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INTEGRATING ENVIRONMENTAL TREATMENTS INTO BUILDING DESIGN PROCESSES IN THE DRY HOT EGYPTIAN CLIMATE

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ABSTRACT

Energy conservation is one of the challenges of our time. With the increase in buildings, energy loss has increased. In addition, most modern designs have not provided appropriate solutions to stop its depletion. Therefore, the research aims to reach a design vision that integrates environmental treatments into the design process stages of buildings and is effective throughout the project life stages in the dry, hot Egyptian climate. Therefore, the study addressed the concept of environmental design and thermal control and its possible strategies for employing treatments according to the stages of the design processes. Thus, the building design is as responsive and interactive with the environment and climate as possible. Then, the study specified the treatments regarding the design elements supporting thermal performance control. Also, it clarified the impact of environmental control strategies and principles on costs during the project life. Accordingly, two experiments of existing buildings that succeeded in achieving flexibility and integration with the surrounding environment were analyzed. That was to demonstrate the benefit of integrating treatments in improving the design of building elements to be more suitable for climatic conditions. The most significant of these techniques was developing the geometric shape of the outer envelope, modifying the proportions of openings and shading methods, and designing them to be consistent with the orientation and path of the sun according to the climate; in addition, choosing appropriate envelope materials for the site and local environmental conditions and adopting mixed ventilation systems and open windows. Finally, the study proposed linking the climate control treatments to the design process stages as a design vision. Consequently, it will facilitate and encourage the investment of these treatments and their strategies in the design to produce responses and thermally balanced buildings to the surrounding environment.

KEYWORDS: Hot Dry, Climate Treatments, Thermal Control, Architectural Design Processes, Environmental.

دمج المعالجات البيئية في عمليات تصميم المباني في المناخ المصري الحار الجاف

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الملخص

تعتبر مشكلة ترشيد الطاقة إحدى تحديات العصر فمع زيادة المباني ازداد فقد الطاقة بجانب ان غالبية التصميمات الحديثة لم توفر حلولاً مناسبة لوقف استنزافها. وبالتالي يهدف البحث الوصول لرؤية تصميمية تدمج المعالجات البيئية في مراحل عمليات تصميم المباني وتكون فاعلة خلال مراحل حياة المشروع ضمن المناخ الحار الجاف المصري. لذلك تمت تناول مفهوم التصميم البيئي والتحكم الحراري واستراتيجياته الممكنة لتوظيف المعالجات وفق مراحل عمليات التصميم ليكون تصميم المبني متجاوب ومتفاعل بيئيا ومناخيا أقصى ما يمكن. ثم تمت تحديد المعالجات التابعة للعناصر التصميمية الداعمة للتحكم في الاداء الحراري. وأيضا تمت توضيح تأثير استراتيجيات ومبادئ التحكم البيئي على التكاليف خلال حياة المشروع. وبناء عليه تمت تحليل تجربتين

للمباني القائمة التي نجحت في تحقيق المرونة والاندماج مع البيئة المحيطة. وذلك لإظهار فائدة دمج المعالجات في تحسين تصميم عناصر المبني لكي تكون أكثر ملاءمة للظروف المناخية. أهم تلك المعالجات كانت تطوير الشكل الهندسي للغلاف الخارجي ليتوافق مع التوجيه والمناخ. بالإضافة إلى دراسة نسب الفتحات ووسائل التظليل وتصميمها وفقاً للتوجيه ومسار الشمس. بجانب اختيار مواد الغلاف الملاءمة للموقع والمناخ والبيئة المحلية واعتماد نظم التهوية المختلطة والنوافذ المفتوحة. وأخيرا تمت اقتراح ربط معالجات التحكم المناخية بمراحل عمليات التصميم بهدف تسهيل وتشجيع عملية استثمار هذه المعالجات واستراتيجياتها في التصميم لإنتاج مباني متوازنة حراريا ومستجيبة للبيئة المحيطة بها.

الكلمات المفتاحية: الحار الجاف، المعالجات المناخية، التحكم الحراري، عمليات التصميم المعماري، المناخ، بيئي، طاقة.

INTRODUCTION

In light of the global energy crisis, the outer envelope of buildings plays a prominent role in energy consumption during attempts to achieve thermal comfort, design, and construct the interior spaces of the same building [1, 2, 3]. That depended on the design and different architectural formations, especially in hot climates [4]. There are attempts by developing countries to import and transfer modern technology without paying attention to its suitability to the local environment, human nature, inherited cultures, and the impact of technology on humans [3, 5]. Consequently, all of the above negatively affects public and mental health and sometimes touches on the personal characteristics of individuals and behaviors within all spaces. The most significant thing noted is environmental treatments were not used as architectural vocabulary stemming from the authentic environment, heritage, and history [6, 7]. Also, not devising new vocabulary that achieves the same concept or environmental function within most new buildings [8]. Consequently, the buildings were very far from being thermally balanced and responsive to the surrounding environment and its conditions.

In light of the global economic crisis and environmental problems, it has become necessary for architects to contribute to solving global environmental issues by reducing energy waste, saving it, exploiting it in optimal ways, and benefiting from passive strategies by finding the best architectural treatments with environmental effect [9, 10, 11]. With the development of technology and modern techniques that have recently emerged, it has become possible to provide appropriate environmental conditions, such as providing natural lighting, achieving thermal comfort in the interior spaces of buildings, improving the sunlight distribution in the space, and controlling direct sunlight [12, 13]. The designs of buildings, both internally and externally, have witnessed and are still seeing a significant change since the end of the last century in the type of used materials, their colors, shapes, and many other transformations. This progress has emerged a new mechanism in architectural thinking [2, 14]. These mechanisms changed the course of architectural thought and construction, whether these changes were negative or positive, and also clarified the architectural features of all aspects of architectural treatments and their construction technology.

Accordingly, achieving the thermal control principle in buildings has become one of the basic concepts that architectural designs must include within different environments [15]. Also, applying the thermal control method to buildings varies according to regions and climatic environments. These methods highlight the environment with a hot, dry climate as areas with specific thermal control strategies that require specific environmental design treatments to achieve them [16, 17]. These treatments are implicitly integrated with the general building design to take on a formal or detailed dimension. Generating many environmental treatments because they vary based on the building's function, its specific areas, and the surrounding environment [18]. These treatments can be utilized during different stages of design to take advantage of the positive climatic features of the area, mitigate any harmful effects, and achieve effective thermal control within the building. The variety of environmental design treatments that can be utilized during the design process, in addition to their varying impact on the strategic goal for which they were used, has made it difficult for a large number of designers to have sufficient knowledge of most of these treatments and the appropriate stage to employ them.

RESEARCH PROBLEM

The phenomenon of buildings having designs that are not compatible with the climatic conditions of the external environment is increasing [4]. Therefore, they depend entirely on mechanical air conditioning methods. Hence, increasing energy consumption to provide suitable environmental conditions, achieving thermal comfort through industrial ways, and not exploiting natural lighting and ventilation. In addition to neglecting to activate design treatments inside or outside buildings being suitable for the environment to benefit from them as climate solutions to achieve a built environment characterized by thermal comfort appropriate for users [2, 16, 18].

Furthermore, it is difficult to determine the environmental design treatments for each climate, especially the hot, dry climate of Egypt, during the design process stages, and not following one of the strategies for thermal control methods: passive or active strategies [10], [19]. Consequently, the building's thermal performance is insufficient and can not controlled, resulting in buildings being thermally unbalanced and unresponsive to the surrounding environment [13], [20].

RESEARCH AIM AND OBJECTIVES

The research aims to reach a design vision that integrates environmental treatments into the stages of building design processes within the hot, dry Egyptian climate by classifying these treatments within these successive stages to facilitate maximum benefit from all possible treatments within the buildings and the surrounding site. Hence, the objectives are:

1) To identify the concept and architectural thinking of environmental design and its role during the design process to support thermal control objectives as a significant feature that must be achieved.
2) To specify and define thermal control strategies to make the design responsive and environmentally interactive by employing environmental treatments in the design elements according to the stages of the design processes and the project's complete life.
3) To clarify the impact of integrating environmental thermal control strategies and principles on costs within the stages of the project life.
4) To examine and analyze existing projects to prove the benefits of adopting climate treatments in the stages and processes of design and linking them to those stages after classifying them to encourage their investment and application to produce buildings that are thermally balanced and responsive to the surrounding environment.
5) To propose a design vision that ensures the achievement of the environmental requirements of the design project by employing possible treatments according to the four strategies for thermal control during the year.

RESEARCH METHODOLOGY

The inductive approach was to clarify and explain the concept and architectural thought of environmental design and its role within design processes. Consequently, the study confirmed the thermal control role and its objectives, which can be achieved through several strategies and employing environmental treatments in the design elements such as form, building materials, openings, and ventilation. These treatments are implemented throughout the design process, from the outside to the inside of the building, to support the design to be responsive and interactive with the climate and the surrounding environment.

Hence, the significance of the analytical approach becomes clear to investigate and assess the impact of integrating environmental control strategies and principles on costs throughout the diverse stages of a project's life cycle. This integration aims to enhance the architectural design development according to its design process stages. However, the climate control elements are the essential design components, and their quality and efficiency cannot be evaluated in isolation. Hence, fundamentally testing these elements in conjunction with other elements within a project or building to reach a cohesive and integrated composition. Consequently, two experiments were studied and analyzed as examples of existing buildings that achieved flexibility and integration with the surrounding environment while dealing with the hot, dry climate. Thus, it is possible to identify the environmental and climate treatments, design elements, and effective methods used. That is to demonstrate the benefit of their impact on improving the design of parts and components of existing buildings to be more suitable for the climate and surrounding environment.

For the study to reach a design vision that achieves the requirements of the environmental aspect of the design project by employing environmental treatments that achieve strategies of resisting heat gain and allowing heat loss and permitting heat gain and resisting heat loss in the hot, dry Egyptian climate throughout the year, according to the design phases. The study relied on the deductive approach that depended on two previous approaches to reach such a design vision for buildings from the outside and inside in a hot, dry climate. That was done by linking climate control treatments, especially those with self-management methods and active methods, to the stages of the design process to facilitate and encourage the process of investing in these treatments and strategies for their application during the design process to produce buildings that are thermally balanced and responsive to the surrounding environment.

1.1. The Concept and Architectural Thought of Environmental Design and Its Role During the Design Process

Architecture is the result of the interaction process between environmental variables and humans. Architecture is an entity that represents the translation of the mutual relationship between these two sides [18, 21]. Therefore, buildings acquire different characteristics according to the regions and climatic environment to which they belong and are called environmentally responsive buildings. However, some of the repercussions of technological development and total reliance on mechanical air conditioning systems without taking into consideration the surrounding environmental conditions have reduced the importance of the building's role as a filter between the external environment and the specifications of the internal environment [2, 17]. This has resulted in buildings with low construction costs and high maintenance and operating costs, assuming the existence of inexhaustible energy sources. Today, the limited energy sources will require embracing different designs to create a stable indoor environment that meets the thermal comfort requirements of humans, hence using and employing designs primarily based on responding to the daily and seasonally changing climatic conditions [13, 22]. Therefore, efficient thermal performance will require a complex interaction between the external environment and the properties of the internal environment, mediated by the building envelope and the mechanical systems of any building, as this interaction is a measure of thermal comfort in the building. Here, the difficulty of dealing with external and internal thermal loads appears in their change from one hour to another and from one season to another. Another difficulty is the numerous possibilities and design alternatives proposed to solve these problems. Here, the role of the ideal or most appropriate design process will appear, as it is the guide that will work to achieve the best formulas for balancing between the design requirements and the requirements of the environmental response from the thermal aspect of the building. Hence, reaching a convincing settlement between these two parties to achieve the concept of thermal control of the building.

1.1.1. Thermal control

When there is a difference between the indoor and outdoor air temperature, it shows the thermal energy transfer from inside the building to its outside environment in winter. On the other hand, thermal energy is transferred from the outside environment to its inside in the summer [20, 21]. The building loses heat in the winter and gains heat in summer. That shows the effect of climatic factors on humans and the built environment through the need to use energy for cooling or heating to provide thermal comfort inside the building [13].

However, achieving thermal comfort with minimal additional heating and air conditioning costs is one of the main requirements for buildings [15, 18]. That makes thermal control an influential feature that must be achieved in designs. With the diversity of the seasons throughout the year, thermal control priorities and levels differ, especially between summer and winter, as they are the most dominant seasons [10, 23]. Hence, this calls for setting objectives to control thermal transfer across building components to ensure the intended thermal comfort remains at the required levels.

Then the thermal control objectives are as follows:

- When the external temperatures are high, outside the thermal comfort range, and the thermal control objectives of the building are:

1) To reduce heat gain from outside the building.
2) To increase heat loss from the building to the outside.
3) To provide a source of internal cooling to eliminate the effect of any heat gain.

- When the external temperatures are low, below the thermal comfort range, and the thermal control objectives of the building are to achieve one or more of the following aspects:

1) To reduce heat loss from the building.
2) To increase heat gain from the sun and external heat sources.
3) To furnish an internal heat source to compensate for each heat loss.

Accordingly, the first two objectives in each group can be achieved using a strategy that relies on constructive or building methods, such as the passive method. On the other hand, the third objective in both groups can be achieved by a strategy that relies primarily on additional energy, such as the active method.

1.1.2. Thermal control strategies

Many methods can be used in climate design for thermal control purposes [4]. They differ depending on the technology used. They all fall under a general classification, namely active and passive methods. Both types rely on thermal control strategies represented by the basic working principles of monitoring the opportunities to allow or prevent thermal transfer defined by heat gain or loss according to the time forecast of the daily and annual climate cycle [8]. The difference between the passive and active methods is evident in the foundations of these methods. While the passive method focuses on increasing the use of renewable energy rather than depleted energy, the passive method focuses on integrating with design "principles" to reduce the need for energy consumption [10]. The passive design principles often include adopting methods that support design decisions at the building level in terms of form, orientation, building materials, and other decisions [24].

Because the passive method is more involved in the design process, its general purposes can be achieved through structural and building techniques that instantly meet the main design decisions in its various stages [25]. The passive method in building design depends on benefiting from the positive effects of the surrounding climate, and it closes off from it when the climate is the opposite. Therefore, it requires greater architectural privacy to benefit from the opportunities to conserve the provided energy by the surrounding circumstances [26]. In addition, it brings to mind the image of the old traditional buildings that have proven their efficiency and success in adapting to environmental conditions for many years. Many have tried to devise a method that explains the types of self-thermal control strategies according to the summer and winter seasons. The methods of applying these strategies have varied at the design level. Also, they have taken several forms with the diversity of climate characteristics university, such as cold, hot, dry, moderate, warm, humid, coastal, desert, and semi-desert climate. Because of the comprehensive nature of self-design objectives, they are incorporated into all stages of the design process to become influential architectural elements, starting from defining the design concept through making external formal decisions and determining the criteria for selecting building materials.

1.2. Employing Environmental Treatments According to The Design Process Stages from Outside to Inside of The Building

Many studies have focused on classifying the design processes of buildings or projects into four stages. Each stage includes a set of climate control treatments summarized in **Table 1**, which can be employed according to each specific design stage to achieve the above-mentioned thermal control strategies. These climate treatments have been proposed according to an approach parallel to the design process. This approach starts with the design of the site and outdoor spaces and ends with the detailed design of the openings and the selection of building materials [20]. Also, many climate treatments suit the different climates of the world. As for the treatments that are suitable for the hot, dry climate according to each of the four stages, they are as follows:

1) Site planning and design phase and building mass

The possibility of controlling the effects of the external environment of the building is wide within this phase. Methods of avoiding the harsh conditions of the external environment may vary and take several forms, such as determining the direction of seasonal winds to choose the most appropriate orientation for the building mass and employing adjacent and planted trees to shade from direct sunlight [4]. It is also possible to benefit from any water source on the site to improve the microclimate area surrounding the building [14]. It is also possible to control the external site finishing materials that affect one manner or other the building's thermal performance.

There is a significant impact on core design decisions that helps avoid the harmful effects of the external environment in both summer and winter and produce a building with high thermal performance efficiency. One of these decisions is to reduce the external surface area of the building mass to reduce its exposure to the external climate. It is also possible to bury the most extensive possible volume of the building mass under the ground to reduce its exposure to all external environmental influences. Also, orienting the building mass in the southern direction, which increases solar gain in winter and thermal avoidance in summer, has a significant impact on the level of thermal performance of the building. Therefore, the designer's orientation of this stage is to search for projecting, distributing, and choosing the ideal place for the building within the site and investigating the best direction for directing the building. That requires studying both the movement of the sun and the direction of the local winds and investigating the direction of the local winds and dust storms to exploit the site components like the adjacent buildings and trees for protecting the building mass. Also, it is recommended to plant trees and shrubs within the site for shade, dust repelling, and moderating the area climate surrounding the building block.

2) Building plan design stage

Some design treatments are utilized at the level of the internal plan to increase the thermal performance efficiency of the building, such as employing transitional spaces between the internal and external environments [11]. An example is treating the central courtyard to help create a microclimate or internal environment close to the thermal comfort zone [13]. Also, the internal air movement process can renew the air continuously using an air catcher and create vertical air paths that achieve air movement inside the building [6]. Besides, spaces can be distributed according to their occupancy times based on the movement of the sun to increase solar gain in winter or avoid it in summer.

At this stage, the designer's approach is to reduce the negative impact of these harsh conditions on the building mass due to the harsh external climate in hot, dry areas. For this reason, it is preferable to reduce the building's external area by using compressed shapes containing a small surface area to volume ratio often directed inside using internal courtyards. Also, it is preferable to shade the building's openings and external spaces from the sun in the summer.

3) Building envelope design stage:

Many treatments are used to reduce heat gain in summer and heat loss in winter through the building mass. That is by controlling the properties of building materials to have a high thermal capacity, using insulators, or shading the walls and ceilings with sunshades and climbing plants [23]. Also, roofs can be treated as one of the most exposed surfaces to solar radiation by using secondary roofs, planted roofs, and basin roofs as an additional layer separating the internal and external environment [2]. Besides, double walls and roofs protect the building from direct solar radiation in the summer, change the air mass surrounding the building, and store solar energy for heating purposes in the winter.

The designer's approach at this stage is to benefit from the daily variation in temperatures between night and day so that the walls and ceilings have a pre-controlled thermal performance. That can be achieved using materials with specific structural properties, such as materials with the high thermal capacity and materials with low thermal conductivity and insulators. Also, it is recommended to pay extra attention to shading the walls and ceilings from the sun's rays to reduce the amount of rays they may receive daily.

4) Openings design stage:

The decisions to design building openings depend on two main pillars; the first is controlling natural ventilation, and the second is controlling solar radiation to reduce heat gain through the openings in the summer and increase it in the winter [15]. Hence, there is a set of treatments to achieve these two pillars. These treatments reduce the proportion of glass areas on the facades and shade these openings from the summer sun rays. Besides, choosing the appropriate direction for the openings, controlling their areas for natural ventilation purposes, using glass materials with heat-insulating and solar-reflective properties, and employing some details of the openings to reduce air leakage through them in summer and winter [20].

The designer's approach at this stage is to design the building's opening treatments by controlling:

The first is solar radiation achieved by choosing the correct shape of the glass openings, their orientation, and shading, such as reducing the percentage of glass openings in the eastern and western facades and shading them.

The second is natural ventilation through adopting healthy ventilation strategies during moderate periods and employing the stack effect, which depends on the drop in temperatures at night to cool the building mass as a result of the difference in density between the air inside and outside as a result of the difference in temperature and humidity.

Table 1: Classification of environmental treatments according to the design stage to improve the thermal performance of a building.

No.	Staged design processes	Related treatment of climate control strategies
1	**Site planning and design stage and building mass**	To utilize the terrain and surroundings for shading, reduce the reflectivity of external finishing materials, eliminate wind disturbances in summer and winter, and use evaporative cooling on site. To reduce the surface area of the building mass, orient the building mass, and bury the building structure. To study the shape and orientation of the building, landscape the site, invest in water bodies within the site, design open spaces, and choose external finishing materials for the land surrounding the building. To form the exterior design of the building and building elements, orient the building, and consider the surface-to-volume ratio.
2	**Building plan design stage**	To use the central courtyard and wind catcher, construct an air shaft inside the building, and shed spaces and activities with the sun's movement. To use compressed or integrated shapes and shade the external spaces. To design the internal walls and partitions of the building.
3	**Building envelope design stage**	To use secondary roofs, insulate materials, high thermal capacity materials, and reduce walls and roofs. To use climbing plants and trees for shading, planted roofs, basin roofs, and double walls and roofs. To use insulators with High thermal capacity materials, materials with low conductivity, and shade walls and roofs. To Select roof and exterior wall finishing materials (colors and texture of exterior finish), building materials, interior finishing materials, and insulating materials for roofs and walls.
4	**Opening design stage**	To reduce openings, orient openings, shade openings, control opening areas, and use materials with insulating properties. To use construction details for openings to reduce air leakage. At the level of solar energy protection treatments, choose opening shapes, and shade openings, and decrease opening ratios. To choose the building opening pattern, open shape. At the level of natural day treatments, use the cross-ventilation phenomenon, and stack effect to dispose of excess heat.

This method is compatible with many trends in building design, which were also formulated according to the natural sequence of design stages divided into four. Each stage comprises a set of recommendations that were later translated into design treatments according to the different kinds of climates.

Hence, achieving environmental design requirements and thermal control strategies cannot be isolated from other life requirements. But they must all be in line with economic aspects, social and local conditions, and in a way that achieves the functional and symbolic requirements of the building or project so that the design style or approach followed is responsive or interactive in terms of climate and environment and with the rest of the requirements and needs of humans or users.

1.3. Environment and Climate-Responsive Design

The approach, method, or methodology of environmentally and climatically responsive design always seeks to make the surrounding conditions of the building within the comfort zone or at least as close to it as possible [23], [27]. The basic idea behind climate-responsive design is to consider climate as a design criterion in all aspects of the building and the built environment and approach the ideal comfort zone to improve the built environment states compared to the external environment conditions [13]. The thermal comfort zone for hot, dry climates is determined by dry bulb thermometer temperatures and relative humidity within the optimum thermal comfort zone range between 22.5 and 28.5 degrees Celsius and relative humidity between 30% and 70% [15].

Making changes to these four stages of the design processes in sequence from the outside to the inside is to make the possibility of controlling the internal conditions of the building as significant as possible. Besides, considering them as stages of environmental climate design, employing environmental treatments according to those stages during the design processes from the outside to the inside of the building was previously mentioned.

1.4. Design Elements Supporting the Control of The Thermal Performance of The Building or Project

For any building beginning to be designed, its thermal performance can be controlled through a set of design elements that have the most prominent impact on thermal performance to produce better buildings and efficiency in terms of energy use and provide a comfortable internal environment [14]. These elements are called design variables, as in **Table 2**, and they are:

1) Form: this can be controlled either through the ratio of external surface area to volume or by orienting the building in the direction that gains the least thermal energy in the summer and the highest thermal energy in the winter [6], [17].

The first main design decisions determine the size of the different blocks and develop the external shape of the building. Then comes the second stage of designing the building form. During this stage, the overall shape of the building is according to two influential strategies: compact versus complex forms. For example, compact shapes are best in climates that require the least possible heat gain, such as hot, dry climates. However, their ventilation and lighting will be indirect. But with complex shapes, which have the possibility of natural ventilation, it is easier and better.

2) Building materials: this means specifying the efficiency of external surfaces for absorption and reflection. The use of heat-resistant or reflective insulators or insulators with thermal capacity. The possibility of shading walls and external surfaces [11], [28].

One of the essential things is the speed of response of the building mass according to its construction materials to thermal effects and their internal and external changes. That is related to the properties of the used materials, such as thermal conductivity and heat capacity, determined during this stage.

3) Openings: they refer to the possibility of controlling the openings on several levels, such as the opening size, location, orientation, the glass type used in the openings, and properties, in addition to mechanisms for shading the openings, such as external umbrellas fixed or movable or internal barriers, such as curtains [18, 27].

There are several methods for controlling thermal energy through the building envelope. These methods include controlling solar radiation through shading or reflectivity of external wall surfaces, controlling glass openings of all types and directions, and controlling internal natural ventilation. That provides an opportunity for the designer to make design decisions regarding any control methods he will adopt during this stage.

4) Ventilation: this refers to dealing with ventilation as a double-edged sword. That is because the building needs to dispose of unwanted heat through ventilation when the internal temperature increases from the external temperature [7]. At the same time, there is a need for the method of constructing openings to be tight to reduce air leakage that occurs in summer and winter when the same contrast occurs between the internal and external temperatures, which are often during the day in summer and at night in winter [4].

The internal planning of the building aims to integrate the envelope with the body within a single composition to divide the building internally in some way. This method allows for the permeability of light and heat in the winter and controls in the summer, besides increasing natural ventilation within the building spaces comfortably and without internal obstacles.

Table 2: Classification of environmental treatments according to design variables to improve the thermal performance of the building.

No.	Design variables	Dependent treatment of each variable
1	**Form**	To consider surface/volume ratio and building mass orientation; To minimize building size, building exterior shape, and building mass detail; and To shade surfaces and walls, achieve absorption and reflectivity of surfaces and walls, and use insulators and materials with high thermal capacity.
2	**Materials**	To invest in the specifications of different glass materials. To use thermally insulating materials. To consider properties of building materials, such as thermal conductivity, heat capacity of materials, and select finishing materials.
3	**Openings**	To control the opening size, orient openings, have thermal properties of glass materials, and shade openings.
4	**Ventilation**	To ventilate the building mass and reduce air leakage in the summer and winter (to and from) a building. To integrate the envelope with the mass to allow light and heat to pass through in winter and reduce them in summer, in addition to natural ventilation.

1.5. The Impact of Integrating Environmental Control Strategies and Principles into The Project Life Stages on Costs

Integrating these strategies and principles increases the initial cost of the building but reduces the long-term operating cost [1]. That supports the application of climate treatments and keeps it within the acceptable comfort range [20]. The type of treatments proposed by the study within each stage are initially preventive treatments. As the design process progresses in depth into secondary or detailed design decisions, environmental treatments shift from preventive to curative [16]. The overlap between potential treatments, development stages of the design processes, and project life is as follows in **Table 3**:

1) The preliminary studies: within the site study and outdoor space design phase, decisions regarding site selection and comprehensive building sizes significantly impact the environment and energy [8, 17]. Decisions that consider environmental aspects often have positive effects to decrease future operating costs.
2) The preliminary and final design stage: designing the building mass and developing initial concepts about the geometrical formation and orientation [22]. The decisions regarding alternatives to the building's shape, height, and orientation have a beneficial influence on comfort and energy levels and have little effect on increasing construction costs remarkably.
3) The final design stage: is to select building materials, distribute openings, and detail the building mass from the inside and outside [27].
4) Quantities, specifications, and details preparation stage: glazing systems and thermal insulation materials reduce needing energy [23]. However, no matter how efficient the glass and insulation materials are, they will not completely cover up errors in orientation, improper shape, or even large glazing areas. That will lead to an increase in the value of operating costs over the life of the building.
5) The implementation stage: decisions regarding the selection of building materials are made, which often have a specific impact on the level of the indoor environment, user comfort, and thermal performance of the building [6].

According to the design process, environmental treatments are classified into two types, i.e. Corrective and preventive treatments. The preventive treatments are taken in the early stages and the latter in the late stages of the design process. Preventive decisions ensure high-performance efficiency and significant flexibility and are more thoughtful. Corrective decisions attempt to improve performance or enhance internal environmental conditions. Climate treatments are design elements, and the quality and efficiency of these elements cannot be judged without testing their composition and application with a group of other elements within a project or building to come up with a single, integrated composition.

Table 3: Development stages of design processes during the building life with the impact of incorporating environmental control principles at construction and operating costs.

No.	Integration Phase of Environmental Control Strategies and Principles	Integration Opportunities	Cost Impact
1	Preliminary studies	Very High	Few within the proposed design alternatives
2	Preliminary design	High	Few, according to the decisions regarding the development of the approved proposal
3	Final design	Good	Medium, according to the accuracy of the used details and the required calculations to improve the building's performance.
4	Development of final design	Limited	Greater due to the possibility of adding more treatments or replacing them with new treatments
5	Preparation of BOQ, specifications, and details	Very Limited	Greater due to the need for accurate description and mention of implementation details, and when adding
6	Implementation	Very Limited	Very high cost when adding, changing, or having modifications
7	Use	Very Limited	Very high cost with the difficulty of adding, changing, or modifying

1.6. Case Studies

Two experiments were studied and analyzed: the Sea Towers in the United Arab Emirates and the Central Bank of Iraq building in Baghdad. They are examples of existing buildings that succeeded in flexibility and integration with the surrounding environment to deal with the hot, dry climate and relied on the self-sufficient and effective method, as in **Tables 4** and **5**. Then, the environmental climate treatments, design elements, and strategies for each method were extracted so that architects could follow in their designs for new buildings or try to improve the design of parts and components of existing buildings to be more suitable for the climate and surrounding environment. Accordingly, a design vision can be reached for buildings from the outside and inside in the hot, dry climate.

- Criteria to select the two case studies:

1) The selected buildings must have been implemented and operated for a while and have passed the design and preliminary study stage.
2) They must be located within a hot, dry climate similar to the local Egyptian climate.
3) The buildings must be newly constructed within the last twenty years.
4) The selected buildings must have been evaluated according to international evaluation systems and have obtained one of their certificates.

- Criteria to analyze the two selected case studies:

1) To follow a parallel approach to the design process and serve the design variables and climate environmental treatments associated with each variable. This approach starts with the design of the site and outdoor spaces, then ends with the detailed design of the openings and the selection of building materials, utilizing and integrating many climate treatments compatible with the hot, dry climate.
2) To show and explain each of the environmental climate control treatments used within each case study during each of the four stages of the design process, summarized in **Table 1**.
3) To clarify the benefit of each treatment that could be employed according to each specific design stage to achieve the thermal control strategies targeted for each case study to allow or prevent thermal transfer defined by heat gain or loss.

1.6.1. The first Case Study (Bahar Towers - Abu Dhabi)

The Sea Towers is a development project in the Emirate of Abu Dhabi, United Arab Emirates. It is an innovative and environmentally friendly twin tower that comprises 29 floors and a height of 145 meters. It serves as the headquarters of the Abu Dhabi Investment Council and the main offices of Al Hilal Bank by Aridas Company [29]. It was also selected in 2013 by the World Council on Tall Buildings and Urban Habitat to be among the best architectural designs in compatibility and innovation that comply with all environmental standards, as shown in **Fig. 1**.

Fig. 1. The external architectural composition of the twin towers of the Abu Dhabi Sea Towers and their relationship with the surrounding local environment. On the right is the complete closure of the triangle units, and on the left is the opening of those units during daylight hours [29].

The design concept is inspired by Mashrabiya, a geometrically carved wooden lattice screen that was placed on the windows of traditional Arab architectural houses to provide privacy, visual visibility, and protection from the sun's rays, as shown in **Figs. 2, 3, and 4,** which shows the details of the interaction of moving triangles with climatic conditions. The Al Bahr Towers are environmentally friendly and are among the first buildings in the Arabian Gulf region to receive the Silver rating of Leadership in Energy and Environmental Design (LEED), and came in second place in the Emporis Skyscraper Awards 2012 after competing with 300 of the best high-rise projects in the world.

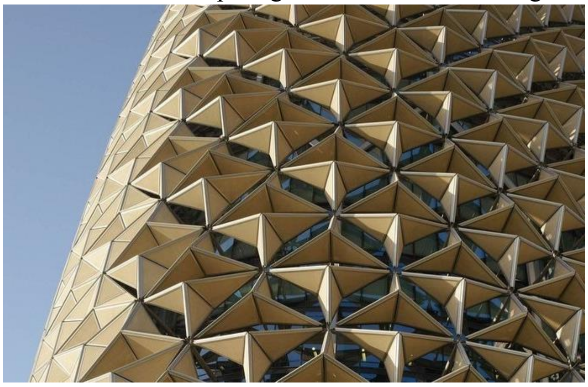

Fig. 2. The triangles that make up the outer wall in front of the glass envelope are covered with finely perforated glass fibers. These fibers are programmed to respond to the sun's movement and are equipped with sensors that allow them to open or close completely or partially, depending on changing weather conditions [29].

Fig. 3. The ability of the external triangular units to provide shade for the building and its interior space and allow for adequate lighting and good ventilation [30].

Fig. 4. Various positions of the external triangular units according to the external environmental conditions provide flexibility with all conditions [30].

Table 4: The impact of environmental treatments in the Al Bahr Towers building in Abu Dhabi, according to each design stage on improving the thermal performance of the towers.

No.	Staged design processes	Impact of treatments used in Al Bahr Towers Building - Abu Dhabi
1	Site planning and design stage and building mass	The facades of the towers were designed in a traditional Arabic architectural style. A notable feature of these towers is a protective wall composed of 2,000 glass segments that resemble an umbrella. This wall can open and close automatically, responding to the position and intensity of the sunlight. The design draws inspiration from the "Mashrabiya," which are intricately carved wooden lattice screens traditionally used on the windows of Arabic homes to shield them from the sun. The world's largest computerized facade cools a honeycomb facade of the towers. These elements, which open and close in response to the sun's movement, help reduce internal heat gain by about 50 percent. Solar panels on the roof to heat water were used, and the tower overlooks the sea from all directions. The outer envelope had a glass cylinder form, supported by a structure carrying an intelligent dynamic shading system, and programmed to respond instantly to solar radiation intensity, sun direction, and temperatures. The design concept is culturally and environmentally appropriate and meets the objectives of the Abu Dhabi 2030 Development Plan. The exterior design of the Al Bahr Towers is conscious of the environment and considers the local environment and surrounding climatic conditions. The exterior design is streamline designed that combines architectural innovation with advanced technology in environmental systems and intelligent building control and management systems. This process is done automatically and instantly through the building's intelligent management system (BIMS), which reduces solar gain and achieves the highest energy efficiency in cooling and ventilation operations. The northern facade of each tower also includes photovoltaic cells that generate approximately 5% of the total energy required for the building.
2	Building plan design stage	The tower's design was inspired by the traditional "Mashrabiya" that adorned the windows of conventional Arab homes since the 14th century. This clever architectural design of the Mashrabiya provides both shade and privacy to the interior spaces. The towers can accommodate between 1,000 and 1,100 employees each. At the same time, it allows for a constant view of the connection outside and to the surrounding environment. Adjustable shades help reduce internal heat gain from sunlight by about 50%. That reduces glare, improves daylight penetration, reduces reliance on artificial lighting, and saves energy. The top floor of the towers features shaded internal gardens along the southern façade, which mitigate the effects of sun exposure, with large areas

		used for meetings and breaks; besides, a wide range of shared facilities, including prayer rooms, restaurants, and a lecture hall.
3	Building envelope design stage	The movable wall is located two meters from the exterior facade of the buildings in an independent frame. This wall consists of triangles, each covered with micro-perforated glass fibers and programmed to respond to the sun's movement. These triangles are equipped with a combination of sensors that open the units in case of changing weather conditions. The building management system dynamically controls the facade of the Al Bahr Towers. That creates a ventilated space that acts as a thermal insulator, supports air movement with the chimney effect, supports natural ventilation of spaces, reduces the heat transfer rate between the inside and outside U-value, and helps cool the outer shell of the building. Chosen stone or stone colors were like finishing materials for the surface. Also, external walls were to match the surrounding environment colors, especially in the external fixed parts of the building. The south-facing roofs of each tower feature photovoltaic cells, generating approximately 5% of the gross energy required for water heating from renewable sources. The ventilation and cooling strategy is considered mixed ventilation and an openable outer envelope in some spaces. It is characterized by merging natural and artificial ventilation, thus reducing annual energy consumption and creating a healthy indoor environment. The shading system units are made of non-opaque microfiber glass, which achieves a degree of transparency with good thermal insulation and penetration of natural light while preventing solar radiation from entering the interior spaces.
4	Opening design stage	At the level of natural daylight treatments, the cross-ventilation phenomenon and the stack effect were used to dispose of excessive heat. This dynamic Mashrabiya reduced the amount of solar radiation entering the building by half. Hence, it saves a lot of electricity consumed by air conditioning and the ability of the awnings to provide shade to the building. In addition, the ability of the awnings to provide shade for the building pushes the designers to dispense with dark glass that blocks external light at all times. That saved electricity consumed by lighting during the day. The percentage of openings on the northern facades is 90% of the area of the same facade. But it ranges from zero to 75% of the area of the southern facade. The openings are shaded by movable shading elements that react to the sun’s movement through the intelligent building management system. The intelligent building management system with sensors and motors controls their movement. This system reduces solar gain by 50% and glare and dazzle to improve the natural lighting of the interior spaces. That leads to the highest energy efficiency in cooling, ventilation, and artificial lighting and the reduction of carbon emissions by 1,750 tons/year. The openings adapt instantly to the solar radiation of similar glass facades. The building's orientation and the sun's path were studied to suit the sun's direction and the temperature, monitored by a miniature weather station.

1.6.2. The Second Case Study (Central Bank of Iraq Building in Baghdad)

The Central Bank of Iraq building is in Baghdad's Al-Jadriya neighborhood and is the organization's new headquarters. At 173 meters tall and 90 thousand square meters inside, it is among the tallest structures in Iraq. It has three stories below ground and 35 floors above. It has a museum, offices, gold and cash storage warehouses, and green areas around the building.

It was completed in 2023, as shown in **Fig. 5,** where its facades overlook the Tigris River in the center of Baghdad. Its high, towering exterior shell is distinguished by a unique design that combines innovative architectural formation and compatibility with the surrounding orientation and climatic conditions.

The building has won the 2023 CTBUH exterior envelope design creativity award. It has received a very good BREEAM and Silver (50-59 points) rating from LEED, and the design office is Zaha Hadid. It was the first project designed by Zaha Hadid in Iraq.

Fig. 5. The external architectural composition of the Central Bank of Iraq building and its relationship to the surrounding local environment on the right, as well as to the surrounding urban area and the Tigris River on the left [31].

The design concept is to raise the Central Bank of Iraq on the banks of the Tigris River in the capital, Baghdad. The building is characterized by a dynamic design, and the building design translates to the core values of the bank, which are strength, stability, and sustainability. It reflects the historical importance of the Tigris River, as it was the main trade route for the city and a source of fresh water for thousands of years. The design presents a side of contemporary values rich in traditions and historical relationships.

The project consists of a tower and a base. The tower has a small base that widens in the middle to improve the design performance. Then, the building body narrows again until the top of the tower. The base was designed horizontally toward the river and contains a lobby that provides natural lighting inside the entrance overlooking the river.

As shown in **Figs. 6 and 7**, the project's facades were covered with an external structure that forms alternating patterns of open and closed elements that simulate light reflections and enhance the dynamic design. Also, it serves the purpose of providing multiple areas of light and shadow within the tower. The structure covers the entire tower base and begins to open up as it rises to the top, as the parts of the structure move away from each other vertically and extend along the length of the tower. The base is also covered with the same structural panels as the project appears as a single mass.

Fig. 6. The distinctive architectural design of the northern facade on the right and the southern facade on the left of the Central Bank of Iraq building [31].

Fig. 7. The dynamic design of the sun breakers changes with height along the body of the building as the angles of sunlight change to the facades of the Central Bank of Iraq building [31].

Table 5: The effect of environmental treatments in the Central Bank of Iraq building in Baghdad according to each design stage on improving the thermal performance of the building.

No.	Staged design processes	Impact of treatments used in the Central Bank of Iraq building in Baghdad
1	Site planning and design stage and building mass	The building envelope is tall and towering with a unique design combining innovative architectural form with compatibility with the surrounding orientation and climatic conditions. The building is located on the banks of the Tigris River and features a dynamic design. The building's design translates the bank's core values of strength, stability, and sustainability, reflecting the historical importance of the Tigris River. The river has been the city's main trade route and source of fresh water for thousands of years. The design offers a contemporary expression of values rich in tradition and historical connections. The tower has a small base that widens in the body midpoint to improve design performance. It then narrows back to the tower top. The base design is horizontally toward the river and contains the lobby that provides natural lighting inside the entrance overlooking the river.
2	Building plan design stage	The facades are mainly shaded, as the horizontal projection of the tower is designed as a square, increasing its area towards the top by increasing the area of the horizontal projections of the floors until the tower's middle. That helps in self-shading large areas of the facades and the body of the building. The design of the outer envelope of the Central Bank of Iraq Tower depended on the principle of mixed ventilation through open windows. It achieves a combination of natural and artificial ventilation. Therefore, relying entirely on artificial ventilation in tall buildings leads to high energy consumption and the creation of an unhealthy indoor environment.
3	Building envelope design stage	The facades are covered with an external structure that forms alternating patterns of open and closed elements that simulate light reflections and enhance the dynamic design. Also, it serves the purpose of providing multiple areas of lighting and shadow within the tower. The external envelope design of the Central Bank of Iraq Tower carries environmental awareness and consideration for the local environment and surrounding climatic conditions. Its outer shell was streamlined and designed to combine engineering innovation with high efficiency in dealing with high temperatures and solar radiation. The geometric shape of the mass has vertical concrete breakers on the southern, eastern, and western facades. The dimensions and directions of the breakers change in a streamlined manner along the tower height due to their design having dimensions and angles according to the sun's path. That is to protect the internal spaces from excessive solar gain and increase the energy consumption efficiency in cooling and artificial ventilation works.

4	Opening design stage	The external envelope design of the Central Bank of Iraq Tower departed from the traditional image of a building with identical glass facades. The building orientation and the sun path were studied so that the proportions of the openings of each facade would suit the proportions of solar radiation exposed to it. Consequently, large glass surfaces were employed on the northern facades. The selected vertical concrete breakers provide the insulation and shading for the openings within the southern, eastern, and western facades. That increased the efficiency of energy consumption and increased the rates of thermal comfort in the interior spaces. The proportion of openings on the north facades represented 75%, while they represented 20% of the area of the southern, eastern, and western facades. In addition to using concrete breakers in the southern, eastern, and western facades, their dimensions change. Thus, the breakers reduce the heat transfer rate between the interior and exterior U-value by using curtain walls of double-insulated glass on the northern facade. The used vertical breakers of reinforced concrete are wrapped with locally manufactured artificial stone cladding. Therefore, achieving efficiency in the consumption of cooling energy for the interior spaces and saving the implicit energy consumed in their manufacture, transportation, and installation.

It is clear from the above that the buildings under study (Al-Bahr Towers and the Central Bank of Iraq) used several common means and methods in dealing with the climate and surrounding environment. Several results showed that these means had an influential impact on the environmental performance of the buildings. The most important of these means was studying the geometric shape of the outer envelope, as in **Tables 4 and 5**, and consistently designing it with the orientation and climate. Also, employing the proportions of openings and shading methods, creating them according to the orientation and sun path, choosing suitable envelope materials for the site, climate, and local environment, and adopting mixed ventilation systems and open windows in the buildings.

These two case studies are Al Bahr Towers in Abu Dhabi and the Central Bank of Iraq Building in Baghdad, which confirmed what the research adopted from the study begins regarding the importance of employing environmental treatments according to the stages of the design processes from the building outside to the building inside within the four stages previously mentioned in **Table 1**. They are the stage of planning and designing the site and building mass, the designing stage of the building plan, the designing stage of the building envelope, and the designing stage of the openings.

RESULTS AND DISCUSSION

After being exposed to the possibility and reliable opportunity to link the stages of design processes with the application of strategies of the self-climate environmental control method for the building or project, which were represented in the design treatments for any building that is being designed. Whether at the theoretical inductive level based on thought and concepts and the analytical level from applied examples through a group of design elements. They can be divided into strategies specific to hot weather and others specific to cold weather. Therefore, these strategies focused on introducing design treatments that can be used to improve and control the thermal performance of the building. The approach to introducing treatments was also classified according to the design phase in which they can be employed, as shown in **Table 1**.

The issue of linking climate control treatments to the design process stages, especially those with passive methods, has become critical to a group of researchers. Such a link was to facilitate and encourage integrating these treatments and investing in their application during the design process to produce thermally balanced buildings that respond to the surrounding environment, as the study demonstrated in the Central Bank of Iraq building in Baghdad. The same active methods can also be employed, which depend on movement in the building parts, especially the outer shell, as in the Al Bahr Towers in Abu Dhabi, during the same design process stages. The design and planning factors within the design process stages are among the most significant factors through which the architect can control the energy amount related to the building received in summer and winter to obtain thermally suitable spaces. That reduces the energy required for heating, mechanical air conditioning, and moving parts of the building, which require periodic maintenance, which increases the operating cost in the long term.

After identifying the set of environmental design treatments that achieves the objectives of thermal control strategies suitable for a hot, dry climate, it becomes clear that these treatments have their diversity and variation in their impact on the design. Such treatments should be integrated with the architectural product within a thoughtful intellectual, functional, and aesthetic system consistent with the designer's ideas and the requirements of the basic design situation. Therefore, it is necessary to take these treatments, in whole or in part, into consideration during the design stages because they directly affect the level of thermal performance of the building and its overall efficiency, as well as the levels of thermal comfort and the level of performance and activities of users. Based on what was mentioned in the inductive and analytical parts of the study, the design process, according to the environmental perspective, goes through several stages. They were extracted in four stages that move the designer from the main design decisions related to generalities to decisions regarding the finer details.

Therefore, a design vision can be proposed that employs, incorporates climate control treatments, and links them according to the sequence of the design process stages, as in **Fig. 8**. These treatments will be addressed and focused on treatments compatible with the hot, dry climate as the prevailing climate in Egypt, without focusing on the rest of the climates and classifying them into summer and winter, as in **Table 6**.

These treatments are classified into four thermal control strategies for each season, two for hot seasons and two of cold seasons:

- The hot climate strategy is to resist heat gain and allow heat loss.
- The cold climate strategy is to heat gain and resist heat loss.

As shown in **Fig. 8**, the proposed design vision steps and levels consider the cost factor and the type and degree of treatment, whether preventive or curative. Then, the designer can adopt one of the thermal control strategies according to the climatic conditions affecting the project and throughout the year. In addition, the designer can endure the opportunity to determine one of the four stages of the design process to deal with his design freely, treat all parts of the building, and raise the level of its thermal performance and response to environmental conditions. Finally, the designer reviews and ensures the treatment performance as an integrated whole with all the building elements or other employed and integrated treatments during the remaining stages of the design process. If the performance is not accepted, the designer can refer back to the environmental treatments that achieve each strategy within any of the four stages of the design process.

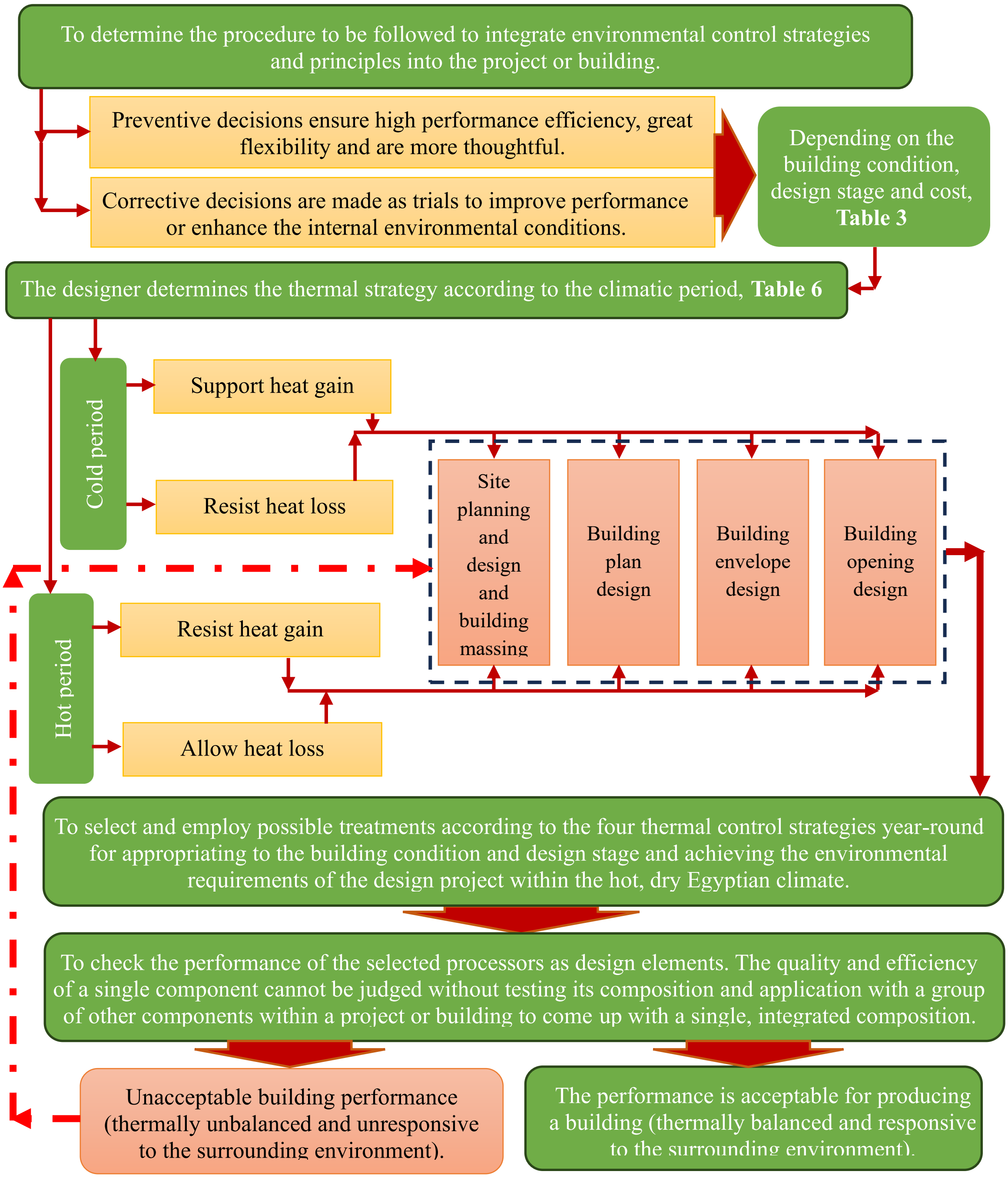

Fig. 8. The proposed design vision structure that employs and integrates climate control treatments according to thermal control strategies and links them to the building condition and design phase according to the sequence of design process stages throughout the year.

Table 6: Environmental treatments achieved for heat gain resistance, heat loss allowance, heat gain allowance, and heat loss resistance strategies in the hot dry Egyptian climate throughout the year according to the design stages.

No.	Design processes and stages	Environmental treatments achieved for each strategy			
		Heat gain resistance	Heat loss allowance	Heat gain allowance	Heat loss resistance
1	Site planning and design stage and building mass	To reduce the external surface area of the building envelope. To shape and orient the building mass. To achieve thermal equivalence of the building envelope. To bury the building structure under the ground layer or raise the ground layer for ground protection. To cover the ground and plant trees. To use adjacent areas and plants for solar shading. To reduce the reflectivity of the external ground surfaces opposite the windows. To use the central courtyard within the building plan.	To attract summer breezes through shaping and directing the building mass. To use adjacent areas and plants to attract summer breezes.	To form Building mass and orientation. To increase the solid surfaces to absorb solar radiation.	To reduce the external surface area of the building envelope. To bury the building structure under the ground layer or raise the ground layer for ground protection.
2	Building plan design stage	To use the central courtyard, wind catcher. To form an air shaft inside the building. To plan and scheme spaces and activities with the sun's movement. To use compressed or integrated shapes - shading the external spaces. To design the internal walls and partitions of the building. To shade balconies.	To employ the phenomenon of evaporative cooling on site. To optimal select the location of spaces with internal heat sources within the horizontal plane. To use the open plan to allow internal airflow. To employ vertical spaces to allow internal airflow. To use air catchers.	To project and plan open spaces or courtyards and skylights in the building plan following the sun's movement.	To use an external wind barrier at the entrance.

3	Building envelope design stage	To use insulating materials that resist heat flow through the building envelope. To use materials with a high thermal capacity in the building envelope. To use radiation-reflecting materials on the building's external surfaces. To shade walls. To use double walls and roofs to ventilate the building shell. To use climbing plants around the building envelope. To shed roofs. To use planted roofs.	To use basin ceilings. To use insulators, materials with high thermal capacity, others with low conductivity, and shading of walls and ceilings. To determine finishing materials for the surface and external walls (colors and texture of the external finish). To choose building materials, interior finishing materials, and insulating materials for the ceiling and walls.	To employ glass surfaces. To increase the surfaces exposed to solar radiation.	To use insulating materials to resist heat flow through the building envelope. To utilize planted roofs. To employ insulating materials with high thermal capacity. To control the shading of walls and ceilings.
4	Opening design stage	To reduce openings and control the area of openings within doors and windows in walls. To use glass with insulating properties. To employ materials with insulating properties. To use construction details for openings to reduce air leakage. At the level of solar energy protection treatments (choosing opening shapes - shading openings - reducing opening ratios - choosing the building opening pattern). At the level of natural day treatments (using the phenomenon of cross ventilation and stack effect to get rid of excess heat).	To orient door and window openings to increase natural ventilation. To control the area of openings to increase airflow. To use wing walls to direct winds into the building.	To concentrate glazing ratio (glass use) on the southern facades.	To minimize door and window openings in the walls. To use architectural details for doors and windows to prevent air leakage through.

Based on **Table 6**, the heat gain resistance strategy is the one that has the most significant interest in working and integrating environmental treatments into the design process stages due to the nature of the hot, dry climate in the summer. As for the most significant design treatments with high repetitions that were identified from the previous two **Table 1 and Table 2**, they were as follows:

1) The site and building mass design treatments were the most frequent treatments related to the building mass orientation, the building mass design, the formation of the building surfaces, and the design of the building's external spaces.
2) Building plan design treatments were the most frequent regarding the shading of building parts, the usage of wind catchers, and the projection and placement of exposed spaces and courtyards following the sun's movement.
3) Building envelope design treatments were the most frequent regarding insulating materials and materials with high thermal capacities, shading or planting walls and ceilings, integrating them with the surrounding environment, and determining the colors and materials of interior and exterior finishing.
4) Building opening design treatments were the most frequent treatments related to building ventilation, controlling the area of openings, directing openings, shading openings, and using types of glass with insulating properties.

CONCLUSIONS

The main conclusion is the design vision that ensures the fulfillment of the environmental requirements of the design project through a set of treatments. They could be classified according to thermal control strategies into four stages that correspond to the four stages of the design process, namely, the site planning and design stage, the building mass, the building plan design stage, the building envelope design stage, and the design stage of the building openings, which the building goes through from the initial stages to its final stages. Thus, the designer can choose between the environmental treatments that are the most appropriate for each design stage or the design elements that could be identified, namely, form, building materials, openings, and ventilation.

It should be emphasized that it is not required for the designer to employ all environmental design treatments in the project or building. However, there is a scope in which variety can be achieved by integrating and investing in the maximum number of appropriate treatments according to the surrounding environmental conditions. Due to the difference in importance and priority of environmental design treatments according to the nature and location of the building targeted for design.

Then, two experiments were analyzed: the Sea Towers in the Emirates and the Iraqi Central Bank as examples of existing buildings that successfully achieved flexibility and integration with the surrounding environment within the hot, dry climate as an example of the Egyptian climate. The results showed that the most common means and methods in dealing with the climate and the surrounding environment have the most outstanding impact on the environmental performance of buildings. These means and methods include studying the geometric shape of the outer envelope and designing it in a way that is compatible with the orientation and climate. Besides, the proportions of openings and shading methods depend on the orientation and sun path, choosing suitable envelope materials for the location, climate, and local environment, and adopting compound ventilation systems, open windows, and fixed and mobile breakers in buildings.

Thus, it is possible to identify the environmental climate treatments, design elements, and effective methods used to show the benefit of their impact on improving the design of parts and components of existing buildings to be more suitable for the climate and surrounding environment. Based on the statement of the influence of integrating environmental control strategies and principles on costs during the project life and depended on identifying the treatments related to the design elements supporting thermal performance control. To achieve the environmental design concept and thermal control and its possible strategies for employing treatments according to the stages of the design process so that the building design is as responsive and interactive environmentally and climatically as possible. Thus, a design vision can be reached to integrate environmental treatments into the stages of the building design process and is effective throughout the project life stages within the hot, dry Egyptian climate. The vast majority of modern designs provide appropriate solutions to stop energy depletion by achieving thermal control in their performance to solve the problem of energy conservation with the increase in the number of buildings.

Therefore, it is necessary to consider the environmental treatments available for use in the design project in a broader way so that a number of them can be employed and exploited within the design decisions in a manner that suits the special nature and multiple design requirements of each building. When environmental requirements are considered from the initial stages of the design process, the designer has the potential to achieve a high climatic response. However, if the environmental aspects are not considered except in the later design stages, the possibility of attaining intermediate requirements will be limited to parts and details. At these later stages, the designer's freedom to achieve environmentally efficient buildings is restricted to a limited space.

Therefore, the designer must pay attention and focus on environmental treatments that are compatible in their benefits with achieving the functional, symbolic, formal, and structural requirements of the project. Consequently, the architectural product will be more integrated and more aware and contribute to rationalizing energy and resource depletion.

RECOMMENDATIONS AND FUTURE STUDIES

1) When designing a building, the designer should aim for the best possible quality to improve the built environment and provide users with the right thermal comfort range. To achieve biodiversity and enhance air quality, the designer must consider the requirements of the indoor environment. To provide users with the right level of thermal comfort and conserve the most energy possible for lighting, cooling, and heating the building, it should also be more sensitive to environmental factors.
2) It is necessary to halt the practice of creating uniform models for all building types and their diverse applications and distributing them across the nation without considering regional variations in social and climatic conditions.
3) Before beginning to design the building in general and the facades in particular, it is necessary to look into the surrounding conditions and the factors that affect the increase in thermal loads. That is because windows and walls are sources of energy drain and linked to the building's excessive energy needs.
4) Architects must be encouraged to use passive solutions to attain thermal comfort and include them in their designs because they significantly and effectively reduce energy consumption and improve user thermal comfort.
5) For determining which modern environmental technologies are suitable for the climate in which the building is located and how well they meet the climatic requirements of the building's interior spaces, an analytical study must be conducted before choosing any of the many types and shapes of materials that are used, as well as their cost, method of use, and ability to withstand heat.
6) Architects' efficiency and understanding level regarding the significance of environmental standards and how to apply them in design will increase with the activation of contemporary environmental design courses and their dosage within engineering colleges, making them a vital component of the educational system.
7) To dispel the widespread perception that environmental design techniques provide a traditional look that is not contemporary and that such techniques come with expensive construction and maintenance costs, besides to increase public understanding and community culture regarding these techniques and their traditional and modern terminology.
8) The methodology of researching thermal comfort within architectural spaces must be transformed into an educational issue studied in all Arab regions to raise the value of applied scientific criticism of the construction process within Arab cities.
9) The building codes should be activated to serve environmental design vocabulary and integrated into strict laws and legislation, which force a designer and an owner to make buildings have sound climatic solutions appropriate to the surrounding environmental conditions.
10) Architectural awareness of architectural treatments should grow within the design stages of each type of building and according to the thermal control strategies of each season. This may affect correcting the current urban path and highlighting a true identity for architecture in the Middle East that is based on realistic scientific logic and aims primarily at human comfort throughout the year and supporting sustainability plans and visions.

CONFLICT OF INTEREST

The authors have no financial interest to declare concerning the content of this article.

REFERENCES

[1] F. Belaïd and V. Flambard, “Impacts of income poverty and high housing costs on fuel poverty in Egypt: An empirical modeling approach,” Energy Policy, vol. 175, no. February, 2023, doi: 10.1016/j.enpol.2023.113450.
[2] S. Seyam, “The impact of greenery systems on building energy: Systematic review,” J. Build. Eng., vol. 26, p. 100887, 2019, doi: https://doi.org/10.1016/j.jobe.2019.100887.
[3] Z. Liu, W. Li, Y. Chen, Y. Luo, and L. Zhang, “Review of energy conservation technologies for fresh air supply

in zero energy buildings," Appl. Therm. Eng., vol. 148, pp. 544–556, 2019, doi: 10.1016/j.applthermaleng.2018.11.085.

[4] D. Mazzeo, N. Matera, G. Peri, and G. Scaccianoce, "Forecasting green roofs' potential in improving building thermal performance and mitigating urban heat island in the Mediterranean area: An artificial intelligence-based approach," Appl. Therm. Eng., vol. 222, no. December 2022, p. 119879, 2023, doi: 10.1016/j.applthermaleng.2022.119879.

[5] J. Taylor et al., "Towards a framework to evaluate the 'total' performance of buildings," Build. Serv. Eng. Res. Technol., vol. 39, no. 5, pp. 609–631, 2018, doi: 10.1177/0143624418762662.

[6] I. A. H. S. Al-Shamy, "The role of building technology in achieving thermal comfort for architectural spaces," J. Egypt. Soc. Eng., vol. 50, no. 2, pp. 95–75, 2011, [Online]. Available: https://2u.pw/IhwG6DqY

[7] O. A. I. Masood, M. I. A. Al-Hady, and A. K. M. Ali, "Applying the Principles of Green Architecture for Saving Energy in Buildings," Energy Procedia, vol. 115, pp. 369–382, Jun. 2017, doi: 10.1016/J.EGYPRO.2017.05.034.

[8] A. N. E. D. A. Zeid, "Architectural mass as a tool to achieve thermal comfort in the external urban space," J. Egypt. Soc. Eng., vol. 58, no. 3, pp. 53–47, 2019, [Online]. Available: https://egsen.journals.ekb.eg/article_177682.html

[9] K. Salah Eldin Elkhayat, "Entrance To Control The Use Of Renewable Buildings Energy In Egypt Study Of Coastal Hot And Humid Areas In Egypt," JES. J. Eng. Sci., vol. 45, no. 1, pp. 98–117, 2017, doi: 10.21608/jesaun.2017.116093.

[10] M. Dabaieh and E. Johansson, "Building Performance and Post Occupancy Evaluation for an off-grid low carbon and solar PV plus-energy powered building. A case from the Western Desert in Egypt," J. Build. Eng., vol. 18, pp. 418–428, 2018, doi: 10.1016/j.jobe.2018.04.011.

[11] M. Kenisarin and K. Mahkamov, "Passive thermal control in residential buildings using phase change materials," Renew. Sustain. Energy Rev., vol. 55, pp. 371–398, 2016, doi: 10.1016/j.rser.2015.10.128.

[12] A. B. Mohammed, "Green Roofs to Treat the Local Dwelling Environment Problems Within Egypt's Vision 2030," Mansoura Eng. J., vol. 49, no. 2, pp. 1–18, 2023, doi: 10.58491/2735-4202.3139.

[13] G. ghonemy G. hesham mohamed Sobh, "Evaluation of the effect of the bio-interface on thermal and visual comfort in educational spaces using computer simulation," Nile J. Archit. Civ. Eng., vol. 1, no. 1, pp. 1–16, 2021, doi: 10.21608/njace.2021.233351.

[14] N. Kohler, "From the design of green buildings to resilience management of building stocks," Build. Res. Inf., vol. 46, no. 5, pp. 578–593, 2018, doi: 10.1080/09613218.2017.1356122.

[15] M. Helal, A. almuntalb Ali, and N. Abd alkareem, "Evaluation Of The Thermal Performance Of Spaces For Drawing Halls In Building, Of Architecture Department, Faculty Of Engineering, Assiut University," Assiut Univ. Bull. Environ. Res., vol. 23, no. 2, pp. 1–18, 2020, [Online]. Available: https://journals.ekb.eg/article_145530.html

[16] M. V. Shoubi, M. V. Shoubi, A. Bagchi, and A. S. Barough, "Reducing the operational energy demand in buildings using building information modeling tools and sustainability approaches," Ain Shams Eng. J., vol. 6, no. 1, pp. 41–55, 2015, doi: 10.1016/j.asej.2014.09.006.

[17] F. Kheiri, "A review on optimization methods applied in energy-efficient building geometry and envelope design," Renew. Sustain. Energy Rev., vol. 92, no. April, pp. 897–920, 2018, doi: 10.1016/j.rser.2018.04.080.

[18] B. Chenari, J. Dias Carrilho, and M. Gameiro Da Silva, "Towards sustainable, energy-efficient and healthy ventilation strategies in buildings: A review," Renew. Sustain. Energy Rev., vol. 59, pp. 1426–1447, 2016, doi: 10.1016/j.rser.2016.01.074.

[19] M. N. M. Ahmed, A. B. M. Goda, and S. M. S. Elattar, "A Methodology for Evaluating Sustainable Building Technology to Raise the Efficiency of Urban Clusters: Analytical Study," Int. J. Membr. Sci. Technol., vol. 10, no. 5, pp. 916–929, 2023, doi: 10.15379/ijmst.v10i5.3627.

[20] H. Hammad, M. Abdelkader, and A. Atef Faggal, "Investigating the Thermal Comfort Conditions in an Existing School Building in Egypt," JES. J. Eng. Sci., vol. 45, no. 3, pp. 344–359, 2017, doi: 10.21608/jesaun.2017.116274.

[21] R. F. Rupp, N. G. Vásquez, and R. Lamberts, "A review of human thermal comfort in the built environment," 2015. doi: 10.1016/j.enbuild.2015.07.047.

[22] I. L. Wong, "A review of daylighting design and implementation in buildings," Renew. Sustain. Energy Rev., vol. 74, no. February, pp. 959–968, 2017, doi: 10.1016/j.rser.2017.03.061.

[23] H. M. Taleb, "Using passive cooling strategies to improve thermal performance and reduce energy consumption of residential buildings in U.A.E. buildings," Front. Archit. Res., vol. 3, no. 2, pp. 154–165, 2014, doi: 10.1016/j.foar.2014.01.002.

[24] M. A. Haggag, "The use of green walls in sustainable urban context: With reference to Dubai, UAE," WIT Trans. Ecol. Environ., vol. 128, pp. 261–270, 2010, doi: 10.2495/ARC100221.

[25] A. Monge-Barrio and A. Sánchez-Ostiz Gutiérrez, Passive energy strategies for Mediterranean residential buildings : facing the challenges of climate change and vulnerable populations. 2018.

[26] N. H. Hefnawy and N. M. Ibrahim, "Towards Green Cities as an Approach to Achieve Climate Change Adaptation Case Study : Green Sharm El Sheikh , Egypt," J. Eng. Res., vol. 8, no. 2, 2024.

[27] ahmed haleem, “The role of solar breakers in achieving light comfort in educational spaces Case study: Egyptian Educational Buildings,” 2021. doi: 10.21608/erj.2021.209796.

[28] J. L. Fernández-Solís and I. Mutis, “The Idealization of an Integrated BIM, Lean, and Green Model (BLG),” in Green Technologies, US: IGI Global, 2011, pp. 1979–2011. doi: 10.4018/978-1-60960-472-1.ch809.

[29] A. N. Al-Minshawi, “The impact of building technology and the environment on the architectural space and its role in achieving thermal comfort. An applied study of the project (Al Bahr Towers in Abu Dhabi),” J. Al Azhar Univ. Eng. Sect., vol. 11, no. 38, pp. 343–359, 2016, [Online]. Available: https://jaes.journals.ekb.eg/article_19483.html

Websites

29. https://fidic.org/node/8776 (Accessed 29/10/2024)
30. https://www.re-thinkingthefuture.com/rtf-fresh-perspectives/a1834-10-of-uaes-most-sustainable-buildings/ (Accessed 29/10/2024)
31. https://www.dezeen.com/2024/08/21/zaha-hadid-architects-central-bank-of-iraq-baghdad/ (Accessed 29/10/2024)