مجلة الفنون والعمارة

JOURNAL OF ART & ARCHITECTURE

مجلة علمية دولية محكمة فصلية تصدرها

كلية الفنون الجميلة - جامعة المنصورة

1

المؤتمر العلمي الدولي الأول

التكامل بين الإبداع والتكنولوجيا والابتكار

كلية الفنون الجميلة - جامعة المنصورة

الأبحاث - عمارة

المجلد الأول - العدد الثالث - يوليو 2025

The Print ISSN: 3062-570X

The Online ISSN: 3062-570X

دمج الذكاء الاصطناعي لتعزيز التصميم البيوفيلي في البيئات الحضرية: دروس مستفادة من مشروع إلينيكون

Integrating AI for Enhanced biophilic design in Urban Environments: Lessons from The Ellinikon Project

م. يارا مصطفى فؤاد

معيد بقسم العمارة –كلية الفنون الجميلة –جامعة المنصورة

المؤتمر العلمي الدولي الأول

التكامل بين الإبداع والتكنولوجيا والابتكار

كلية الفنون الجميلة - جامعة المنصورة

مجلة الفنون والعمارة

JOURNAL OF ART & ARCHITECTURE

مجلة علمية دولية محكمة فصلية تصدرها

كلية الفنون الجميلة - جامعة المنصورة

المجلد الأول - العدد الثالث - ٢٠٢٥

مجلة الفنون والعمارة
JOURNAL OF ART & ARCHITECTURE

Integrating AI for Enhanced biophilic design in Urban Environments: Lessons from The Ellinikon Project

دمج الذكاء الاصطناعي لتعزيز التصميم البيوفيلي في البيئات الحضرية: دروس مستفادة من مشروع إلينيكون

م. يارا مصطفى فؤاد
معيد بقسم العمارة -كلية الفنون الجميلة -جامعة المنصورة
yoetamostafa@gmail.com

Abstract:

Applications of Artificial Intelligence (AI) in the fields of design and planning become increasingly common. At the same time fears related to the threats of disconnectedness from nature towards applications of AI in managing and shaping our living environments are rising. The concept of biophilic design holds the potential for bridging the gap between urban population and nature. Biophilic architecture aims to create an environment that enhances connectivity between humans and nature to improve physical, mental, and emotional well-being.

Consequently,. This research aims to explore how AI technologies can be integrated into the various stages of biophilic urban design—pre-design, design, and post-design—and to assess their impact on achieving biophilic outcomes. A comprehensive literature review is conducted to identify key concepts, frameworks, and roles of AI in urban planning. From this, an analytical matrix is developed to map AI functions to biophilic design goals. Using real-world case studies like The Ellinikon Project in Athens, this research sheds light on how AI can support indicators of successful biophilic urban design.

The results indicate that the integration of AI into urban design is not just an enhancement; it's a necessity for the sustainable, efficient, and equitable growth of our cities. As we continue to face urban challenges AI stands as a powerful ally in creating better urban futures.

Keywords: Biophilia, urban spaces, biophilic urban design, Artificial Intelligence (AI), designs stages.

الملخص

تزداد تطبيقات الذكاء الاصطناعي (AI) في مجالات التصميم والتخطيط شيوعًا. في الوقت نفسه، تتزايد المخاوف المتعلقة بتهديدات الانفصال عن الطبيعة تجاه تطبيقات الذكاء الاصطناعي في إدارة وتشكيل بيئاتنا المعيشية. يحمل مفهوم التصميم البيوفيلي إمكانية سد الفجوة بين سكان المدن والطبيعة. تهدف العمارة البيوفيلية إلى خلق بيئة تعزز التواصل بين البشر والطبيعة لتحسين الرفاه البدني والعقلي والعاطفي. وبالتالي، يهدف هذا البحث إلى استكشاف كيفية دمج تقنيات الذكاء الاصطناعي في المراحل المختلفة للتصميم الحضري البيوفيلي - ما قبل التصميم، والتصميم، وما بعده - وتقييم تأثيرها على تحقيق

النتـائج البيوفيليـة. أُجريـت مراجعـة شـاملة للأدبيـات لتحديـد المفـاهيم والأطـر والأدوار الرئيسـية للـذكاء الاصطناعي في التخطيط الحضري. ومن هنا، طُوّرت مصفوفة تحليلية لربط وظائف الذكاء الاصطناعي بأهداف التصميم البيوفيلي. باستخدام دراسات حالـة واقعيـة مثـل مشـروع Ellinikon فـي أثينـا، يُلقـي هـذا البحث الضوء على كيفية دعم الذكاء الاصطناعي لمؤشرات نجاح التصميم الحضري البيوفيلي. تشير النتائج إلى أن دمج الذكاء الاصطناعي في التصميم الحضري ليس مجرد تعزيز، بل هو ضرورة لنمو مدننا المستدام والفعال والعادل. ومع استمرارنا في مواجهة التحديات الحضرية، يظل الذكاء الاصطناعي حليفًا قويًا في بناء مستقبل حضري أفضل.

Research Significance

This research is significant as it addresses the growing need to integrate nature in urban environments through the use of Artificial Intelligence. As cities face mounting challenges such as climate change, loss of biodiversity, and deteriorating public health, biophilic urban design emerges as a sustainable and human-centered response. However, traditional methods of planning and design often fall short in capturing the complexity of environmental systems and user needs.

Objectives

Explore how artificial intelligence (AI) tools and techniques capable of analyzing and designing biophilic environments to extract biophilic design elements across all design stages.

Methodology

This research adopts a dual methodology that combines both descriptive and analytical approaches to comprehensively explore the role of Artificial Intelligence (AI) in enhancing biophilic design within urban environments.

Firstly, the descriptive method was employed to review and analyze existing literature and theoretical frameworks related to biophilic design and the integration of AI in architecture and urban planning. As a key output of this theoretical review, a matrix framework will be developed that organizes the applications of AI in the three main stages of biophilic urban design (pre-design, design, and post-design), and maps them to specific biophilic goals and outcomes. This matrix will serve as an analytical tool for the next stage of the research. Secondly, the research applies an analytical case study method focusing on The Ellinikon Project in Athens, Greece. This project was selected as a pioneering example of large-scale integration between AI technologies and biophilic urbanism. The previously developed matrix will be used to systematically assess how AI was applied at different stages of the project and to what extent it contributed to achieving biophilic design objectives

Introduction

People relieve stress in urban environments through natural spaces, and for over 30 years, increasing studies have demonstrated the psychological and physiological health benefits of the importance of nature in urban areas. However, recently, people have increasingly resided in concrete environments devoid of these spaces in their daily lives. Therefore, contemporary architecture seeks to achieve healthy and sustainable urban environments, most notably biophilic architecture (Shih-Han, Hung & Chang, 2020). Biophilic design is an architectural concept that bridges the gap between modern buildings and the innate human longing for nature. In addition, it promotes physical and mental well-being while aligning with several Sustainable Development Goals. (Thampanichwat, et al., 2025)

With the development of artificial intelligence (AI) technologies and their increasing importance in many fields, which represents a paradigm shift in how cities evolve to meet both ecological and human-centric goals it has become possible to leverage these tools to improve the efficiency of biophilic designs and accurately assess their effectiveness. In this context, artificial intelligence (AI) plays a leading role in supporting and developing biophilic applications, by combining technology with the authenticity of the natural world and its ability to analyze environmental and behavioral data, generating design solutions that are responsive to both nature and humans. This thoughtful integration ensures that AI is a tool to enrich the experience of integrated green spaces in biophilic design, rather than replacing them. Thus, the need arises to connect biophilic design and planning and the applications of AI in urbanism to achieve achieving sustainable, health-oriented, and resilient urban environments. (Vileniškė, et al., 2024)

Literature Review

This study explores the intersection between Artificial Intelligence (AI) and biophilic urban design, highlighting how technological advancements can enhance the integration of nature into urban environments.

1. Biophilic design

Biophilic design is an attempt to reflect the intellectual concept of biophilia on the built environment. Biophilia is the inherent human affinity for connecting with natural systems and processes, so it Is a design approach that aims to connect humans with nature in the built environment (Adityo, 2024) and create a design theory whose goal is to preserve the benefits of nature's reflection on the built environment, or to reuse nature in the built environment. Biophilic design seeks to compensate for and restore these benefits. (Samir, et al., 2024)

Biophilic Urban Spaces

An urban space is where the interactions between people and the urban environment occur producing a variety of different experiences. The concept of urban place goes beyond the physical characteristics of the built environment. According to Macdonald the urban place is the public realm that needs to shift its direction in public values in order to take advantage of ecological opportunities that each particular environment may have. The concept of meaning is incorporated into the concept of urban space where thoughts, behaviors, activities, and life emerge and occur. The experience with the natural environment consists of views of nature and landscapes, whereas attitudes and emotions towards wildlife constitute part of this meaning, which in turn is related to the concepts of sense of place and place attachment. (Amat1, et al., 2020)

The Emergence of a Biophilic Perspective on Cities

biophilic cities as "those that are abundant in nature (trees, greenery, animals, and gardens) and in opportunities to connect with and experience this nature" (Beatley & Newman , 2013).the recognition of the innate human affiliation with nature and the need to put contact with nature at the center are the basic premises of this approach.

Biophilic Design categorized into two:

1. Vernacular or place-based design that create place attachment by connecting culture, history, ecology within geographic context,
2. Organic design, natural approach, directly, indirectly and symbolic approach. (Amat1, et al., 2020)
   The two basic dimensions of biophilic design can be related to six biophilic design elements: Environmental features- Natural shapes and forms-Natural patterns and

processes- Light and space-Place-based relationships -Evolved human-nature relationships

These six elements are then revealed in more than 70 biophilic design attributes. (Wijesooriya, et al., 2023)

Biophilic design goals:

The primary goal of biophilic design is to revitalize the interaction between humans and nature in the built environment. It also aims to harness the positive effects of this interaction, observing and documenting them in tangible, practical models of interaction with nature. It also seeks to steer architecture toward a more human experience by leveraging biophilic knowledge in architectural design. (Samir, et al., 2024)

principles of biophilic urban design:

Interactions: Three primary interactions are distinguished in biophilic urbanism: the impacts of nature on human beings and the built environment, the impacts of human beings and the built environment on nature and the impacts of the built environment on both nature and human beings (Vileniškė, et al., 2024)

Dimensions: Beatley and Newman identify four conditions for biophilic urbanism as shown in table (1): biophilic conditions and infrastructure, biophilic behaviors, patterns, practices, lifestyles, biophilic attitudes and knowledge and biophilic institutions and governance. (Amat1, et al., 2020)

KEY QUALITIES	ATTRIBUTES
Biophilic Conditions and Infrastructure	- Percentage of the population within a few hundred feet or meters of a park or greenspace - Percentage of city land area covered by trees or other vegetation - Number of green design features (e.g., green rooftops, green walls, rain gardens) - Extent of natural images, shapes, forms employed in architecture and seen in the city - Extent of flora and fauna (e.g., species) found within the city;
Biophilic Behaviors, Patterns, Practices, Lifestyles	- Average portion of the day spent outside; - Visitation rates for city parks - Percent of trips made by walking - Extent of membership and participation in local nature clubs and organizations;
Biophilic Attitudes and Knowledge	- Percent of residents who express care and concern for nature - Percent of residents who can identify common species of flora and fauna;
Biophilic Institutions and Governance	- Priority given to nature conservation by local government; percent of municipal budget dedicated to biophilic programs; - Existence of design and planning regulations that promote biophilic conditions (e.g., mandatory green rooftop requirement, bird-friendly building design guidelines); - Presence and importance of institutions, from aquaria to natural history museums, that promote education and awareness of nature - Number/extent of educational programs in local schools aimed at teaching about nature - Number of nature organizations and clubs of various sorts in the city, from advocacy to social groups.

Table 1- dimensions of biophilic cities (and some possible indicators thereof). **(Beatley & Newman , 2013)**

General principles: General principles of biophilic urbanism include: cities of abundant nature and natural experiences; bio diverse cities; multisensory cities; cities of interconnected, integrated natural spaces and features; immersing in and surrounding inhabitants with nature; becoming outdoor cities; embracing the blue as well as the green - the marine and aquatic as well as the terrestrial; celebration of nature in small and the large scales; citizens caring and engaging with nature. (Vileniškė, et al., 2024)

Addressing Different Scales of urban Spaces

Biophilic concepts can be applied on different granularity levels of architecture spaces as shown in figure (1). They will have a large-scale impact on the urban level, but they will also be positively experienced by the individual in the home and work environment. The most desirable result occurs when many different built scales, ranging from the very small to the largest, all possess biophilic qualities. As in nature, all the scales contribute. If the design and construction follow biophilic principles, then the result will be perceived as coherent even though the visual information is complex. (M. Ramm1, et al., 2024)

Figure 1- Biophilic green elements in urban design cities **(hidalgo, 2014)**

2. AI (Artificial intelligence) in Architecture and urban design

The emergence of technologies and artificial intelligence in the field of architecture has led to many benefits, lies in its endeavor to improve the reality of smart architecture by obtaining fast and accurate analysis and modeling data. Preparing a set of proposals and modifying them easily, in addition to enabling the client to visualize the project by presenting possible scenarios and possibilities in different ways and with the smallest details. It also assists the designer in the stage of preparing the architectural design idea in order to see the architectural space, to test the design capabilities and ideas, their suitability, and to choose the best among them. In addition to the importance of using AI in architecture of facilitating and accelerating the planning, design and implementation processes, with the highest quality and the least time and effort (Abdel Rijal , 2025). So, it can be implemented into every stage of design from concept design to post realization. (Sezer, 2024)

Three Key Elements of urban Design

The three key elements of urban design include environmental information collection, plan generation, and design evaluation. Building environment information extraction is a foundation in the design process, which involves collecting and screening the information that is essential to building design from the environment (Kučera & Pitner, 2018)

The goal and evaluation of design is the key to ensure that the design meets human needs and expectations. AI aids by optimizing designs for diverse user groups, extracting preferences implicitly, and accelerating evaluations. (Yangluxi , et al., 2025)

Challenges of AI Technology in urban Design

As shown in figure (2) The main challenges of applying AI in the field of urban design and planning were mainly related to the limited knowledge of available software and applications which are numerous and continuously develop which sometimes makes it difficult to follow up with the latest updates. This is followed by financial and time constraints noting that additional time and money are required to create the base case before any analyses are generated. Data interoperability was also highlighted depending on the source and form of data and the required analysis and available versions of software programs. Additionally, the gap between education and practice is another main concern that does not prepare practitioners for the most up to date in the international market. (Ismaeel, 2022)

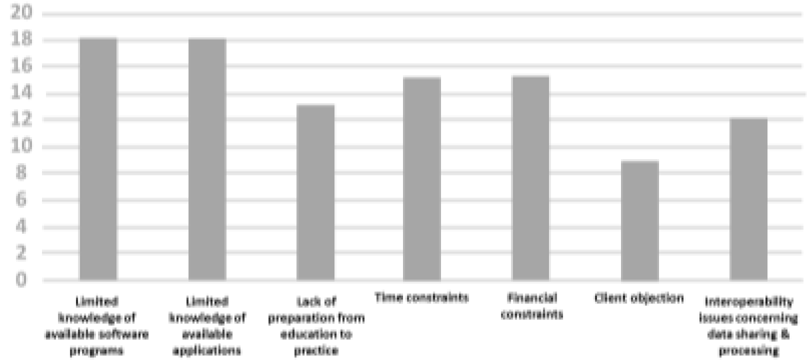


Figure 2- Survey response for challenges of applying ai in design (Ismaeel, 2022)

As a result, AI workflows can be applied at different stages of the entire design process, fully reflecting the integration of technology and innovation, which not only enhances efficiency, but also ensures compliance and revolutionizes the architectural design industry. (Yangluxi , et al., 2025)

The role of Ai in biophilic urban design

In recent years, advancements in tech have ushered in the era of Artificial Intelligence. As we explore the potential of AI in biophilic design, simply put, by analyzing user data and environmental factors at rapid speeds, AI can efficiently create highly optimized plans to foster healthier and more inspiring places to live, work, and learn. (Sezer, 2024)

3. Application of AI in different stages of urban planning for biophilic Qualities for cities

1. Pre-design
2. Design
3. Post-design stage: monitoring, operation, maintenance and user experience.

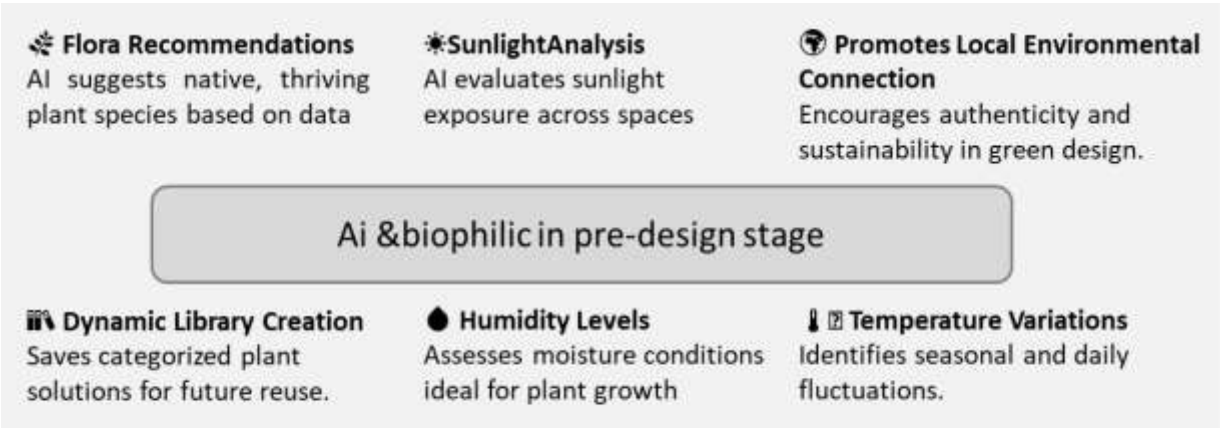
Pre-design Stage

Data analysis: Urban and landscapes are complex ecosystems, bustling with diverse variables that interplay in complex manners.

These variables encompass tangible elements like buildings, roads and parks, as well as dynamic factors such as population density, traffic flow, users' needs, functional and socio-economic activities. Each of these components generates a vast amount of data, which can be daunting to analyze manually (Chiancone, 2023).Here comes the role of AI that provides major support to deal with all these data that may be very difficult to process without computational technologies. Consequently, this is positively reflected on the design process by reducing the time required for the starting phase of design. (Amer, 2023)

Figure 3 – how AI can analyze environment factors and Give recommendation (chat gpt, designed by author)

This information can be used to inform design decisions and improve the effectiveness of biophilic interventions. Design process involves deeply analyzing the current state of conditions when beginning a project, as this helps to understand the pre-existing space which is essential for planning and optimizing the potential of a project. (Sezer, 2024)



Artificial intelligence (AI) can play an essential role in assisting biophilic in a variety of ways:

- Personalize biophilic environments based on individual preferences and needs. By learning from user behavior and feedback, AI systems can adjust lighting, temperature, and other biophilic element settings to create an optimal environment for each user. (Adityo, 2024) .AI can integrate data on users and preferences, environmental conditions and local ecology to create personalized and adaptable urban spaces.
- Integrate data on users and preferences, environmental conditions and local ecology to create personalized and adaptable urban spaces (Babin, 2024)
- Analyze existing urban landscapes and propose optimal layouts for green infrastructure networks, considering factors like connectivity, biodiversity and accessibility. This can involve designing connected green corridors, strategically placing parks and gardens and optimizing street tree planting for maximum ecological and social benefits, considering their potential role as community centers and in disasters management (Ric, 2024)

Furthermore, by understanding how these specific design choices influence users' reactions, AI can become a powerful tool for designers carried out the study of identifying biophilic elements and qualities in the photographs of urban green spaces. (Vileniškė, et al., 2024)

(Shih-Han, Hung & Chang, 2020) Used image recognition in Google Vision AI to understand selected elements in an urban green space. This study explored the possibility of utilizing the AI-based image recognition system for classification of landscape related label content in the images of urban green areas and predicting the impact of the features of the environment on people's psychological state.

Once the data is gathered, AI is a helpful tool to sort, organize, and analyze this information. With its vast knowledge base, AI can aid in the identification of suitable plant species aligned with both macro and microclimates in the project. (Sezer, 2024)

Figure 4 - Using Google Vision AI, the study extracted labels from images of natural environments-built environments in the urban green space that were used as independent variables**. (Shih-Han, Hung & Chang, 2020)**

The Design Stage

Application of AI for biophilic design optimization

Artificial intelligence (AI) can play an essential role in assisting biophilic architectures in a variety of ways:

- Generative design**:** AI can generate and optimize biophilic designs by considering parameters such as solar orientation, airflow, integration of natural elements, and user preferences. AI algorithms can explore multiple design options and propose solutions optimizing performance and biophilic aesthetics.

Urban design	Architecture	Interior design
Developed a generative algorithm that generates a spatial layout by considering several biophilic parameters, including access to nature (Gradišar, et al., 2022)	Developed a framework to optimize façade design, considering natural lighting performance, energy efficiency, and biophilic aesthetics (Yang, et al., 2023)	Deep learning models on an extensive database of room images to predict visual comfort levels based on features such as the number of plants, type of lighting, and color palette. (Nitu , et al., 2022)

Figure 5- Some of the studies reviewed the use of AI to optimize biophilic design through design three levels (designed by the author)

- Simulation and modelling**: figure (7)** AI can perform biophilic environment simulation and modelling to predict performance, thermal comfort, air quality, and other aspects. It helps architects make the right design decisions and optimize the integration of natural elements into the building.AI can be employed to design a green network throughout cities, offering multiple options for environmental enhancement and urban planning (Ric, 2024)

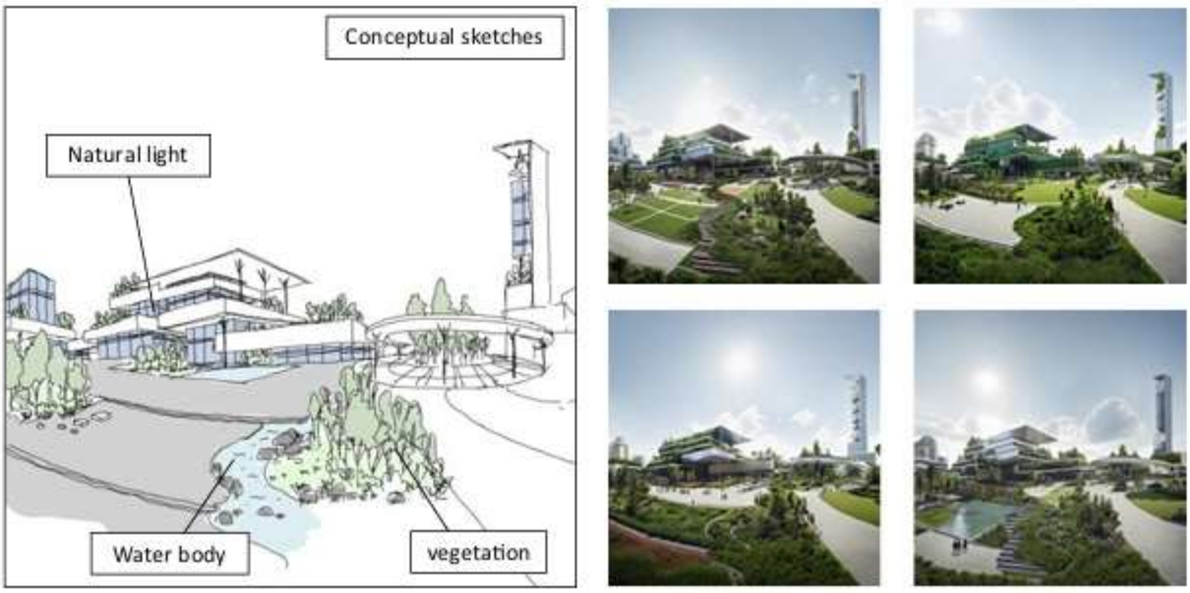


Figure 6- the use of AI in design stage to integrate biophilic elements in the design **(Adityo, 2024)**

This experience facilitates designers in refining their designs more efficiently. With a better understanding of how their designs will interact with the site, designers can streamline the design process, ultimately creating designs that are truly tailored to the site and its surroundings. Importantly, these technological advancements are not confined to the design phase, as AI can also be transformative in the post-implementation maintenance phase, ensuring long-term sustainability and well-being in built environments. (Sezer, 2024)

Post-design: monitoring, operation, maintenance, user experience

AI can simulate natural processes, helping urban planners understand how different design elements may impact ecosystems and biodiversity and visualize the impact of their decisions before they are made (Babin, 2024) .AI can simulate numerous urban development scenarios in a fraction of the time it would take manually.

As AI can also be transformative in the post-implementation maintenance phase, ensuring long-term sustainability and well-being in built environments.

- **Continuous Monitoring:** After implementation, Artificial Intelligence (AI) emerges as a continuous monitor, providing real-time insights into vital environmental parameters such as air quality, moisture, temperature levels, and the health of water features. By analyzing light levels, AI ensures optimal conditions for plants within the design, fostering sustainable architecture (Sezer, 2024)
- **Real-time adaptation:** The AI system can monitor and adjust the building environment based on environmental conditions and user preferences. For example, the system can adjust lighting, temperature, and humidity to optimize user comfort and well-being while maximizing biophilic benefits.
- **Predictive maintenance:** AI can monitor and predict the maintenance needs of biophilic elements such as plants, hydroponic systems, and water features. AI can identify potential problems and recommend proactive maintenance actions by analyzing data from sensors and monitoring systems.
- **Evaluation and feedback:** AI can help in the performance evaluation of biophilic designs by analyzing post-occupancy data and user feedback. These insights can refine future designs and inform best practices in biophilic architecture.

Table 2-The areas of application of AI in all the three stages of design process in biophilic urban design (author

stage	Pre design	design			Post design
	Data analysis	Simulation	Idea elaboration, generation of designs	Visualization	monitoring, operation, maintenance, user experience
AIM	Analysis of natural patterns, urban design principles, plant species and habitats Analysis of existing landscapes Analysis of data on users and preferences, environmental conditions, local climate, and local ecology Analysis of participants and users feedback.	Simulation of natural and social processes	Generation of planning and design solutions using AI algorithms trained on datasets of natural patterns and urban design principles Generation of images from texts (detailed descriptions of desirable parameters)	AI can forecast the future needs of a city's infrastructure (Babin, 2024) and generate a model of how the city might under various scenarios.	AI can monitor ecosystem performance in real time Dynamically adjusts irrigation,lighting and [illegible]ance schedules based on environmental data

مجلة الفنون والعمارة
JOURNAL OF ART & ARCHITECTURE

stage	Pre design	design			Post design
	Data analysis	**Simulation**	**Idea elaboration, generation of designs**	**Visualization**	**monitoring, operation, maintenance, user experience**
AIM	Analysis of natural patterns, urban design principles, plant species and habitats Analysis of existing landscapes Analysis of data on users and preferences, environmental conditions, local climate, and local ecology Analysis of participants and users feedback.	Simulation of natural and social processes	Generation of planning and design solutions using AI algorithms trained on datasets of natural patterns and urban design principles Generation of images from texts (detailed descriptions of desirable parameters)	AI can forecast the future needs of a city's infrastructure (Babin, 2024) and generate a model of how the city might evolve under various scenarios.	AI can monitor ecosystem performance in real time Dynamically adjusts irrigation,lighting and maintenance schedules based on environmental data
TOOLS	- **TensorFlow and PyTorch** can be employed for data analysis and pattern recognition, assisting in the extraction of insights from urban and environmental datasets to inform biophilic design)	- **Unity3D with ML Agents** simulating and optimizing various aspects of urban planning, such as resource allocation and environmental impact) - **OpenAI Gym** while traditionally associated with reinforcement learning, OpenAI Gym can also be adapted for simulating and optimizing various aspects of urban planning, such as resource allocation and environmental impact)	- **UrbanistAI** allows users to express design preferences through visualizations and translates them into actionable information for urban planners; can be used to explore design options that incorporate user preferences for nature connection and access to green spaces) - **SpaceMaker AI** (offers functionalities for generating and optimizing urban layouts, including building placement, street networks and public spaces; can be used to explore layouts that prioritize green infrastructure integration, pedestrian connectivity and potential for incorporating biophilic elements)	- **Bentley Generative Components** with creative application, could potentially be used to explore biophilic design options, such as optimizing building forms for natural light or designing nature inspired building facades - **Autodesk Generative Design** It has applications in architectural design and urban planning, including considerations for biophilic elements) - **Midjourney** and other text-to-image generation platforms	- **Urban Monitoring Platforms CityIQ** collects valuable information about the city environment to improve public safety - **IBM Maximo, BrainBox AI** Predictive Maintenance Tools (Detects damage, or decline in landscape or infrastructure) - **ETwater, Netafim** AI-controlled watering based on plant needs, soil moisture, and weather

Table (3) To systematically evaluate the role of Artificial Intelligence in enhancing biophilic urban design, a matrix framework was developed that maps AI applications across the three main stages of the design process—pre-design, design, and post-design—and aligns them with specific biophilic goals and outcomes. This framework serves as an analytical tool to identify how AI contributes to key functions such as environmental analysis, generative design, simulation, and post-occupancy monitoring. By categorizing AI tools and techniques according to their stage of intervention, the matrix clarifies the direct and indirect impacts of AI on various dimensions of biophilic design, including ecological sensitivity, sensory engagement, and long-term sustainability.

Table 3- Matrix of AI Applications across Design Stages and Biophilic Outcomes

Design Stage	AI Applications	Biophilic Urban Design Functions	Impact on Biophilic Outcomes
1. Pre-Design	- Environmental data analysis (climate, biodiversity, land use) - User behavior & needs prediction - Image recognition & scenario modeling	- Identify ecological assets- Understand user - nature interaction - Site suitability & landscape mapping	• Data-informed early planning • Site-sensitive planning Preservation of natural systems • Foundation for biophilic vision
2. Design	- Generative design (based on nature-related parameters) - Simulation (light, airflow, thermal comfort, biodiversity) - Deep learning for space layout	- Optimize spatial experience with nature - Enhance visual & sensory connection - Maximize access to greenery	• Human-nature connection • enhanced Functional green infrastructure • Design harmony with nature
3. Post-Design	- IoT sensors for real-time environmental data - Predictive maintenance - User feedback analysis	- Monitor plant and ecosystem health - Evaluate comfort, light, and air - Adapt systems to preserve biophilic quality	• Long-term biophilic resilience • Dynamic adaptation to nature and users • management Continuous enhancement of biophilic

The Ellinikon Case study

The Ellinikon is a world-leading mixed-use development on a prime seafront location, reinstating the standards of the Mediterranean coastal urban living. These principles have been applied to create a master plan that reflects a global vision, while keeping the characteristics and ambiance of the Athenian Riviera and Greek environment and lifestyle.

In Table (4) this case study was selected due to its relevance, innovation, and alignment with the research objectives. It represents a pioneering example of applying artificial intelligence to enhance biophilic design in a real-world context, offering valuable insights into both the opportunities and challenges associated with its implementation.

Table 4- criteria for choosing the Ellinikon project as a case study (author)

Criteria	Justification
Integration of AI Technologies	The Ellinikon is a leading example of a smart city that incorporates AI tools such as digital twins, IoT, and simulations in planning, design, and operation stages.
Biophilic Urban Design Focus	The masterplan places strong emphasis on green infrastructure, ecological restoration, and human-nature interaction—core to biophilic principles.
Scale and Significance	It is Europe's largest coastal park project (2 million m²), making it a large-scale testing ground for AI and biophilic integration.
Innovation in Design Approach	Uses AI-powered tools like and generative design to model sustainable, human-centered environments.
Availability of Data and Reports	Project documentation, certifications (LEED, WELL), and media coverage provide accessible and reliable sources for analysis.
Relevance to Research Aims	Aligns directly with the research goal: exploring how AI enhances biophilic design throughout the urban design stages.
Replicability and Model Potential	Serves as a transferable model for future smart-biophilic cities globally, especially in coastal or Mediterranean contexts.

The Ellinikon is envisaged to become a paradigm of integrated and sustainable living through its "15-minute city" principles **figure (9)** offering a truly 360-degree experience to its residents, tenants, guests and employees. The complete regeneration of the former airport site into an all-rounded destination composed of several clusters, each one with distinct character, combining residences, shopping, working, leisure, entertainment and cultural activities, revolving around a 2,000,000 sq.m. Park; the largest coastal park in Europe at the heart of The Ellinikon. (Anon., 2023)

The Ellinikon builds on Athens' rich civic and architectural history. This landmark urban regeneration project integrates modern living, green spaces and cutting-edge technology. The project will have a positive impact on the lives of Athenians and visitors alike – by bringing more nature into the city, boosting the city economy and creating jobs.

Figure 7-the Ellinikon city master plan **(Anon., 2023)**

Sustainability and technology at the heart of Ellinikon

The future smart city of Ellinikon plans to utilize advanced technology solutions such as 5G, smart energy management, digital twins, IoT sensors, and AI. These innovations aim to efficiently manage various aspects of the city, enhancing habitability for its future citizens and visitors (Anon., 2023). **The city features the following projects** Figure (9):

1. **Riviera Tower:** Scheduled for completion in 2026, it will be Greece's first skyscraper, set to become a landmark of architectural pride. It has already achieved LEED Gold pre-certification, and its facade features innovative biophilic design elements.
2. **The Experience Park :**The Experience Park, spanning two million square meters, will be the largest coastal green space in Europe, where one million new native plants and trees will be planted. Environmentally, the Experience Park will feature rain gardens designed to manage rainwater effectively. Existing surfaces will be repurposed for the construction of park furniture and pathways. An impressive 86 different species of trees will be planted, totaling 31,000 trees, along with over one million Mediterranean plants.

3.**Riviera Galleria :**Riviera Galleria, a commercial center, will feature international haute couture firms, renowned designer stores, and emerging brands. (Burbano, 2024)

4. **Experience Center:** serves as a space where visitors can discover, in-depth, the redevelopment project through more than 22 unique, natural, and immersive technological exhibits and digital activities. (designboom, 2024)

Figure 8-the main projects in the Ellinikon city **(Anon., 2023)**

The aim of Smart City is to redefine the urban lifestyle in Greece and Europe. And wants to harmonize all the needs of people, the environment and the economy. This is to be achieved through various focal points that have been set in the planning and development of Ellinikon:

- Accessibility: An AI-supported, user-friendly app bundles all digital and physical services in Ellinikon, from bike hire to bill payment, and makes them easily accessible via smartphone.
- Mobility: Intelligent parking aids and micro-mobility options such as bicycles and electric scooters ensure environmentally friendly transport.
- Electric vehicles: widespread use of electric vehicles.
- Place making: enhancing sense of place
- Early Scenario Modeling & Client Engagement: **figure (10)** Planners used Carbon Conscience to compare design alternatives during concept development (e.g., reducing paving, increasing native restoration).

Figure 9- Carbon Conscience App supports data-informed design decisions using AI, particularly in the early design stage **(Architizer, 2025)**

- Resource efficiency: IoT technologies are used to manage water and waste, maximize recycling and support the integration of renewable energy. Intelligent lighting increases comfort, efficiency and safety. First Large-Scale Green Infrastructure Project in

Biodiversity: rigorous analysis identified foundational plant species that provide ecological benefits including habitat structure and food provisioning for local wildlife. The plan calls for the protection and reuse of the existing seed bank of grasses and geophyte species indicative of the existing site's novel ecosystem, while 31,287 new trees representing 86 species were selected for their ecosystem services and adaptability to the site's distinctive soil profile.

Table 5-matrix of Impacts of Using AI on Biophilic Outcomes in the Ellinikon Project (Author)

Design Stage	AI Application	Function	Biophilic Design Contribution	Impact on Biophilic Outcomes
Pre-Design	Digital Twin Modeling	Simulates layout, daylight, airflow, and land use	Optimizes location for parks, green corridors, and water features	• Informed site-sensitive planning • Preservation of native ecosystem and biodiversity • Formation of Europe's largest coastal park • Improved ecosystem connectivity and disaster resilience
	Environmental Data Analysis	Analyzes climate, biodiversity, topography	Informs selection of native plants, ecological restoration zones	
	Predictive Scenario Modeling	Projects outcomes for pollution, traffic, and growth	Ensures long-term resilience of green and blue infrastructure	
Design	AI-Driven Landscape Optimization	Recommends layout of plant species, terrain design lighting systems that adjust according to the season and time of day	Enhances biodiversity, seasonal appeal, and user engagement	• Stronger visual and physical connection to nature • Improved mental well-being of users • Increased visual comfort and biophilic • aesthetics in urban interiors and exteriors • Greater emotional engagement with the environment • Reinforced sense of place
	Smart Building Design Tools	Adjusts form/orientation using light, heat, and ventilation simulations applications make every building "smart" and improve the daily lives of residents.	Improves daylight access, energy efficiency, and connection to outdoor nature	
	Integrated Mobility Planning	Optimizes pedestrian, bike, and transit pathways	Promotes walkable, green connections between natural and built environments	
Post-Design	IoT-Enabled Environmental Monitoring	Tracks air, soil, humidity, and temperature in real time	Maintains ecological health of landscapes, adapts to environmental changes	• Ongoing adjustment of biophilic conditions • Predictive maintenance of plants and natural systems • Achieved LEED Gold certification for key buildings • Integrated passive cooling and sustainable energy
	AI-Driven Energy & Water Management	smart grid infrastructures to monitor and control energy consumption	reduce consumption and carbon emissions	
		Manages HVAC, irrigation, and lighting based on use and weather	Saves resources and supports plant vitality and user comfort	
	Behavioral Analytics	Studies how people use public/natural spaces	Enables adaptive improvements to green areas and user-centered design	

Results Analysis and Interpretation

The analysis of The Ellinikon Project demonstrates a comprehensive integration of Artificial Intelligence (AI) throughout the design, planning, and operational phases, significantly enhancing biophilic outcomes. The application of the previously developed matrix revealed that AI technologies played a pivotal role in achieving key biophilic design objectives, such as ecological restoration, human-nature interaction, and long-term sustainability.

In the pre-design stage, AI tools were used to process large-scale environmental datasets—including climate conditions, biodiversity, and soil profiles—which informed ecologically sensitive site planning. Tools such as GIS mapping and scenario modeling enabled planners to preserve existing ecosystems, select optimal planting schemes, and predict the impact of interventions on the local environment. This stage laid a strong foundation for embedding nature-based solutions in the master plan.

During the design stage, AI-powered generative design algorithms and environmental simulations were employed to optimize spatial configurations, maximize access to natural light and airflow, and enhance the visual and sensory connection to nature. The use of the Carbon Conscience tool, for example, helped designers evaluate and compare low-carbon, high-biodiversity design alternatives. AI also facilitated user-centered design by modeling behavioral patterns to enhance public interaction with green spaces.

Conclusion:

Research has highlighted the extensive range of applications that AI, can have in advancing biophilic urbanism and developing nature-based solutions in urban. By analyzing existing literature, it is evident that AI can contribute to every stage of biophilic urban planning and design. These stages include general research and analysis, pre-design, design, and post-design stages, from the initial analysis of environmental conditions to the implementation of advanced technologies and explored how AI can streamline the design process, optimize environmental parameters, and enhance user experience in built environments.

By leveraging AI's data analysis, optimization, and decision-making capabilities, biophilic architectures can become more responsive, adaptive, and effective in creating healthy, enjoyable environments that connect humans with nature. Collaboration between architects and AI experts can result in innovative solutions that advance the goals of biophilic architecture and improve occupant well-being.

Recommendations and Suggestions

By harnessing AI’s capabilities for data analysis and predictive modeling, designers can create spaces that not only promote well-being but also foster a deeper connection with nature. From selecting optimal plant species to simulating real-life experiences through VR, AI offers boundless opportunities for innovation in sustainable architecture. As we look to the future of design, it’s crucial to embrace these technological advancements and explore their potential to shape a more sustainable and harmonious relationship between humans and the environment.

- Integrate AI Early in the Design Process: Urban planners and architects should adopt AI tools during the pre-design and concept development stages to simulate environmental performance and prioritize biophilic features from the outset
- Encourage Interdisciplinary Research: Foster collaboration between architects, ecologists, data scientists, and urban planners to develop innovative AI-basophilic tools.
- Ensure Ethical AI Use in Design: Address transparency, bias, and data privacy when using AI to influence public space and ecological decisions.

References

Abdel Rijal , M., 2025. Towards an advanced scientific methodology for using artificial. *Mağallaẗ Al-ʿimārah wa Al-Funūn wa Al-ʿulūm Al-Īnsāniyyaẗ*, 10(50).

Adityo, 2024. The Role of Neuroscience and Artificial Intelligence in Biophilic. *JARINA - Journal of Artificial Intelligence in Architecture*, Volume 2.

Amat1, r. et al., 2020. *A Dimension of Biophilia in Urban Design.* Kuala Lumpur, IOP Publishing.

Amer, N., 2023. Architectural Design in The Light of AI Concepts and. *MSA ENGINEERING JOURNAL,* 2(2).

Anon., 2023. *The Ellinikon.* [Online] Available at: https://theellinikon.com.gr/en/[Accessed june 2025].

Architizer, 2025 . *Architizer.* [Online] Available at: https://architizer.com/projects/the-ellinikon-metropolitan-park-and-costal-front/ [Accessed 2025].

Babin, N., 2024. *Shaping Future Cities: The Revolutionary Role of AI in Urban Planning and Simulation,* s.l.: linkdin.

Beatley, T. & Newman , P., 2013. Biophilic Cities Are Sustainable, Resilient Cities. *sustainability journal.*

Burbano, . L., 2024. *fira barcelona.* [Online] Available at: https://www.tomorrow.city/ellinikon-greeces-futuristic-smart-city-project-in-an-abandoned-airport/ [Accessed june 2025].

Chiancone, C., 2023. *Revolutionizing Urban Planning with Generative AI: A New Era of Smart Cities.* [Online] Available at: https://www.linkedin.com/pulse/revolutionizing-urban-planning-generative-ai-new-era-smart-chiancone/[Accessed june 2025].

designboom, 2024. *the ellinikon takes shape — what we know so far about greece's 15-minute smart city.* [Online] Available at: https://www.designboom.com/architecture/the-ellinikon-takes-shape-greece-15-minute-smart-city-athens-05-18-2024/ [Accessed june 2025].

Gradišar, L., Klinc, R., Turk , Ž. & Dolenc, d. M., 2022. Generative Design Methodology and Framework Exploiting Designer-Algorithm Synergies. *MDPI.*

hidalgo, . a. . k., 2014. *BiophiliC desigN, restoratiVe.* Bogota - Colombia, Colors of Care: The 9th International Conference on Design & Emotion.

Ismaeel, W., 2022. *Challenges for applying artificial intelligence in the field of urban design and.* cairo, resaearch gate.

Kučera, A. & Pitner, T., 2018. Semantic BMS: Allowing usage of building automation data in facility benchmarking. *Advanced Engineering Informatics,* Volume 35.

Li, L., Liu, Y. & Jin, Y., 2024. Generative AI-enabled supply chain management: The critical role of coordination and dynamism. *International Journal of Production Economics,* Volume 277.

M. Ramm1, . T. et al., 2024. Artificial Intelligence Evaluates How Humans Connect to the. *MDPI.*

Nitu , M. et al., 2022. A Biophilic Design Approach for Improved Energy Performance in Retrofitting Residential Projects. *Sustainability.*

Ric, S., 2024. *Green Cities Artificial Intelligence.* [Online] Available at: https://scholarsbank.uoregon.edu/items/31296ac9-644a-4937-a864-22da1d7af34c

Samir, O. M., fawzy, S. & Mokhtar , G., 2024. The Biophilic design of the Interior Environment in Mamluk). *‹Maǧallaẗ Al-ʿimārah wa Al-Funūn wa Al,* Volume 19.

Sezer, B., 2024. *MOSS.* [Online] Available at: https://moss.amsterdam/2024/05/17/sustainablearchitecturewithai/[Accessed June 2025].

Shih-Han, Hung & Chang, . C.-Y., 2020. Using AI to Extract Biophilic Design Elements and Predict Health. *APRU Sustainable Cities and Landscapes PhD Symposium.*

Thampanichwat, C. et al., 2025. The Architectural Language of Biophilic Design After Architects. *MDPI.*

Vileniškė, i., Zaleckis, K. & Viliūnas, g., 2024. POTENTIAL APPLICATIONS OF AI IN BIOPHILIC URBANISM. *NEW DESIGN IDEAS,* Volume 8.

Wijesooriya, N., Brambilla , A. & Markauskaite , L., 2023. Biophilic design frameworks: A review of structure, development techniques and their compatibility with LEED sustainable design criteria. *Elsevier Ltd.*

Yang, L., Li, J. & Zhao, Z., 2023. A Generative Urban Space Design Method Based on Shape Grammar and Urban Induction Patterns. *New Technologies and Methods in Spatial Planning.*

Yangluxi , L., Chen, . H., Yu, P. & Yang , L., 2025. A Review of Artificial Intelligence in Enhancing Architectural. *MDPI,* 15(3).

Yip, H., 2020. Prologue to Tai Kwun: Commercialism or Community?. *rbanie and Urbanus,* Issue 6.

Zelnik, . M., DeChiara, J. & Panero, . J., 1991. *time saver standards for interior design and space planning.* singapore: mcgraw-hill.

مجلة الفنون والعمارة

JOURNAL OF ART & ARCHITECTURE