



VISTA INTERNATIONAL JOURNAL ON ENERGY, ENVIRONMENT & ENGINEERING



Integration of Biophilic Design principles to enhance the urban environment

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ABSTRACT

With urbanization on the rise, there's a growing need for city planning strategies that promote both human well-being and health of environment. This research explores the potential of biophilic design principles in achieving this goal. The hypothesis proposes that integrating these principles, which focus on reconnecting humans with nature in the built environment, will lead to a measurable increase in urban biodiversity. This, in turn, is expected to create a healthier ecosystem for city dwellers.

This paper reviews the primary findings of current research on biophilic design and its impact on urban biodiversity. It outlines a research methodology to evaluate the hypothesis, potentially using case studies related to cities that have implemented biophilic design elements. This research seeks to provide valuable insights into biophilic design which can contribute to a more balanced and sustainable urban environment, fostering the flourishing of human and ecological health.

Keywords : *Biophilic urban, urban environment, biophilic principles, urban biophilia, biophilic architecture, environmental architecture.*

1. Introduction:

The rapid pace of urbanization presents a significant challenge like balancing the needs of a growing human population with the health of our planet's ecosystems. Cities, while centers of innovation and economic activity, often come at the expense of biodiversity. Reduced green spaces, habitat fragmentation, and pollution all contribute to a decline in the variety and abundance of plant and animal life within urban environments. This loss of biodiversity can have a cascading effect, impacting everything from air and water quality to human health and well-being.

However, there's a growing movement which bridges this gap between urban development and ecological health. Biophilic design, the concept of using the concepts of biophilic design in the built environment, offers a promising approach. With integrating principles like access to natural light, vegetation, water features, and natural materials, biophilic design aims to reconnect humans with nature within urban spaces.

This research investigates the potential of biophilic design to foster a more balanced urban ecosystem. Our hypothesis proposes that incorporating biophilic

design principles into city planning will lead to a measurable increase in urban biodiversity. This, in turn, is expected to promote a healthier ecosystem for city dwellers, potentially improving factors like air and water quality, as well as providing habitat for pollinators and other beneficial organisms.

By exploring the existing research on biophilic design and its impact on urban biodiversity, this paper aims to contribute valuable insights into the potential of this approach for creating more sustainable and healthier urban environments where both human needs and ecological well-being can thrive

2. Literature review:

Stephen R. Kellert is the author of book Biophilic Design and explains biophilic design as an approach that fosters beneficial contact between people and nature in modern buildings and landscapes. This book explains a framework for using nature in the built environment to meet human needs. Author's guiding principles are to honor and celebrate nature while creating a multisensory and enriching urban environment. There are the 3 features and characteristics that make up Kellert's biophilic framework [1].

2.1. Kellert's Features and characteristics of biophilic design:

Below are the three features and characteristics that make up Kellert's biophilic framework.

1. Direct experience of nature
2. Nature experienced indirectly
3. Experience of space and place

Above features can be further characterized as follows:

2.1.1. Direct experience of nature:

Direct experience is coming into physical contact with the elements of nature. Direct experience of nature can be implemented by -

1. **Light** : Provides natural forms, patterns, and shadows; it also facilitates comfort and wayfinding. Day and season orientation is also

made possible by light. This can be incorporated into buildings through clerestories, glass, skylights, atriums, and reflecting materials as shown in Fig.1. This encourages the interest and wellbeing of the locals [1].



Fig.1. Use of light in building [2]

2. **Air** : The senses of temperature, humidity, and ventilation are carried by air. Such circumstances can be created via windows and other passive methods as shown in Fig.2. But alterations to these components can have a major positive impact on the occupant productivity and comfort [1].



Fig.2. Natural Ventilation Solutions in Interior Design [3]

3. **Water** : As water has multiple modality properties, it may be used to add movement, sound, touch, and sight to a building. Humans have a deep affinity with water, and when used

properly, it may lower stress and enhance happiness, performance, and general health. Water features can therefore be incorporated into designs, including fountains, wetlands, aquariums, and other bodies of water as shown in Fig.3 [1].



Fig.3. Water body at Titan Integrity Campus [4]

4. Plants : Adding vegetation to a building’s exterior and interior spaces encourages a strong bond with the natural world. This should be abundant (make use of green walls or a large number of potted plants as shown in Fig.4.), and some of the vegetation should be in flower since research has shown that plants reduce stress and enhance productivity, performance, and physical well-being [1].



Fig.4. The Bosco Verticale, a residential tower [5]

It features over 900 trees and 20,000 plants, providing natural air purification and insulation for the building’s occupants [5].

5. Animals: Gardening, aquariums, green roofs,

and animal feeds can help, although it’s not easy [1]. This interchange fosters delight, curiosity, and cerebral stimulation [6]. Animals feeds as shown in Fig.5.



Fig.5. Workstation in the natural outdoor environment along with farm animals and farms with tree shadow

6. Weather : Knowledge of weather has historically been linked to human survival and fitness, and it continues to promote mental stimulation and alertness. Not only may weather be seen right away through windows and transitional spaces as shown in Fig.6. But it can also be created artificially by adjusting the air in the space [1].



Fig.6. Experiencing weather from window [7]

2.1.2. Nature experienced indirectly :

The term indirect experience describes coming into contact with images or representations of nature. Indirect experience of nature can be implemented by -

1. **Images of Nature :** A space can incorporate images of nature via paintings, photos, sculptures, murals, films, etc. as shown in Fig.7. It has been shown that inhabitants experience both intellectual and emotional satisfaction from these visuals [1].



Fig.7. Use of nature inspired wallpapers in indoors [8]

2. Natural materials can develop a patina over time, which changes and stimulates reactions from individuals [9]. Stone and wood to incorporate these elements into constructions can be used. Natural materials and furniture in interior design can be used. Leather has frequently been suggested as a Biophilic material, but as leather is a byproduct of the meat industry and animal agriculture contributes significantly to climate change, faux, or plant-based, leathers made from cacti, pineapple skin, or mushrooms, are now considered as good

substitutes. It is also evident that destroying nature and animals in an attempt to feel closer to them is counterproductive and goes against the idea of biophilia. Application of bamboo as a natural material is shown in Fig.8.



Fig.8. Use of bamboo in construction [10]

3. **Natural Colors :** These are also known as earth-tones or natural hues, the colors that are commonly found in nature are usually subdued tones of brown, green, and blue. These natural tones should be reflected in building color schemes as shown in Fig.9. Brighter colors are to be utilized with caution; a study found that people found red blossoms on plants to be tiresome and distracting [9].



Fig.9. Use of Lunawood for natural colors and finishes [11]

4. Simulations of Natural Light and Air :

Creative interior lighting design and mechanical ventilation systems can take the role of natural ventilation and lighting systems in locations where they are impractical. [1] With small changes to air velocity, humidity, and temperature, designers can mimic natural airflow. By utilizing reflective materials, natural geometries that allow light from the fixture to pass through, and various lighting types, they can also produce variations in illumination [1] as shown in Fig.10.



Fig.11. Hotel Haitang Bay in Sanya, China [13]

6. Evoking Nature :

This approach applies traits from the natural world to shape the project’s structural layout. These could be artificial objects or pieces that mirror the characteristics of natural landscapes, including varying plant heights found in different ecosystems or specific animal, aquatic, or plant characteristics [1]. as shown in Fig.12.



Fig.10. Villa Kavel 1 by Studioninedots. Photography by Peter Cuypers [12]

5. Naturalistic Shapes :

By adding these different elements to a space, one can make it more interesting and complicated, turning it from a static area. Columns and facade patterns inspired by nature are two ways that architects might use natural shapes and forms into their work as shown in Fig.11 [1].

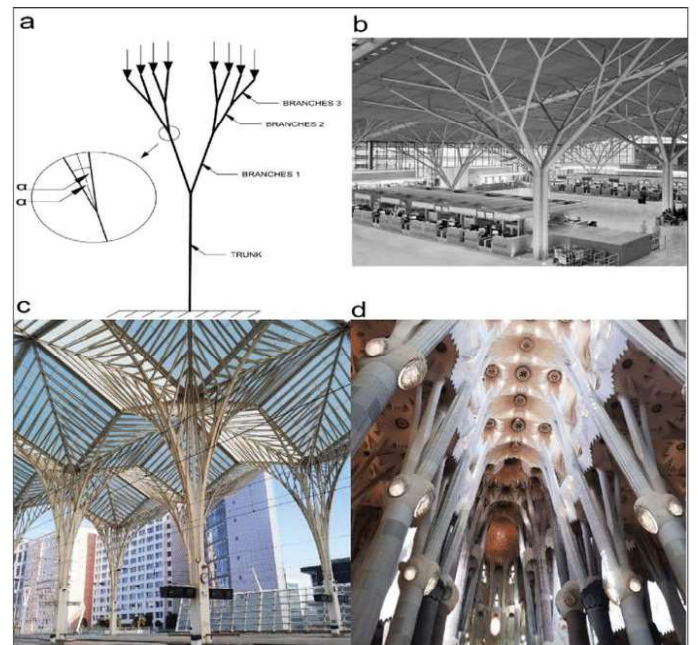


Fig.12. Examples of basic structural elements inspired by natural processes: (a) research and design based geometry, (b) arboreal structure, Airport, Stuttgart, Germany, 2004, (c) Canopy at Railway Station, Lisbon, 1998, (d) Sagrada Familia, Barcelona [14].

7. Information Richness : This can be achieved by designing environments that pique resident's curiosity by being challenging and complex without being excessively noisy [1]. This feature attempts to integrate these elements into the building's surrounds because many ecosystems are complex and full of many abiotic and biotic components.

8. Change and the Patina of Time : Individuals find it intriguing how nature ages (as shown in Fig.13.), adjusts, and transforms over time just like themselves. One approach to accomplish this is to use organic building materials that are prone to weathering and color change, which enables us to observe minute changes in our built environment over time [1].



Fig.13. Use of Natural stone beautifully aged [15]

9. Natural Geometries : Facades and structural elements can be designed using fractals, which are repetitive, varied patterns seen throughout nature. These geometries can include hierarchically ordered scales and winding flows (as shown in Fig.14.) in addition to straight lines and sharp angles [1]. Examples of naturally occurring geometry that is frequently used are the patterns found in honeycombs and water ripples.



Fig.14. Use of natural geometrical patterns in architectural design [16]

10. Biomimicry : Biomimicry is a design approach that mimics natural processes to solve technological and human issues. Building with these built-in features can inspire human ingenuity and awareness of the natural world [1]. Lotus temple is one of the best example of Biomimicry in building designs in INDIA as shown in Fig.15.

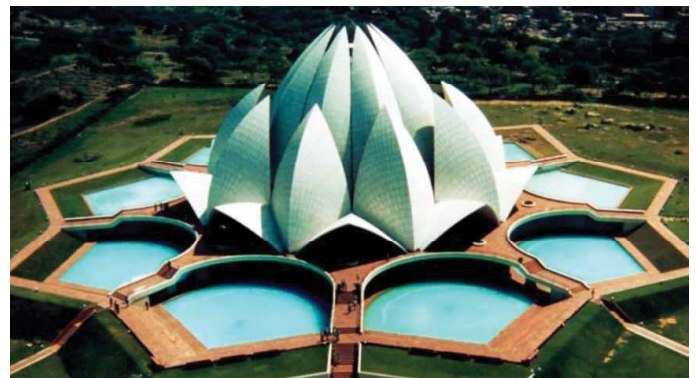


Fig.15. Biomimicry of lotus flower done in Lotus temple [17]

2.1.3. Experience of space and place:

Spatial relationships are used by the sense of location and space to improve well-being. These can be implemented by -

1. Prospect and Refuge: Prospect highlights horizons, activity, and potential threat sources, while refuge refers to the building's capacity to offer cozy and nurturing inner spaces (alcoves, dimmer lighting) [6]. as shown in

Fig.16. Balconies, alcoves, lighting variations, and spaciousness (savannah setting) are a few examples of design components.



Fig.16. Can Feliz by Jorn Utzon [18]

2. **Organized Complexity** : The idea behind this approach is to mimic the necessity for controlled variety in design, which is achieved by the architecture of the building's repetition, variation, and detail [6].
3. **Integration of Parts** : When several components work together to form a whole, inhabitants are satisfied. Examples of this include interior areas that are designed with distinct borders or that incorporate a central focal point [1].
4. **Transitional Spaces** : Features that provide access from one area to another while maintaining a sense of openness and comfort include porches, decks, atriums, doorways, bridges, fenestrations, and foyers [6].
5. **Mobility** : The ability for individuals to move around areas comfortably, especially when they are complicated; this gives residents a sense of security and can be achieved by clearly identifying access and exit points [1].
6. **Cultural and Ecological Attachment to Place** : Developing a cultural sense of place in the constructed environment fosters identity and human connection [1]. This is achieved by designing with the topography and history of

the area in consideration as shown in Fig.17. By creating environments that encourage the utilization of native flora and fauna, ecological identity is achieved [6].



Fig.17. Ecological attachment to place represented by Falling Water by FLW [19]

2.2. Effects of Biophilic design on mental health and wellbeing:

A center part of biophilic urban communities is encouraging occupant communication with encompassing nature. This part investigates the emotional wellness and prosperity benefits related with such cooperation's. Various investigations have exhibited the positive effect of nature openness. For example, Ulrich in 1984 analyzed the impact of emergency clinic room sees on careful patients. Patients with admittance to nature sees recuperated more rapidly and experienced less nervousness contrasted with those with restricted sees. This proposes that openness to nature can help recuperation by advancing positive feelings and diminishing pessimism. Past medical clinic settings, research has shown comparable patterns. Concentrates on like Richardson in 2007 found that neighborhoods with additional green spaces had occupants taking part in more elevated levels of actual work, prompting worked on cardiovascular and psychological wellbeing. These results show that incorporating biophilic elements into residential areas can improve mental and physical health, resulting in a happier and healthier society [20].

The positive affect of introduction to nature on human wellbeing is well reported. Considered by White in 2019 illustrate that investing at slightest 120 minutes per week in urban green spaces leads to measurable improvements in these areas [21]. Additionally, researchers found that even brief exposures to nature, like seeing green rooftops for 40 seconds, can offer therapeutic benefits, such as improved attention [22]. However, the scale and amount of green space integration are crucial considerations. Kellert in 2018 highlights that isolated plants or token greenery have negligible effect. Alternately, excessive greening can become a burden due to components like extra building materials, structural requirements, and ongoing maintenance costs [4].

Vegetation is a key figure in the urban heat island index. Trees and greenery help decrease urban heat by bringing down surface and air temperatures. Mid-afternoon temperatures can be as much as 11°C hotter in highly developed urban regions compared to nearby regions with vegetation. Shade trees give quick heat relief to individuals working outside. A well-placed shade tree near a house can decrease indoor temperatures and, therefore, the energy required to keep a home cool. Trees offer assistance individuals, save money and remain comfortable but they can also decrease genuine risks from heat exposure. Extreme heat can be dangerous and is the leading weather-related cause of death. Urban trees can help improve air quality and ensure human wellbeing. Leaves absorb gaseous toxins, such as ozone and nitrogen dioxide and dangerous particulate matter. Some environment services from trees are challenging to measure. For example, urban forests give living space for wildlife, support biodiversity, and give access to nature all of which can help individuals feel healthy and associated. Number of physical and mental wellbeing benefits are also been connected to trees [23].

Clients of the Shanghai-based one thousand trees mixed-use building profoundly value the incorporation of natural components, including trees, plants, and green spaces, finding them engaging and conducive to relaxation

2.3. Economic benefits of Biophilic cities:

While biophilic design often focuses on

environmental and social benefits, economic advantages should not be overlooked. In a market-driven world, clear economic incentives are crucial for widespread adoption of biophilic principles within biophilic cities.

2.4. Reduced Absenteeism and Increased Productivity:

Studies by Terrapin Bright Green in 2012 demonstrate a clear link between access to nature and employee well-being. Their research suggests that office workers with views of nature take significantly less sick leave compared to those without. This translates to a reduction in absenteeism-related costs for employers. Similarly, Soderlund and Newman (2015) found that biophilic design can enhance workplace productivity, leading to substantial economic benefits for businesses and, by extension, the city as a whole [20].

2.5. Crime Reduction and Public Safety:

The potential crime-reduction benefits of biophilic design are also noteworthy. Research in Chicago (Soderlund and Newman, 2015) suggests a decrease in crime rates in areas with more greenery. This translates to cost savings for municipalities in areas like law enforcement. It is important to acknowledge that socioeconomic factors might also play a role in crime rates, and further research is needed to isolate the specific impact of biophilia in this context [20].

Overall, economic considerations support the integration of biophilic design principles in cities. Reduced absenteeism, increased productivity, and potential crime reduction all translate to financial benefits for businesses, residents and city governments.

2.6. Design Elements of Biophilic Cities:

Biophilic design principles can be incorporated into various aspects of the built environment to create a more natural and restorative experience for city dwellers. The table below outlines examples of biophilic design elements at the building, street, and neighborhood etc. scales:

Table 1. Design Elements of Biophilic Cities [24]

| Criteria | Design elements of biophilic cities |
|--------------|---|
| Building | Green rooftops, Sky gardens, Green atria, Rooftop garden, Green walls, Daylight interior spaces, Green courtyards, Biomorphic approach, Opening window, Indoor potting plant. |
| Block | Clustered housing in green areas, Native species yards and spaces, Green streets, Urban trees, Low impact development (LID). |
| Street | Edible landscaping, High degree of permeability, Stream daylighting, Stream restoration, Urban forests, Ecology parks, Green connection, Pavement to park, Green street. |
| Neighborhood | Community gardens, Neighborhood parks, Pocket parks, Green grey fields, Green brownfields, Urban creeks / riparian areas, Urban ecological networks, Urban park, Green schools, City tree canopy, City green roof |
| Community | Community forest/orchards/garden, Green utility corridors, River systems, Riparian systems, Floodplains. |
| Region | Regional greenspace systems, Greening major transport corridors, Sustainability hub, Permaculture nursery, Organic market. |
| Environment | Enhance native species ratio, Large water area |
| Sensory | Aromatic plant, Natural sound |

Table 1 provides a starting point for considering how biophilic design elements can be integrated into different urban contexts. By strategically incorporating these elements, cities can foster a deeper connection between residents and nature, improve human well-being, and promote a healthier urban ecosystem.

3. Case studies : Authors have narrated various case studies as follows :

3.1. Paley Park, Zion Breen Richardson Associates, New York

Designed by Zion Breen Richardson Associates in 1963, Paley Park made its debut as a pocket park in 1967. This ground-breaking design is a prime example of biophilic architecture in a small urban area. The east and west ivy walls connect visitors to nature, while the south-facing entry maximizes light exposure. The highlight is a 20-foot waterfall on the north wall that serves as both a visual draw and a noise-cancelling, relaxing soundtrack. Honey locust trees planted amidst rough-cut stone tiles add a layer of greenery, and moveable furniture allows for flexible use and personalization, solidifying Paley Park's place as a biophilic design pioneer [25].

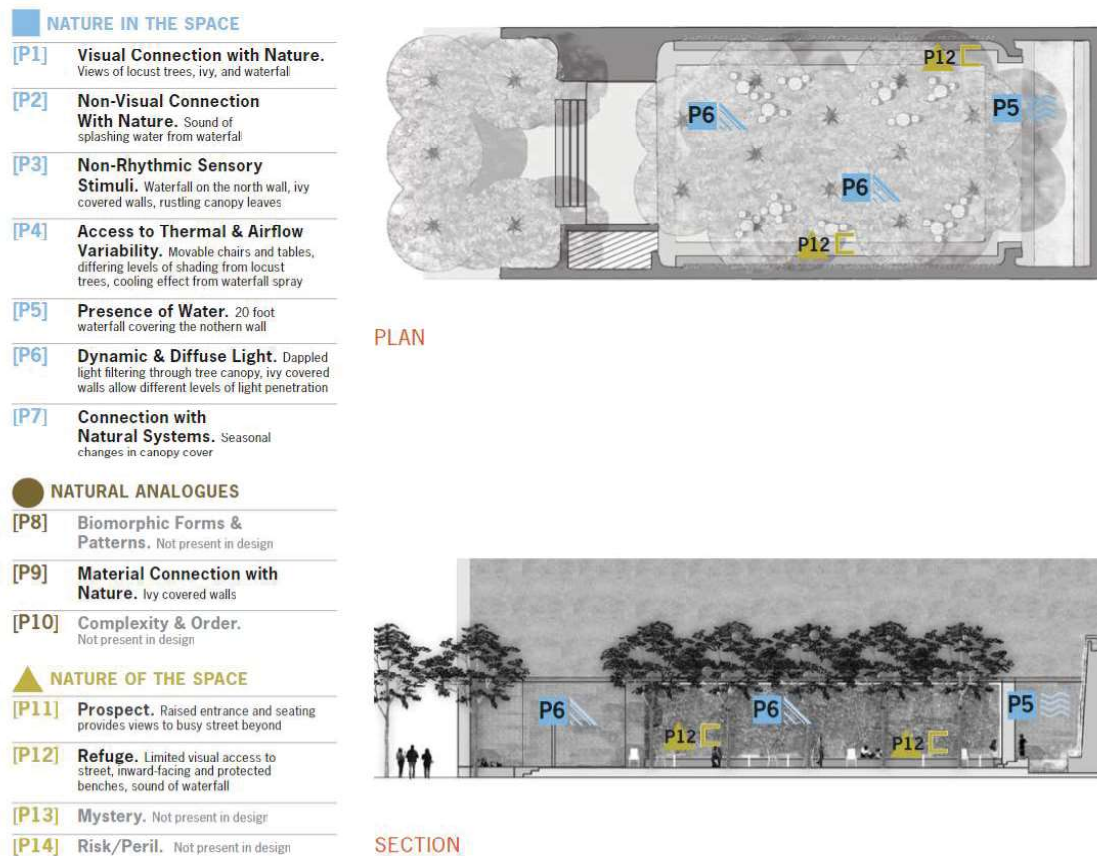


Fig.18.Plan and section of Paley Park along with biophilic elements included in this park design [25]

Fig.18 outlines various biophilic design patterns incorporated into the park’s design as explained below:

- i. Visual Connection with Nature (P1): The park features a variety of plantings, including honey locust trees, ivy covering the east and west walls, and planters throughout the space.
- ii. Non-Visual Connection with Nature (P2): The sound of splashing water from the waterfall provides an auditory connection to nature.
- iii. Non-Rhythmic Sensory Stimuli (P3): The sound of the waterfall is a natural and calming sound, in contrast to the constant rhythm of traffic noise typical of an urban environment.
- iv. Access to Thermal & Airflow Variability (P4): The moveable chairs and tables allow visitors to choose sunny or shaded areas.
- v. Presence of Water (P5): The 20-foot waterfall is a central design feature and provides a visual and auditory connection to nature.
- vi. Dynamic & Diffuse Light (P5): The open design allows sunlight to penetrate the space, while the trees provide dappled shade in some areas.
- vii. Connection with Natural Systems (P7): The Park incorporates plant life and water features, creating a miniature ecosystem within the urban environment.
- viii. Biomorphic Forms & Patterns (PB): The design references natural forms through the use of curving benches and planting beds.

- ix. Material Connection with Nature (P9): The use of natural materials such as stone and wood throughout the park strengthens the connection to nature.
- x. Prospect (P11): The open design allows for long views through the park, providing a sense of spaciousness within a small area.
- xi. Refuge (P12): The planting beds, waterfall, and moveable furniture create a sense of enclosure and provide a refuge from the busy city streets.

Paley Park's success in attracting over 500,000 visitors annually underscores the power of biophilic design in creating vibrant and restorative urban spaces. It demonstrates that even small-scale interventions can significantly enhance the well-being of city dwellers as shown in Fig.19 [25].

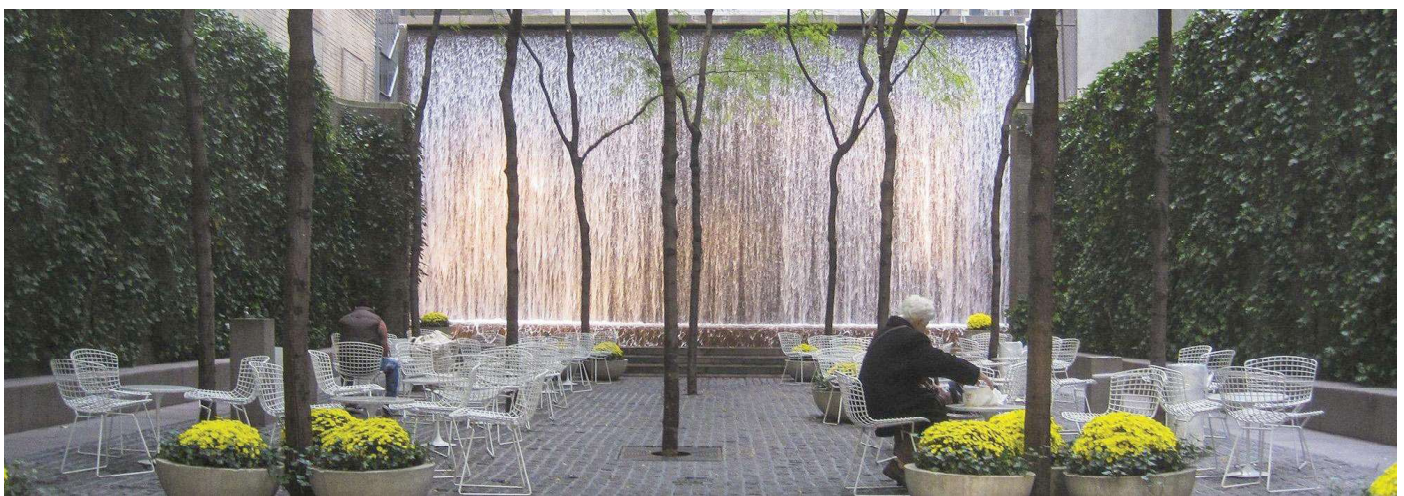


Fig.19.View of Paley Park [26]

3.2. Health benefits :

Paley Park's biophilic design fosters a multitude of health benefits for visitors. The park's signature waterfall plays a key role, inducing positive psychological and physiological responses, including stress reduction and lowered blood pressure. Research suggests our inherent preference for water contributes to improved concentration, memory, and a calmer state [P1].

Furthermore, the park incorporates non-rhythmic sensory stimuli through the waterfall's sound. This contrasts with the constant rhythm of urban noise pollution and has been linked to improved heart rate, blood pressure, and attention compared to environments with constant noise [P3].

The park's design also provides refuge through elements like plantings and the waterfall. This sense of safety allows visitors to relax and lower their attention to external stimuli, as evidenced by observations of people reading, closing their eyes, and escaping from their surroundings [P12].

In essence, Paley Park's biophilic design creates a holistic environment that promotes stress reduction, improves cognitive function, and fosters feelings of safety and well-being. This park serves as a powerful case study for the positive impact biophilic design can have on human well-being in the urban environment [25].

3.3. Titan Integrity Campus: A Sustainable Biophilic Design Case Study

While the Paley Park case study illustrates biophilic design in a compact, public urban area, Bangalore, India's Titan Integrity Campus shows off the practice's implementation on a larger corporate scale. A healthy

and productive work atmosphere is created by integrating diverse biophilic features throughout the campus, which was designed with sustainability and employee well-being as top priorities.

The Titan Integrity Campus's primary biophilic design elements are as follows:

3.3.1. Direct Experience of Nature:

The following are some of the ways that the campus encourages employees to have a direct relationship with nature:

1. **View to Nature:** Ample windows and natural light let in views of the surrounding countryside for staff members. Such viewpoints may lessen stress, boost work satisfaction, and promote mood and cognitive performance, according to research.
2. **Terrace Gardens:** During breaks, staff members can take advantage of the designated terrace gardens on each floor, which provide them with an opportunity to go outside and spend time in nature as shown in Fig.22. This can lessen mental exhaustion and encourage renewal. The gardens can also be used for unofficial gatherings or solitary work, which encourages a connection to nature during the working day and may enhance concentration and creativity.
3. **Airflow:** Natural ventilation is promoted by the open terraces and free-flowing design as shown in Fig.22. This reduces the need for air conditioning while simultaneously enhancing comfort and air quality, which may boost output. Wind tunnels improve the flow of natural air even more. When the weather permits, common areas are planned to be open and unconditioned, enhancing exposure to fresh air.
4. **Water:** An existing lake is extended by a bio-lake located on the eastern side as shown in Fig.22. This water feature provides a visual connection to nature and creates a habitat for wildlife, fostering environmental responsibility. The bio-lake can also control the microclimate by evaporatively cooling the surrounding air.
5. **Light:** The building's five atriums, which connect each floor vertically, let natural light flow deep into the structure as shown in Fig.20. This not only reduces reliance on artificial lighting but also creates a sense of community, togetherness, and encourages interaction between departments.



Fig.20. Atrium designs at Titan Integrity Campus [27]

6. Gardens: The arrangement of the gardens resembles a “vertical park.” Green terraces are found on every floor, extending from a bottom floor seaside park to a rooftop sky parkas shown in Fig.21. Employees have more opportunity to engage with nature around the building because to the abundant flora [28].

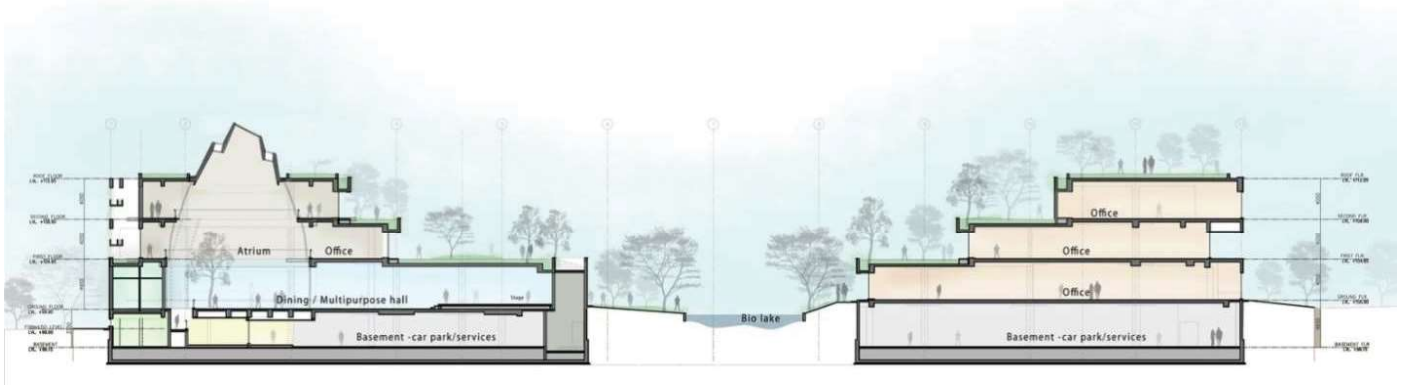


Fig.21. Section along the Titan Integrity Campus showing view of the nature from various levels, atriums acting as light and air vents, bio lake along with terrace greens [27]



Fig.22. Lush green Biophilic design of Titan Integrity Campus [27]

3.3.2. Indirect Nature Experience:

1. Connection with Nature: Even in the constructed environment, the campus’s use of natural materials fosters a closer relationship with the natural world.
2. Building Form: The building’s flowing shape, which mimics the lake’s organic curves and may be an example of biomimicry as previously said, encourages a relationship with the environment as shown in Fig.23.
3. Free flow Form Connects with Nature: The open layout of the building and its connection to the terrace gardens further enhance the feeling of nature’s interwovenness with the constructed world as shown in Fig.23.
4. Green Terraces as Relaxation Areas: The organic shape of the green terraces not only adds more green space but also gives workers a visually soothing and comfortable work environment as shown in Fig.23.



Fig.23. Indirect & direct experience of nature in Titan Integrity Campus [27]

3.3.3. Experience of Space & Place :

1. Prospect: Unobstructed views are created by the raised planned and open area on the ground floor as shown in Fig.24. A distant view appears unobstructed in open work environments.



Fig.24. Unblocked view to nature in Titan Integrity Campus [28]

3.4. Case study on Biophilic urbanization in Singapore:

The Singapore Green Plan 2012 (Ministry of the Environment and Water Resources 2012), launched in 2002, is a government blueprint which wants to protect nature in Singapore. This plan implementation is done as follows

- Rebuilding natural areas lost to development
- Conducting biodiversity surveys to gather information on plant and animal life
- Creating new parks and trails connecting them
- Building a center for information on nature
- Creating a way to measure how healthy nature is in cities
- These actions help cool down the city, manage rainwater, and save energy [29].

3.4.1. Streetscape plans – Streetscape Greenery Master Plan (SGMP):

Singapore is aiming to become a true “city in a garden” by planting trees extensively throughout the city. Their main strategy is to create a continuous layer of trees above all major roads. This plan, called the Streetscape Greenery Master Plan, goes beyond just planting trees. It aims to give each area of the city its own character along the roads, with different types of trees used depending on the location, like parks having a different feel from coastal areas. There’s also a program in place to protect particularly scenic roads with mature trees, ensuring they remain a beautiful part of the city [29].



Fig.25.Before and after images of parkway [29]



Fig.26.Before and after images of coastal area. [29]

3.4.2. Singapore’s Park Connector Network (PCN) :

Singapore has an amazing network of green corridors called the Park Connector Network (PCN) that stretches across the island. This ambitious project aims to eventually have over 300 kilometers of paths, making it possible to walk or cycle almost anywhere in Singapore. As of 2012, over 200 kilometers were already built, with a major north-south connector planned for the future. The PCN cleverly utilizes underused spaces like drainage reserves and road shoulders to create these green pathways [29].

A great example is the West Loop Connector Park, which links eight smaller parks boasting diverse activities and interesting wildlife. Pioneered by the Singapore Botanical Gardens, the PCN goes beyond just connecting green spaces; it connects people with parks and helps conserve local knowledge about the importance of nature. In short, the PCN offers an extensive network of green connectors that promote healthy living by encouraging walking and cycling, connects key areas of the city, utilizes underutilized spaces, provides diverse activities, and all while being linked to Singapore’s rich botanical heritage [29].



Fig.27. Before and after images of coastal area [30].

3.4.3. Hort Park: Singapore’s Green R&D Hub:

HortPark is a one-of-a-kind park in Southeast Asia, designed with a focus on nature and people. Located within the Southern Ridge Park, it experiments with green walls and roofs, showcasing how cities can be designed with nature in mind. These experiments serve as inspiration for planners and builders across Singapore, with the green wall and roof technology being actively implemented throughout the city. With ongoing research since 2003, HortPark is a hub for recreation, education, and research on nature, pioneering advancements in green infrastructure that serve as a model for cities around the world [29].

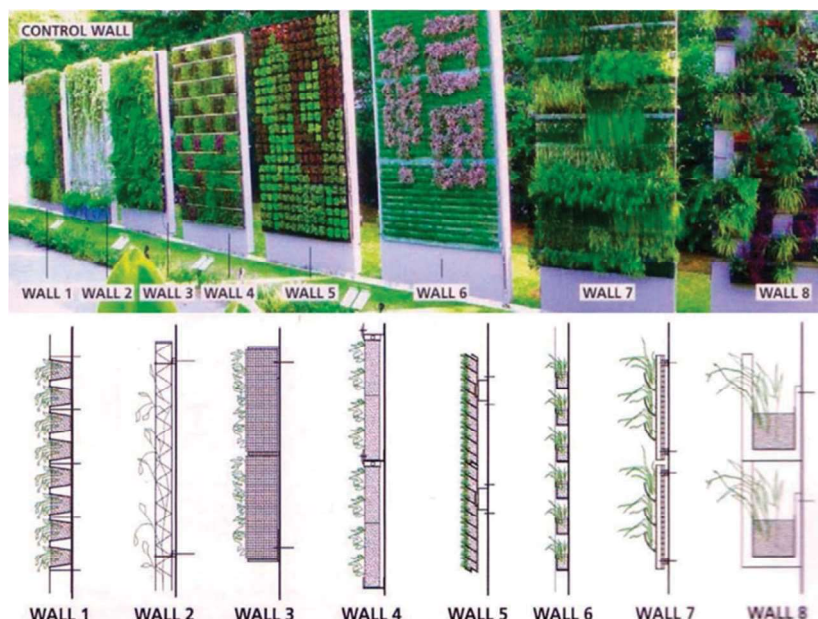


Fig.28.Hort Park R&D facility on green walls. [29].

3.4.4. Gardens by the Bay

Singapore’s Gardens by the Bay is a brand new, amazing garden built next to the Marina Bay Sands. This \$1 billion project completely transformed a formerly unused area of land by the water into stunning natural spaces. The gardens feature unique “Super Trees” and special areas designed to teach visitors about nature and how it works. These gardens are a dramatic symbol of how cities can incorporate nature into their design [29].



Fig.29. Gardens of bays [31]

3.4.5. How has it all worked out?

Singapore’s efforts to add more greenery between buildings have been a success! Satellite images show that even with a 70% population increase, the amount of green space has grown by 20% between 1986 and 2007. This shows they have been effective in incorporating nature into the city. And just like community gardens are moving to rooftops, the next big thing for Singapore seems to be adding greenery to building walls, roofs and balconies [29].

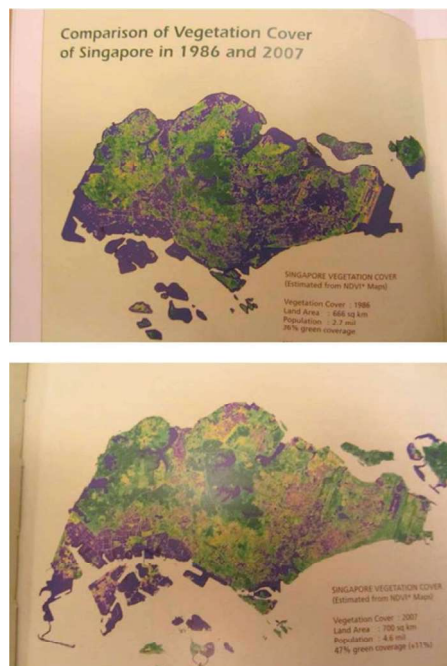


Fig.30.Singapore in 1986 and 2007, showing a 20% increase in canopy cover [29].

3.4.6. Biophilic urbanization, its planning regulations, initiatives and schemes in Singapore

Singapore's approach to biophilic urbanism extends beyond parks and connectors, reaching right up the sides of buildings! This greening effort is a collaborative one, with both public and private sectors participating.

To encourage this vertical landscaping, Singapore has implemented several measures. First, they have strong planning regulations. These regulations are like blueprints for different areas of the city. They set aside space for parks and connectors, and importantly, they dictate how much greenery needs to be incorporated into buildings. For instance, in the heart of the shopping district, new or renovated buildings must replace their entire footprint with green space! This can be achieved through rooftop gardens, vertical plant walls, or even green balconies. These regulations ensure that even in densely populated areas, people have access to nature throughout the city [29].

Another key player is the Building and Construction Authority (BCA) Green Mark scheme. This program evaluates the environmental sustainability of new developments. Buildings that incorporate biophilic design elements, such as green walls and roofs, can achieve a higher Green Mark rating, making them more attractive to tenants and buyers. This program incentivizes developers to go beyond the minimum requirements set by the planning regulations [29].

Finally, the government's Sky-Rise Greenery Initiatives program provides financial subsidies to help building owners defray the cost of installing and maintaining green features. This program makes biophilic design more accessible and encourages wider adoption across the city [29].

Through a combination of strong regulations, financial incentives, and a focus on sustainability, Singapore has fostered a thriving biophilic urban environment, not just on the ground, but climbing up the sides of its buildings as well [29].

To help building owners and developers get started with biophilic technologies like green roofs and walls, the Singapore government created the Sky Rise Greening Initiative (SRGI). This program offers financial assistance during the initial stages, making it easier and more attractive to incorporate these innovative green features into their buildings [29].

3.4.7. Conclusion from Singapore case study

Singapore is a shining example of how cities can embrace nature. They have shown that adding green spaces and green buildings can actually improve the environment in a city, even making it more diverse than the original natural areas. This approach is inspiring other Asian cities to find ways to incorporate nature into their dense urban environments.

Singapore's success is due to their innovative urban planning strategies. It has been proven that these plans can be affordable and have strong public support. It has also shown that demonstrations of new ideas can be quickly adopted across the city. Government support through incentives and research funding plays a big role in encouraging innovation. Finally, strong political leadership is key to driving these changes forward.

The next step for biophilic urbanism is for cities with different climates to adapt these ideas. Even established cities like Singapore can improve by measuring the many benefits of greenery, such as how it helps with animal and plant life, energy use, water use, and people's health and happiness.

3.5. Inferences : The inferences drawn from the case studies are given in Table 2.

Table.2. Inferences from case studies

| Case study name | Place | Scope of biophilic design application | Inferences |
|---|------------------|---------------------------------------|---|
| 3.1. Paley Park | New York | Park level | Paley Park exemplifies how biophilic design can transform even tiny urban spaces. The park’s multi-sensory elements, focus on passive comfort, refuge from the city, and potential for social interaction showcase the power of biophilic design to enhance well-being and connection with nature in the urban environment. |
| 3.2. Titan Integrity Campus | Bangalore, INDIA | Building and campus level | The Titan Integrity Campus demonstrates how biophilic design can create healthy, sustainable workplaces. By incorporating elements like natural light, green spaces, and nature-inspired design, the campus promotes employee well-being and fosters a connection with nature, even within a corporate environment. This case study suggests that biophilic design goes beyond aesthetics, offering a holistic approach to users health and environmental responsibility. |
| 3.3. Case study on Biophilic urbanization in Singapore: | Singapore | City level | Singapore’s biophilic city plan is a government-driven success story. Strong policies and collaboration between agencies ensure biophilic design is a priority throughout development. Their long-term vision, with initiatives like one million new trees, prioritizes public access to green spaces. This top-down approach offers a model for other cities to create healthy, sustainable environments. |

4. Conclusions :

This research has explored the potential of integrating biophilic design principles into urban planning. After reviewing the features and characteristics of biophilic design, we established its capacity to enhance urban biodiversity, promote mental health and wellbeing, and generate economic benefits. The Singapore case study served as a powerful example, showcasing how a city can successfully implement biophilic strategies at various levels, from extensive park networks and green corridors to vertical greening on buildings.

The key takeaway is that biophilic urban planning offers a measurable solution to the challenges faced by modern cities. After fostering a connection with nature, these strategies demonstrably increase urban biodiversity, creating a healthier environment for city dwellers. Improved mental well-being, economic benefits from increased property values and tourism, and a more sustainable urban ecosystem are all potential outcomes.

Looking ahead, further research is needed to quantify the precise impact of biophilic design on various aspects of urban living. Additionally, exploring how biophilic principles can be adapted to different climatic conditions and existing urban structures will be crucial for widespread adoption. After prioritizing biophilic design, cities can pave the way for a greener future, fostering a healthier and more vibrant environment for all residents.

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