Application of Bioclimatic Architecture Principles for Thermal Comfort in Educational Buildings: A Case Study of the Nigeria Police Academy, Wudil Kano.

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Abstract

Bioclimatic architecture integrates climatic conditions and natural resources into building design to enhance thermal comfort while reducing energy dependency. In regions like Wudil, Nigeria, where the climate is predominantly hot and dry, the application of bioclimatic principles becomes crucial, particularly in educational environments. This study evaluates the application of bioclimatic architecture strategies in the design of a proposed School of Postgraduate Studies at the Nigeria Police Academy, Wudil. Using a descriptive qualitative approach, architectural surveys, direct observation, and case studies of two existing postgraduate schools in Northern Nigeria were conducted. Findings reveal partial implementation of bioclimatic principles in existing facilities, with significant potential for improvement through design strategies such as site orientation, natural ventilation, and use of thermal mass, courtyards, and landscaping. The study concludes that the adoption of comprehensive bioclimatic strategies can significantly enhance thermal comfort and sustainability in educational buildings in hot-dry climates. Recommendations include emphasizing passive cooling strategies and single-banking design concepts during both design and construction stages.

Keywords: Bioclimatic architecture, Thermal comfort, Educational buildings, Nigeria Police Academy, Hot-dry climate

1. Introduction

High energy costs have become one of the biggest drawbacks of institutional buildings when trying to provide thermal comfort, thus there is a great need for knowledge and a desire to provide comfortable interiors with the least amount of active (artificial) means. Sassi (2021) highlights that "Bioclimatic design strategies encompass a spectrum of passive techniques that can substantially reduce the reliance on mechanical systems, leading to energy savings and improved sustainability."

According to Martinez (2012), Bioclimatic architecture is the architecture of a place, taking into consideration the specific climatic conditions of the place, using free resources to reduce environmental impacts and energy consumption. Therefore, it is expected that buildings will include the environment and be in touch with the local climate of the area in which they are constructed. Its focus is to integrate buildings into their natural environment considering the climatic factors of the location for a particular design.

In the words of Simos Yannas (2020), a prominent figure in the field of sustainable architecture, bioclimatic design is described as "the art and science of designing buildings that harmonize with the local climate, aiming to provide thermally and visually comfortable, healthy, and energy-efficient spaces."

Buildings that are bioclimatic are created using the resources and climate of the area (energy and materials). Bioclimatic structures utilize solar energy (solar radiation) effectively and need less concrete and aluminum than conventional structures advocate the use of materials made of stone, earth, and wood that produce a lot of energy. Bioclimatic architecture, which harnesses the natural elements and local climatic conditions to design buildings that are energy-efficient, comfortable, and ecologically sensitive, has emerged as a promising approach. Oladipo, F. O., & Akinola, A. S. (2020) said this approach is particularly relevant in regions like Nigeria, where climatic factors play a significant role in the built environment's performance.

According to Pritchard and Mueller (2019), in regions with significant variations, building often struggle to maintain optimal indoor conditions without excessive reliance on mechanical systems.

The World Green Building Council (2021) emphasizes that Education institutions have a unique opportunity to lead by example in sustainability, integrating environmentally responsible practices into their physical infrastructure and curriculum. Therefore, the failure to implement bioclimatic approaches might result in poor thermal comfort, an overreliance on mechanical cooling systems, and higher operating costs in educational institutions.

The Nigeria Police Academy in Wudil, Kano, serves as an important educational institution for training law enforcement personnel. As the academy aims to provide a conducive learning environment, it becomes imperative to integrate bioclimatic design principles that align with its educational mission and contribute to the overall well-being of its occupants.

2. Literature Review

2.1 Bioclimatic Architecture Principles

2.2 Bio Climatic Design principles

Therefore Bioclimatic buildings can be achieved by considering the whole building life from design process through to construction. According to Bruse (2020), a leading authority in the field, bioclimatic design involves an integrated approach that considers passive strategies, such as

orientation, shading, ventilation, and thermal mass, to optimize a building's performance.

The measures for bioclimatic design are generally focused on the local climate of an area, therefore includes the following principles

1. Building form and orientation: The building needs to be protected from heat gain into the structure especially during the hot periods. This can be reduced by the orientation of the building and materials used for construction (Martinez, 2012).
2. Sun Shading Device: Heat gain into the building during periods of high temperature can also be reduced by using sun shading devices and materials and paints that would permit less penetration of the solar rays (Adedayo, 2013).
3. Natural ventilation and air quality: Through the use of green/living walls, indoor air quality can also be improved as this will capture airborne particles while providing oxygen to liven up spaces. Air locks can also be installed in doors as it reduces the effect of heat on the building envelope (Moon, 2007).
4. Thermal Mass (Use of Building Materials): in cooperate thermal mass material such as stone, bricks or concrete, these materials absorb and store heat, helping to regulate indoor temperature fluctuations and reduce need for excessive heating or cooling.
5. Court-yard: The courtyard is a regulator of air movement within building. Fathy (1998) illustrated the air movement by convection heat transfer where the density of the warm air is less than the moderate cold air, hence, it rises high were an air switching situation happened between the light density (warm air), and the heavy density (moderate cold air), where it makes an air circulation.
6. Use of sustainable power source: Solar energy should be used as an alternative source of energy and also for lightning up the buildings all through the year. Heat protection of the buildings in winter as well as in summer, using appropriate techniques which are applied to the external envelope of the building, especially by adequate insulation and air tightness of the building and its openings.
7. Landscape: Using a native plants in landscaping to minimize water usage and support local ecosystem. Indigenous vegetation is better adapted to the local climate and require less maintenance. Planting trees and incorporating artificial water bodies can also improve the micro climate of the environment.
8. Heating and cooling techniques: Ensure that the glazing materials allow for minimal solar radiation (glare) and sufficient light in the interior spaces. Making sure insolation and solar management are coupled for building day lighting, in order to give interior spaces enough light that is spread evenly.

3. Methodology

3.1 Research method

The major factors that contribute to the selection of a particular research method in research projects are research purposes and circumstances. For this paper, which is qualitative research, an evaluative research method is employed to evaluate the School of postgraduate studies by conducting Case studies .According to Issa (2014), the critical issue about case studies is that all variables connected with the unit (internal and external), have to be thoroughly identified and evaluated. The ultimate goal here is to gather comprehensive information about that unit being studied.

3.2 Population of the study

The population for this study are the existing schools of Post graduate studies in Nigeria. For the purpose of this research two schools are selected both from Northern part of Nigeria because the site is located in the northern part of Nigeria.

3.3 Sample and Sampling techniques

A non-probability sampling technique is adopted, in order to obtain the adequate sample. A purposive sampling technique employed to select the existing School of Postgraduate studies. This sampling technique was chosen because School of Postgraduate studies shares similar characteristics in terms of; geographical regions, climate and cultural. From the sample drawn, three schools were selected for the thesis to represent the population in the country. They are as follows:

I. School of Postgraduate studies, Yusuf Maitama Sule University, Kano.
II. School of Postgraduate studies, Aliko Dangote university of science and technology, Wudil.

4. Findings and discussions

4.1 Introduction

The following sub-headings have been used to discuss the results of the case studies conducted: Background, basic description, facilities that are provided, assessment, and case study selection criteria evaluation of the investigation into bioclimatic concepts in the in architectural design is of school of graduate.

The case studies were chosen based on the sites' locations and that shared the same meteorological characteristics.

I. Yusuf Maitama Sule University, Kano
II. Aliko Dangote University of science and technology Wudil, Kano

4.2 Case Study: School of post graduate Studies, Yusuf Maitama Sule University

4.2.1 Introduction

The Northwest University Kano now referred to Yusuf Maitama Sule University Kano (YUMSUK), is a Kano State Government owned university with a temporary campus located at the center of the city of Kano and a main campus located along Gwarzo Road off Kofar Kabuga in Kano State, Nigeria. It is one of the newest universities established in Nigeria in 2012 which are overseen and accredited by the National Universities Commission.

4.2.2 General Description

The post graduate school is a single complex building located at the main campus Kofar Kabuga , Kofar Ruwa road, Kano state. As shown in plate I. The post graduate school is sharing neighborhood with the School library building and faculty of science building. The building has a rectangular shape which allow a clear passage of air for comfort as shown in plate I, the post graduate school building has few horizontal shading device that protect the direct entrance of sun into the building.

Figure1 Layout of the North West Uni.

Source: Google Earth (2025.)

Plate I: Use of vertical fins in the façade of **School of Post graduate Studies Source:**

Table 1: Evaluation of Bioclimatic Architecture Features – Yusuf Maitama Sule University, Kano

VARIABLES OF STUDY	WEIGHT FACTOR		REMARK
Shading Device	Vertical element of shading device in the building are cooperated, and recessed windows are cooperated in the building.	3	Good
Building form and orientation	The building has a rectangular shape is adopted with the larger size facing the North axis, to reduces solar radiation, into the building and orientation is 75% achieved	4	V good
Natural ventilation and Air quality	Single banking of functional spaces arrangement to achieve cross ventilation. Natural ventilation is 60%	3	Good
Courtyard	There is no presence of courtyard, hence aim not achieve.	1	Poor
Use of sustainable power source	The main source of power is by artificial means. Hence aim is not achieve.	2	Fair
Landscape	Fewer soft and hard element landscape is presence in the exterior of the building.	3	Good
Heating and Cooling	Mechanical refrigeration is use, due to its high thermal mass allows this structure to act as a heat sink. Slowing the rate of temp change within the building and	2	Fair

enabling it to be cooled.

Weight Factor: Excellent = 5, Very Good = 4, Good = 3, Fair = 2, and Poor = 1

Source: Authors field work 2022.

4.2.3 Conclusion

It was observed that the design of school of post graduate studies, North West University kano, partially fulfill some bioclimatic architecture principles, hence making the building less thermally comport. Therefore, for the building to be thermal comport some mechanical and construction technique need to be apply.

4.3 Case Study Two: (School of post graduate Studies, Aliko Dangote University of Science and technology Wudil, Kano

4.3.1 Introduction

Aliko Dangote University of Science and technology Wudil, Kano it is a Kano State Government owned university with a temporary campus located at the city of Kano and a main campus located in Wudil along Gaya Road in Kano State, Nigeria. The university commence academic activities in the year 2001. It is one of the newest universities established in Nigeria in 2012 which are overseen and accredited by the National Universities Commission.

4.3.2 General Description

The post graduate school is a single complex building located at the main campus Wudil, Gaya road, Kano state. As shown below. The post graduate school is sharing neighborhood with the School library building and faculty of science building., the post graduate school building has no shading device that protect the direct entrance of sun into the building as shown in plate II. The building has a rectangular shape with a central courtyard which allow a clear passage of air for comfort as shown in plate. More also shown in the plate is some few landscaping at the exterior of the building that aid in the thermal comport of the School of Post Graduate Studies building.

Plate II The façade of the School of Post graduate Studies, ADUST Wudil. Showing no element of vertical or horizontal shading device.

Source: Authors field work 2025.

Findings from case Study of Aliko Dangote University of Science and Technology, Kano

Table 2: Evaluation of Bioclimatic Architecture Features Aliko Dangote University of Science and Technology, Wudil

VARIABLES OF STUDY	WEIGHT	FACTOR	REMARK
Shading Device	No element of shading device in the building, but there is vender which is accessed through the courtyard	2	Fair
Building form and orientation	A linear rectangular shape is adopted with the larger size facing the North east direction. Hence aim not achieve.	3	Good
Natural ventilation and Air quality	50% of Natural ventilation and Air quality is achieved due to the single banking of the building	4	V good
Courtyard	There is presence of courtyard which is well landscape.	4	V good
Use of sustainable power source	The main source of power is by artificial means. Hence aim is not achieve.	2	Fair
Landscape	Both soft and hard element landscape is achieved in the courtyard, but less soft landscape in the exterior of the building.	3	Good
Heating and Cooling	Naturally without mechanical refrigeration, its high thermal mass allows this structure to act as a heat sink. Slowing the rate of temp change within the building and	2	Fair

enabling it to be cooled.

Source: Authors field work 2025.

Weight Factor: Excellent = 5, Very Good = 4, Good = 3, Fair = 2, and Poor = 1

4.3.5 Conclusion

The design of Post graduate School Aliko Dangote University of Science and Technology, Kano Kano State University of Science and Technology, Wudil, has incorporated 50% of the bioclimatic architecture principles and other principles were incorporated unsatisfactory, only landscaping is fairly achieved. Hence making the building partially comfortable.

4.4 General Summary

A summary of the various applied techniques of bio-climatic principals, their performance rating, whether they perform well or not are shown in table, below from the case studies. It was observed during the fieldwork from the case studies that the most important and frequently occurring bioclimatic principals are (Use of Sun shading devices and Building envelope and orientation) the bioclimatic principals that was not properly implemented are (Use of sustainable power source and Heating and cooling techniques). From the case studies the level of application of bioclimatic principles were; Bayero University, has properly applied with weight factor 5 (excellent), Kano state University of science and technology, Wudil has the weight factor of 4 (very good) and North West University, kano has the low with weight factor of 3 (good), as shown in table below. If the above listed variables and principles are properly and practically applied in academic buildings, then such building will be thermally compote.

Table 3: Comparative Summary of Bioclimatic Design Application in Case Study Institutions

S/N	VARIABLE	SUB-VARIABLE	YUMSUK	ADUST
1	Shadding device	Vertical shading device , horizontal shading device , used of fins trees	3 Good	2 Fair
2	Building form	Building form, building Shape, South ,North orientation	4 V Good	3 Good
3	Natural ventilation and Air quality	Cross ventilation Window type	3 Good	4 V Good
4	Court-yard	Opened court-yard Close court-yard	1 Poor	3 Good
5	Use of solar system Use of wind	Use of solar system Use of wind	2 Fair	2 Fair
6	Landscape	Soft and hard landscape elements Water bodies.	3 Good	3 Good
7	Heating and	heat modulation and	2	2

	Cooling	dissipation techniques evaporative cooling insulations thermal mass	Fair	Fair
	SUMMARY		GOOD	V GOOD

Source: Authors field work 2025.

Weight Factor: Excellent = 5, Very Good = 4, Good = 3, Fair = 2, and Poor = 1

4.5 Study area

Kano State is one of the 36 state of Nigeria, located in the northern region of the country. According to the national census done in 2006, Kano State borders with Katsina state to the northwest, Jigawa state to the northeast, Bauchi state to the southeast, and Kaduna state to the southwest it is located at latitude 11°30N and longitude 8°30E with a total square area of 20,131 km2 (7,773sq mi). The propose site of the school of post graduate studies is located at the Nigeria Police Academy, Wudil Kano.

Figure 2: Map of Nigeria showing kano

Source: (Google.com Map 2025)

Figure 3: Propose site

Source: Google earth (2025)

4.6 Bioclimatic Strategies in Proposed Nigeria Police Academy Wudil Design

The proposed School of Postgraduate Studies incorporates the following principles:

Orientation: Elongated east-west block to minimize solar gain on façades.

Courtyard: A central landscaped courtyard improves airflow, daylighting, and microclimate.

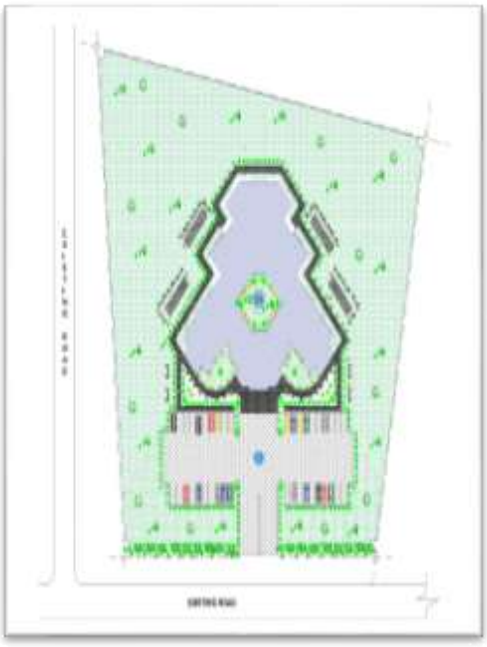
Ventilation: Single-banking layout supports cross ventilation; high ceiling (3.5m) supports stack effect.

Shading: Horizontal overhangs and vertical fins protect window openings.

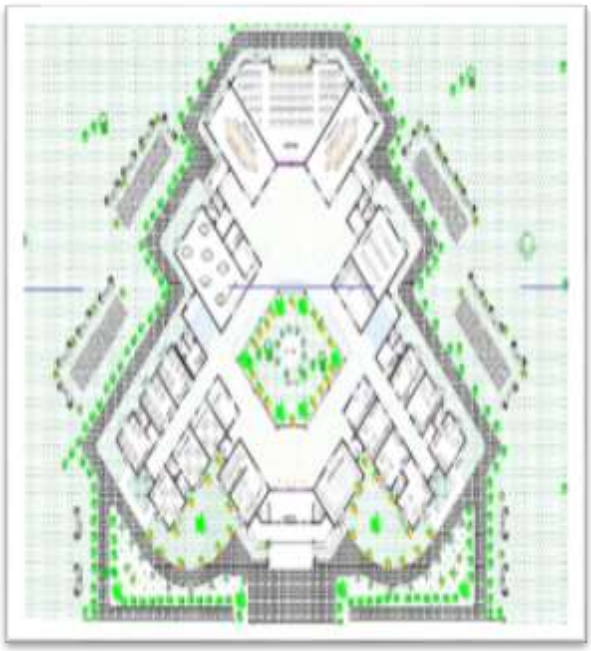
Thermal Mass: Brick and reinforced concrete materials moderate internal temperatures.

Landscape: Native plants, trees, water features (e.g., fountains) enhance comfort and aesthetics.

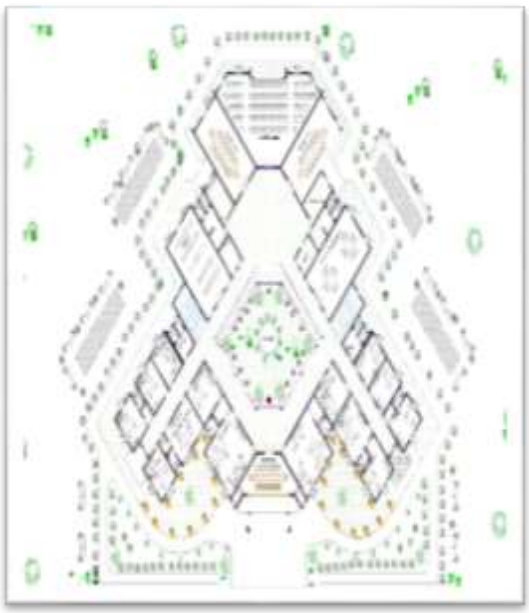
Lighting: Natural daylighting via clerestory and deep windows reduces artificial lighting use.



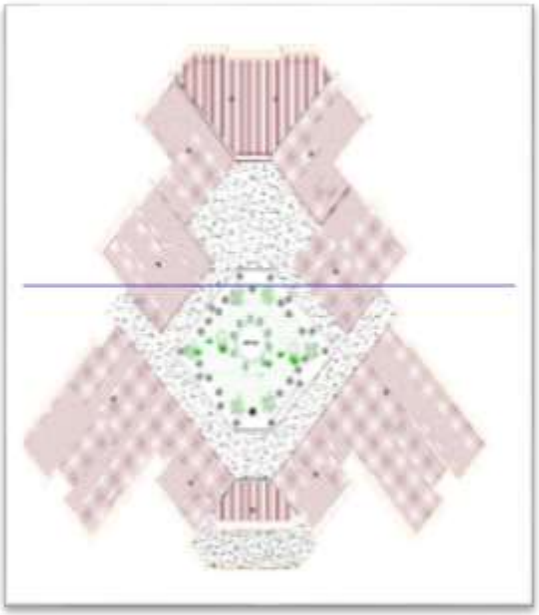
APPENDIX A: SITE PLAN



APPENDIX B: GROUND FLOOR PLAN



APPENDIX C: FIRST FLOOR PLAN



APPENDIX D: ROOF PLAN

APPENDIX E: 3D VIEW

APPENDIX E: 3D VIEW

5. Conclusion Recommendations

The study confirms that bioclimatic architecture offers practical, sustainable design options for educational buildings in hot-dry climates. Findings from case studies show partial

implementation in existing structures, while the Nigeria Police Acadamy Wudil proposal integrates lessons for a more comprehensive application.

The study therefore recommends the following

1. Prioritize passive design at planning stage (orientation, courtyards).

2. Adopt single-banking layouts for airflow.

3. Integrate shading devices and thermal mass in design codes.

4. Emphasize local materials and indigenous landscaping.

5. Promote policy support for performance-based green buildings in public institutions.

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