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Analysis of biophilic architecture based on thermal comfort and energy saving in indoor spaces

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ABSTRACT

This article examines the relationship between humans and the environment, and the positive effects of biophilic architecture on improving the quality of life for individuals in residential spaces. Biophilic architecture integrates natural and biophilic elements in the design of building spaces, highlighting the role of thermal comfort and energy saving in interior spaces. The aim of this study is to present desirable solutions for enhancing human quality of life in residential spaces, and it requires further research to better understand the impacts of biophilia on human performance and health. The article emphasizes the importance of managing natural resources and environmentally friendly buildings with high energy efficiency, as well as the significance of environmental parameters and the performance of plant species in urban environments.

1.Introduction

Modern architecture has distanced humans from nature. The lack of connection with nature and the use of artificial building environments has had a destructive effect on mental tranquility, well-being, and human efficiency in various activities, and for this reason, the necessity of the relationship between humans and nature has become more evident than ever [1]. One of the issues of today's urban life is technological advances that have distanced humans from nature, and the comfort and tranquility of humans have not been sufficiently respected.

Biophilic architecture is one of the new approaches in today's architecture that seeks to design buildings using natural elements in order to achieve mental and psychological peace for humans. In architectural spaces, this relationship between humans and nature can be strengthened with the biophilic architecture approach. Biophilic design is actually a challenge to bridge the gap that has arisen between modern architecture and urban planning and the human need to establish a connection with the natural world. Given that nature and connection with it is an essential need for the survival of the human race in today's world, reaching places with characteristics of this design style is very necessary. Therefore, examining the common factors and characteristics between biophilic architecture and sustainability is important [2]. The Earth, the ecological survival chain, is the supporter and sustainer of us humans. The ability to revitalize is the key to human access and the main origin of architecture. Earth protection, Earth administration, and escape from Earth are more prominently highlighted in the vocabulary of architectural planning and design. Each site is defined by its location, natural land features, local vegetation cover, and its micro and macro climate.

Biophilic design is essentially designing and constructing with nature in mind. However, biophilic design does not mean simply greening buildings with grass and plant coverings to enhance their attractiveness and beauty with trees and shrubs. Rather, biophilic design is a type of architecture considered part of a sustainable approach, integrating natural light, natural materials, natural views, plant coverings, and other experiences of the natural world into interaction with the modern environment. Therefore, biophilic architecture is an effort to reduce the gap between humans and nature [3]. Biophilic architecture is part of a new architectural theory that is closely related to human health, ecological regulations, and sustainability, such as the integration of architectural components that should have an optimal proportion to other building materials [4]. The location and extent of vegetation are mainly dependent on the purpose of the space. However, the final interpretation and implementation of biophilic architecture should be considered in relation to the local regional environment and culture.

2- Research Method

Given the subject, this research is of a descriptive-analytical type, as it examines the analysis of biophilic architecture based on thermal comfort and energy control in internal spaces through theoretical study and description of features. Since thermal comfort and biophilia are considered solutions to environmental needs, it can be said that this research is of the applied type. For collecting information, documentary and library studies have been used. In general, this research is of a theoretical and review type.

3- Biophilic Architecture

The concept of biophilia was first proposed by American biologist Edward O. Wilson in 1984. He defines biophilia as an innate and emotional dependence of humans on living organisms, which has become an inherent and ultimate part of human nature [5]. In other words, for Wilson, biophilia represents a collection of learning rules that have developed over thousands of years, a result of the co-evolution of humans with their environment. Wilson's hypothesis asserts that there is a natural and instinctual connection between humans and other living systems. Biophilic architecture, as one of the sustainable architecture trends, emphasizes returning to the roots of human evolution and seeks to strengthen the connection between the built environment and its natural context [6]. Actually, biophilic architecture is part of a new concept in sustainable architecture that relates to human well-being, ecology, and sustainable development, which includes the integration of architectural forms with natural forms. The goal of biophilic design is to establish a reciprocal relationship between nature and modern humans. From a broader perspective, recognizing the fundamental need of humans to establish a connection with nature, in addition to sustainability and global strategies, aims to create environments that enhance the quality of life. Biophilic design has impacts such as:

Increasing physical health
Enhancing problem-solving ability
Boosting creativity
Reducing stress and anxiety
Increasing satisfaction
Improving collective skills and group work
Raising the level of concentration
Improving social relationships
Reducing violence [7]

Table 1 lists the essential components of this type of architecture:

Biodiversity	• Plant diversity within the building • Designed windows for viewing natural landscapes
mitation of Nature	• Designs inspired by nature • Use of natural patterns, forms, and textures • Fractal shapes
Sense of Vitality	• Use of decor, natural materials, and spaces designed to create a sense of joy
Perspective	• Visibility in the field of view • Presence of insight corridors

Table 1: Elements of Biophilic Architecture in Interior Spaces

4- Energy in Biophilic Architecture

Our body converts food into energy. The rate of this conversion is largely dependent on the level of body activity. The released energy is dissipated as heat in the body, and to a small extent, it is used for external work. Comfort mostly depends on the ease of the body. In this way, the body can create a balance between energy production and heat gain on one hand, and heat loss on the other hand, so that the internal body temperature remains constant at 37 degrees Celsius. Factors influencing comfort depend on personal variables (activity and clothing) and environmental biological variables (air temperature, average solar radiation, air speed, and humidity). The second category of variables has a direct dependence on the building's technology and design. The sensitivity of the interior space's function to the occupants' activity and other personal factors is very different [8].
It is possible that the energy between different parts of internal spaces changes. There is also a possibility of energy change when doors are opened. Air changes of around 5 cubic meters per hour are measured when doors are opened, and it is calculated that someone who has participated in the

architectural program of a biophilic habitat has opened and closed doors 130 times a day. Another type of energy change is energy infiltration, in which building energy is wasted in two ways: infiltration and transmission. Infiltration occurs where there are awning windows on the exterior facade of the building. The difference in air pressure at the moment of infiltration allows a large amount of air to easily enter or leave. A building with good insulation may have around 38% seasonal heat loss due to infiltration [9]. As a result, by reducing the biological rate of infiltration, solar heating can reach 90% without any problem. The problem is that infiltration is difficult to reduce to this level. With the entry of high-quality air through stripped awning windows and sealing the joints of the building, air changes for a standard building can decrease from 1.5 to around 0.5.

4-1. Energy in Biophilic Design

In biophilic design, energy must be incorporated into various functional spaces in architecture by allocating it to all thermal zones.

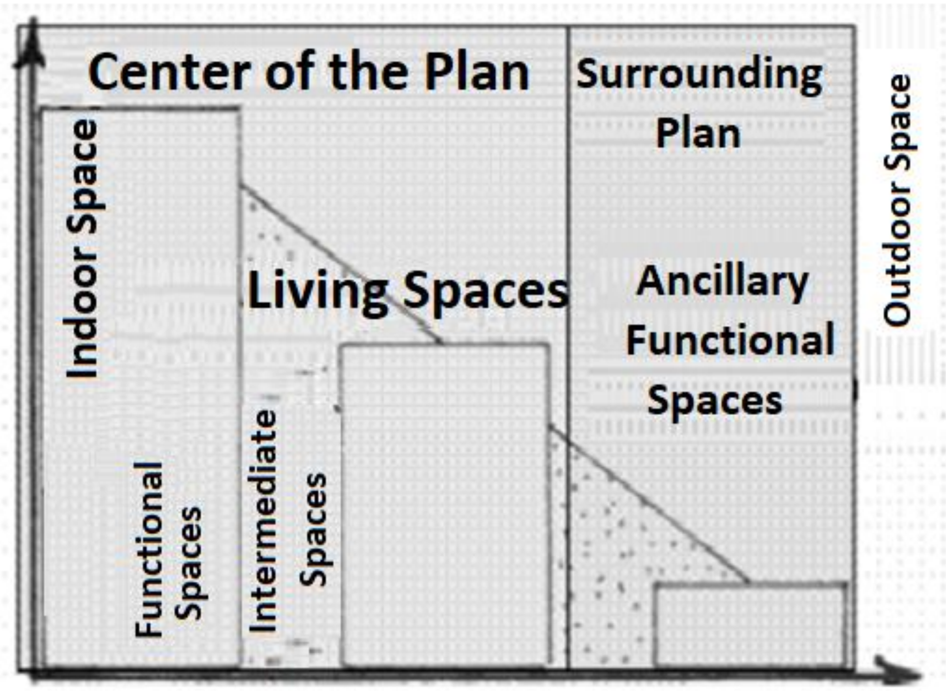

Figure 1: Hierarchy of Functional Spaces

The first step in passive biophilic architecture is to demonstrate the distribution of energy in the shape and volume of the building and every area where the energy distribution should be harmonized with the functionality and activities in those spaces. This issue is important in terms of thermal levels in different architectural spaces. This form of thermal hierarchy is changeable in architectural planning. It would be better for internal spaces with the same internal temperature to be placed together. Additionally, the best location for functional main spaces is near the center of the architectural plan, and spaces with higher temperatures should be placed around the plan [10].
As a result, architects should not place spaces with significant temperature differences next to each other. The architect should make the most use of natural ventilation in the building's indoor space to transfer energy outdoors. This temperature difference is necessary for natural ventilation through air circulation. Architects can utilize thermal layering of air by placing warmer spaces on higher floors. Thermal zoning is one of the vital considerations in environmentally friendly buildings that have been designed recently. On the other hand, in the current building, the main architect determines the

arrangement of spaces. The architect should adapt to the current layout and determine which spaces to use.

[11] Thermal zone is an enclosed air space that is characterized by easy air circulation, and its thermal conditions are relatively stable. In most cases, each architectural space that contains a door is considered a separate zone. Sometimes, different parts of large spaces may have varying temperatures. In such cases, the space can be divided into smaller zones, and adjacent elements can be defined as vents. In this way, heat can flow freely between zones, but the thermal properties of different zones must be analyzed separately.

For example, we want the temperatures of different functional spaces in a residential building to be different, such as a bathroom being very hot, a living room being calm, and a bedroom having a moderate temperature. Passive biophilic architecture identifies and accommodates these differences, creating thermal zones for different functional spaces in the building. Thermal zoning provides the best possible match between the distribution of architectural spaces and the distribution of available energy. Thermal zones include:

Functional spaces

This region consists of a main functional space within the building. The optimal temperature for these areas in residential spaces, for example, is between 18 to 21 degrees Celsius. The best location for functional spaces is usually at the center of the building. The heat that emanates from ancillary functional spaces can infiltrate these areas [12]. Another suitable option is to install windows on the southern, eastern, and southeastern facades of the building in cold and temperate climates, and install a window on the northeastern facade in hot climates.

Service areas

This region includes services. The optimal temperature for this region is between 20 to 23 degrees Celsius. This region has a moderate temperature and can be located around the building to create natural ventilation or next to main functional spaces to create a warm, air-exchange environment.

Communication spaces

This region includes storage areas, intermediate spaces, passage areas, terraces, underground spaces, and others. The optimal temperature for this region for buildings in cold and temperate climates during winter is less than 16 degrees Celsius, and for buildings in hot climates during summer, less than 28 degrees Celsius.

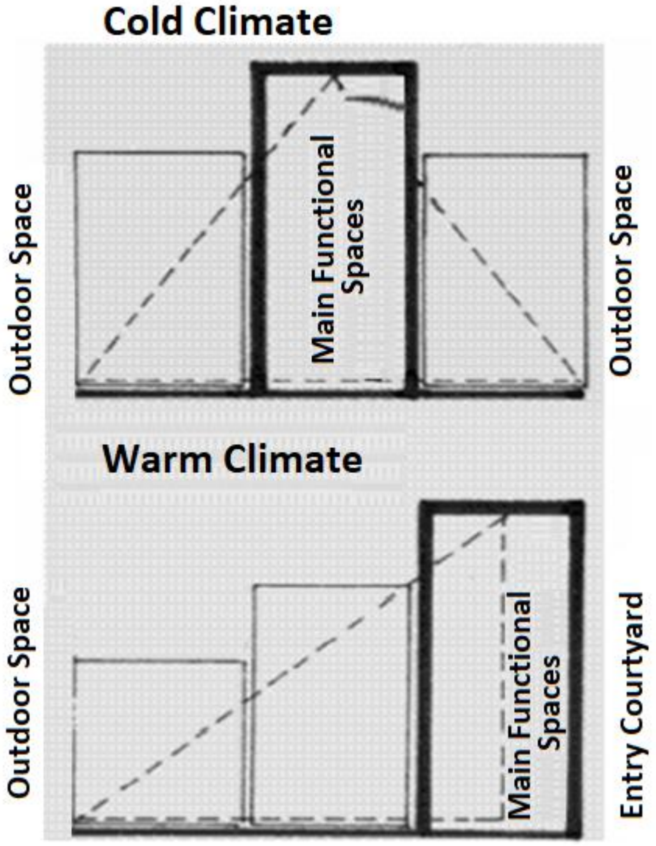

Figure 2: Location of Main Functional Spaces in Interior Spaces

5- Green Architecture in Biophilic Architecture

5-1- Green Building Elements

The term "green building elements" refers to elements with plant cover or ecosystem that cover the external facade of a building. These elements consist of a thin layer of living vegetation on a conventional system [13]. Modern dry green spaces do not have a heavy weight and can barely support the weight of the pots and planters on top of urban buildings. Instead, they are robust and lightweight systems that not only have aesthetic value but also provide insulation and are beneficial for resolving urban environmental issues. The plant cover on external elements protects them from direct sunlight and improves their thermal performance. Optimized green building elements, which will be described later, have a leafy area between 5 and 10 times larger than green spaces and are much more effective and economical for creating a livable climate in cities.

Usually, the green part that surrounds the architectural structure appears in the form of a green roof and less in the form of an external green facade. The external green facade is found in traditional architecture in rural areas, although it may also be seen in urban areas. Today, plants are rarely used as the outer facade of a building. A green roof or facade, as it may initially seem, does not indicate a forgotten structure. On the contrary, it has numerous positive effects in terms of design, construction, health, and ecology. The function of these elements does not only limit to covering the building facade. Green roofs and facades have an indirect impact on the comfort of occupants and play a significant role in shaping the aesthetic appearance of the building. Biophilic architectural elements play a significant role in creating balance between humans and the environment.

5-2- Green Architecture in Biophilic

Energy Conservation Strategies

Effective heat management is the most important evaluation for energy efficiency in different parts of a building. Passive biophilic architecture requires a dense insulation system that ensures minimal heat loss and high thermal comfort. Every building needs a façade, floor, external walls, and roof; passive biophilic architecture focuses on unlimited advancements in these building components. Therefore, a high-quality thermal insulation can be an additional component [14].

Green building elements have numerous advantages for the environment and humans, including improving the urban heat island effect, reducing urban ecological damage, and preserving rainfall water and air pollutants. They also reduce energy costs, clean the air, reduce rainwater runoff, increase the durability of the roof due to lower surface temperatures, and provide better protection against UV rays. Moreover, they create recreational spaces in urban areas, improve urban aesthetics in non-natural areas, and many more.

Studies show that recreational activities in natural environments, such as parks and gardens, are necessary for controlling stress and meeting other non-stress-related needs. This type of green element adds value and salability to the building. People who use the green spaces adjacent to their buildings experience answered aesthetic needs and preserve their happiness. Psychological research shows that natural scenery helps to maintain human focus, keeps them away from themselves and worrisome thoughts, and ultimately improves their health [15]. In a study, researchers randomly assigned patients to rooms that were identical except for their exterior views: one room had a view of lush trees, and the other had a view of a concrete wall.

Regional Climates

Green building elements have a significant impact on the building's heat gain and loss, humidity, air quality, and thermal radiation in the surrounding environment. Along with other green buildings, green elements can play a role in transforming the city's climate. In the summer, the temperature of sandy green spaces can rise to between 50 to 60 degrees Celsius with a 25-degree increase. Temperatures in areas with a grass cover will not exceed 25 degrees, resulting in energy cost savings. A 20-centimeter-thick under layer with a 20 to 40-centimeter-thick grass layer acts as a composite insulation material, similar to a mineral wool insulation with a thickness of 15 centimeters. When the outdoor temperature varies between 25 to 30 degrees, the spaces under green building elements are at least 3 to 4 degrees cooler than the surrounding outdoor air. Green building elements, due to the increased vegetation in urban landscapes, have a synergistic effect with the urban heat island effect. The plants surrounding their environment cool it down through natural evaporation and transpiration cycles [16]. By utilizing green building elements in cities and non-porous asphalt, it is possible to cool the city. This approach reduces the urban heat island effect in the summer. Additionally, it plays a role in reducing greenhouse gas emissions and adapting urban areas to a warmer future climate.

For marketing, it is possible to move towards a trend that prioritizes well-being and health, better quality of life, and modernity. The economic biophilic architecture provides the opportunity to apply suitable and cost-effective measures to significantly reduce energy consumption (such measures are beneficial for health, ecology, and the economy) [17]. Often, a conflict appears in architecture between economic aspects on one hand and the quality of architectural products on the other. Our mission is to find a tool to demonstrate balance, a balance that can be created through a functional and structural architecture that produces a flawless, economic, and valuable building [18]. The optimal idea of biophilic architecture clearly establishes a balance between quality and all economic aspects.

6- Conclusion

The main goal of biophilic architecture is to provide a comprehensive summary of its characteristics in a comprehensible and organized manner, enabling builders, designers, planners, and architects to be aware of the importance of environmental connection in all their construction projects. Briefly speaking, biophilic design is a type of architecture aimed at reducing the gap between humans' daily connection with nature. It is essential to note that biophilic architecture is not limited to increasing green spaces in buildings, but it involves a collection of various factors to solve the problem. Therefore, the biophilic design and architecture approach has the ability to provide numerous benefits. This approach encompasses a wide range of social, environmental/ecological, economic, spatial, and managerial aspects at the city and building levels. In terms of designing biophilic spaces indoors for thermal comfort, architects should use suitable design methods. Using natural sunlight for heating spaces in winter and solar shades and photovoltaic coatings for controlling heat in summer can be effective. Additionally, using suitable ventilation systems and thermal insulation systems can also help improve thermal comfort. Furthermore, energy control is an important aspect of biophilic design. By utilizing smart energy control systems, architects can reduce energy consumption and also benefit from renewable energy sources such as sunlight and wind. For example, using solar energy generation systems and smart electrical management systems can help improve energy control and reduce energy consumption in indoor spaces. In summary, biophilic design, considering thermal comfort and energy control, can improve the quality of life of individuals in indoor spaces and also help preserve the environment and reduce energy consumption.

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