South American Publishing

SAP Environmental Research and Ecotoxicity. 2024; 3:101
doi: 10.56294/ere2024101

ORIGINAL

Bioclimatic Architecture: A Holistic Approach to Sustainability in Design

Arquitectura Bioclimática: Una Aproximación Integral a la Sostenibilidad en el Diseño

Louis Enrique Ali Quispe[1], Juan Alberto Almirón Cuentas[1], David Hugo Bernedo-Moreira[1]

[1]Universidad Peruana Unión. Perú.

Cite as
Ali Quispe LE, Almirón Cuentas JA, Bernedo-Moreira DH. Bioclimatic Architecture: A Holistic Approach to Sustainability in Design. Environmental Research and Ecotoxicity. 2024; 3:101. https://doi.org/10.56294/ere2024101

Publication History
Submitted: 16-05-2023
Revised: 29-09-2023
Accepted: 10-02-2024
Published: 11-02-2024

Corresponding Author
Louis Enrique Ali Quispe

ABSTRACT

Objective: the article aims to describe the importance of bioclimatic design applied to various buildings, seeking to understand how these strategies can improve user comfort and reduce the adverse environmental impact associated with the construction and use of buildings. It focuses on passive strategies that take advantage of the specific climatic conditions of each region to optimize the thermal and environmental performance of buildings.
Method: a narrative review of the scientific literature was carried out, using several databases, with search descriptors including the terms "Bioclimatic Architecture" and "Passive Design". A search was carried out from March to April 2024, excluding duplicate articles and those that did not meet the research objectives. A total of 97 initial articles were identified, and 14 relevant articles were finally selected for the review.
Results: the review identified 14 outstanding articles in the field of bioclimatic architecture. These articles address different aspects, including case studies and comparative analysis, focusing on how bioclimatic strategies are applied in different regions and contexts. Among the topics explored are thermal comfort in different types of buildings and the integration of technologies in bioclimatic design.
Conclusions: the conclusions of the article indicate that bioclimatic architecture is a promising solution to improve people's comfort and reduce the environmental impact of buildings. The effective implementation of these strategies requires a deep understanding of local contexts and collaboration between architects, engineers and other stakeholders to achieve successful results. Furthermore, the relevance of considering not only modern aspects but also ancestral knowledge and technologies in bioclimatic design is highlighted.

Keywords: Architecture; Bioclimatic Architecture; Integral Approach; Sustainability in Design.

RESUMEN

Objetivo: el artículo tiene como objetivo describir la importancia del diseño bioclimático aplicado en diversas edificaciones, buscando comprender cómo estas estrategias pueden mejorar el confort de los usuarios y reducir el impacto ambiental adverso asociado con la construcción y el uso de edificaciones. Se enfoca en estrategias pasivas que aprovechan las condiciones climáticas específicas de cada región para optimizar el desempeño térmico y ambiental de los edificios.
Método: se realizó una revisión narrativa de la literatura científica, utilizando diversas bases de datos, con descriptores de búsqueda que incluían los términos "Arquitectura Bioclimática" y "Diseño pasivo". Se llevó a cabo una búsqueda desde marzo hasta abril de 2024, excluyendo artículos duplicados y aquellos que no cumplían con los objetivos de la investigación. Se identificaron 97 artículos en inicial, siendo seleccionados finalmente 14 artículos relevantes para la revisión.
Resultados: la revisión permitió identificar 14 artículos destacados en el ámbito de la arquitectura bioclimática. Estos artículos abordan diferentes aspectos, incluyendo estudios de caso y análisis comparativos, enfocándose en cómo se aplican las estrategias bioclimáticas en diversas regiones y contextos. Entre las temáticas exploradas se encuentran el confort térmico en diferentes tipos de edificaciones y la integración de tecnologías en el diseño bioclimático.
Conclusiones: las conclusiones del artículo indican que la arquitectura bioclimática es una solución prometedora para mejorar el confort de las personas y reducir el impacto ambiental en las edificaciones. La implementación efectiva de estas estrategias requiere una comprensión profunda de los contextos locales y una colaboración entre arquitectos, ingenieros y otros grupos de interés para lograr resultados exitosos. Además, se destaca la relevancia de considerar no solo los aspectos modernos sino también los conocimientos ancestrales y tecnologías en el diseño bioclimático.

Palabras clave: Arquitectura; Arquitectura Bioclimática; Aproximación Integral; Sostenibilidad en el Diseño.

© 2024; The Authors. This Open access article is distributed under the Creative Commons Attribution 4.0 license (https://creativecommons.org/licenses/by/4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

INTRODUCTION

Bioclimatic architecture, a discipline focused on optimizing the use of natural resources to design efficient and sustainable buildings, has gained increasing relevance in recent decades.[1] Based on fundamental principles such as the use of solar energy, natural ventilation, the appropriate selection of materials, and integration with the environment, this architectural trend seeks to mitigate the environmental impact of buildings, reduce energy consumption, and improve the quality of life of users.[2] In a current context marked by climate change, resource scarcity, and growing demand for sustainable solutions, bioclimatic architecture is emerging as a key tool for building a more ecological and resilient future.[3]

A narrative review of this topic is of utmost importance, as it consolidates existing knowledge on the various strategies, techniques, and approaches that make up bioclimatic architecture.[4] This review offers a comprehensive overview of its evolution and practical applications. It critically analyzes the challenges and opportunities associated with its implementation in different geographical and cultural contexts. In addition, the narrative review facilitates the identification of research gaps and opens up new lines of exploration that can contribute to innovation in sustainable architectural design. According to Inga et al.[5], bioclimatic architecture is the design of buildings that adapt to and take advantage of the climatic characteristics of the region where they are located. These buildings are intelligently designed to protect against high summer temperatures and low winter temperatures. A fundamental aspect of bioclimatic architecture is to achieve a balance between overheating and cooling.

According to information from the International Energy Agency, cities represent only 3 % of the planet's total surface area but are responsible for consuming approximately 67 % of global energy. This excessive consumption significantly affects the depletion of natural resources and negatively impacts the environment. For this reason, it is imperative to carry out exhaustive research on using renewable energies and implementing innovative energy-saving systems.[6] It is essential to seek sustainable alternatives to reduce dependence on non-renewable energy sources and decrease the environmental impact of energy consumption, ensuring a more sustainable future for cities and the planet.[7] On the other hand, by taking advantage of the region's climatic characteristics and using intelligent design strategies, these buildings can significantly reduce the need for conventional heating and cooling systems, resulting in lower energy consumption and a lower environmental impact. Bioclimatic architecture is a sustainable and efficient solution for constructing buildings harmoniously with their climatic environment.[8] In this regard, in Europe, during the summer months, design strategies are implemented to help prevent overheating, such as adequate shading, building orientation to take advantage of natural breezes, and the use of heat-reflective building materials. On the other hand, during the winter months, the aim is to maximize solar heat gain and minimize heat loss through proper orientation, the use of thermal insulation, and the incorporation of elements such as water walls or solar energy collection systems.[9]

In Asia, buildings are specifically adapted to local climatic and socio-cultural conditions, using materials and methods available in the region. A detailed understanding and review of bioclimatic design strategies can improve indoor thermal efficiency without air conditioning, essential for reducing carbon emissions in rural areas. Around the world, various bioclimatic analysis tools have been developed to study the climatic characteristics of traditional architecture and improve human thermal comfort.[7]

In this context, bioclimatic architecture has gained significant importance in the global construction industry. In response to this growing interest and recognition, this article describes the significance of bioclimatic design applied to various buildings. The aim is to understand how these strategies can improve user comfort and reduce the adverse environmental impact associated with the construction and use of buildings. This approach is based on the passive strategy that takes advantage of the specific climatic conditions of each region to optimize the thermal and environmental performance of buildings.

METHOD

A review was conducted to explore the scientific literature in various databases. To optimize the search, specific descriptors were used, such as "Bioclimatic Architecture" and "Passive Design." In addition, the Boolean operators AND and OR were used to refine and broaden the results. The search period extended from March to April 2024, covering articles published between 2020 and 2024.

As a result, 97 articles were identified through the established search chain. Sixty articles were excluded: 29 duplicates, 20 that did not meet the research objectives, and 12 that did not meet the inclusion criteria. Finally, 14 relevant articles were selected for inclusion in the review.

RESULTS

The review identified 14 articles, which were found in various databases.

Table 1. Selection of articles

Title	Cite	Type / Objective / Main Results
Confirmation Factors of Building Bioclimatic Microclimate	8	The research focuses on the design of bioclimatic buildings in southern Kazakhstan, adapted to local climatic conditions. The methodology includes the analysis of climatic parameters, such as temperature and wind, and the evaluation of building orientation. In addition, vernacular architecture is compared with historical bioclimatic alternatives, and evaluation criteria for sustainable buildings are proposed. Design strategies include green roofs, ventilation systems, and renewable energy. The research concludes that there is a growing demand for these buildings, highlighting the importance of proper planning to optimize the microclimate and quality of life.

Suitability of the Bioclimatic Architectural Design Concept and the Archievement of Thermal comfort in the Building (Case Study of Baitul Musyahadah Mosque in Banda Aceh City)	6	The research is qualitative, using observations and interviews to collect data on thermal comfort in the Baitul Musyahadah Mosque. The main conclusions indicate that many attendees perceive the interior as warm and demand more air conditioning, highlighting flaws in the original design and confirming the need for bioclimatic improvements.
Achieving Thermal Comfort through the Design of a Tourist Hotel – (Huancayo)	5	The research is experimental, descriptive, and applied, using bioclimatic diagnostic tools such as Mahoney tables and a psychometric abacus. The conclusions highlight the importance of designing a tourist hotel in Huaytapallana that guarantees thermal comfort, using local materials and methods that optimize energy efficiency and sustainability.
Socio-Economic Barriers to Adopting Energy-Saving Bioclimatic Strategies in a Mediterranean Sustainable Real Estate Setting: A Quantitative Analysis of Resident Perspectives	4	The study is quantitative research, using questionnaires to collect data from 150 residents in Paphos, Cyprus. Socioeconomic barriers to bioclimatic design are identified, highlighting the influence of costs on renovation decisions. It is concluded that financial incentives can improve the adoption of sustainable energy strategies in construction.
Bioclimatic design of average housing during the oil boom in Tampico, Mexico	10	The research is qualitative and focuses on the analysis of bioclimatic strategies in houses in Tampico (1912-1930). The methodology includes climate characterization, house surveys, and user interviews. It concludes that the houses incorporate adequate bioclimatic strategies, improving indoor comfort and highlighting their environmental heritage relevance.
Bioclimatic Architecture and Urban Morphology. Studies on Intermediate Urban Open Spaces	3	The research is a study of bioclimatic architecture and urban morphology, using computational fluid dynamics (CFD) simulations to evaluate thermal comfort. It concludes that combining cool materials with vegetation significantly improves thermal comfort and mitigates the urban heat island effect during the summer.
Methods in the Traditional House of Banjar Gajah Baliku	2	The research is descriptive and qualitative, complemented by a quantitative approach. Field observations, interviews, and temperature analyses were used. It concludes that the traditional Gajah Baliku house complies with the nine principles of bioclimatic architecture, with an average temperature of 25.45 °C, in the optimal comfort category.
Sustainability strategies focused on thermal comfort and embodied energy in an emerging housing development in the Andean region of Ecuador	11	The research is bioclimatic and addresses thermal comfort in emerging housing in Ecuador. The methodology consists of defining a model and strategies, followed by simulations and embodied energy calculations. It concludes that the proposed model achieves comfort temperatures with less embodied energy than other social housing.
Thermal comfort in the vernacular architecture of the parish of Chuquiribamba, Ecuador	12	The research is evaluative, using design analysis and thermal simulation methods. Four types of vernacular housing were selected in Chuquiribamba. The conclusions highlight the thermal benefits of traditional materials, demonstrating their adaptation to the climate and the importance of valuing ancestral construction knowledge.
Bioclimatic Architecture Strategies in Denmark: A Review of Current and Future Directions	9	The objective of the study was to identify appropriate bioclimatic strategies to promote passive design in construction or renovation projects in Denmark in response to climate change. A literature review following the PRISMA diagram was used, complemented by the analysis of 25 real projects. The results show that passive heating strategies focus on solar gains, insulation, and thermal mass, while passive cooling strategies focus on natural ventilation and solar protection. These strategies are expected to remain relevant.
Bioclimatic design strategy of vernacular architecture in the south-east of China: a case study in Fujian, China	7	The research is a field study on bioclimatic strategies in the vernacular architecture of Fujian, China. Mahoney's Table was used to identify strategies, and surveys were conducted on 907 buildings. The conclusions highlight that strategies vary according to local conditions, exceeding the recommendations of the table.
Thermal Comfort Analysis Using System Dynamics Modeling—A Sustainable Scenario Proposition for Low-Income Housing in Brazil	13	The research is an analysis of thermal comfort in low-income housing in Brazil, using system dynamics modeling. The methodology includes simulations of natural ventilation strategies and sustainable materials. The conclusions highlight the need for affordable solutions to improve comfort and reduce energy costs.
The Sustainable City: Advances in Renewable Energy and Energy Saving Systems	14	The article presents research on advances in renewable energy and energy-saving systems for sustainable cities. The methodology includes reviews of previous studies and analysis of technological implementations. The conclusions highlight the need to integrate clean energy and efficient systems to reduce energy consumption and improve urban quality of life.
Indoor Thermal Comfort Analysis: A Case Study of Modern and Traditional Buildings in Hot-Arid Climatic Region of Ethiopia	1	The research is a comparative study of thermal comfort in modern and traditional buildings in Semera, Ethiopia. It uses subjective methods (ASHRAE thermal comfort scale) and objective methods (temperature and humidity measurements). It concludes that 88 % of occupants of traditional houses are satisfied, compared to 22 % in modern buildings.

The search focused mainly on scientific articles, although numerous theses and dissertations related to the topic were also found. However, due to their less empirical nature and specific focus, the latter were not included in the review, as they did not provide the desired scientific support for the study. As a result, a final corpus of 14 articles relevant to the review was compiled (table 2).

Table 2. Years of publication of selected studies

Year of publication	Number of studies
2024	3
2023	8
2022	1
2021	1
2020	1
Total	14 items

Table 3. Countries where the studies were conducted

Main places of study	Asia (China)
	Europe (Denmark)
	Brazil
	Ecuador
	Mexico
	Peru

Table 3 provides information on the year of publication of the articles, followed by the countries that have been studied. This approach allows readers to gain a more comprehensive and up-to-date understanding of the latest research in the field. By showing the chronology of publications, the diversity of countries examined, and emerging trends or patterns in the scientific literature that are easier to identify, Table 3 provides a more complete picture of the research landscape.

CONCLUSIONS

Relevance of Bioclimatic Architecture: bioclimatic architecture emerged as a promising solution for improving indoor comfort in buildings and reducing the environmental impact of construction. It emphasizes the need to design concerning local climatic conditions.

Passive Strategies: Passive strategies that take advantage of each region's specific characteristics to optimize thermal performance, such as proper orientation and the use of appropriate temperature-regulating materials, are particularly noteworthy.

Interdisciplinary Collaboration: the effective implementation of bioclimatic strategies requires close cooperation between architects, engineers, and other professionals in the sector to ensure a successful design adapted to local needs.

Research and Comparative Analysis: the literature review identified 15 relevant studies that analyze different aspects of bioclimatic architecture. These studies promote knowledge about its evolution and application in global contexts, suggesting the need for further research in unexplored areas.

Valuing Ancestral Knowledge: the article highlights the importance of integrating not only modern technologies but also ancestral building knowledge into bioclimatic design to improve building sustainability.

FINANCING

None.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

CONTRIBUTION OF AUTHORSHIP

Conceptualization: Louis Enrique Ali Quispe, Juan Alberto Almirón Cuentas, David Hugo Bernedo-Moreira.
Writing – original draft: Louis Enrique Ali Quispe, Juan Alberto Almirón Cuentas, David Hugo Bernedo-Moreira.
Writing – review & editing: Louis Enrique Ali Quispe, Juan Alberto Almirón Cuentas, David Hugo Bernedo-Moreira.

BIBLIOGRAPHIC REFERENCES

1. Hailu H, Gelan E, Girma Y. Indoor Thermal Comfort Analysis: A Case Study of Modern and Traditional Buildings in Hot-Arid Climatic Region of Ethiopia. Urban Science 2021;5. https://doi.org/10.3390/urbansci5030053.

2. Hafizha F, Jairina SNI. Study of Bioclimatic Architecture Methods in the Traditional House of Banjar Gajah Baliku. Civil Engineering and Architecture 2023; 11:2857-68. https://doi.org/10.13189/cea.2023.110801.

3. Battisti A. Bioclimatic architecture and urban morphology. Studies on intermediate urban open spaces. Energies 2020; 13:1-20. https://doi.org/10.3390/en13215819.

4. Vassiliades C, Minterides C, Astara OE, Barone G, Vardopoulos I. Socio-Economic Barriers to Adopting Energy-Saving Bioclimatic Strategies in a Mediterranean Sustainable Real Estate Setting: A Quantitative Analysis of Resident Perspectives. Energies 2023; 16. https://doi.org/10.3390/en16247952.

5. Inga MA, Huanuco HSB, Garcia JLP, Garcia CRP. Achieving Thermal Comfort through the Design of a Tourist Hotel – (Huancayo). Civil Engineering and Architecture 2024; 12:668-84. https://doi.org/10.13189/cea.2024.120202.

6. Fuady M, Munadi R, Kevin MA. Suitability of the Bioclimatic Architectural Design Concept and the Achievement of Thermal Comfort in the Building (Case Study of Baitul Musyahadah Mosque in Banda Aceh City). Civil Engineering and Architecture 2023; 11:3642-50. https://doi.org/10.13189/cea.2023.110630.

7. Huang H, Xie YQ, Chen JJ, Liang S, Chen ZJ. Bioclimatic design strategy of vernacular architecture in the south-east of China: a case study in Fujian, China. International Journal of Low-Carbon Technologies 2024;19:1-17. https://doi.org/10.1093/ijlct/ctad079.

8. Sakenova S, Konbr U, Kisselyova T, Aimagambetova Z, Mugzhanova G, Amandykova D. Conformation Factors of Building Bioclimatic Microclimate. Civil Engineering and Architecture 2024;12:350-60. https://doi.org/10.13189/cea.2024.120126.

9. Bugenings LA, Kamari A. Bioclimatic Architecture Strategies in Denmark: A Review of Current and Future Directions. Buildings 2022;12. https://doi.org/10.3390/buildings12020224.

10. Orozco-Cejudo A, Rosas-Lusett MA, Deasiain-Alberich ML. Bioclimatic Design of Middle Housing in the Times of the Oil Boom in Tampico, Mexico (1912-1930). Habitat Sustentable 2023;13:92-105. https://doi.org/10.22320/07190700.2023.13.02.07.

11. Torres-Quezada J, Lituma-Saetama S. Sustainability Strategies Focused on Thermal Comfort and Embodied Energy of Emerging Housing in the Andean Region of Ecuador. Habitat Sustentable 2023;13:42-55. https://doi.org/10.22320/07190700.2023.13.01.04.

12. Giovanni A, Jumbo D. Thermal comfort in the vernacular architecture of the Chuquiribamba Parish Ecuador 2023;13.

13. Liaw C, da Silva VE, Maduro R, Megrè M, de Souza Inácio Gonçalves JC, Santos EM dos, et al. Thermal Comfort Analysis Using System Dynamics Modeling—A Sustainable Scenario Proposition for Low-Income Housing in Brazil. Sustainability (Switzerland) 2023;15. https://doi.org/10.3390/su15075831.

14. Perea-Moreno AJ, Hernandez-Escobedo Q. The sustainable city: Advances in renewable energy and energy saving systems. Energies 2021; 14:2-4. https://doi.org/10.3390/en14248382.