planning and Development in accordance with Law No. 119 of 2008 and its executive regulations, Chapter Two, Article (75) - p. 14

[5] Abdel Aziz, Lubna - **Upgrading valuable heritage areas** - Master's thesis - Faculty of Engineering - Cairo University - 2001

3.3. Policies for the Development of Heritage Buildings

Historical and heritage buildings are originally buildings with historical authenticity, distinctive architectural and urban character. They are registered according to the Egyptian Law No. 119 of 2008, which stipulates that they should be protected, preserved, and their urban character should be maintained. Additionally, efforts should be made to redevelop them if they are in a deteriorated condition.

Historical and heritage buildings are often perceived as old, backward, and unsuitable for the current era. It is believed that they are unable to accommodate many modern functions and requirements. They also face various challenges, including the mixing of historical and valuable buildings with modern ones on one hand, and unregulated urban growth and informal housing on the other hand. Moreover, they are subject to the deteriorating effects of social, economic, and population changes, leading to urban decay in general.[6]

And there have been multiple perspectives and directions in the approach and method of enhancing the efficiency of heritage buildings. And those policies can be divided into three groups:

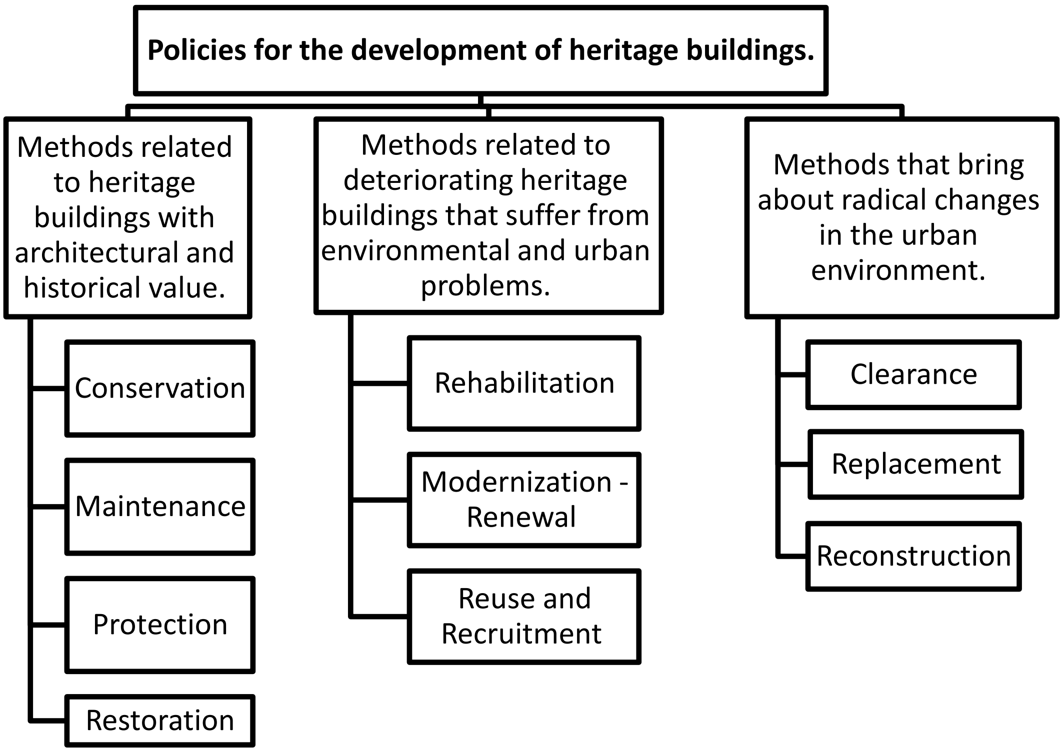

Figure 3. Policies for the development of heritage buildings

Reference: Researcher

[6] 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. 28

3.1.1 Methods related to heritage buildings with architectural and historical value

- Conservation: the minimum level of required intervention to reduce the extent of change and modification to the structure, divided into preventive conservation and remedial conservation.
- Maintenance: aimed at prolonging the assumed lifespan of buildings structurally and architecturally, divided into preventive maintenance, corrective maintenance, and emergency maintenance.[7]
- Protection: the beginning of direct dealing with historical areas or areas of value in order to keep them in their current state and prevent structural deterioration.[8]
- Restoration: a specialized process aimed at preserving and showcasing the aesthetic value of the archaeological structure, based on respecting the original material and reliable documents.

3.1.2 Methods related to deteriorated heritage buildings.

- Rehabilitation: It is a scientific method that arises from the society's need to benefit from valuable areas by injecting vital and functional capacities that restore the usefulness of dilapidated buildings and areas, leading to the continuous development of valuable areas. This is achieved through optimal utilization of available resources and aims to elevate and preserve their cultural character.[9]
- Upgrading and renovation works: These are generally specialized operations for old buildings used in functions that require it, in order to align with the required functional performance level, improve efficiency, and for heritage buildings, upgrading works involve comprehensive changes and redesign of the building's parts and interior spaces.
- Reuse and repurposing: It involves putting valuable buildings into use either with the same original function but after addition and renovation according to the requirements of the era, or by completely changing the function. It is divided into reuse, adapted reuse, integrated reuse, and conversion and transformation works.[10]

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[7] 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

[8] Al-Zahrani, Abdul Nasser bin Abdul Rahman - Urban Heritage Management - book - Saudi Society for Archaeological Studies - 2012 - p. 112

[9] 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

[10] 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

3.1.3 Methods that bring about radical changes in the urban environment.

- Removal: It is done for areas that are of no value and are in poor condition, with no benefit from repairing or renovating them as most of them are dilapidated and pose a danger in their existence.
- Replacement: It is considered a moderate form of removal policy, which can avoid the damage caused by removal to the social and economic structure of the area.
- Reconstruction: It is the process of reshaping and rebuilding architectural work when it is disintegrated. This occurs in cases of wars and natural disasters, and it is done when parts of the building with value collapse, necessitating its reconstruction.

4 SMART ARCHITECTURE

4.1 Definition of the smart building and its characteristics

The idea of the smart building emerged to support communication between the building systems, including air conditioning, ventilation, security and safety systems and other systems, with the aim of meeting the needs of building users and increasing productive efficiency and the return on investment of the building.

4.2 The emergence and appearance of smart buildings

The term "Intelligent Building" emerged in the United States in 1980, where at that time it referred to buildings that used remote communication systems and building management systems. The development of smart buildings at that time was associated with information technology (IT).

With the progress and development of computer hardware, and the spread of small computers. It began to benefit from this modern technology in building control systems. In the mid-1980s, and due to the large increase in the use of computers in workplaces. Control systems focused on lighting, heating, cooling systems to create a suitable environment for individuals. In the early 1990s, most problems related to information technology were solved, leading to rapid progress in the construction of smart buildings, which occurred in the mid-1990s.[11]

4.3 Smart buildings classification

The historical evolution of smart architecture can be divided since its emergence in the 1980s until now into three time periods as follows:

[11] Santamouris , M - Environmental Design Of Urban Buildings An Integrated Approach- Earth Scan London UK P 67 - 2006

Automated Buildings 1981-1985	Responsive Buildings 1986-1991	Effective Buildings 1992 till now
• Depend on pre-programmed mechanical systems and controls to manage the building. • Smart control systems such as lighting, heating, and air conditioning control systems are used to increase efficiency. • Lacks flexibility in responding to conditions and user needs.	• adapt to environmental changes and user needs effectively. • Interact and dynamically respond to the needs of its users and the surrounding environment. • Provide greater flexibility in building systems management.	• Automated systems integrate with dynamic responsiveness. • They employ artificial intelligence and analytics to enhance performance. • Designed to be sustainable and reduce energy and natural resource consumption. • Encourages recycling and the use of sustainable materials in construction.

Table (1) Historical division of smart architecture since its emergence in the 1980s

Reference :Himanen,M- The Intelligence of Intelligent Building – VTT Publications - 2003

4.4 Design Requirements in the smart building

Smart building is the building that has the ability to make decisions or respond to changes for the user, as it is the building that provides modern and environmentally friendly technology systems (lighting - air conditioning - heating - security - fire alarm - etc.)[12]

Smart building can be considered as a system consisting of a number of subsystems that interact with each other using various components, and information and communication technology is an aid for interactions between various subsystems.[13]

Where smart technical progress and its implementation mechanisms affect all aspects of life, and this impact is observed in the field of architecture through building materials, management and operation systems, smart building elements emerged represented in

- The smart systems through which the building is managed.
- Smart materials and their characteristics
- Smart envelopes that represent the link between the world outside and the interior space of the building

[12] 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

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

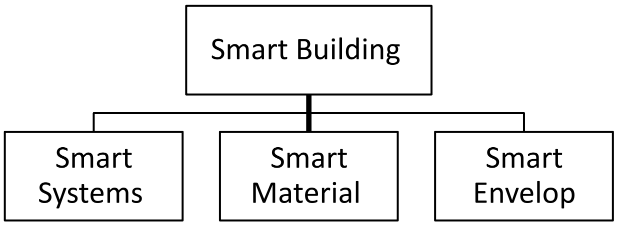

Figure 4. Smart building components

Reference: Researcher

4.4.1 Smart Systems

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

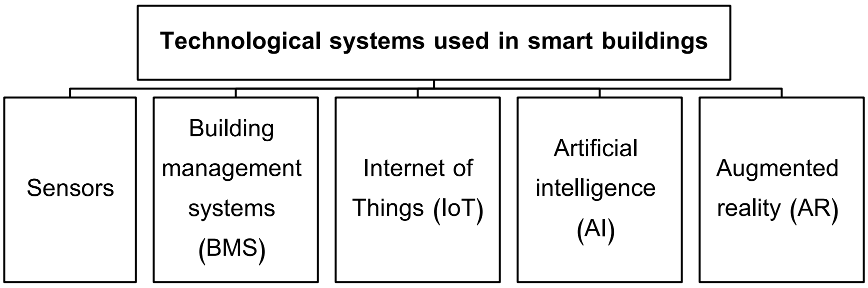

Figure 5. Technological systems used in smart buildings.

Reference: Researcher

Sensors: can be used to monitor a variety of conditions in a building, such as temperature, humidity, air quality, and occupancy. This data can be used to improve the efficiency of building systems and to ensure the safety of occupants.

Building Management Systems (BMS): Building management systems collect and analyze data from sensors and use it to control and monitor HVAC, lighting, and other systems. They can be used to automate tasks, such as turning off lights in unoccupied rooms or adjusting the thermostat based on occupancy and weather conditions.

Internet of Things (IoT): IoT refers to the network of physical devices connected to the Internet. These devices can be used to collect and transmit data about a building's environment and operations. This data can be used to improve the efficiency of building systems and provide insights into their performance.

Artificial Intelligence (AI): AI can be used to analyze data from sensors and BMS systems to identify trends and patterns. AI can also be used to automate tasks, such as scheduling maintenance and responding to security alerts.

Augmented Reality (AR): A technology that superimposes a computer-generated image over a user's view of the real world, thus providing a composite view. Augmented reality can be used in smart buildings. Augmented reality can be used to provide guidance to users inside the building, especially in large or complex buildings.

4.4.2 *Smart Materials*

Materials have the ability to sense and react to their surroundings, in a required and predetermined manner, so that they can instantaneously change their physical properties (such as shape, color and density). in response to natural or artificial stimuli. In some cases, they take corrective actions and achieve this goal through integration between different elements. Incorporated into these documents, such as: sensors, processors and computers.[14]

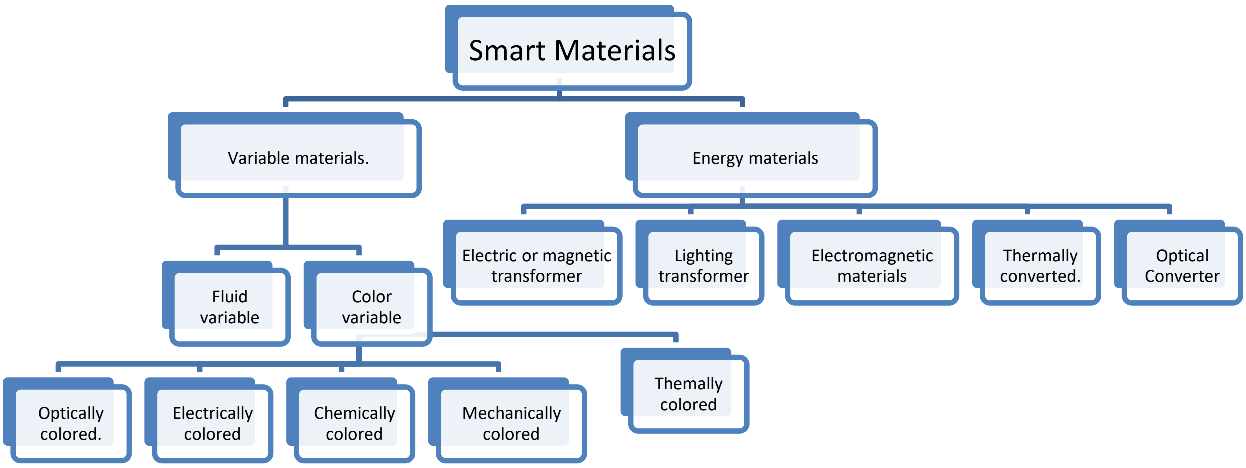

Figure 6. Types of Smart Materials.

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

4.4.3 *Smart Envelope*

Is a composition of building elements that work to protect the building from external weather conditions. It performs functions that can be individually or cumulatively adjusted to respond to expected environmental changes in order to maintain comfort with minimal energy usage. The

[14] 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

envelope elements also have the ability to adapt automatically through self-regulating adjustments to their own configuration.[15]

The smart envelope differs from the traditional facade in that it includes variable devices that allow control over the adaptation of the building envelope to act as a mediator of the climate in this way.

The smart envelope can be defined as the external envelope of the building that uses sensors, motors, and software to monitor and control the environmental conditions of the building. This works to improve energy efficiency, sustainability, and comfort in buildings.

The intelligence scale is evaluated by determining the level of self-control, as there are two levels of adaptive behavior in the building envelope: the micro level and the macro level.

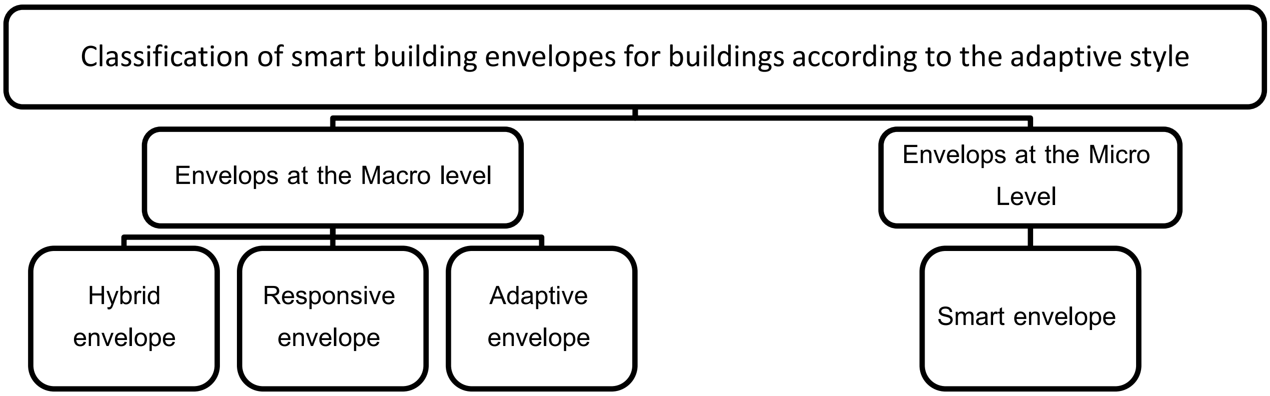

Figure 7. Classification of smart building envelopes for buildings according to the adaptive style.

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

5 ANALYTICAL APPROACH

5.1 Saruq Al-Hadid Museum Development – Dubai

5.1.1 Historical Overview

The museum is located in the historical Al Shindagha neighborhood in the heart of Dubai Emirate, on an area of 1,100 square meters. The neighborhood is made up of a fabric of historical buildings that form the nucleus of old Dubai city. The new museum combines traditional Emirati architecture with modern techniques, and it is a symbol of the revitalization of this historical neighborhood. It tells the story of one of the most important archaeological sites discovered in the United

Figure 8. Sarouq Al-Hadid Museum

Reference: www.dm.gov.ae

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

Arab Emirates so far and the most mysterious. The museum uses state-of-the-art technology to explore the site of Saruq Al-Hadid. The museum is the place where the artifacts of Saruq Al-Hadid site are exhibited to visitors. It is considered one of the unique and important archaeological sites, as it was one of the main centers for copper smelting and manufacturing tools and various utensils in the region since the beginning of the Second Iron Age (800-1270 BCE). The site includes a wide archaeological area estimated to be around 2,000 square meters, which contains archaeological landmarks that extend from the 3rd millennium BC to the end of the Iron Age. It features a sandy mound that rises between 5-7 meters above the original site, and it provides a wonderful picture of the skills and achievements of the site's inhabitants who worked in this factory.

5.1.2 Architectural Description

Sarooq Al Hadid Museum of Antiquities is a historic building in its own right and an important part of Dubai's history. This building was constructed by Sheikh Juma bin Maktoum Al Maktoum in 1928. The house consists of two floors, with the museum occupying the ground floor. In the middle, there is a spacious courtyard. The house is considered one of the most beautiful remaining examples of Dubai's historical architecture and is built using local materials such as coral rocks, gypsum, and imported sandalwood.

Figure 9. Museum Floor Plan

Reference: www.dubaiomg.com

Accessed Apr 2023

5.1.3 Museum Contents

Excavations at the site has led to the discovery of many archaeological artifacts, reaching up to ten thousand various pieces. These include a collection of rare artifacts unlike any in the archaeological inventory of the United Arab Emirates, as well as large quantities of gold jewelry, bronze and copper tools and vessels, and bronze weapons including daggers, long swords, knives, and spearheads, as well as iron weapons such as long

Figure 10. Museum artifacts

Reference: www.dubaiomg.com

Accessed Apr 2023

swords, arrowheads, spearheads, daggers, stone seals, and pottery vessels of various sizes and shapes. [16]

5.1.4 Museum Activities

The museum offers a series of activities and experiments suitable for all age groups and their level of interest in the museum's content. While searching for answers to unanswered questions on the site, experts through different audio systems begin exploring the results, studying the facts and theories behind the discovered tools and the chronological sequence of the site.

Figure 11. Smart Screen

Reference: www.dubaiomg.com

5.1.5 Smart Techniques used in the Museum

The museum relied on the AVI&SPL consulting office, which developed some smart applications used in the museum, including:

- Visual, audio, and smart touch screen systems during the implementation phases.
- Visual control systems in the project and their use in smart display screens, whether in wall or museum displays.
- Use of control systems in internal visual communication systems and internal surveillance cameras in the museum.
- Use of interactive display stations for visitors of all ages to perform some tasks carried out by experts in Sarouk al-Hadid, where they can reshape a vessel, assemble a skeletal structure of an animal, and interview an archaeologist, and perhaps even assist experts in solving one of the puzzles of Sarouk al-Hadid.

Figure 12. Smart Screen

Reference: www.dubaiomg.com

Accessed Apr 2023

[16] National Register of Historic Sites - Sarooq Al-Hadid Museum Site – 2017

5.2 Renwick Gallery of the Smithsonian American Art Museum

5.2.1 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.[17]

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

5.2.2 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.[18]

Figure 14. Renwick Gallery Floor Plan
Reference: www.aiaohio.secure-platform.com
Accessed Apr 2023

5.2.3 Smart Techniques used in the Museum.

The team worked on conducting interviews, site surveys, and reviewing historical records dating back to the mid-nineteenth century. The renovation process involved energy and water use, replacing all heating, ventilation, air conditioning, plumbing, fire protection systems, integrating electrical and mechanical systems, adding LED lighting throughout the building, data and information systems, climate control, and updating infrastructure with sustainable and cost-effective technologies using smart building features.

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

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

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

5.2.4 Intelligence traits in heritage building

5.2.4.1 Building Management System

The building is equipped with a Central Building Management System (BMS) located in the basement. It controls and monitors the building's systems and performs its task more efficiently using Neural Networks, which are capable of creating a network of artificial cells that simulate the functions and biological processes of human brain cells. The building management system relies on information from the Nervous System, which consists of two networks of cables through a set of sensors. The building has been enhanced with a large number of BMS Monitors that read the inputs from the building management system and send outputs to control the various building systems.[19]

5.2.4.2 Office Automation

The building has been supported by high-level communication and information systems, where the building contains a local operating network (LON) and a distribution line or data carrier for European electrical installations - (European Installation Bus ELB), and the use of wired communication systems connected to computers to control both service systems and information systems.[20]

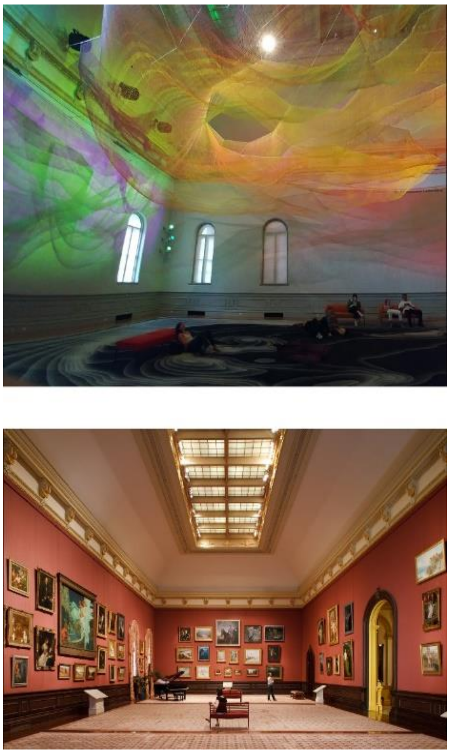

Figure 16. Exhibition halls before and after renovation

Reference: *www.wbdg.org*

Accessed Apr 2023

5.2.4.3 Response to changes in the internal and external environment:

The building has limited response through all building control systems (lighting, ventilation, heating, cooling) and their integration, where the building responds according to its programmed systems to perform specific functions according to specific inputs and through a pre-prepared database.[21]

5.2.4.4 Occupant's control

Building occupants have been provided with control panels on the computer screen, allowing building occupants to control heating and cooling according to designated areas, in addition to controlling lighting.

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[19] Renwick Gallery Of The Smithsonian American Art Museum Retrieved from https://www.wbdg.org/additional-resources/case-studies/renwick-gallery

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

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

5.2.4.5 *Compatibility with the environment and sustainability:*

The building has achieved LEED Silver certification. The building operates according to the EUI standard, approximately 100 kilobytes annually, which is 50% of the renovation rate in 2012. More than 90% of the building's structure has been reused, lighting energy for display areas has been reduced by 80%, and HVAC consumption has been reduced by 35%.

Environmental efficiency is achieved through integration of natural and artificial lighting, where exhibition lighting has been renovated with energy-saving LED bulbs. The building uses the Zumtobel Lighting system, which is a computer controlled by sensors, and based on the information sent by these sensors, the appropriate lighting system is determined. The new lighting system has reduced the building's lighting energy consumption by 70% even with an increase in visitor numbers.

The building contains a number of sensors that provide the building management system with information and data related to the external and internal environment, such as wind speed and direction, external and internal temperature, relative humidity, building occupancy rate, lighting intensity, and density. Based on this data, the building management system makes building control decisions.

5.2.5 *Use of renewable energy sources:*

The building relies on solar energy to provide natural lighting and optimize energy consumption through the use of a responsive industrial lighting system.

5.2.6 *Virtual reality:*

The building systems have been enhanced to support a range of innovative virtual museum display programs. The building uses interactive technologies such as augmented reality and virtual reality to provide visitors with a good experience by creating simulations of different cultures and integrating them into the real environment.[22]

Figure 17. Virtual Reality Techniques

Reference: *www.washingtonian.com*

Accessed Apr 2023

[22] Renwick Gallery Of The Smithsonian American Art Museum Retrieved from https://www.wbdg.org/additional-resources/case-studies/renwick-gallery

5.3 Analysis of intelligent systems used in buildings.

	sensors	Building management systems (BMS)	Internet of Things (IoT)	Artificial intelligence (AI)	Augmented reality (AR)
Saruq Al-Hadid Museum Development – Dubai	• Using of sensors throughout the building • Using lighting sensors	• Control systems for visual communication systems and cameras in the museum. • Fire alarm and firefighting system. • Smart lighting systems. • Visual and audio systems and smart touch screens.			• Utilizing interactive display stations, visitors can engage in tasks that were traditionally performed by specialists. These tasks include reshaping and rebuilding an animal skeleton, as well as conducting interviews with archaeologists.
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 and density	• 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 different cultures and integrating them into the real environment.

Table (2) Analysis of intelligent systems used in buildings

Reference: Researcher

6 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.

7 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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