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The Potentials of the Interaction of Biomimicry and Artificial Intelligence Technology in Participatory Urban Design

Katılımcı Kentsel Tasarımda Biyomimikri ve Yapay Zekâ Teknolojisi Etkileşiminin Barındırdığı Potansiyeller

Feyza Nur Çimen[1], Sebla Arın Ensarioğlu[2]

Öz

Biyomimikri, doğadaki canlıların tasarım ve işlevlerinden ilham alarak insan yapımı çözümler geliştiren bir disiplindir. Bu yaklaşım, sürdürülebilirlik ve verimlilik açısından yenilikçi ve etkili çözümler sunmayı hedefler. Yapay zekâ, bilgisayar sistemlerinin insan benzeri zekâya sahip olmasını sağlayan bir teknoloji alanıdır. Bu sistemler; veri analizi, öğrenme ve problem çözme gibi görevleri gerçekleştirerek insanlara yardımcı olabilir ve karmaşık sorunları çözmede büyük potansiyele sahiptir. Bu makale; katılımcı kentsel tasarım, biyomimikri ve yapay zekâ teknolojilerinin etkileşimini kentsel planlama ve tasarım alanındaki potansiyellerini değerlendirmektedir. Biyomimikri; doğadan ilham alarak yapılan tasarımların ve süreçlerin kentsel alanlarda nasıl kullanılabileceğini araştırır, yapay zekâ teknolojileri ise kentsel sistemlerin verimliliğini artırmak için analitik ve öngörü yeteneklerini kullanır. Makalede iki kavram özelinde kentsel ölçekte yapılmış örnekler tartışılmakta ve bu paydaşların bir araya gelmesinden kaynaklanan faydalar ele alınmaktadır. Biyomimikri prensiplerinin kentsel planlama ve tasarımda kullanılması, sürdürülebilirlik, enerji verimliliği, doğal kaynakların etkin kullanımı, enerji ve kaynak tasarrufu, adaptasyon ve dayanıklılık gibi konulara katkı sağlar. Yapay zekâ teknolojileri ise büyük veri analitiği, öngörü yetenekleri ve otomatik karar verme sistemleriyle kentsel alanlarda karmaşık ve zor problemleri çözerken verimlilik artışı sağlar. Bu çalışma kapsamında, biyomimikri ve yapay zekâ teknolojilerinin kentsel planlama ve tasarım alanındaki etkileşiminin ortaya çıkarılmasına yönelik katılımcı bir süreç modeli önerilmektedir. Bu alanda sürdürülen araştırmaların artması planlama süreçlerinin optimizasyonuna ve sürdürülebilir kalkınma hedeflerinin karşılanmasına katkı sağlayacaktır.

Anahtar Kelimeler:, Biomimikri, katılımcı kentsel tasarım, kentler, kentsel tasarım, sürdürülebilirlik, yapay zekâ

ABSTRACT

Biomimicry is a discipline that develops human-made solutions inspired by the design and functions of living things in nature. This approach aims to provide innovative and effective solutions in terms of sustainability and efficiency. Artificial intelligence is a field of technology that enables computer systems to have human-like intelligence. These systems can assist humans by performing tasks such as data analysis, learning and problem solving and have great potential in solving complex problems. This article evaluates the interaction of participatory urban design, biomimicry and artificial intelligence technologies in the field of urban planning and design. Biomimicry explores how nature-inspired designs and processes can be used in urban spaces, while AI technologies use analytical and predictive capabilities to improve the efficiency of urban systems. The article discusses examples of both concepts at the urban scale and discusses the benefits that arise from bringing these stakeholders together. The use of biomimicry principles in urban planning and design contributes to issues such as sustainability, energy efficiency, efficient use of natural resources, energy and resource conservation, adaptation and resilience. Artificial intelligence technologies, on the other hand, increase efficiency while solving complex and difficult problems in urban areas with big data analytics, predictive capabilities and automated decision-making systems. In this article, a participatory process model is proposed to reveal the interaction of biomimicry and artificial intelligence technologies in urban planning and design. Increasing research in this field will contribute to the optimization of planning processes and the realization of sustainable development goals.

Keywords: Biomimicry, participatory urban design, cities, urban design, sustainability, artificial intelligence

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INTRODUCTION:

Recently global population growth, rapid urbanization, wars, and environmental changes overcomplicate the challenges of urban areas more and more. In this context, solutions beyond traditional methods are needed to achieve sustainability and efficiency goals. The future of earth ecosystems is progressively dependent on the patterns of urban growth (Küçükali, 2016), highlighting the critical role of urban development in shaping the environment. In 1942, architect Jose Luis Sert argued that cities are living organisms and urban biology should be considered instead of urban planning (Batty and Marshall, 2009). Due to the development of artificial intelligence technologies, the city, which has turned into an ecosystem that self-regulates operations such as collecting, filtering and analysing real-time data sets, began to gain the characteristics of a living organism (Kirwan & Zhiyong, 2020).

Within the scope of this article, applied examples involving the relationship between biomimicry and urban design and/or artificial intelligence and urban design are analyzed. The potential of the interaction of these concepts for the establishment of the city are discussed. The interaction in question reveals a unique approach in the field of urban design.

1. Biomimicry and Basic Principles

The term biomimicry was first coined in 1962. This term is a combination of the words "bios" (life) and "mimikos" (imitation). Biomimicry refers to the imitation of a type of existence by another (Volstad & Boks, 2012). Benyus (1997) defines biomimicry as a conscious emulation of the genius of nature and innovation inspired by nature. Biomimicry offers a chance to adopt a systemic perspective of the world and to live within the limits of the planet. This approach recognizes that we are surrounded by millions of organisms and ecosystems from which systemic inferences can be made about how to survive and thrive. These organisms face similar challenges posed by human regulation; they must conserve resources and act without harming their environment, while performing tasks such as regulating warming, filtering water, extracting energy, and so on.

Biomimicry aims to adopt fundamental principles inspired by nature and integrate them into man-made systems. This approach encourages innovations in areas such as energy efficiency, material utilization, water cycle and recycling. Biomimicry aims to make man-made solutions more effective and sustainable by utilizing examples of diversity, harmony and sustainability in nature.

1.1. Biomimicry and Urban Design

Cities are places where people exist in interaction with other living creatures and with each other. Therefore, in cities, components such as infrastructure, parks, plants and animals form a system that interact with each other. Biomimicry aims to produce solutions that meet the needs of present and future generations by taking inspiration from the functions, processes and systems of nature in urban design (MacCowan, 2012). Guerreiro (2011) emphasizes that the city is not an artificial organism, but a living one in constant motion, while Newman and Jennings (2008) define cities as sustainable ecosystems. Biomimicry benefits sustainability by increasing the scale of learning from nature in urban design. According to Pedersen Zari (2007), the more the scale of learning from nature approaches to the ecosystem level, the more sustainable the designs become. For example, natural ventilation systems of buildings can be designed inspired by the ventilation systems in termite nests. There are urban examples of rainwater collection and recycling systems in cities which are inspired from the natural water cycle.

Furthermore, inspiration can be taken from nature for the protection and integration of green spaces and ecosystems within the city. Biomimicry offers sustainable, efficient and human-oriented solutions in urban design inspired by the functioning of nature. This approach aims to harmonize cities with natural ecosystems, enabling people to live in a healthier and more sustainable environment, while strengthening cities as long-lasting and self-sufficient systems. In the example presented by Matt Grocoff in Figure 1, the similarities between the biological structure of a leaf and the structures of organically developed pre-industrial cities such as Venice concretely illustrate the connection between biomimicry and urban design.

Figure 1: Matt Grocoff's Comparison of the Structure of a Leaf and the Structure of Self-Organizing, Pre-Industrial Cities such as Venice, Italy - URL1

2. Basic Principles of Artificial Intelligence

Artificial intelligence is a branch of science and engineering that enables computer systems to imitate human-like intelligence abilities by creating intelligent machines and programs capable of achieving goals and performing tasks requiring human intelligence, focusing on the computational aspects rather than biologically observable methods (McCarthy, 2004). Basically, the working principles of artificial intelligence can be expressed as follows: Machine Learning, Natural Language Processing, Computer Vision, Logical Reasoning, Sentiment Analysis, Automated Decision Making, Autonomous Systems, Deep Learning, Interactive Systems (Wang, 2023). These principles provide an overview of the basic principles of artificial intelligence. However, since artificial intelligence is a rapidly developing field, especially currently, new methods, algorithms and techniques are constantly being discovered and their application areas are expanding in various disciplines. Therefore, the development and application areas of artificial intelligence are expanding day by day and creating interactions between different disciplines.

2.1. Artificial Intelligence and Urban Design

Since the 1960s, urban planning researchers started to develop artificial intelligence (AI) methods (Langendorf, 1985). The relationship between AI and urban design was seen as a scientific endeavor. Over the years, artificial intelligence (AI) in the planning discipline started to adopt more advanced methods and has been successfully applied. In recent years, rapid advances in big data and AI techniques have enabled a deeper understanding of the development and design of cities (Kamrowska-Załuska, 2021). It has identified six main areas to support the planning process of artificial intelligence tools at the urban scale (Kamrowska-Załuska, 2021): Large-scale urban modelling (Rienow, Stenger, & Menz, 2014), frequency and speed generating conditions for capturing urban processes such as rapid urbanization (Hwang, Lee, & Kim, 2019; BaezaR, 2018; Aschwanden et al., 2021), regional growth outside the master plans of legal city boundaries (Allmendinger & Haughton, 2009), high granularity allowing in-depth analyses while at the same time providing a broader perspective for revealing the dynamics behind complex urban processes and structural patterns (Yigitcanlar, Kankanamge, & Vella, 2021; Sun & Shao, 2020), collaborative perception of the city (Ghahramani et al., 2021; Haqbeen et al., 2021), empirical urban research expanding the scope of possible analyses (Filomena, Verstegen, & Manley, 2019).

Today's urban AI-based tools are developing qualities that support the creation of plans that show possible development and evaluation scenarios that allow the evaluation and design of urban change, rather than the outcome. These developments include studies on urban physical design generation with AI-based search algorithms such as genetic algorithms. Artificial intelligence techniques are effectively used in urban planning in areas such as data analysis, forecasting, decision making and design, all of which contribute to the generation of cities as more sustainable and livable.

3. Artificial Intelligence and Biomimicry Interaction

Artificial intelligence is inspired by nature thanks to its ability to understand, mimic and improve the complexity of biological systems. On the other hand, biomimicry aims to generate solutions to various technological problems by modelling rational designs and processes in nature. The intersection of these two disciplines creates a unique opportunity for interaction in learning from nature and improving nature with artificial intelligence. The first occasion that this interaction was first seen was in 1950s; when Alan Turing and John von Neumann, the pioneers of modern Computer Science, developed one-dimensional computing machine models and discovered two-dimensional cellular automata, explaining textural patterns distributed in nature and self-reproduction (Casey & Cai, 2023). Artificial Intelligence pioneers Marvin Minsky and others developed neural networks to simulate the processes of perception and cognition that are the keystone of today's deep learning algorithms (McCarthy, Minsky, Rochester & Shannon, 2006). The method of formation of artificial intelligence principles is a biomimicric approach. Artificial intelligence develops more effective, energy-efficient and environmentally friendly technologies using biomimicry principles.

Nowadays, the integration of biomimicry principles into different disciplines through artificial intelligence is an approach that is being discussed. The results of the Artificial Intelligence x Biomimicry Architecture competition, organized by NEA and the Antoni Gaudi Foundation, focusing on the interaction of biomimicry and artificial intelligence in the urban context, express forms of production that are relevant to the topic explored in this paper. This architecture competition used Midjourney, a text-driven rendering tool (Yin, Zhang & Liu, 2023) rooted in the Stable Diffusion AI painting paradigm.

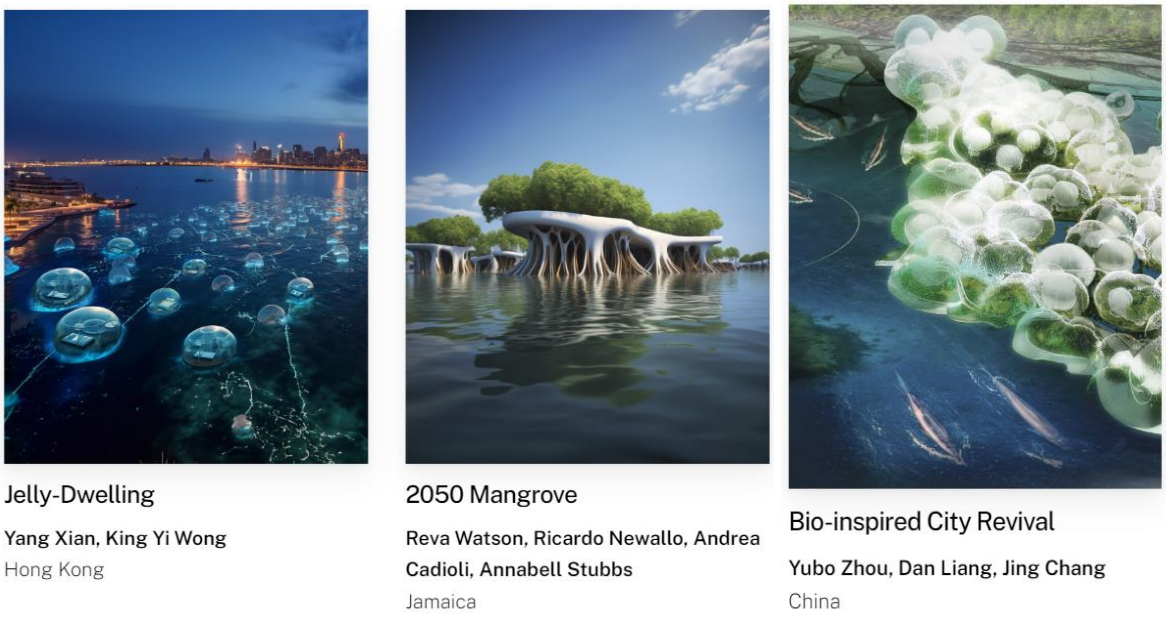

Figure 2: Ai-Biomimicry Competition Finalist Works; Jelly-Dwelling, 2050 Mangrove, Bio-inspired City Revival. - URL2

Jelly-Dwelling offers a settlement concept design for Hong Kong region by generating visuals from text with the Midjourney artificial intelligence application (Figure 2). Mimicking jellyfish metabolism in the marine ecosystem, the design of the shelter acts as a marine waste collection and treatment machine, collecting waste from the ocean and converting it into energy for the people inside the jelly shelter. 2050 Mangrove (Figure 2), the solution designed for Jamaica region, mimics the root systems of mangroves and aims to restore the coastline and treat wastewater, contributing to the biodiversity of the region. Bio-inspired city revival (Figure 2), proposed for the Chinese region, proposes the possibility of revitalizing cities inspired by the adaptability of algal organisms (Never Enough Architecture, 2023).

In this context, the interaction between artificial intelligence and biomimicry provides various possibilities for technological progress as well as the development of solutions in harmony with nature. Therefore, promoting research and projects that combine these two disciplines makes significant contributions to future technological developments.

4. Participation in Urban Design

Participation in urban design processes is a critical approach that aims to take into account the opinions, needs and expectations of urban dwellers and stakeholders. Participation plays a vital role for urban planning to become more democratic and sustainable. This process ensures that local inhabitants are effectively involved in decision-making processes in urban development. Residents and other stakeholders should be able to have a say in the design and development of urban spaces and influence the production of the solutions to their needs. Participation brings together various perspectives to ensure that urban design projects are more comprehensive, diverse and sustainable. In this context, the active participation of various segments of society improves the quality of cities by supporting urban spaces to be more equitable, accessible and livable. Creating a situation where people can act according to their own environmental needs and distinguish between the technical and aesthetic judgements of experts requires a change in the consciousness of both people and professionals (Sanoff, 2008).

Participation in urban design processes has been further strengthened with the emerging software and technological solutions and the change mentioned by Sanoff has started to be realized. In the current era, mobile applications, virtual platforms and online feedback tools are effectively used to increase the contribution of urban residents and stakeholders to urban development. By using social media and other socially generated information arising from their participation in social, economic or civic activities, citizens are transforming from passive subjects of inquiries and research studies to active producers of knowledge (Thakuriah, Tilahun & Zellner, 2014). These AI-supported applications make it easier for communities to participate in surveys, express their opinions and actively participate in urban design projects. By this way, more people can participate in urban planning processes, reflecting various perspectives and needs more effectively in the design of urban spaces. With the increase in artificial intelligence-supported applications, the importance of participatory urban design approach has been further emphasized and these technological developments allow the inhabitants of cities to play a more effective role in urban spaces.

5. Methodology

The theoretical framework of the research is analyzed under the titles of biomimicry concept and basic principles, artificial intelligence concept and basic principles and urban design interaction, artificial intelligence and biomimicry interaction, participation in urban design. In this context, the definitions of the concepts, their technological components, layers and the periods when they were first discussed in the literature were mentioned. Following the establishment of the theoretical infrastructure, examples of applications and designs that reveal the effects of biomimicry and artificial intelligence concepts on the city are analyzed. In the study, which was designed as a qualitative research, document analysis (documentary scanning) method was used as data analysis method. Among the examples focusing on biomimicry and/or artificial intelligence, examples that were implemented or designed on an urban scale were selected. In the evaluation made, a comparison table has been created regarding the framework in which the selected examples use the concepts and approaches of biomimicry and artificial intelligence in the urban context. As a result of analyzing the positive and negative qualities of the examples examined in the conclusion and evaluations section of the article, a participatory urban approach proposal that reveals the interaction potential of biomimicry and artificial intelligence technology in the context of urban design has been created.

6. Case Analysis and Findings

In line with the aim of the study, a selection of international examples is constituted to reveal the use / interaction of biomimicry and artificial intelligence at the urban scale. Within the scope of the research, a total of four examples are analyzed. Within the scope of the research, a limited number of examples were analyzed due to the limitations of the article structure. However, there are other studies in literature that examine the interaction of biomimicry and artificial intelligence. The results of these studies can guide different future research. The first example is an urban planning project planned and implemented by emulating the behavior of monsoon forests in Lavasa, India. The second example is the harbor city of Kalundborg in Denmark, which is designed according to the symbiotic life fiction. The third example is the eco-smart city plan for the city of Langfang in China, inspired by the natural water cycle. In this city formation, it is proposed to use smart systems 12 artificial intelligence in the construction of infrastructure clusters. The last example is Songdo City, a smart city concept located in Incheon, South Korea. After analyzing all the examples, a table is created to compare the use of artificial intelligence and biomimetic methods in each of the cases.

The international examples selected within the scope of the study show how the behavioral patterns of biomimicry at the urban scale in different geographies are or can be applied in urban planning and

design. In addition, examples of how the concept of smart city as a field of use of artificial intelligence in the working principles of functioning and infrastructure systems are or can be applied are also discussed.

6.1. Lavasa City

Lavasa is a planned urban design project located in the state of Maharashtra, India (Figure 3). Lavasa is in a region under the influence of Monsoon rains. Depending on the climate zone of the location, rainfall intensifies periodically, while drought is experienced in other periods. Therefore, to create an effective water management design, a project inspired by the systemic principles of Monsoon forests that used to exist in the region but were lost because of agricultural activities was designed (Rossin, 2010).

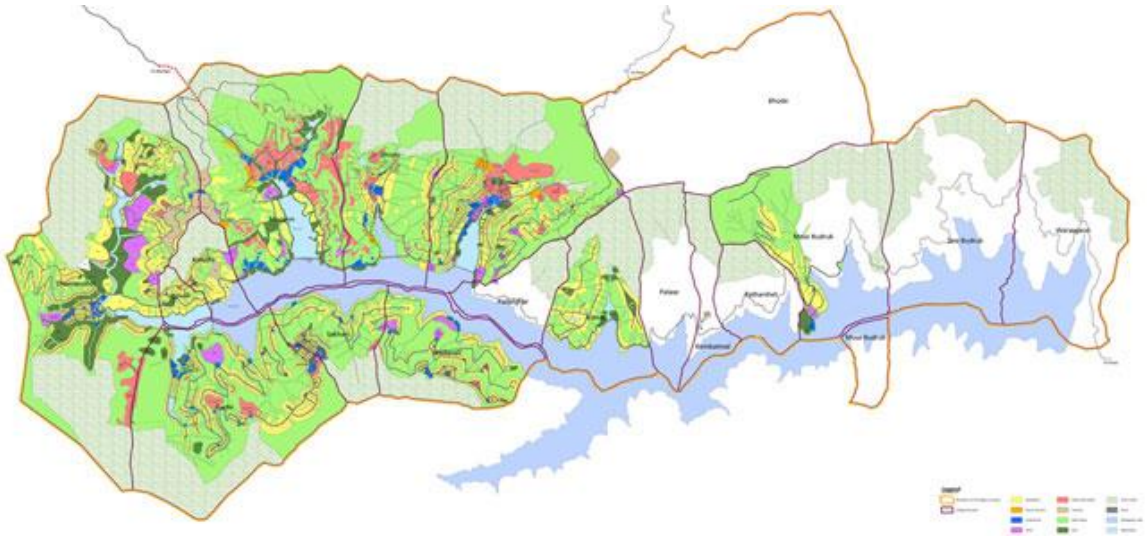

Figure 3: The Location of the Urban Centers of Lavasa Along the New Dam Lake- URL3

Monsoon forests retain water in the dry season by preventing evaporation after the rainy season to effectively manage water and maintain soil quality (Blanco et al., 2021). The ecosystem characteristics of the monsoon forests are the basis for the urban design concept of Lavasa, as defined by HOK Architects and the Biomimicry 3.8 design team: water harvesting, solar energy gain, carbon sequestration, water purification, evaporation, and nitrogen and phosphorus cycling. The design project also has design objectives such as breaking the rain with structural canopies and utilizing water harvesting systems to prevent rainwater erosion (Buck, 2017; Lazarus & Crawford, 2011). The plan of the Davese settlement in Lavasa (Figure 4) shows a design to protect the city from floods by utilizing the formal characteristics of anthills as well as the canal system and solid foundations (Smart, 2019).

Figure 4: Davese Plan- URL4

In the design of the biomimicric urban approach of the city of Lavasa, the behavior of the Monsoon forests in its geography became a source of inspiration. Also, the urban canal system network was created by being inspired by the formal characteristics of anthills. As a result, the planning of Lavasa city was inspired by nature in terms of behavior and form.

6.2. Kalundborg Port City

Kalundborg, one of the sea voyage destinations close to the Baltic entrance from the North Sea, is a city in Denmark designed by utilizing the principles of symbiotic life. "Symbiosis" refers to a relationship in nature in which two living creatures live together and benefit from each other (Erhenfeld JR, 1997). The principles of symbiotic life express the basic rules that arise in symbiotic relationships between different organisms. These principles include the following evolutionarily developed strategies to ensure the sustainability of symbiosis and mutual benefit between the parties: associations in which both organisms are dependent on each other and the existence of one provides an advantage to the other, resource sharing that ensures the effective use of environmental resources, balanced reciprocity between the parties. Industrial symbiosis is defined as the exchange of materials and energy between two independent industrial enterprises close to each other (Ayres RU, 1989), reflecting a similar interaction and system in nature.

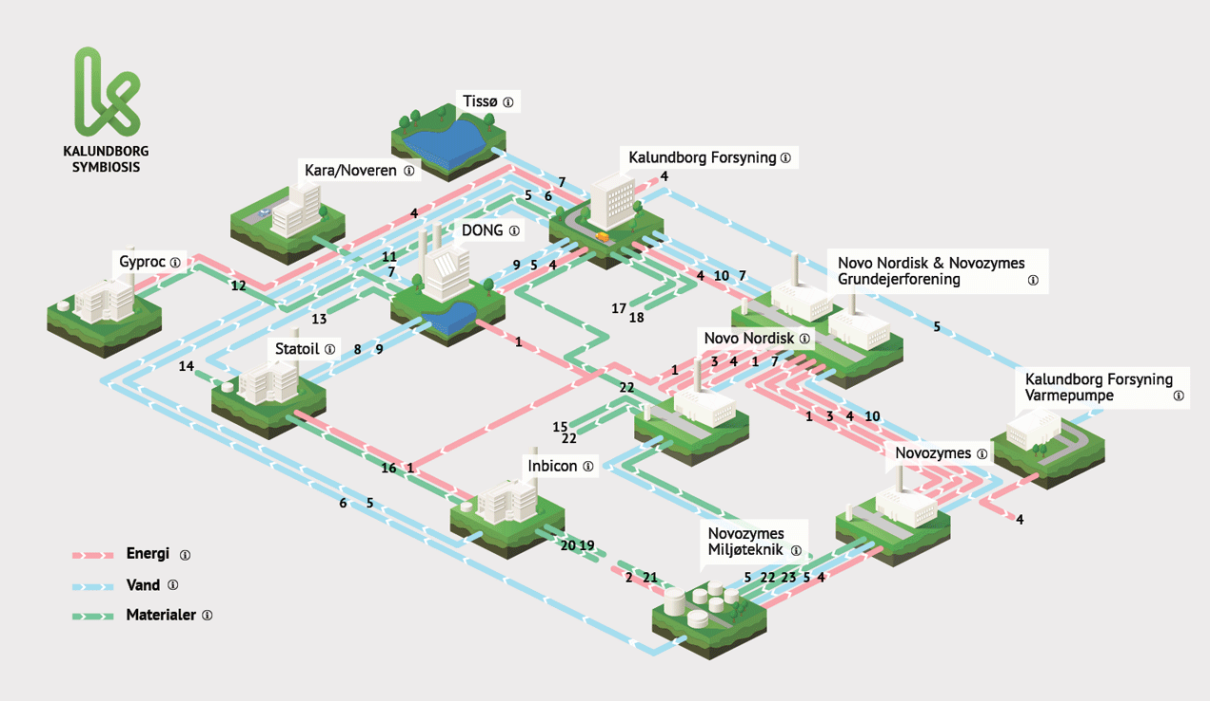

Figure 5: Closed System- URL5

The port city of Kalundbord is an example of the most important industrial symbiosis cities. In this system, waste products are shared between different industries by buying and selling them in a closed loop shown in Figure 5, and a significant reduction in environmental impacts is achieved by reducing resource consumption. The system in Kalundborg is based on the exchange of materials and energy between enterprises (Özkan et al., 2018). The Kalundborg model has been applied in different industrial areas around the world and this example has also been included in educational program (Valentine, 2016). These are listed as follows: Landskrona / Sweden Industrial Symbiosis Application, South Korea Eco Industrial Park (EEP), Tianjin / China Industrial Symbiosis Programme.

The biomimicric urban design approach of Kalundbord was inspired by symbiosis behavior. The design of the industrial system was inspired to approach the goal of energy conservation and zero waste in the functioning of the system. As a result, it is inspired by nature as a principle of behavior.

6.3. Langfang City

The city of Langfang consisted of an ecosystem covered with deciduous forests 4000 years ago. However, because of urbanization and deforestation, local water resources dried up. The problem of water scarcity has emerged. To supply water, water was pumped from the Yangtze River, but this method limited the flexibility of the city and caused inefficient results. As an alternative, the eco-smart city plan proposes to improve development patterns and enrich natural habitats by integrating environmentally sensitive ecological systems. The design (Figure 6) is inspired by the natural water cycle of the region. Green areas have been strategically designed so that water can meet the soil efficiently and sufficient water supply is provided to the city. In addition, a valuable landscape area has been generated with the designed green areas. With the eco-smart city plan of Langfang, a design project including landscape and water elements such as green corridors and a network of blue roads (Figure 7) was created (Lazarus & Crawford, 2011).

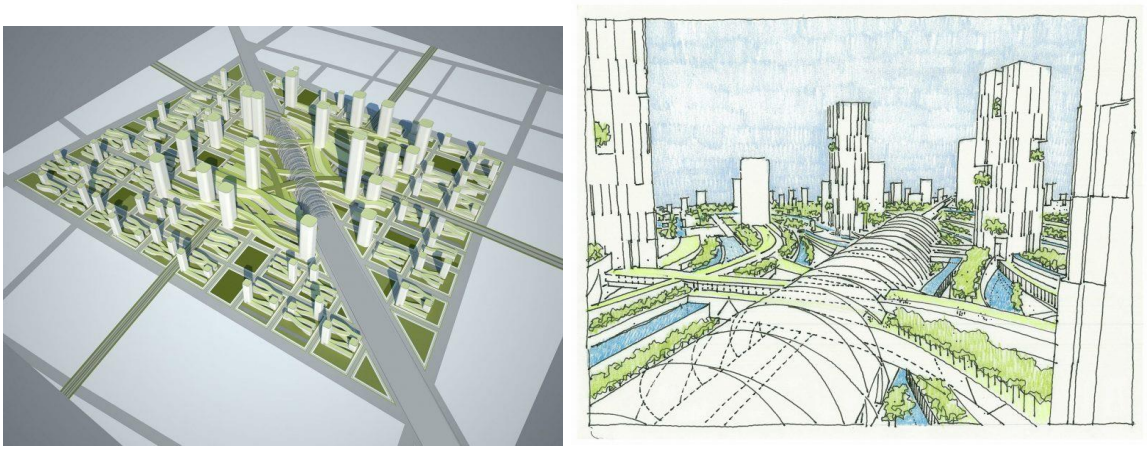

Figure 6: The Langfang Chinese Case Model- URL6

Figure 7: Green Zones Diagram and Water Zones Diagram- URL7

The biomimicric urban approach proposed for Langfang city is designed to realize the idea of revitalizing the water zones that existed in nature in the past. The design of the city is inspired by the former water cycles found in nature.

6.4. Songdo City

Songdo is a smart city located in Incheon, South Korea. Built in 2015, this city has a population of 167,346 people. Songdo is spread over an area of 600 hectares on the Incheon coast, 30 km southwest of the capital Seoul. The city has more than 20,000 residences and more than 1,000 places of business. Songdo's urban infrastructure is built using digital networks and geographic information systems, and all residents can access these systems from their residences (Karapınar, 2017, p. 17). In addition, 40% of the city is covered with green areas (Figure 8). In Songdo, environmentally friendly transport systems such as electric and hybrid vehicles, rail public transport systems and bicycle networks are also included. In Songdo, rainwater is collected and used for irrigation needs of urban landscape areas (Baek, 2015).

Figure 8: Songdo Master Plan- URL8

This smart city, where artificial intelligence-supported systems are used, hosts LEED (Leadership in Environmental and Energy Design) certified projects on waste management, energy consumption and green areas (Doost Mohammadian & Rezaie, 2020). In Songdo city, a different system has been designed for waste management. Accordingly, there are no rubbish bins in the public space and the rubbish is collected and recycled underground in integration with smart building systems (Baek, 2015).

The methods developed by the cases analyzed within the scope of the article in the context of biomimicry and artificial intelligence use are evaluated in the comparison table. In the table, the characteristics of each project such as the country, year, scale, type are given and the methods of using biomimicry and artificial intelligence are expressed (Table 1).

Table 1. Generated method of use of comparative biomimicry and artificial intelligence concepts in urban scale of the in the evaluated cases

Name	Contry	Year	Scale	Type	AI usage method	Biomimicry usage method
Lavasa City	India	It was founded in 2000.	Urban Scale	City plan	x	Behaviorally inspired by the water retention feature of monsoon forests. Inspired by the formal features of anthills, an urban canal system network was created.
Kalundborg Port City	Denmark	Symbiosis activities started with the development and implementation of the project in 1961.	Urban Scale	City plan	x	Inspired by symbiosis behavior, a system targeting zero waste in the industrial zone has been proposed.
Langfang City	China	Langfang Eco-Smart City Master Plan was awarded the 2010 Urban Design Achievement Award. It has not been implemented yet.	Urban Scale	City plan and city functioning	It is said that smart technologies are integrated into the program for the construction of residential, office and other infrastructure clusters. No information has been provided yet.	The construction of the city was inspired by the water cycles found in nature in the past.
Songdo City	South Korea	2015	Urban Scale	City Functioning	Rainwater is collected and used in modern irrigation. Its infrastructure is organized with AI-supported systems.	x

As can be seen from Table 1:

- In the city of Lavasa, the concept of biomimicry is inspired by the behavior of Monsoon forests and urban design fiction is created.
- Inspired by the symbiosis behavior in the city of Kalundborg, zero waste generation is aimed.
- In the case of Langfang city, artificial intelligence is utilized in the design of the infrastructure system, while the biomimicry method is used in urban design fiction by drawing inspiration from natural water cycles.
- In Songdo city, artificial intelligence is utilized in the design of infrastructure systems and the collection of rainwater and its use in irrigation activities.

According to the findings obtained because of the sample analysis, it has been determined that the concepts of biomimicry and artificial intelligence are not used in interaction at the urban scale. In the city of Langfang, it has been observed that both concepts are used independently from each other, but there is no direct interaction between them. Within the scope of the sample, biomimicry method is generally used in the design phase of the urban plan, while artificial intelligence applications are activated in the functioning of urban systems.

RESULTS AND CONCLUSION:

Biomimicry is an approach that aims to use organisms, systems and processes in nature as inspiration for design, engineering and innovation. This approach involves understanding the effective solutions that various organisms in nature have developed evolutionarily and developing man-made systems inspired by them. Biomimicry plays an important role in the search for solutions to issues such as sustainability, efficiency and innovation. The basic principle of this approach is to understand nature's rational solutions and use them in technology to provide effective solutions to human problems. These solutions are defined as an interdisciplinary field that seeks innovation using time-tested patterns and methods. The biomimicric approach requires a holistic organization between different disciplines and has been applied in many different fields, especially following the developments of evolutionary

artificial intelligence. This offers the potential to influence and combine different areas of expertise such as deep learning, economics, cognitive neuroscience, biomedical engineering, space exploration and other related fields.

As a result of the analyses and qualifications of the samples examined in the article, a participatory urban approach proposal (Figure 9) covering the interaction potential of biomimicry and artificial intelligence technology is created. The stages of this proposal are developed from Lang's urban design process stages, except for the implementation stages. These stages consist of five steps according to Lang (2005): Understanding phase, design phase, selection phase, implementation phase and post-implementation phase. Lang (1994) claims that all phases include actions such as analysis, thought generation, synthesis, prediction, estimation, evaluation and decision making.

According to the proposal developed within the scope of the article, urban formations are analyzed with the participation of urbanites, expert opinions and artificial intelligence applications, taking into account their physical, social and historical qualities. As a result of the analyses, biomimicric urban design approach proposals are created with artificial intelligence or designer. Among the proposals, artificial intelligence or urbanite or designer determines the biomimicric urban approach proposal and realizes the selection phase. AI or designer develops solution proposals for the selected biomimicric urban design approach and realizes the design phase by multiplying the possibilities. The AI or the designer or the urbanite selects the possibility that is most suitable for the unique parameters of the city among the alternatives presented and the preliminary design phase is completed.

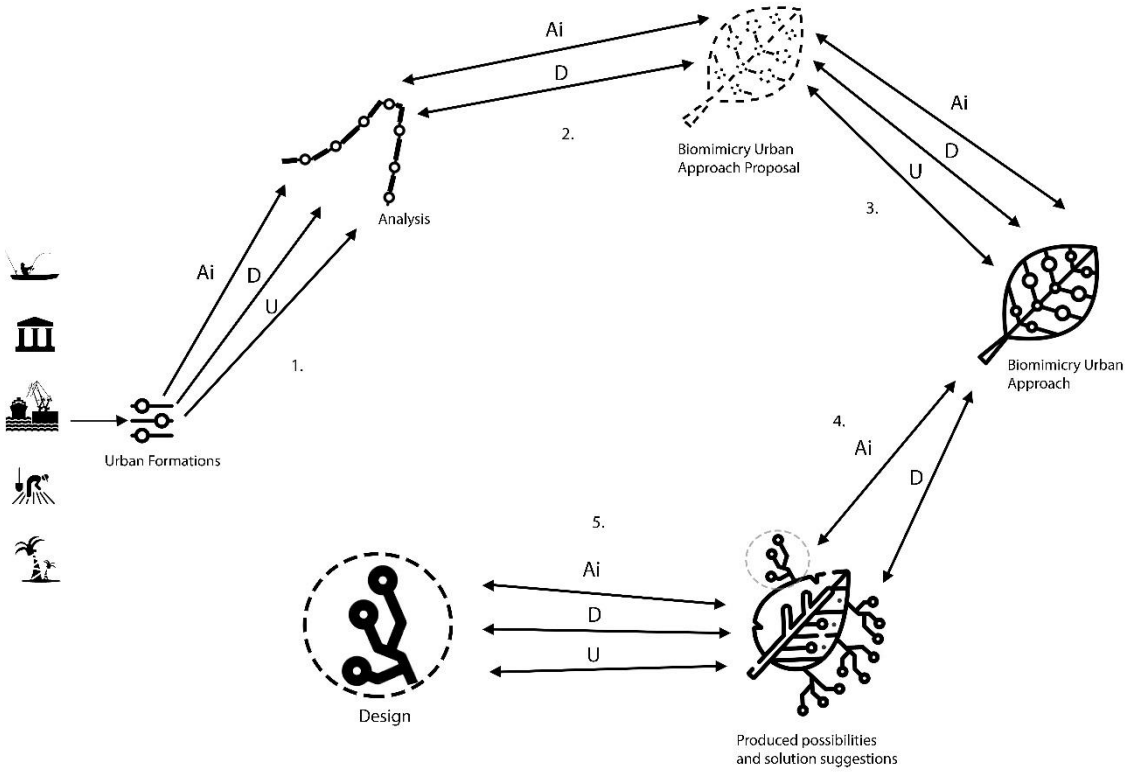

Figure 9: Biomimicry and Artificial Intelligence Technology Interaction in the Formation of a Participatory City as a Living Organism Proposed by the Author; Ai: Artificial Intelligence, D: Designer, U: Urbanite

In the proposal, alternative constructs and therefore combinations are formed. In Phase 1, to provide an accurate and comprehensive result of the analysis data, it is not recommended to make a choice between artificial intelligence, designer and urbanite, all alternatives participate. For this reason, the combination result is calculated as x1 for Phase 1. In Phase 2, citizen participation is not included due to lack of specialized knowledge. Artificial intelligence or designer suggestions are included. In Phase 3, the selection among the proposals is made by the AI or the designer or the urbanite. For the determined biomimicric urban design approach proposal, artificial intelligence or designer as an expert creates alternatives with possibilities and solutions. In the last stage, the artificial intelligence or designer or the urbanite chooses the design among the generated design proposals. In total, 36 different scenarios (Figure 10) are created.

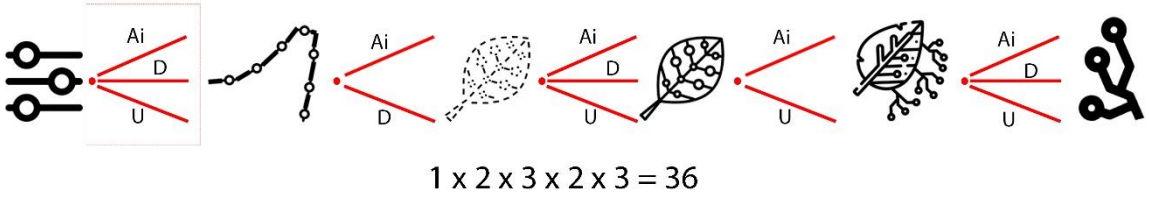

Figure 10: Author-Recommended Combination of Interaction Suggestions

Table 2: Combinations of Biomimicry and Artificial Intelligence Technology Interaction in the Formation of the City as a Living Organism Proposed by the Author

STAGES and STAKEHOLDERS	SELECTIONS																																	
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.	27.	28.	29.	30.	31.	32.	33.	34.	35.	36.
1.STAGE AI,D,U																																				
2. STAGE AI/D																																				
3. STAGE AI/D/U																																				
4. STAGE AI/D																																				
5. STAGE AI/D/U																																				

AI,D,U AI D U

The Potentials of the Proposed Approach (Table 2) are as Follows:

- Working with the biomimicry discipline at the design stage, during and after design of a dynamic and living organism such as a city has a positive effect in terms of sustainability.
- In the proposal, reading and interpreting city-related data inputs through artificial intelligence ensures that accurate information is processed quickly.
- Using the biomimicry approach in urban design and including artificial intelligence as a tool in this process will increase the solution alternatives quantitatively. In this way, stakeholders who are influential in the shaping of the city (designers, urban residents, public officials, etc.) will have the opportunity to choose among many possible urban configurations.

- The proposal takes into account the combinations and scenarios generated by the involvement of different actors at various stages. This allows rich design proposals to emerge from multiple perspectives.

- In the proposal, the process of selecting among the alternatives generated at different stages is taken into account. This increases the flexibility of the design and increases the potential to adapt to changing needs and conditions. Different choices can be applied to different cities and the results can be compared.

- The proposal indicates that artificial intelligence developments can play an important role within this approach. This emphasizes the proposal's capacity to adapt to future technological developments.

The interaction between biomimicry and artificial intelligence has some limitations. This study sheds light on research questions that can help to increase participatory design applications of the biomimicry approach at the urban scale through artificial intelligence. Some of these questions are as follows:

- What is the tool and interface of the Artificial Intelligence-Biomimicry interaction-based design approach proposal to transform participatory urban goals into technical solutions?

- Which disciplines should be utilized while developing the interface of the participatory urban design approach proposal based on Artificial Intelligence-Biomimicry interaction?

- How should the characteristics and ecological performance of the urban environment be included in the evaluation of a design project created in line with the proposal of a participatory urban design approach based on Artificial Intelligence-Biomimicry interaction?

- In a design project generated in line with the proposal for a participatory urban design approach based on Artificial Intelligence-Biomimicry interaction, through which methods and interfaces it is possible to create inferences made through artificial intelligence through the biomimicric approach selected for the built environment in question?

- What is the practical applicability of the AI-Biomimicry interaction-based design approach in translating participatory urban goals into technical solutions?

- How should the effects of projects developed using a participatory urban design approach based on Artificial Intelligence-Biomimicry interaction be evaluated on stakeholders and society?

- How should the participatory urban design approach based on Artificial Intelligence-Biomimicry interaction encourage social participation through biomimicry methods?

- In the participatory urban design approach based on Artificial Intelligence-Biomimicry interaction, how should the inferences made by artificial intelligence be effectively communicated to the stakeholders in the design process?

- In the participatory urban design approach based on Artificial Intelligence-Biomimicry interaction, how should the selected biomimicry solutions be made compatible with city planning?

- How should artificial intelligence and biomimicry training programs for designers and urban planners be created to support the participatory urban design approach based on Artificial Intelligence-Biomimicry interaction?

As a result, the biomimicry design approach - artificial intelligence interaction is full of new challenges and unknowns for researchers, as it is a field that has not been studied before. Additionally, the presented approach proposal will require programming knowledge when converting it into a model. This may pose an obstacle for some researchers and designers. However, the potential of the proposed approach is also quite high. This approach includes current and future research topics. Therefore, the proposed design approach incorporating biomimicry-artificial intelligence interaction offers an exciting opportunity for further advancements and exploration in the future. Integrating high-quality urban design knowledge and tools in line with current requirements into the theoretical foundations of the biomimicry approach and, within this framework, utilizing artificial intelligence tools in both design and implementation processes will contribute to obtaining efficient and rapid results by increasing human-artificial intelligence interaction.

Compliance with Ethical Standard

Conflict of Interest: The author declares that there is no conflict of interest.

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