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Integrated Assessment of Thermal Performance, Passive Design Strategies, and Occupant Comfort in High-Rise Residential Buildings in Ikoyi, Lagos, Nigeria

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Abstract

This study examined the thermal assessment and thermal comfort of some selected high rise residential buildings in Ikoyi, Lagos, Nigeria. The field observations and questionnaire survey were used and the data was tabulated and analyzed descriptively which resulted in the total number of respondents being 293 residents. The results indicated that there were significant variations in how climate responsive design features, including building orientation, natural ventilation, daylighting, spatial organization, and incorporation of landscape were utilized. The towers of Infinity Tower, Osborne Tower, Riverside Apartment and Labana Luxury Apartment showed a positive thermal-responsive performance, and the towers of Cilonzes Height showed the lowest performance. Also results indicated a high reliance on mechanical cooling, 72.7% of residents being air conditioned. While most reported good thermal conditions, most comfort was obtained by use of active cooling devices, not passive design. The study concludes that in tropical high-rise residential buildings, the effective passive design strategies have a significant contribution to improve thermal comfort and sustainability.

Keywords: Passive Design, Sustainable Architecture, Thermal Comfort

I. INTRODUCTION

Over the last few decades, the residential building industry in Nigeria has experienced a lot of changes in the wake of the escalating need for housing infrastructure, rapid urbanization, and economic growth (Moore, 2019). Lagos is the commercial and population hub of the country and as such, has emerged as one of the main sites for residential development (Fatai, 2021). The city of Lagos, which has been characterized, historically, by a dense population and low-rise buildings, has become a metropolitan city with a mix of low, mid and high-rise housing. Condominiums, one of these developments, have proven to be an important type of vertical housing that can meet the increasing demand of urban population growth. The transition highlights the need to make the best use of the scarce urban land and the rising demand for housing.

High-rise buildings are commonly understood as tall structures that go beyond the typical height of surrounding buildings and require elevators or other mechanical systems to move people vertically through multiple floors. While there's no single, universal definition for what qualifies as a high-rise, different organizations have provided working guidelines based on height, use, and safety considerations. For instance, the International Building Code (IBC) defines a high-rise as any building where the highest occupied floor is more than 23 meters above the ground level accessible to fire trucks and emergency services (International Code Council, 2018). This definition is often used by architects, engineers, and safety regulators because it helps determine what kind of structural systems and fire safety measures are needed. Building Practice Limited (2025) also defines high-rise as any building with the highest occupied floors ranging between 7 floors and 40 floors. This definition will be adopted in this study as it specifies the minimum and maximum floors that qualify a building as high-rise.

Although the number of high-rise residential buildings in the city of Lagos has been growing, the majority of the developments have been oriented towards meeting the quantitative demand for housing with only a small consideration of the quality of indoor environments. Therefore, many residential buildings are not effective in reducing one of the most significant factors that impacts occupants' well-being, which is thermal comfort (Jiboye et al., 2020). Thermal comfort refers to the state of feeling comfortable in one's thermal environment, which is affected by factors like temperature, humidity, and air velocity in the environment, as well as the insulation of the clothing and the metabolic rate of the person (ASHRAE, 2020). It is essential to the health, productivity and wellbeing of occupants. But ensuring thermal comfort in warm-humid climate of Lagos, specifically in the building, is a special challenge, particularly for buildings without climate responsive design measures. Indoor thermal environment of buildings with poor ventilation and overheating can lead to poor health, less sleep quality, less productivity and less quality of life for the building users (Olusanya, 2015).

Thermal comfort is not just about the comfort of the occupants of residential buildings, but also about the environmental and economic performance of the building. When the thermal environment in a building becomes less satisfactory, the use of mechanical cooling systems becomes more important for the occupants to maintain a satisfactory thermal environment. This dependence on air-conditioning will continue to consume more energy and also cause environmental degradation; and is not sustainable for energy deficient countries like Nigeria (Karimi et al., 2023). Although there is increasing awareness of its significance, thermal comfort is not yet fully established in the practice of architecture, as many residential

developments have paid more attention to functionality and commercial concerns than to climate responsive design (Adebamowo and Adeyemi, 2019).

Previous studies have revealed that thermal comfort is affected by both external and internal conditions, and have suggested various methods to measure and make improvements to the thermal environment. Predicted Mean Vote (PMV) and Predicted Percentage Dissatisfied (PPD) models are most popular thermal comfort assessment models (Parkinson et al., 2019; Zhao et al., 2021). But these models are also found to overestimate thermal discomfort in naturally ventilated buildings in warm-humid climate (de Dear, 2020). This constraint has prompted the creation of the adaptive thermal comfort model, which takes into account the adaptive behavioural responses that people adopt to adjust to their thermal environment, including the opening of windows, turning on fans, adjusting clothing and changing activity levels (Nicol and Humphreys, 2002; Carlucci et al., 2018). There has been renewed research interest in recent years that suggests that occupants in tropical climates are more tolerant of higher temperatures in their buildings than the conventional comfort models indicate (Kim et al., 2021; Tartarini et al., 2022).

Environmental monitoring, occupant survey, and comfort indices are also used to evaluate thermal comfort of buildings. Environmental monitoring includes air temperature, relative humidity, mean radiant temperature, air velocity, and surface temperatures; and occupant surveys include thermal sensation, preferences, and adaptive behaviours (Onuma et al., 2025; Sheikh Khan et al., 2021). In the same vein, research related to the influence of the vertical variation of the microclimate, the stack effect, the façade design, the solar gains and hybrid cooling systems on the thermal comfort of occupants of high-rise residential buildings has been studied (Wang et al., 2021; Cook et al., 2022; Otoo et al., 2024; IEA Annex 80). While such studies have contributed to the comprehension of thermal comfort in residential buildings, they also highlight the need for design approaches which are suitable for tropical urban climates in addressing the particular thermal issues in high-rise residential built-up areas like Lagos.

To address these, the study seeks to evaluate thermal comfort conditions in high-rise residential developments, examine the effectiveness of passive design strategies adopted in these buildings, identify the architectural and environmental factors influencing occupants' thermal comfort, and develop a climate-responsive design framework that will guide the planning and design of sustainable high-rise residential condominiums in Lagos, Nigeria and can as well serve as guide in other tropical climate region.

II. RESEARCH METHODS

The research adopts a case study approach within a mixed-methods framework to enable an in-depth investigation of how building design influences thermal comfort in high-rise residential buildings. Similar buildings are examined through environmental monitoring, occupant comfort surveys, and structured observations to link objective data with subjective perceptions, while thermal comfort is assessed using PMV/PPD and adaptive comfort models (ASHRAE, 2020). An observation checklist is also employed to systematically capture building features and occupant behaviour, ensuring efficient and safe data collection within the security constraints of Lagos, Nigeria (Paparini et al., 2021).

Multistage sampling technique was adopted, and Ikoyi, Lagos, is purposively selected for the study because it is characterized by diverse high-rise residential buildings, a distinct climate,

and significant urban growth. The selection of Ikoyi is further supported by its diverse resident population, ranging across age groups, genders and its relevance to the study's focus on thermal comfort in high-rise residential buildings. Thus, the choice of Ikoyi is justified by its high concentration of high-rises and representation of diverse users' experiences.

In the first stage of sampling, zones/estate within Ikoyi was identified; findings from the reconnaissance survey indicate that there are Five (5) such areas. The second stage involve identifying all high-rise residential buildings located along each of these zones/estate.

In the third Stage, the high rises to be used for the study was selected, and fifty percent (50%) of the identified residential high rises in each zones was selected, Zones with only one residential high rise, the high rise was purposively selected and where there is no high rise shall be void. At the end of the selection, total of seven (7) high rises was used for the study (see Table 2). These buildings were chosen based on their design orientation, façade characteristics, height, ventilation strategy, and apartment configuration. Such variation provided a diverse representation of the built forms and living conditions that shape thermal comfort experiences in the area. This selection process ensured that only buildings with distinct architectural and environmental attributes were included, offering meaningful insights into the thermal comfort challenges of modern high-rise living in Ikoyi

In the fourth stage, the total number of occupants in each of the high rise buildings was obtained from the respective management offices. A total of 1,100 occupant was recorded across the 7 high rises: Sisi Paris (104), Osborne Tower (112), Cilonzes Height (61), Mason Apartments (184), Riverside Apartment (293), Labana Luxury Apartment (114), Infinity Tower (202).

III. RESULTS AND DISCUSSION

This section presents the results of findings after evaluating thermal comfort in the 7 selected high-rise residential buildings in Ikoyi, Lagos. The data were analyzed using descriptive statistical tools such as frequency counts and percentages. The findings are discussed in line with the objectives of the study.

Building Environmental Design Features and Sustainability Indicators

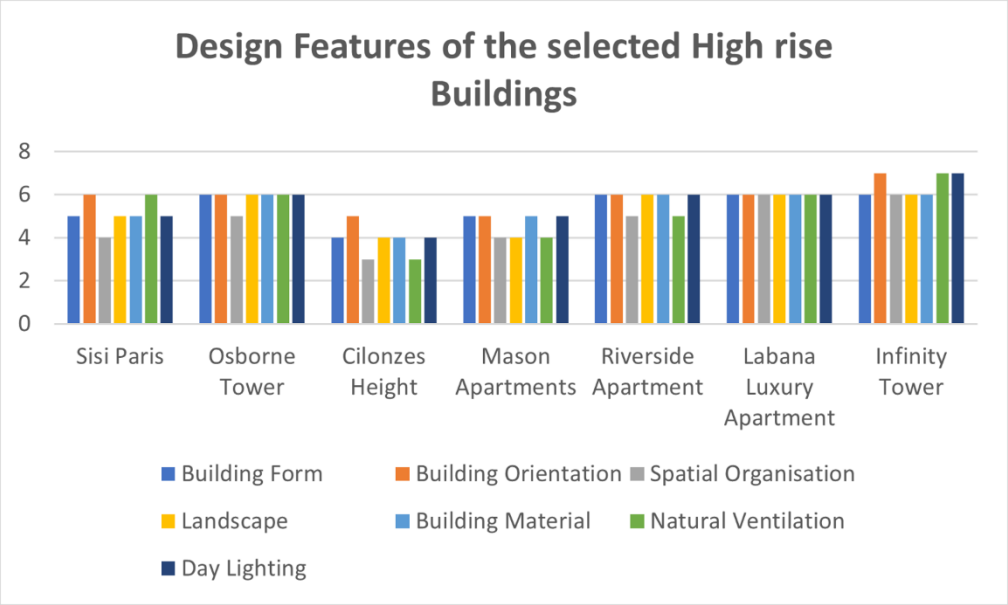


Figure 1: Observation Schedule of the selected High rise buildings*Source : Author's compilation from field work, 2026*

1 – Absolutely Inadequate **2** – Inadequate **3** – Slightly Inadequate **4** – Neutral **5** – Slightly Adequate **6** – Adequate **7** – Absolutely Adequate

Figure 1 shows the assessment of selected high rise residential buildings with respect to major building design features, and climatic design strategies significantly affecting thermal comfort and environmental performance. The following parameters are evaluated: Building form, building orientation, spatial organization, landscape design, building materials, natural ventilation, daylighting. Each building's score reflects the level of climatic responsive design principles that were incorporated into the buildings.

The results show significant differences among the buildings selected in relation to their thermal-responsive characteristics. Although in general the building scores were not that different, buildings like Infinity Tower, Osborne Tower, Riverside Apartment and Labana Luxury Apartment achieved higher scores on most variables, which means a more integrated use of sustainable and climate-responsive design strategies. In contrast, Cilonzes Height consistently had the lowest scores indicating a lack of passive environmental design principles.

As far as building form is concerned, each of Osborne Tower, Riverside Apartment, Labana Luxury Apartment and Infinity Tower received 6 points, which suggested they were more appropriate for climatic adaptation and thermal regulation in terms of massing, façade articulation and their overall configuration. Sisi Paris and Mason Apartments received a moderate climatic response score of 5. The lowest value of 4 was registered by Cilonzes Height and represents a less efficient building form which can add to the heat gain in the building and can degrade the environmental performance.

For building orientation, Infinity Tower scored the highest, 7, for orientation with respect to prevailing wind direction and solar exposure. Osborne Tower, Riverside Apartment and Labana Luxury Apartment also scored highly with a 6, indicating good positioning to provide better air flow and reduce solar heat gain. Sisi Paris, Cilonzes Height and Mason Apartments

have slightly lower scores indicating moderate implementation of the principles of orientation.

Significant differences between the buildings were found for the assessment of spatial organisation. Labana Luxury Apartment and the Infinity Tower achieved the top marks of 6, and showed a good internal arrangement of rooms to facilitate efficient use, comfort and air movement. The other five buildings performed satisfactorily and had scores of 5.0. However, the interior arrangement of spaces was not very climatic responsive and covered only 3 points at Cilonzes Height.

Riverside Apartment, Labana Luxury Apartment, Infinity Tower and Osborne Tower scored high for landscape design with 6 indicating good integration of greenery and outdoor environment features, which help to improve the microclimatic cooling as well as environmental quality. Sisi Paris and Mason Apartments performed moderately with scores of 5 and 4 respectively, indicating less landscape treatment and environmental buffering. Cilonzes Height once again had a relatively low score of 4, indicating inadequate landscape treatment and/or lower environmental buffering.

As for building materials, most of the buildings got average scores, especially Osborne Tower, Riverside Apartment, Labana Luxury Apartment and Infinity Tower with scores of 6. These indicate the use of materials that have greater thermal qualities, durability and climatic adaptation. Sisi Paris and Mason Apartments were both awarded 5, reflecting moderate use of climate appropriate materials, and Cilonzes Height received 4, reflecting a more uninformed approach to selecting materials that consider thermal performance.

The most significant differences between buildings were found in the parameter of natural ventilation. Infinity Tower scored the highest with a score of 7, having the best integration of passive ventilation techniques including cross-ventilation, operable openings, and airflow optimisation. Osborne Tower and Labana Luxury Apartment got good scores of 6, demonstrating effective ventilation design. Riverside Apartment received 5 and Mason Apartments received 4, both suggesting moderate performance for ventilation. Cilonzes Height achieved just 3 marks showing poor natural ventilation provision and may have an impact on the thermal comfort in the building's interior, leading to a higher reliance on mechanical systems for cooling.

In the same way, Infinity Tower achieved the highest score of 7 in terms of daylighting and so it demonstrated good use of natural light by appropriate window sizing, façade treatment and space planning. Osborne Tower, Riverside Apartment and Labana Luxury Apartment achieved 6 indicating good daylighting and less dependence on artificial lighting. Sisi Paris and Mason Apartments scored moderately at 5, and Cilonzes Height scored at 4, which was not high enough due to lack of daylight optimization.

From a general perspective, the results showed that the Infinity Tower achieved the highest overall climatic responsive results when compared with the other buildings selected, with the highest score for most of the parameters. Osborne Tower, Riverside Apartment and Labana Luxury Apartment also demonstrated excellent passive design elements that promote thermal comfort and sustainability. In contrast, Cilonzes Height had the lowest scores in almost every category, suggesting that it was less successful in applying the principles of climate-responsive design.

The results consequently indicate that the implementation of proper building orientation, efficient spatial organization, proper landscaping, appropriate use of climatic materials, effective natural ventilation and optimized daylighting have a significant influence on the

thermal performance and environmental quality of high-rise residential buildings in tropical cities like Lagos.

Thermal Comfort and Performance Assessment

This section evaluates residents' cooling equipment usage, comfort perception, satisfaction levels, and spatial heat discomfort patterns.

Mechanical Cooling Usage Patterns

Table 1: Cooling Equipment and Usage Patterns (N = 293)

Variable	Category	Frequency (f)	Percentage (%)
Cooling Equipment	Air Conditioning	213	72.7
	Fan	80	27.3
Frequency of Use	Always	141	48.1
	Often	77	26.3
	Occasionally	75	25.6

Source: Author's Field Survey, (2026)

Air conditioning is the most used cooling system with 72.7% of respondents using the system which is evident in Table 1 and 27.3% using fans as the primary source of cooling. This high air conditioning preference indicates that there is a high perceived thermal stress in apartments. In the tropical climate that typifies high density urban centres such as Lagos, it is no wonder that active cooling systems are used. Nevertheless, the level of reliance is worrying as far as construction thermal efficiency is concerned.

Almost half of the respondents (48.1%) said they always use mechanical cooling and 26.3% said they use it frequently. The proportion of infrequent users was 25.6% with insignificant proportions of infrequent and non-use. This trend reflects habitual and not situational cooling behaviour. The long periods of daily operation are also indicative of cooling systems performing more environmental control functions than comfort add on functions.

The implication here is that the fact that it depends heavily on air conditioning could imply that there is no passive ventilation, solar shading, or insulation performance. Such dependence, in terms of energy sustainability, adds to the higher electricity consumption and higher household energy spending. Passive cooling improvement would assist in reducing the level of mechanical cooling without impacting on occupant comfort.

Thermal Satisfaction and Spatial Heat Discomfort

Table 2: Thermal Satisfaction and Heat Discomfort (N = 293)

Variable	Category	Frequency (f)	Percentage (%)
Thermal Satisfaction	Satisfied	141	48.1
	Neutral	88	30.0
	Dissatisfied	64	21.8
Heat Discomfort Location	Living Room	96	32.8
	Bedroom	99	33.8
	All Spaces	98	33.4

Source: Author's Field Survey, 2026

Although Table 2 showed that 48.1% of the respondents stated that they were contented with the thermal environment, there was a considerable 21.8% who said that they were not. The moderate conditions of comfort as indicated by the 30% neutral answers are possibilities of being moderate depending on the availability of mechanical cooling. The levels of satisfaction thus emerge as conditional, as opposed to being a measure of naturally thermally efficient building performance.

The ratio of heating discomfort is almost the same among bedrooms, living rooms and apartments in general. These rates of discomfort were slightly greater in bedrooms (33.8%), and it might be associated with keeping warm at night and the absence of cross-ventilation. The almost identical distribution through spaces indicates that there are systemic issues of thermal performance as opposed to room-specific problems.

The level of satisfaction appears to be rather high but it should be compared to the high level of relying on air conditioning above. The results imply that the acceptable comfort levels are obtained with the help of the mechanical intervention, but not of the passive environmental control. The sustainable residential design strategies would then need to be geared towards improved envelope performance, shading systems, and ventilation efficiency in order to reduce the active cooling systems.

IV. CONCLUSION

Summary of Findings

The study revealed that degree of integration of climate-responsive design strategies of selected high-rise residential buildings in Ikoyi had significant impact on the thermal comfort and environmental performance. The buildings, which showed effective building orientation, natural ventilation, daylighting, landscape integration and use of climate appropriate materials, like Infinity Tower, Osborne Tower, Riverside Apartment and Labana Luxury Apartment, achieved better thermal performance, while Cilonzes Height had the lowest. It was also found that there is high reliance on mechanical cooling systems with the majority using air conditioning to create a comfortable indoor environment. While much of the respondents were happy with the thermal environment, it seems that the thermal environment comfort was achieved mainly due to the active way of cooling the environment rather than the passive way of designing it. Overall, the study has confirmed that passive and sustainable design concepts significantly contribute to the achievement of thermal comfort and to lower heat gain and improve environmental performance of high-rise residential buildings in tropical urban climates like Lagos.

Recommendations

High-rise residential buildings should be designed to optimize thermal comfort and minimize heat gain by employing appropriate orientation, shading techniques, cross-ventilation, and effective spatial organization.

Use of climate-responsive building materials that reduce heat absorption and improve indoor thermal performance.

Proper window size and positioning, operable windows and effective façade design should be considered to maximize natural ventilation and daylighting in buildings, minimizing mechanical ventilation needs.

The government needs to adopt policies that encourage energy-efficient and climate-friendly building design in high-rise housing projects

Future Research

- Assessment of thermal comfort strategies in High-rise residential buildings in Nigeria
- Comparative Analysis of Thermal Comfort Across Different Residential BuildingTypologies
- Impact of Urban Heat Island Effect on High-Rise Residential Buildings
- Assessment of Renewable Energy Integration in Residential Buildings

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