

The Role of Modern Technologies in Reducing Heat and Sustainability Through the Building Envelope

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Abstract

Smart technologies have greatly affected buildings, so buildings have a distinctive identity that derives from the presence of kinetic systems that have an effect on reducing heat. Where the use of smart technologies and remote sensing systems in buildings helped to achieve the highest levels of control in the various standards that help preserve the external and internal environment, Technologies help achieve resource sustainability and reduce costs. Therefore, smart technologies have become intertwined with the concepts of sustainability.

And it has an impact on the main aspects of the building such as function, construction and form, as the external envelope is considered one of the most important aspects affected by the sustainable building, Especially if the shape is linked to smart technologies in the building's outer shell in hot areas. The research aims to determine the extent of the impact of technology on the outer shell, the moving elements in the facades, and their role in sustainability. And to protect it from climate changes and solar radiation to provide comfort to its users in hot areas. To achieve the goal of the research, a methodology was developed in the research that begins with introducing the concept of intelligence and the outer shell, and previous studies, and then analyzing the examples. One of the most important findings of the research is that the use of technology in architecture It provides convenience to users and helps with sustainability.

Key words: Smart technologies, facades, sustainable, building envelope

Search Objective:

In view of the studies that linked smart buildings to the basic aspects of a sustainable building, we found that there is a lack of the role of smart technologies in the outer envelope and mobile architecture elements to maintain sustainability in hot areas.

The research aims to determine the role of smart technologies on the outer cover of the external facades in order to achieve the standards of sustainability, by clarifying the impact of these technologies on buildings in hot areas similar to our environment, and to solve the research problem and achieve its goal, it is necessary to define its method.



The scientific analysis approach was used in field visits for some examples to find out the details of these moving elements and their effect on temperature, and the documentary approach with an accurate description of their manufacturing methods and the use of raw materials and modern methods in their construction and implementation.

1-Introduction

The great development of technology had the greatest impact on architecture, from the stage of the design production process to the final product. Especially if it is related to modern and smart technologies, as well as its connection to issues of sustainable development. As a result, architecture in this era is no longer isolated from environmental matters that have begun to threaten the world, to provide maximum comfort and safety for the occupants of the building. Where smart technologies help to design sustainable buildings, and some of those technologies are affecting the main aspects of architecture such as functionality, construction and form, and the outer cover is one of the aspects affecting sustainable architecture. In a hot area, make use of them in our environment

2-The concept of intelligence: It is necessary at the beginning to know the concept of intelligence in order to define what is called smart buildings. Scientists have put forward definitions of intelligence, including:

(Stern) describes intelligence with the ability to adapt to problems (1) if intelligence is related to the individual's adaptation to the surrounding environment, balance and compatibility with its forms by taking previous practices with the mechanism of his speech, with the possibility of changing the reality of the situation.

2-1- Smart architecture is the architecture that requires intelligence at every stage starting with the process of design, construction, works and maintenance of its systems and components, and because of that there is a difference in the definition of the smart building from one place to another. In Europe, the smart building focused on the requirements of individuals, and in America, the smart building focused on technical and technological progress. As it determines (Smart Building Institute in the United States of America) "The smart building is defined as providing an open and economical environment by activating four basic elements of its own, which are the structural structure, systems, services and management.

As for (Cardin), a smart building is defined as a building consisting of control systems for its services in a fully automatic manner (2). As for the Asian Institute of Smart Buildings in Hong Kong - (AIIB) - linking the features of the smart building in achieving sustainability standards, and defining it as being designed and constructed in accordance with standards that guarantee the preservation of the environment, meeting the desires of the user, and achieving

building values sustainable, and the most important features of the smart building are conservation and sustainability, as it focused on providing environmental efficiency in addition to the functional and technical requirements for the spaces.

Kell (1996) defines smart building as providing a good environment, with the use of technology, and the possibility of managing the building with a computer connected to the building systems, as well as achieving sustainability standards.

A smart building is a responsive architecture that provides all building occupants with cost effective approved environmental conditions, through continuous interaction between its four basic elements: places (fabric - structure - building facilities): processes (monitoring - systems) people (services - users) and management (maintenance). performance) and the interrelationship between them.

The proactive control system - that is, what is known as the remote sensing system - such as controlling the curtains technically, as the study determined what technology is used in smart buildings, as smart buildings can be simple or technically advanced depending on the specific circumstances

The smart building combines various systems for managing resources, achieving maximum technical performance, saving operating and investment costs, and flexibility, with innovative and technologically adaptable installations in its physical, environmental, and organizational settings.

The study indicated the link between smart building and sustainability, through continuous adaptation to face any change in the future. , such as dealing with social and technological change and adapting for a short or long term to meet the needs of people

Smart facades are an innovative solution to enhance sustainability in building environments, as they aim to enhance user comfort and reduce energy consumption. These facades are intended to be responsive to the local climate, the external environment, thermal and visual comfort, and indoor air quality. The smart building envelope uses remote sensing and system automation such as opening and closing windows, blinds, or turning on/off air conditioning or lighting(22). Thus, the architecture is responsive to the needs of users at the level of internal or external space or the architectural elements of the building.

Gadakari (4) presented a comparison between the attributes of smart buildings and sustainability practices and shows the fact that there is a great overlap between them. Smart buildings have the potential to enhance efficiency and lower energy consumption. They can also reduce water use, improve user comfort, safety and security, air quality and light levels indoors which work to provide thermal comfort for the occupants of a smart building. The study was able to conclude that smart buildings are sustainable. a It is clear from the foregoing that the study clearly emphasized the functional aspect achieved by the smart building, through the basics of sustainable development (economic, social and environmental), in addition to the necessity of integrating the architectural design; Green technology and smart systems to achieve sustainability and energy saving

The study (5) dealt with the importance of using computers in the building and advanced control systems to create a comfortable and productive built environment for users, and showed that the use of a set of systems that govern the architectural units in the building to take advantage of the renewable natural energies from the environment to achieve sustainable design. The study confirmed that the response of the outer shell of the building can contribute to reducing energy dissipation in buildings, and help maintain comfort levels.

The outer shell operated with smart technologies is able to operate the building, as smart elements can be created in the architecture and are able to respond to what is expected, and reach sustainability in the future.

At Merck Serono's headquarters in Geneva, it includes a movable roof, whether by sliding or rotating, in order to mitigate the internal climate of the building. The building offers a kind of transparency and dynamism, and the new vision of materials technology in an artistic style

It has been shown from the foregoing that the use of modern technologies in the building affects it in many aspects that may be formative, structural or functional in order to reach an environmentally sustainable architecture, especially the impact of these technologies on the shape of the external facade of the building, and the possibility of its reflection on our environment, especially in the field of kinetic response to the external environment in the design

After presenting the knowledge of the subject, it was found that the activation of the four elements of the smart building has an important impact on the response of the external composition of the sustainable building through the features of its outer envelope.

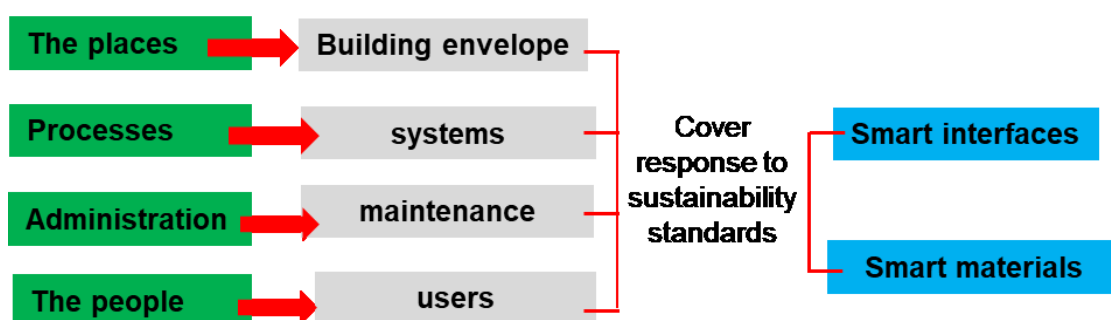


Figure 1: The response of the formal formation to the sustainability criteria by activating the four elements of the smart building

3-The role of smart technologies to achieve sustainability

The use of technology helps to sustain the building (6) ,as there is a compatibility between design considerations that reflect architecture trends, and technology on the other hand, which is a fundamental pillar of sustainability in architecture .

Smart architecture aims to reduce the consumption of natural energies and the use of natural materials in construction, in addition to that it achieves two very important goals at the same time(7).

On the other hand, the Asian Institute for Smart Buildings in Hong Kong (2006) linked the AIIB to the possibility of achieving sustainability standards using smart technologies, and defines a smart building as a building that is designed according to a selection compatible with environmental standards that ensure the preservation of the environment and aims to meet the desires of the user and achieve building values. Sustainable, declaring preservation and sustainability the most important features of this building, and in the case of sustainable buildings and cities, the integration of sustainable design methods and smart technologies not only reduce energy consumption and reduce environmental impact, but also reduces construction and maintenance costs, creates a comfortable work environment and improves the health of users (8) .

There are many smart technologies that affect the three aspects of architecture (form, construction, and function). On the formal side, the impact of smart technologies appears in the emergence of new forms and types of new covers, as well as smart coated materials. Smart technologies also affected the way the building is executed, in terms of walls and ceilings. In the processes of intelligent response to external influences. (5) technologies also affected functional relationships, change in user behavior and its relationship to building components.

The most important characteristic of smart buildings is their ability to respond to external conditions, and the external building envelope - the facades - represents the effective tool for this role, as it separates the external and internal space and thus can act as a controller in the dynamic reaction of the building and an effective organizer of the relationship between the outside and the inside, and the smart façade differs In contrast to the traditional facade, it has control and control devices, so the possibility of adapting the outer building envelope to perform its work as a climate-regulating medium (9) .

The smart cover is defined as a composition of building elements exposed to external weather to perform a range of functions to respond to environmental variables to maintain user comfort with minimal energy consumption. Within this cover, the interface elements are adaptable through their ability to self-adjust to modify and change the shape (9).

The most important function of the smart envelope is to provide comfort to the occupants of the building, such as thermal comfort through the use of double facades, and the control of light, shading, ventilation, and heat resistance. The envelopes are classified as follows:

-Intelligent Envelope :The smart cover depends on integrating technologies with the facade of the building to improve the internal environment and reduce energy consumption. The role of this technology is as follows:

Acquisition of knowledge and understanding of the surrounding environmental conditions (both internal and external conditions) through a variety of sensors. Processing and analyzing information and strategic thinking.

- Decision making and automatic control of the kinetic elements that make up the envelope and are linked to the central management system of the building, to implement the adaptation decision dynamically.

Based on the foregoing, we can say that the smart adaptive building envelope is the envelope that integrates artificial intelligence technologies, which understand and collect information about the surrounding environmental conditions, and analyze it to make the decision to modify the facade. (Multi Story Façade: The presence of an undivided air space between the outer façade and the inner casing, and large ventilation holes are made at the bottom and top of the façade that allow air to enter and exit from the inner space.



Figure2: GSW building, Intelligent façade , Active façade, Ability to learn and respond in time Combines automatic and occupant control(10)

-Kinetic Envelope :The kinetic envelope is defined as the casing that incorporates a set of components that have the ability to move.



Figure3: Al-bahar tower- Kinetic façade- Working with mechanical systems Acting based on outdoor environment condition- Moveable façade

Where It consists of rotating slats powered by a motor. When the slats are closed, they act as a closed interface. When opened, they allow increased ventilation through the air cover between the layers of the cover.

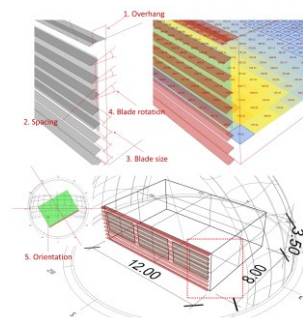


Figure 3: Viking by Crown, Sydney, Australia, This kinetic façade is enhanced by its form and colour Dynamic parameters of the louver shading and the room orientation.

-Dynamic Facades: Interfaces that are described as dynamic are defined as interfaces that have the ability to move in a way that depends on mechanical systems.



Figure 4: Oval cologne office-Adjustable to environmental conditions Mobile systems

-Interactive Facades :The envelope that is described as interactive is defined as the envelope that depends on the existence of continuous communication for the exchange of information between the various influences surrounding the envelope and its components (through input systems), as well as the existence of communication between the components built for the cover (computer intelligence and physical movement elements) to complete the response. Continuous communication (interaction) is one of the most important roles played by the built-in artificial intelligence technology in the building, as shown in Figure (5)

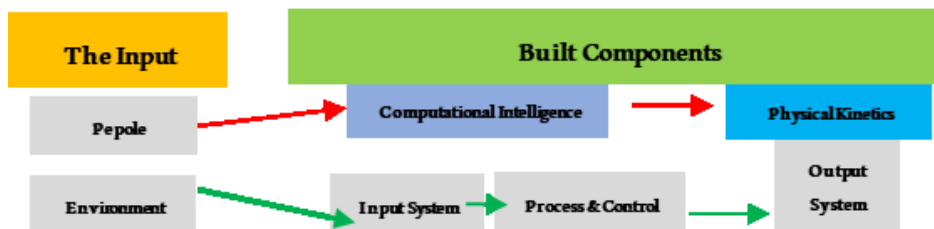


Figure5: The continuous communication and dialogue between the different stimuli and the components of the interface.

-Adaptive envelope :The cover described as adaptive is the cover that has the ability to bring about a process of continuous dynamic change of its behavior and features in response to environmental variables.

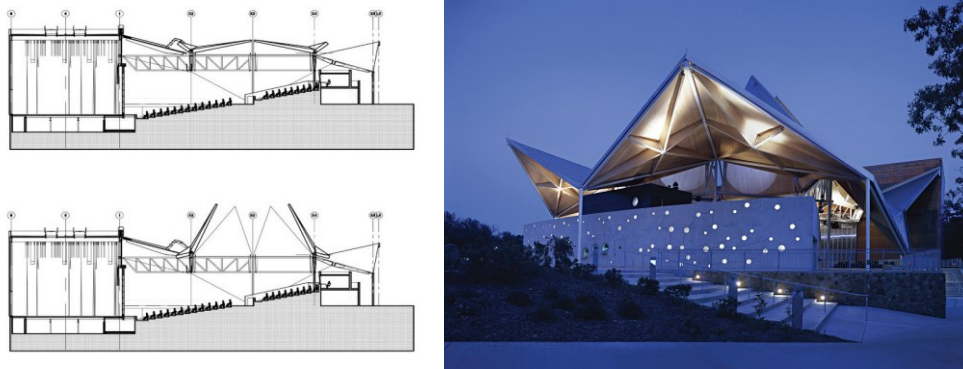


Figure6: Bengt Sjostrom Theatre

-Responsive envelope : The cover that requires the integration of Computational Intelligence systems and technologies and kinetic elements, whether with moving parts or smart materials and surfaces, in the facades of the building.



Figure 7: Kiefer Technic showroom -Responsive façade- Thermochromic polymers- smart windows- Similar performance characteristics to an ‘intelligent’ façade Usage of sensors, actuators, and control devices



Figure 8: The administrative building in Germany (ARAG VERSICHERUNG), the use of the front of the box air column to make differences in pressure and benefit from natural ventilation in tall buildings, and by dividing the facade, it works as ventilation columns linked to openings every eight floors.

After what was subtracted from the theoretical part, it became clear that (the external envelope of the building, the structural aspect, as well as the function) was affected by smart technologies.

Examples:4-

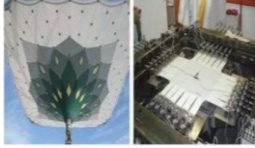
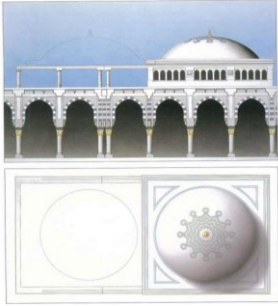

A number of sustainable smart buildings located in hot areas were selected and analyzed, which can be used in Egypt to reduce the temperature inside the building, and reduce energy.

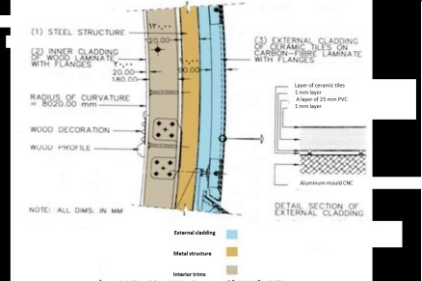
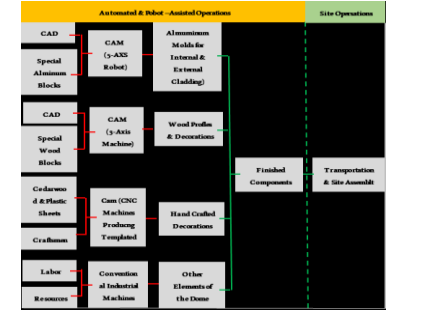
When searching and surveying, the study included three buildings with administrative-cultural effectiveness (Table 1), within an area dominated by hot climates.

The analysis will be limited to the outer envelope of the building and some movable architectural elements, given that it is more an expression of the role of smart technology on the current cover of the sustainable building.



Table I: Analysis of the envelopes of smart sustainable buildings in hot areas

Architecture elements in the internal architecture of Al-Haram Al Nabawi	
<p>The development of building materials and technologies had a major role in the use of highly mobile architecture systems. This is largely evident in the design of mechanical umbrellas with automatic opening and closing, and the movement of movable domes. in the Holy Prophet's Mosque,</p>	
<p>Building description</p>	<p>Automated awnings:</p> <p>The project initially included the construction of 182 umbrellas on the pillars of the mosque's courtyards, then 68 umbrellas were added in the eastern courtyards, bringing the total number of umbrellas to 250 as shown in Figure (9), and one umbrella remains about 57 m, and the total area of the shaded areas is about (104,000). m, it can accommodate about (209,000) worshipers, and the height of the end of the umbrella fabric in the open state is about (15.0) m, and in the closed state it is about (21.3) m. The umbrella opens or closes automatically,</p>
	<p>Figure 9: Detailed drawings showing the horizontal position and the vertical sector of the umbrellas of the Prophet's Mosque(11)</p>
<p>Smart external envelope</p>	<p>Transparency : lighting</p> <p>The open umbrellas reduce the access of direct sunlight to the square during the day, while allowing hot air to rise to the top when they are closed at night.</p> <p>The semi-transparent cover of the umbrellas blocks the sun, but allows light to pass through, and the design also includes a night lighting system.</p> <p>Each of the high and low sets of parachutes are opened respectively with a slight time delay so that their structures do not collide with each other.</p> <p>Air movement and lighting :air movement</p> <p>Numerous experiments were conducted on models of the umbrella in the so-called wind tunnel to expose it to wind currents that simulate reality and by using the computer, which helped to determine the thicknesses and dimensions of the elements and units of the umbrellas as shown in the computer applications in Figure 10. The umbrellas were designed to withstand wind speeds of up to 97 miles-hour. In both open and closed states. To prevent the umbrellas from tearing during the opening and closing process, the system is equipped with a wind speed monitoring device, and ensures that they are stopped when the speed exceeds 22.5 miles per hour.</p> <p>Design SL has carried out several tests to study the entire structure of the umbrellas initially as a model under the applied loads so that their folding sequences can be simulated , as shown in Figure 11.</p>
	<p>Figure (10): Comparison of the effect of heat on the fibers and fabric of the umbrella through technology</p> <p>Figure (11): A study of the effect of atmospheric influences on the umbrella elements (12)</p>

	<p>This also allows them to modify and compare different shapes and structures with high efficiency, which simulate and analyze the aerodynamic behavior of the systems, as in Figure 12. And when temperatures in the shade can exceed 45 degrees, The controls for the awnings are coupled to the building's air-conditioning system. Air outlets at the base and mid-shaft of the umbrella circulate cool air, So that the entire quadrangle is cooled evenly and effectively, and a group of 436 mist fans have been installed in the umbrella poles distributed over the courtyards of the mosque. Each fan has 16 mist holes designed to prevent water from dripping when it is turned off. The fan aims to humidify the outside atmosphere in the courtyards of the mosque under the umbrellas by absorbing heat energy in the air. It needs 200 liters of treated water per hour at the inner columns of each column</p>	 <p>Figure (12): Site simulation study model and air elasticity behavior analysis, before project implementation (13)</p>
<p>Building description</p>	<p>- Movable roofs or sliding domes . Description of the movable domes in the Prophet's Mosque: The inner courtyards were covered by 27 movable domes that provide the mosque space with natural lighting and ventilation. For the entire area of the yard, with dimensions or completely, as it allows the entry of light and air, with a partial opening of 18 x 18 m. It has an area of 324 m, a radius of 7.35 m, and a height of 16.65 m above the ground level of the mosque. The domes move on four wheels of steel, covered with an external metal to protect against rust. The opening and closing of the domes is controlled by a central computer capable of opening and closing them together or both separately. The process of opening and closing the motors takes one minute, while the process takes thirty minutes manually. The design of the dome was taken into account to move in the worst conditions and with a wind force of 100 km/ h.</p>	 <p>Figure (13): Horizontal and vertical projection of its title, the Prophet's Mosque (14)</p>
<p>Smart external envelope</p>	<p>Air movement and lighting Transparency: Lighting: The domes have an important role in transmitting lighting to the interior, as the windows of the domes are designed for the sun to enter every day from the dome according to sunrise and sunset throughout the year. Thus, the mosque becomes always lit. Thus, it reduces energy consumption and maintains sustainability The movement of the air, as it pulls the hot air that rises upwards, and it exits from the windows overlooking the sunny side, while the windows on the shaded side enter the cool moist air, allowing the entry of air currents and benefiting from the movement of air through the windows of the domes Treatment: Improving the glass to reduce the effect of direct sunlight and achieve the maximum amount of light</p>	 <p>Figure (14): A picture of the domes when they are opened during the early hours of the day to carry out the air renewal process</p>

<p>External Cover Type: Smart interfaces Smart materials</p>	<p>Smart materials : Divide the casing into similar strips. Using the computer to distribute ceramic tiles in specific geometric shapes. -Using a CNC-machined robot to manufacture the mold used in the manufacture of the casing and to locate each slab. - -Covering the tiles with carbon fiber and epoxy glue with backings for the casing. - Shipping the slides and assembling them on site . The dome carries a steel structure consisting of 24 semi-circular pillars, and three rings of steel bridges. The structure covers the entire area and carries internal and external coverings and insulation layers. Sliding domes motion design : The design of façades and movable roofs using technology helps to double the volume of production from 10 to 15%, in addition to saving costs and achieving sustainability.</p>	 <p>Figure 15: Vertical section of one of the moving dome layers(15)</p>  <p>Figure 16: Planning & Design of the Sliding Domes and their construction System</p>
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The International Renewable Energy Agency building, UAE

<p>Building description:</p>	<p>The headquarters of the International Renewable Energy Agency represents a real turning point in reducing energy demand by 50%, and is an example to follow in sustainability. Building shape: The building consists of three interconnected buildings with an area of 31,983 square meters, and it is the first building to receive a certificate of sustainability according to the classification of buildings from the Abu Dhabi Urban Planning Council</p>	 <p>Figure 17: The International Renewable Energy Agency building</p>
<p>Smart external envelope</p>	<p>Transparency: the surrounding offices appear from the glazed facades with a large ceiling height of more than 3 m, allowing daylight to penetrate the center of the building from the inside. Movement: The façades include horizontal and vertical shading devices to reduce the effect of direct sunlight, and the direction and position of the shading varies according to the façade on which it is installed. Treatment: Improving the glass to reduce the effect of direct sunlight and achieve the maximum amount of light The facades of the building are designed with a simple curve to reduce the effect of sunlight at any time</p>	 <p>1-Rippling Façade 2-Perforated Façade Figure 18: The International Renewable Energy Agency building facades</p>

<p>External envelope Type: Smart interfaces Smart materials</p>	<p>Smart double facades: The building consists of three buildings connected to each other within a unified framework in the facades of the three buildings, through the use of sunbreaks.</p> <p>Smart materials: The glass used in the facades has been processed by 30% to reduce the effect of direct sunlight, while allowing daylight to enter (16)</p> <p>On the roof of the building there are solar panels (photovoltaic cells) with a capacity of 1000 square meters on the roof, which achieves approximately 8.5% of the total energy requirements of the building</p> <p>Sustainable smart materials: recycled steel was used as well as aluminum, and sustainable local building materials (17)</p>	<p>Figure19: smart double facades</p>
<p>King-Fahad National Library in Riyadh-KSA The architect, Gerber</p>		
<p>Building description</p>	<p>The King Fahd National Library building is considered one of the most important cultural buildings in the Kingdom of Saudi Arabia.</p> <p>The shape of the building: It is characterized by dealing with the facade with a traditional element - tent membranes - with a modern vision. As for the expression of sustainability, it was through the use of modern energy concepts that pass through all the activities of the building with methods and techniques (18)</p>	<p>Figure20: King-Fahad National Library in Riyadh</p>
<p>Smart external envelope</p>	<p>The facades were treated to protect the building from direct sunlight and allow sufficient light to enter while preserving the building's transparency.</p> <ul style="list-style-type: none"> - Resistance: White films were used with a three-dimensional support, and they were tightened with strong wires with the building structure. <p>Transparency: three-dimensional refraction of light, combining required sun protection with adequate light penetration (18).</p> <ul style="list-style-type: none"> - Flexibility: Flexibility in the movement of white membranes with a smart technique - The movement of white films and modern technology, and benefit from the sun - Dynamic: the movement changes according to the temperature during the day and night <ul style="list-style-type: none"> - This façades have been developed to include ventilation and cooling for the building by means of layered - ventilation and floor cooling., thermal comfort is increased and energy consumption significantly 	<p>Figure21:King Fahad National Library, Gerber Architekten (Source: author): (a) the cruciform plan enclosed in a “cube” building; (b) the plastic figuration of the diamond-shaped curtains on the facade; (c) the expressive value of the envelope composed by white membranes</p> <p>MEMBRANE FACADE</p>

<p>External envelope Type: Smart interfaces Smart materials</p>	<ul style="list-style-type: none"> - External Cover Type Smart Dual Interfaces: Using double cover, moving elements - The materials of the external cover are smart materials: the use of white films, in order to allow the sun's rays to reach, as well as inspired by the Arab tent. The project is a redesign and refurbishing the old existing building of the library to improve its use and performance, renovations and retrofits for existing buildings to include sustainable design attributes reduces operation costs and environmental impacts, and can increase building resiliency. -The new design integrates the old domed-roof library with the new building and combines regional building traditions with modern technology (Design Build Network). -Replacing the old concrete dome with a steel and glass dome that continues to be a cultural symbol of the library and bring natural lighting. . The whole building is covered by a new roof, punctuated by skylights under which white membranes gently distribute the light throughout the entire interior 	<p>Figure 22: The key element of the façade is a cladding made up of rhomboid textile awnings. Inserted white membranes, supported by a three-dimensional, tensile-stressed steel cable structure, act as sunshades and interpret the Arabian tent structure tradition in a modern, technological way</p>
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5-conclusions :

- The use of smart technologies in the outer cover of the building has a great role in controlling the temperature inside the building, especially in hot areas, and it also helps to produce new materials that help design innovative and sustainable ideas.
- The use of smart materials - has a good effect in reducing energy consumption, especially local materials with sustainable characteristics - such as traditional limestone, white films, and wood.
- The nature of the building's work - and its function - affects the external appearance through the choice of the type of external cover or the choice of materials, as well as the nature of the mechanisms used.
- The smart cover contributes to the control of daily environmental changes such as light, humidity and temperature, and the exploitation of natural energies by taking advantage of daylight, natural ventilation, the exploitation of solar energy, and the use of various materials.
- Such as glass units in the walls and ceilings to achieve transparency and create an interactive environment for the user, and the presence of the required sensors on the facades such as sensing rain, temperature, wind direction, sun angles and wind speed.



- In addition to making sure that the smart technologies that deal with the facades - double cover - work to reduce energy consumption and help the sustainability of the building.
- The smart materials used in architecture are not affected by weather fluctuations
- Symmetry was used to maintain the unity and shape of the architectural design in the movable elements, so that the relationship between the formation and the function it performs is not affected, so the same elements and lines directions were used, and the structure of the movable elements became based on foundations and thus be homogeneous

6-Recommendations

- Design benefit from the use of smart technologies, to improve the environment, and make special studies for that, especially in hot areas.
- Concentrating knowledge of the techniques of designing smart building facades that meet sustainability standards, especially among architecture students, in using one of the types of smart covers in their architectural projects.
- The research recommends an overlay between smart technologies and sustainable architecture standards, as they constitute a priority in achieving future architecture, especially with the rapid technical progress in the world.
- Supporting the educational path and interest in holding international and local competitions to find modern means and technology that contribute to raising the efficiency of sustainable architecture.

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