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SYSTEMIC APPROACH IN BIOCLIMATIC MODELING

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The article presents a discussion of the application of a systemic approach in the field of bioclimatic modeling, specifically in relation to architectural and design objects. This approach is presented as a potential response to contemporary ecological and energy challenges. The introduction underscores the intricate nature of bioclimatic modeling, which entails integrating design solutions into the natural environment, adapting them to climatic conditions, and promoting sustainability. The article presents a review of scientific research indicating that a systemic approach allows for the examination of interactions between elements of architecture and design, taking into account the impacts and changes in the surrounding environment.

In the main part of the study, theoretical foundations and practical recommendations for implementing the principles of the systemic approach in bioclimatic modeling are developed. The authors identify principles of systemic analysis (interconnectedness of elements, integrativity, multidisciplinarity, forecasting, wholeness, and hierarchical structure) that form the basis of the research. These principles are examined in detail concerning their implementation in the context of bioclimatic modeling tasks for architectural and design objects.

Based on the presented analysis, it is determined that the application of a systemic approach stimulates innovation in bioclimatic modeling, fostering the creation of new methods and technologies. The article concludes with a discussion on the prospects of integrating the systemic approach into bioclimatic modeling and the research results that could serve as a foundation for further development of sustainable design solutions that address the current needs of modern architecture and design.

Keywords: bioclimatic modeling, systemic approach, sustainable design, architecture, ecology, interdisciplinary

Introduction.

The contemporary world is confronted with significant ecological and energy challenges that necessitate a re-evaluation of the methodologies employed in the design of architectural and design objects. One promising avenue of inquiry is the use of bioclimatic modeling, which entails the creation of objects that are designed to integrate seamlessly into the surrounding natural environment, exhibiting adaptive characteristics that allow them to respond to the prevailing climatic conditions. This methodology represents an effective tool for the development of sustainable design solutions.

The creation of new formative solutions that are designed to adapt to natural and climatic conditions necessitates a process of analysis and systematization. A unifying basis for the implementation of various methods of bioclimatic modeling is a systematic approach, which involves the analysis of the object and the conditions of its functioning, the identification of characteristic subsystems, and the study of the interactions between them. The principal reasons for the auspicious prospect of a systematic approach in bioclimatic modeling are as follows:

▪ Complexity of systems: Modern architectural and design objects are complex systems comprising a substantial number of interconnected elements. The effective management of such systems necessitates the utilisation of analytical tools that facilitate the examination of their structural and functional characteristics on a holistic basis.

▪ Integration of different disciplines: The field of bioclimatic modelling draws upon a diverse range of scientific disciplines, including architecture, engineering, biology, and climatology, among others. The systematic approach ensures the integration of this knowledge into a single concept.

▪ Sustainability: The systematic approach allows for the creation of projects that not only adapt to changes in the environment but also contribute to its preservation.

▪ Innovation: The application of the systematic approach stimulates the development of new methods and technologies in the field of bioclimatic modelling.

This study aims to present the integration of a systematic approach in bioclimatic modeling as a key to sustainable design that meets modern challenges and needs.

Analysis of previous researches.

Research shows that bioclimatic design, which integrates natural resources and adapts to local climatic conditions, contributes to creating sustainable architectural solutions (Dong, Chu., Jie, Jia. 2014; Fryer, R. 2015). The complexity of modern architectural and design objects necessitates an analysis of their structure and functioning, highlighting the need for systematic thinking in their design. According to Панова Л.П. 2007 a systematic approach allows for analyzing complex architectural systems while considering interactions between different elements, thereby enhancing design efficiency. A systemic approach facilitates effective interaction between elements, which is critical for adaptation to climatic conditions. Research, such as (B. Ozarisoy, H. Altan 2021; Кривенко О.В. 2019), indicate the necessity of integrating knowledge from various disciplines to adapt architectural solutions to existing climatic conditions. Moreover, authors in (Fontana, C. 2019; Кривенко О.В. 2019) note that a systemic approach becomes necessary in contemporary design as non-systemic methods no longer ensure the sustainability of design solutions in the context of increasing complexity in the information environment. Therefore, research on integrating a systematic approach into bioclimatic modeling will contribute to achieving sustainable design that requires appropriate development and investigation.

Research Objective.

The goal of this research is to develop a theoretical foundation and practical recommendations for applying a systemic approach in bioclimatic modeling, enabling the integration of various design aspects to create sustainable and comfortable architectural and design objects.

The results of the research and their discussion.

A unifying basis for the implementation of bioclimatic modelling can be established through the application of a systematic approach, which should provide an analysis of the object in question, an examination of the conditions of its functioning, an identification of the characteristic subsystems, and an investigation of the interactions between them. In order to facilitate further research, the following principles of systemic analysis will be adopted:

▪ *Interconnectedness of elements*: This principle posits that the research object can be understood as a system, comprising elements that are interdependent with one another.

▪ *Integrativity*: This involves taking into account all aspects and connections within the system for a complete understanding of its functioning.

▪ *Multidisciplinarity*: This signifies the utilisation of knowledge derived from disparate scientific disciplines for the purpose of analysing systems.

▪ *Forecasting*: This involves forecasting possible changes and outcomes in the system based on the analysis conducted.

▪ *Wholeness*: Understanding the system as a whole, including all its elements and their interactions.

▪ *Hierarchical structure*: Dividing the system into levels and subsystems for more detailed study.

The implementation of these principles allows for a better understanding of complex systems and offers solutions for their improvement. The use of a systematic approach in bioclimatic modelling aims to provide comprehensive and sustainable solutions by considering a significant number of factors and interconnections, creating an ecologically sustainable environment. The aforementioned principles will now be examined in more detail in relation to the tasks of bioclimatic modelling of architectural and design objects.

The principle of interconnectedness of elements. This principle posits that all elements within a system are connected and that changes in one element can trigger a chain reaction, creating new connections and influencing the overall behavior of the system. This principle permits the bioclimatic system to be regarded as a living organism, in which a change in one element gives rise to a chain reaction, creating new connections and influencing the overall behavior of the system. The systematic approach considers the interaction between different elements of the bioclimatic system, including climate, design decisions, natural resources and social demands for design development. It considers the intricate interconnections between individual elements of the system, allowing for a multitude of interaction possibilities among system elements to achieve optimal conditions. To illustrate, in Krivenko (2018), during the bioclimatic modelling of the 'Biotecton' skyscraper using a systematic approach and the principle of interconnectedness, not only were specific technical solutions proposed regarding the formation and structural design of the skyscraper, but also ways to organise their interaction with the surrounding environment while integrating renewable energy sources and meeting internal microclimate parameters. This resulted in comprehensive and sustainable solutions that were capable of adapting to influences from the natural-climatic environment. Therefore, employing a systematic approach with the principle of interconnectedness allows for the creation of complex, sustainable, and versatile bioclimatic solutions in design, taking into account the intricate relationships between different elements of the system.

The principle of integrity. The integrative approach to bioclimatic modelling involves a comprehensive consideration of all aspects and interrelationships within the system as a whole. For example, when developing landscape design objects, the complexity of bioclimatic analysis includes parameters such as climatic conditions, terrain relief, water resources and vegetation characteristics to create an optimal microclimatic environment. The principle of integrativity enables the implementation of variability in bioclimatic solutions, i.e. it considers various possibilities for harmonious interaction between system elements to achieve the expected conditions for design objects. For example, landscape design using this principle considers variability in the placement of greenery, drainage systems and terrain relief to create an optimal microclimate.

The principle of multidisciplinarity. This principle involves the use of knowledge and methods from different scientific fields for bioclimatic analysis and design solutions. Bioclimatic modelling involves knowledge from design and architecture, engineering, climatology, biology, materials science and other sciences and applied fields. A multidisciplinary approach allows the knowledge and methods of these different fields to be combined to produce comprehensive bioclimatic design models. For example, when designing a building using bioclimatic modelling, architect’s work with engineers to optimize solutions for thermal insulation, ventilation systems, natural and artificial lighting, etc. The result is a building that makes effective use of natural resources to provide a comfortable living environment. In addition, the interaction of specialists from different fields of science and technology contributes to the emergence of new ideas and innovative technologies that can be applied in design, taking into account the bioclimate. The collaboration of architects and related specialists during the design phase has led to the development of innovative ventilation systems, the use of solar energy and the management of heat loss, allowing the creation of buildings with minimal impact on the environment.

The principle of forecasting. This principle in a systemic approach involves considering potential future changes and influences on the bioclimatic system during its modelling. For example, when modelling bioclimatic systems for urban development, predictions of changes in temperature, precipitation, wind and

other climatic parameters are taken into account, allowing the creation of sustainable solutions capable of adapting to future changes. In addition, the principle of forecasting allows for the consideration of potential changes in the energy consumption of buildings in the future. When modelling bioclimatic systems for energy efficient buildings, forecasts of changes in energy prices, technological innovations and changes in consumer behaviour are taken into account, allowing the creation of buildings that take into account future needs and economic factors. When modelling landscape design using this principle, potential changes in terrain relief, hydrological regime and vegetation cover are taken into account, allowing the creation of landscapes that can adapt to changing climatic conditions. The design of clothing and footwear, for example, takes into account the durability of materials. In the context of bioclimatic modelling in design, the principle of forecasting is therefore effective.

The principle of wholeness. This principle involves considering the bioclimatic system as a single whole, with each element interacting with other elements. For example, when designing a building using the principle of wholeness, not only are its individual characteristics (e.g. thermal insulation) considered, but also their impact on the overall heat balance and air flows within the bioclimatic system. The principle of wholeness contributes to the creation of comprehensive models that allow more accurate prediction of change and optimization of design in bioclimatic modelling. The principle of wholeness allows for the consideration of emergent properties of the system - properties that arise as a result of the interaction of system elements and cannot be explained by isolated individual components. These properties are the result of synergy (enhancement) in the interaction between system elements, and they manifest only at the level of the whole system, not at the level of individual components. Emergent system properties, such as collective behavior, self-organization and the emergence of new properties, are manifested in various aspects of nature, from the collective movement of animals to the formation of stable ecosystems. For example, urban planning needs to take into account the emergent properties of the urban environment, such as microclimatic features and their impact on the health of residents. This allows for the creation of more sustainable and comfortable urban spaces. By using design solutions in bioclimatic modelling, the design object can acquire new properties that could not be achieved with individual solutions.

The principle of hierarchy. The use of a systemic approach based on the principle of hierarchy means that the system is divided into levels and subsystems for more detailed study, allowing the bioclimatic system to be considered at different levels of organization, from the micro level (e.g. the interaction of individual plants with climatic conditions) to the meso level (e.g. the impact of urban development on the overall city climate). The principle of hierarchy allows consideration of the multi-level organization of bioclimatic systems, from large-scale macroclimatic indicators to background conditions - mesoclimate, with further refinement at the level of assessment of local data, as well as the interaction between these levels. The principle of hierarchy allows the analysis of links and interdependencies between different elements of the bioclimatic system, enabling more effective and adaptive design solutions. For example, when designing a landscape using this principle, the effect of the terrain relief on the microclimate, the drainage system, the vegetation cover and the interaction with the surrounding ecosystems is taken into account, allowing the creation of landscapes capable of adapting to changing climatic conditions.

Conclusion.

The integration of a systems approach into bioclimatic modelling is a promising direction to address contemporary environmental and energy challenges. This approach provides a comprehensive framework for the analysis of complex systems, enabling a holistic understanding of the interaction between different components and their environment, ensuring effective analysis of the structure of the design object and the requirements for its functioning. Incorporating knowledge from different disciplines contributes to the creation of sustainable design solutions that adapt to local natural and climatic conditions. In addition, a systemic approach stimulates the development of new methods and technologies in the field, thereby enhancing design innovation. Further research can focus on the development of specific tools and methodologies for implementing a systemic approach to bioclimatic modelling, such as modelling software, decision support systems and assessment tools. Research on the integration of new technologies, such as Building Information

Modelling (BIM) and Artificial Intelligence, with systemic design can lead to more advanced data-driven approaches. In this way, research results can serve as a basis for the further development of sustainable design solutions that take into account the complexity of the modern environment and societal needs.

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СИСТЕМНИЙ ПІДХІД В БІОКЛІМАТИЧНОМУ МОДЕЛЮВАННІ

У статті розглядається застосування системного підходу при біокліматичному моделюванні об'єктів архітектури та дизайну, що є відповіддю на сучасні екологічні та енергетичні виклики. У вступній частині підкреслюється складність біокліматичного моделювання об'єктів архітектури та дизайну, що передбачає інтеграцію проєктних рішень у природне середовище, адаптуючи їх до кліматичних умов і сприяючи стійкості. У статті розглядаються наукові дослідження, у яких зазначається, що системний підхід дозволяє вивчати взаємодію між елементами об'єктів архітектури та дизайну з урахуванням впливів та змін навколишнього середовища. В основній частині дослідження формуються теоретичні основи і практичні рекомендації для впровадження принципів системного підходу у біокліматичне моделювання. Авторами визначені принципи системного аналізу (взаємопов'язаності елементів, інтегративності, мультидисциплінарності, прогностичності, цілісності, ієрархічності), що складають основу дослідження. Детально розглянуто зазначені принципи системного аналізу щодо їх впровадження стосовно задач біокліматичного моделювання об'єктів архітектури та дизайну. На основі представленого аналізу визначено, що застосування системного підходу стимулює інновації у біокліматичному моделюванні, сприяючи створенню нових підходів і рішень. Стаття завершується висновком щодо перспектив інтеграції системного підходу у біокліматичне моделювання та результатів дослідження, що можуть стати основою для подальшого розвитку стійких проєктних рішень, які враховують актуальні потреби сучасного розвитку архітектури та дизайну.

Ключові слова: біокліматичне моделювання, системний підхід, сталий дизайн, архітектура, екологія, міждисциплінарність.