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Factors Influencing the Perception of Residents on Bioclimatic Design in Residential Buildings in Ilorin Metropolis

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Abstract
This study investigates the factors that influence how residents perceive climate-responsive design strategies in residential buildings within Ilorin Metropolis, Nigeria. Integrating indoor environmental comfort, architectural characteristics, and socio-demographic variables, the research adopts a quantitative approach using a structured questionnaire administered across high-, medium-, and low-density residential areas. A total of 597 questionnaires were distributed, of which 484 valid responses (81 % response rate) were analyzed using descriptive statistics and Chi-square tests at $p < 0.05$*. Findings reveal significant associations between residential density and several environmental perception variables, particularly temperature perception (morning and evening), night-time ventilation, air freshness, lighting conditions, and proximity to major roads. High-density areas exhibited greater heat retention, reduced night-time air movement, and lower perceived air freshness, indicating microclimatic and urban morphology effects. The overall importance ratings show that thermal comfort ranked highest with a Mean Weighted Value (MWV) of 4.1983, followed by noise level (MWV = 4.0785) and light intensity (MWV = 4.0620). Ventilation and air quality were also highly valued, whereas acoustic comfort ranked lowest, though it still remained above the neutral midpoint. The study concludes that thermal and acoustic-related factors are the dominant determinants shaping residents' evaluation of bioclimatic design, highlighting the need for climate-responsive housing strategies tailored to urban density contexts.*

Keywords: *Bioclimatic design; Residential buildings; Thermal comfort; Indoor environmental quality; Residential density; Occupants' perception; Natural ventilation.*

1.0 Introduction

Residential buildings in hot humid and tropical climates must respond effectively to environmental conditions in order to ensure indoor comfort, occupant wellbeing, and energy efficiency. Indoor environmental comfort has therefore become a central concern in building science and architectural research, as it directly influences occupants' health, satisfaction, and behavioural adaptation within their living environments. Early studies on climate-responsive architecture established the importance of aligning building design with climatic conditions (Olgyay, 1963; Givoni, 1998), while more recent research further emphasizes adaptive thermal comfort and passive environmental control strategies in buildings (Nicol et al., 2017; ASHRAE, 2020).Contemporary research further emphasises Indoor Environmental Quality (IEQ) as a multidimensional construct encompassing thermal comfort, indoor air quality, daylighting, and acoustic performance, all of which shape occupants' perceptions of residential environments (Fanger, 1970; de Dear and Brager, 1998; Frontczak and Wargocki, 2011). Increasingly, scholars argue that occupants' subjective evaluations provide essential insights into the real performance of buildings, as measured environmental data alone may not reflect lived experiences or comfort expectations (Nicol and Humphreys, 2002; Kim and de Dear, 2012). In the context of tropical residential buildings, where climatic stressors such as high temperatures and humidity prevail, understanding residents' evaluation of indoor comfort is particularly important for assessing the effectiveness of bioclimatic design strategies.

Beyond environmental conditions alone, architectural and spatial characteristics significantly influence how indoor comfort is experienced and evaluated by residents. Bioclimatic design approaches emphasise building orientation, form, material selection, spatial configuration, openings, and passive ventilation strategies as key mediators between outdoor climate and indoor environmental performance. Studies across tropical and developing regions demonstrate that climate-responsive architectural elements, such as shaded facades, courtyards, deep overhangs, and cross-ventilation layouts, can substantially improve indoor thermal comfort and reduce reliance on mechanical cooling systems (Hyde, 2000; Santamouris and Asimakopoulos,

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2001; Szokolay, 2014). In the Nigerian vernacular and traditional building forms have historically incorporated climate-responsive features that enhance passive cooling and environmental adaptation (Ogunsote and Prucnal-Ogunsote, 2003; Adebayo, 2010). However, contemporary urban housing development has increasingly adopted modern construction materials and compact spatial configurations that may not always align with local climatic realities. Although numerous studies have assessed environmental performance through measurable parameters, relatively limited research has examined how specific architectural features and housing typologies shape residents' evaluation of bioclimatic design effectiveness in real residential settings.

In addition to environmental and architectural factors, socio-demographic and economic contexts play a crucial role in influencing how residents perceive and evaluate indoor environmental conditions. Adaptive comfort theory highlights that comfort expectations vary according to cultural norms, lifestyle, acclimatisation, and personal attributes such as age, gender, activity level, and socio-economic status (Nicol and Humphreys, 2002; de Dear et al., 2013). Research in housing studies indicates that income levels, educational background, household size, and degree of control over the indoor environment affect occupants' tolerance thresholds and satisfaction with environmental conditions. In rapidly urbanising cities across sub-Saharan Africa, socio-economic disparities also shape access to passive design features, housing quality, and environmental awareness, thereby influencing how residents interpret and evaluate building performance. Nigerian housing research has shown that variations in residential density, construction quality, and economic status can significantly affect occupants' comfort perception and overall satisfaction with their homes (Ibem and Aduwo, 2015; Olatunji, 2019). Despite these insights, there remains limited integrated research examining how socio-demographic factors interact with architectural characteristics and indoor environmental performance to shape residents' evaluation of bioclimatic design in tropical residential environments.

Although a growing body of literature addresses indoor environmental quality and climate-responsive architecture, important gaps remain. Existing studies often treat environmental measurements, architectural characteristics, or occupant perception as separate domains, resulting in fragmented understanding of building performance. Furthermore, empirical investigations focusing on residents' evaluation of bioclimatic design within medium-sized tropical cities particularly within Nigerian urban contexts are still relatively limited. Ilorin Metropolis presents a relevant case due to its distinct climatic conditions, diverse residential typologies, and varying socio-economic housing environments. Understanding how indoor environmental comfort, architectural design features, and socio-demographic contexts collectively influence residents' evaluation of bioclimatic design can provide deeper insights into the real performance of residential buildings as environmental envelopes.

This study therefore investigates the factors influencing residents' evaluation of bioclimatic design in residential buildings in Ilorin Metropolis. By integrating indoor environmental comfort assessment, architectural feature analysis, and socio-demographic evaluation within a unified framework, the research contributes to bridging the gap between technical environmental performance and occupants' lived experiences. The findings are expected to inform climate-responsive housing design, support evidence-based architectural practice, and contribute to sustainable residential development strategies in tropical urban environments.

2.0 Materials and Methods

This study employed a quantitative research methodology using a structured questionnaire to assess residents' perceptions of bioclimatic performance in residential buildings in Ilorin Metropolis, Kwara State, Nigeria. While a previous study by Ayinla and Adebayo (2025) analysed bioclimatic design strategies for Student Affairs buildings in a hot-humid climate focusing largely on environmental and architectural design features, this research extends the methodological scope by directly linking occupant perceptions with building performance outcomes, thereby situating environmental responses within the lived experiences of residential users. By integrating socio-demographic and occupancy characteristics alongside bioclimatic performance indicators, the approach offers a more holistic evaluation of how residential buildings function as environmental envelopes, providing original insights beyond prior institutional typology studies.

The study area, Ilorin Metropolis, as shown in Figure 1, highlights the three Local Government Areas: Ilorin West, Ilorin East, and Ilorin South. The initial sample size was 1,193, calculated using Slovin's formula $n = \frac{N}{1+N(e)2}$ at a 95 % confidence level and 5 % margin of error. Following a feasibility assessment to ensure effective field implementation and resource efficiency, the sample was refined to 597 households (Table 1), which remained statistically robust for analysis. Out of the 597 questionnaires administered, 484 were retrieved and found valid, representing a response rate of approximately 81 %. A stratified sampling approach ensured proportional representation across the three Local Government Areas. The household head was surveyed. The questionnaire captured socio-demographic and occupancy characteristics including gender, age, marital status, education, occupation, income, tenure status, length of residence, type of space assessed, and number of occupants alongside residents' perceptions of bioclimatic performance such as overall comfort, natural ventilation, daylight adequacy, shading behaviour, and adaptive strategies.

The field data for this study were collected between June and August 2025 across selected residential neighbourhoods within Ilorin West, Ilorin East, and Ilorin South. This period corresponds largely to the rainy season in Ilorin, which is characterised by high humidity and relatively stable temperatures, making it ideal for capturing occupants' perceptions of thermal comfort under typical hot-humid climatic conditions. Structured questionnaires were administered to household heads to capture residents' perceptions of indoor environmental conditions and the bioclimatic performance of their dwellings.

Data were analysed using descriptive and bivariate statistical techniques. Frequencies, percentages, and cross-tabulations summarised respondent characteristics and perception patterns, while Chi-Square (χ^2) tests examined associations between residential density, socio-demographic variables, and perceived comfort levels, with significance assessed at $p < 0.05$. Participation was voluntary, and informed consent was obtained from all respondents, with anonymity and confidentiality maintained throughout the study.

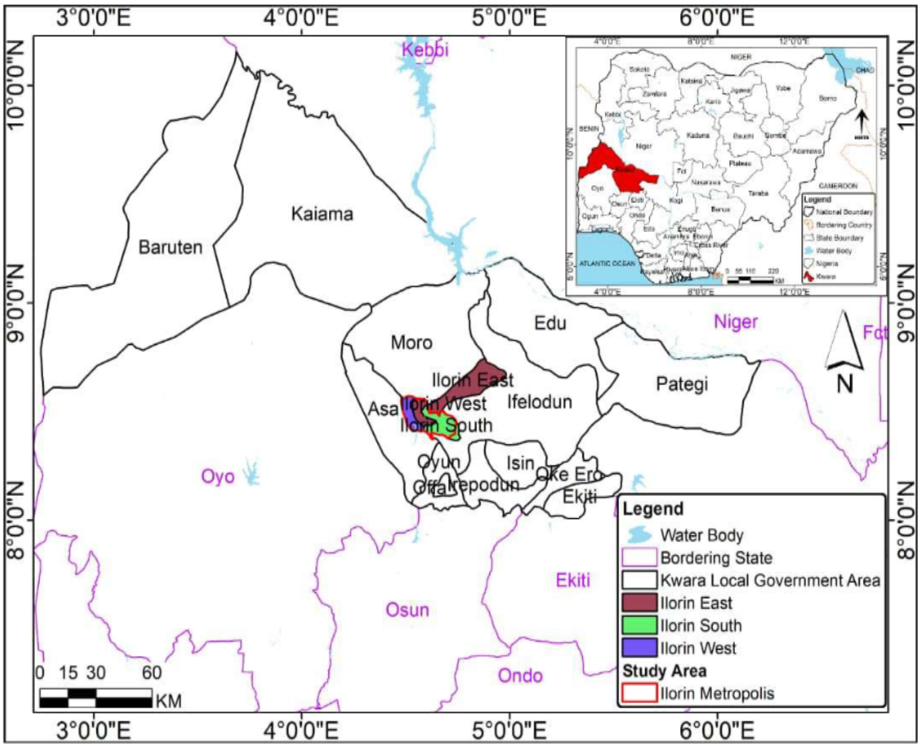

Figure 1: Kwara state in Nigeria, showing Ilorin East, South and West.
Sources: GIS Laboratory, Geography department Nigerian Defence Academy, 2020.

Table 1: Sample size (National Population Commission (NPC) (2006), Author's Compilation (2024)

LGA	2023 Household Projections	Sample Size at (95 %) Confidence Level	50 % of the original size
Ilorin Est	61,474	299	150
Ilorin South	63,342	308	154
Ilorin West	120,574	586	293
Total	245,390	1,193	597

3.0 Results and Discussion

3.1 Respondents' demographic profile

3.1.1 Gender of Respondents

Figure 2 shows that the sample comprises 253 males (52.3 %) and 231 females (47.7 %). This near-equal distribution minimizes gender bias in the data. Gender can influence thermal sensitivity, with studies indicating that metabolic rates and clothing preferences often lead to slight differences in comfort temperatures (Karjalainen, 2007). The balanced sample ensures the findings represent a broad spectrum of comfort perceptions, reducing the risk that results are skewed toward the tendencies of a single gender.

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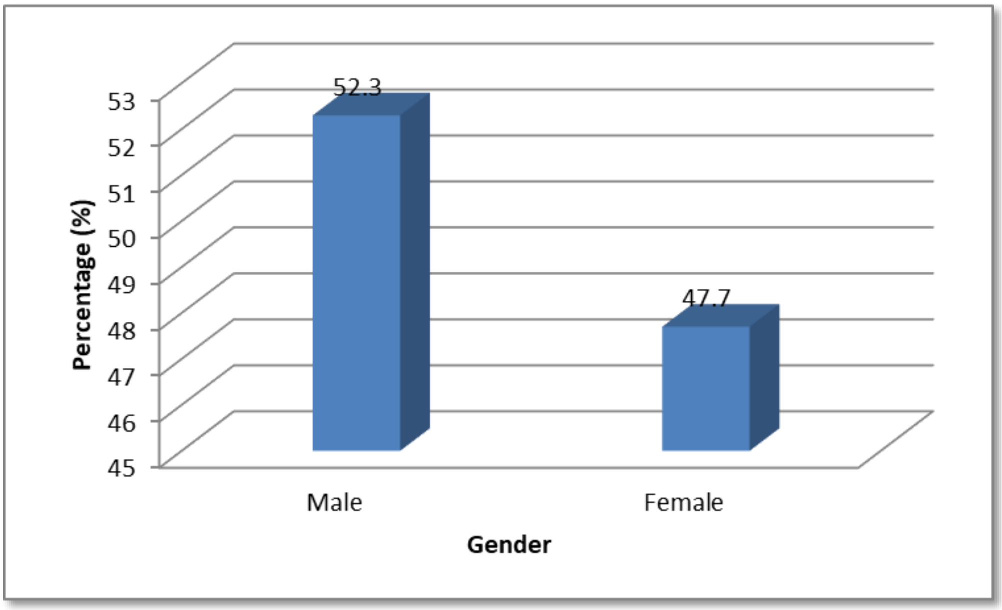

Figure 2: Gender of the Workers

3.1.2 Age of Respondents

The majority of respondents are of working age, with the largest cohort being 31–45 years (43.0 %), followed by 46–60 years (27.3 %) and 18–30 years (20.7 %). Older adults (61+) constitute only 9.1 % of the sample. This age distribution suggests the data primarily reflects the perceptions and behaviours of economically active adults who are likely responsible for household decisions regarding energy use, cooling systems, and home adaptations (Schweiker et al., 2020). The relatively small elderly population indicates that findings related to thermal sensitivity may not fully represent age-related vulnerabilities to heat or cold.

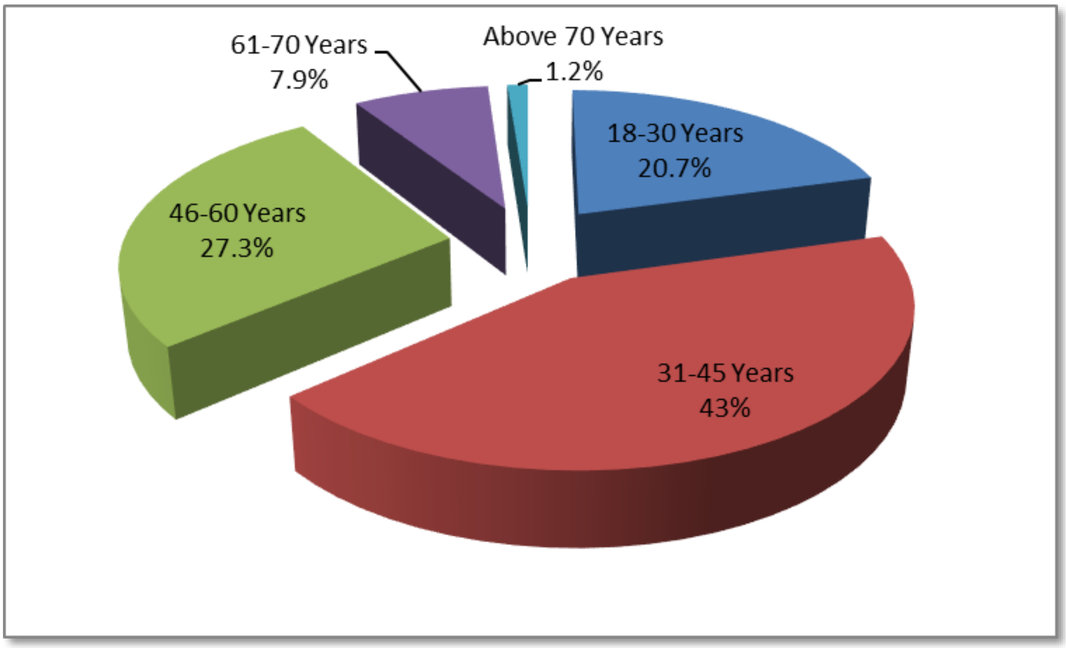

Figure 3: Age of the respondents

3.1.3 Marital Status of Respondents

A significant majority of respondents are married (63.4 %), while single individuals account for 26.0 %, and divorced persons represent 10.5 %. The high proportion of married respondents implies that comfort and adaptation behaviours are often shaped within a family context, involving compromise and collective decision-making (Huebner et al., 2015). This marital structure may influence responses related to space usage, occupancy patterns, and investment in home improvements.

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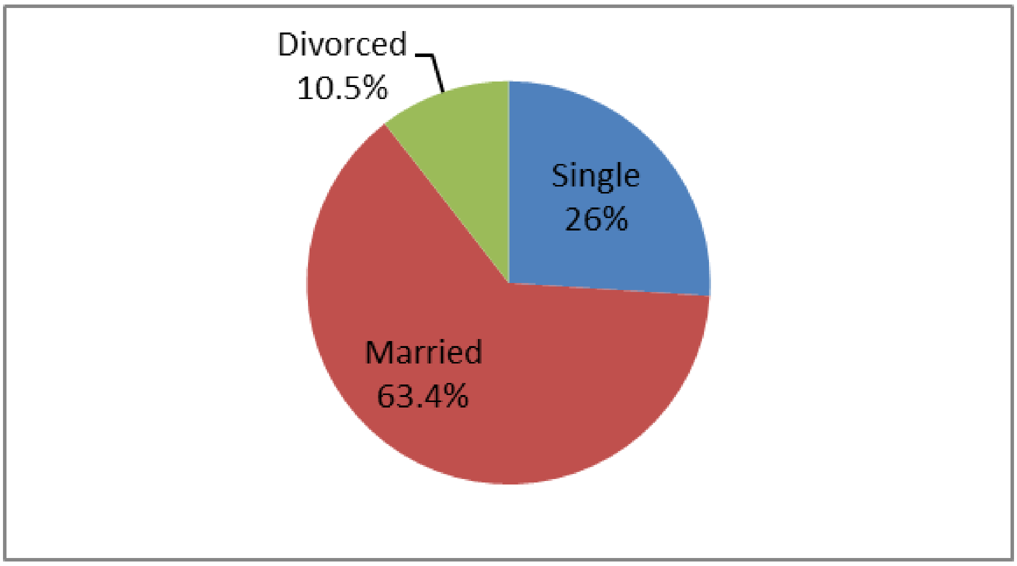

Figure 4: Age of the respondents

3.1.4 Educational Status of Respondents

Educational attainment among respondents is varied but leans toward higher levels. The largest group has completed tertiary education (37.2 %), followed by those with completed secondary school (22.7 %). Those with primary education or lower constitute 39.5 % of the sample. This relatively high level of education suggests that respondents may have greater environmental awareness and a better understanding of bioclimatic concepts, potentially leading to more informed adaptive behaviours and more nuanced responses in the survey (Chen et al., 2020). The presence of a sizable less-educated cohort, however, ensures the sample includes a range of perspectives.

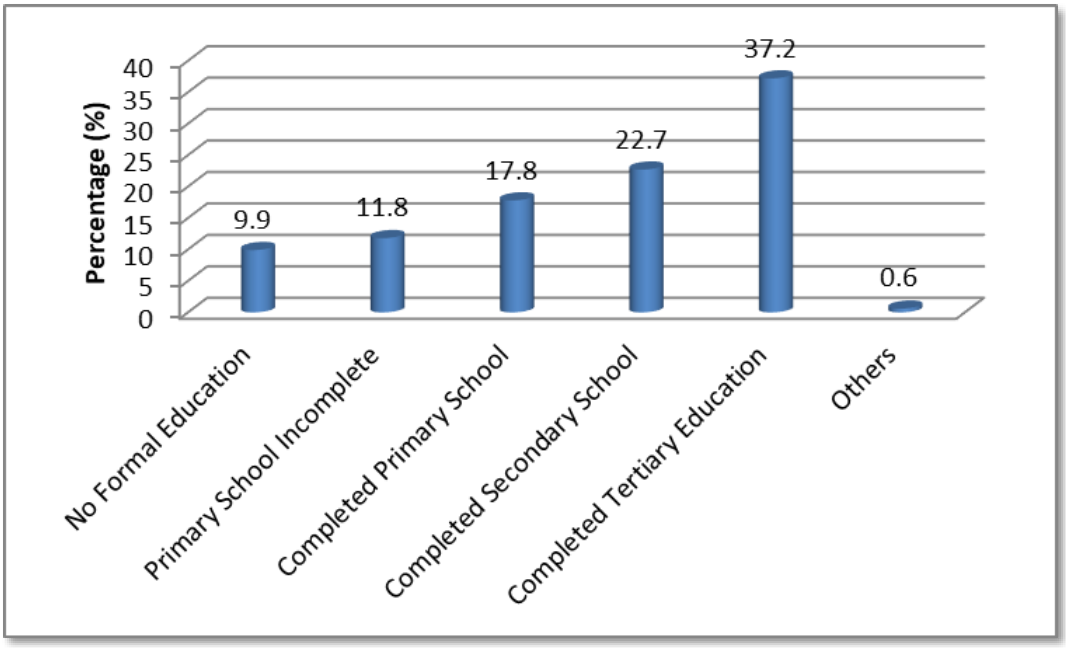

Figure 5: Educational Status of the respondents

3.1.5 Occupation of Respondents

Respondents are predominantly engaged in stable income-generating activities: Civil servants (28.3 %), followed by those in Trading/Business (27.9 %) and the Self-employed (25.2 %). Artisans, Farmers, and Students together account for 18.5 %. The high representation of formal and informal sector workers indicates that most respondents have fixed or regular incomes, which influences their capacity to invest in cooling technologies or housing upgrades. Occupations also affect daily schedules; for example, civil servants may be away from home during peak heat hours, potentially affecting their perception of daytime indoor temperatures (Janda, 2011).

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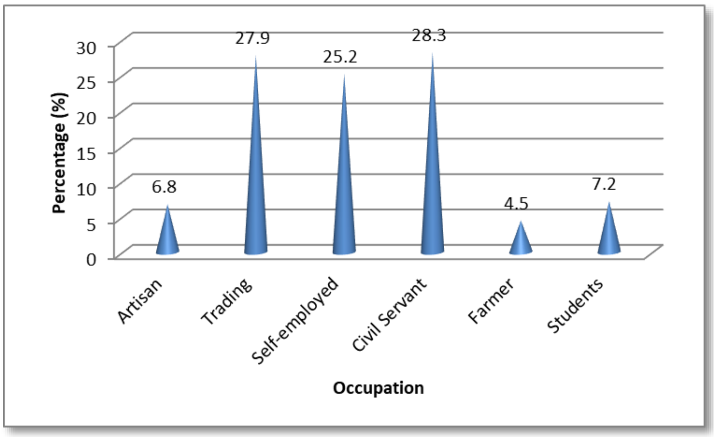

Figure 6: Occupation of the respondents

3.1.6 Monthly Income of Respondents

Income distribution shows clustering in the middle to lower-middle ranges. The largest segment earns ₦ 70,000 – ₦ 80,000 monthly (31.0 %), followed by ₦ 81,000 – ₦ 90,000 (26.0 %). Those earning below ₦ 70,000 constitute 19.2 %, while only 7.2 % earn above ₦ 100,000. This income profile is critical for interpreting adaptive capacity. Financial constraints may limit the ability of many respondents to afford air conditioning, energy-efficient appliances, or retrofits, pushing them toward behavioural adaptations (e.g., natural ventilation, clothing adjustment) as primary comfort strategies (Davis, 2011). The predominance of middle-income households aligns with the focus on typical residential buildings in Ilorin.

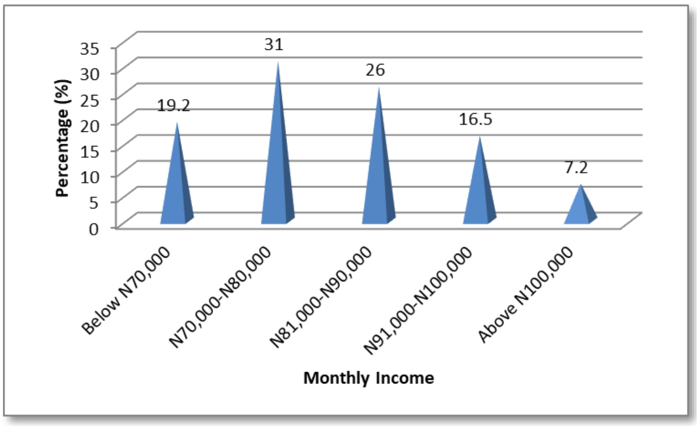

Figure 7: Income of the respondents

3.1.7 Tenure Status of Respondents

Figure 8 shows that nearly half of the respondents live in rented accommodation (45.2 %), while 28.7 % reside in free housing (likely family-owned or employer-provided), and 22.3 % are owner-occupiers. This tenure profile has profound implications for bioclimatic adaptation. Tenants often face a "split-incentive" problem: they bear the discomfort and energy costs but lack the authority or motivation to make structural improvements to the building (e.g., installing external shading, improving insulation). This may explain a greater reliance on low-cost, reversible adaptive behaviours observed in earlier sections (Gillingham et al., 2012).

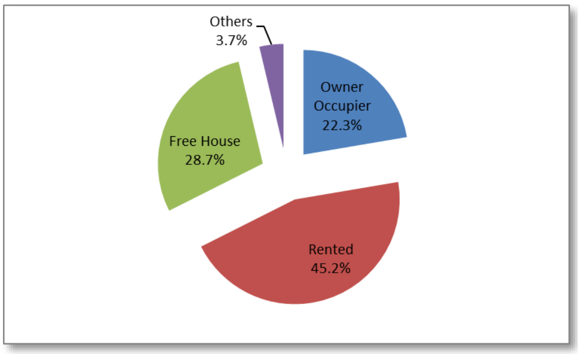

Figure 8: Tenure status of respondents

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3.1.8 Length of Stay in the House

As indicated in the figure 9, a large proportion of respondents have lived in their current home for 2–5 years (42.1 %), with another 29.8 % staying 6–10 years. Only 10.5 % have lived there over 10 years, and 17.6 % for less than 2 years. This indicates a moderately settled but not permanently rooted population. Residents with several years of tenure have likely developed seasonal adaptation routines and are familiar with the bioclimatic quirks of their dwellings. Newer residents (under 2 years) may provide less acclimatized, and potentially more critical, assessments of indoor conditions (Nicol and Humphreys, 2002).

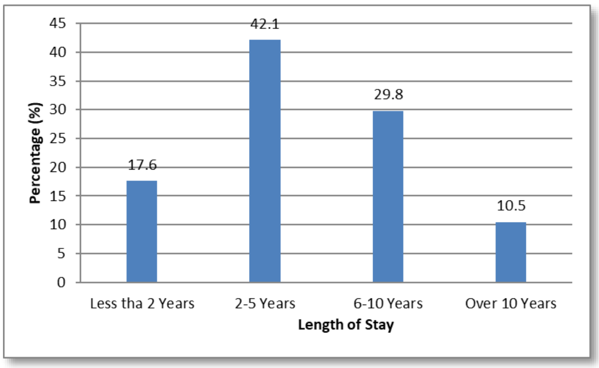

Figure 9: Length of stay of the residents

3.1.9 Usage of the Space

Respondents were surveyed regarding specific spaces within their homes. The largest group was surveyed in bedrooms (44.2 %), followed by living rooms (39.7 %), and kitchens (16.1 %). This distribution is methodologically significant because thermal and lighting requirements vary by room type. Bedrooms are critical for night-time comfort and ventilation, living rooms for daytime occupancy and social use, and kitchens for intermittent high heat and moisture loads. Findings related to comfort and behaviour must be interpreted in light of which space was being evaluated (Wang et al., 2018).

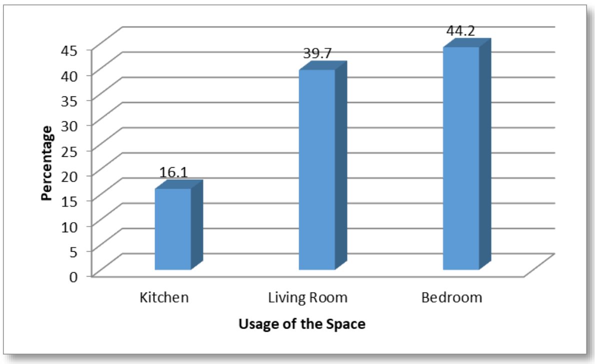

Figure 10: Residents' usage of space

3.1.10 Number of People using the Space

Household size, in terms of space usage, shows that nearly half of the spaces are used by 3–4 people (48.1 %), followed by 5–6 people (29.5 %), and 1–2 people (22.3 %). This indicates moderately high occupancy densities, which can significantly increase internal heat gains from occupants and activities. Higher occupancy may also lead to more frequent window opening for ventilation but could also result in faster heat buildup, influencing both thermal perception and adaptation strategies (Indraganti et al., 2014).

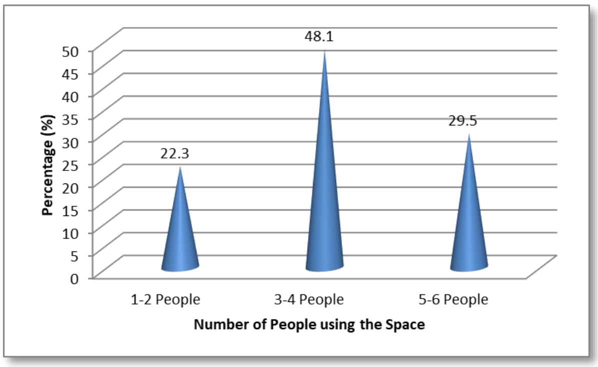

Figure 11: Number of people using the space

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3.2 Factors that Influence the Perceived Bioclimatic Design and Performance of Residential Buildings in Ilorin Metropolis

It is essential to examine the broader determinants shaping how residents assess the bioclimatic performance of their homes. Residents' evaluation is influenced not only by the physical characteristics of buildings but also by environmental conditions, socio-demographic attributes, cultural expectations, and their level of awareness of climate-responsive design strategies.

3.2.1 Physical Status of Respondents

Table 2 shows Physical Status of Respondents. The majority of respondents across all densities self-identify as having an "Average Built" physique, ranging from 49.5% in High-density to 57.0 % in Medium-density areas. Table 2 shows no statistically significant association between residential density and physical status ($\chi^2 = 8.601$, $p = 0.197$). This indicates that the sample's body type distribution is independent of dwelling density, a crucial baseline finding that suggests differences in thermal perception and adaptation behaviours later in the analysis are unlikely to be primarily driven by physiological variation among the groups (Kingma and van Marken Lichtenbelt, 2015).

Table 2: Physical Status of Respondents

Residential Density		Physical Status of Respondents				Total
		Slim	Average Built	Fat	Obese	
High	F	59	105	47	1	212
	% of R	27.8	49.5	22.2	0.5	100.0
	% of C	46.1	41.5	49.5	12.5	43.8
Low	F	29	50	17	4	100
	% of R	29.0	50.0	17.0	4.0	100.0
	% of C	22.7	19.8	17.9	50.0	20.7
Medium	F	40	98	31	3	172
	% of R	23.3	57.0	18.0	1.7	100.0
	% of C	31.3	38.7	32.6	37.5	35.5
Total	F	128	253	95	8	484
	% of R	26.4	52.3	19.6	1.7	100.0
	% of C	100.0	100.0	100.0	100.0	100.0

F = Frequency, % of R= Percentage of Row, % of C= Percentage of Column
($\chi^2 = 8.601$, df = 6, $p > 0.05 = 0.197$)

3.2.2 Types of clothing of the Respondents

Clothing insulation is a key adaptive behaviour. Table 3 shows that "Light clothing" and "Moderate" clothing are the most common across all densities. No significant association with density was found ($\chi^2 = 10.500$, $p = 0.232$). This suggests that, at the time of the survey, residents were dressed similarly regardless of their home's location, implying that immediate clothing choice may be more influenced by activity, time of day, or cultural norm than by macro-scale urban density (Schweiker et al., 2012).

Table 3: Type of Clothing the Respondent is wearing now

Residential Density		**Type of Clothing the Respondent is wearing now**					**Total**
		Nude	**Semi nude**	**Light clothe**	**Moderate**	**Heavy cloth**	
High	F	5	46	69	64	28	212
	% of R	2.4	21.7	32.5	30.2	13.2	100.0
	% of C	50.0	55.4	44.5	36.2	47.5	43.8

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Residential Density	Type of Clothing the Respondent is wearing now					Total
	Nude	Semi nude	Light clothe	Moderate	Heavy cloth	
Low F	1	13	30	45	11	100
% of R	1.0	13.0	30.0	45.0	11.0	100.0
% of C	10.0	15.7	19.4	25.4	18.6	20.7
Medium F	4	24	56	68	20	172
% of R	2.3	14.0	32.6	39.5	11.6	100.0
% of C	40.0	28.9	36.1	38.4	33.9	35.5
Total F	**10**	**83**	**155**	**177**	**59**	**484**
% of R	**2.1**	**17.1**	**32.0**	**36.6**	**12.2**	**100.0**
% of C	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

F = Frequency, % of R= Percentage of Row, % of C= Percentage of Column
($\chi^2 = 10.500$, df = 8, $p > 0.05 = 0.232$)

3.2.3 Closeness of Respondents' House to the Busiest Road

Table 4 provides a critical contextual variable. It reveals a highly significant association ($\chi^2 = 20.847$, $p = 0.000$). A majority of High-density residents (57.5 %) live "Close to the road (< 20 m)", compared to only 38.0 % in Low-density. Conversely, 50.0 % of Medium-density residents live "Not too far (20-50 m)". This directly links high-density living with proximity to traffic, a major source of noise, air pollution, and heat, which fundamentally shapes the environmental challenges residents must adapt to according to Kleerekoper et al., (2012).

Table 4: Closeness of Respondents' House to the Busiest Road

Residential Density	Closeness of Respondents Houses to the Busiest Road			Total
	Close to the road (< 20 m)	Not too far (20-50 m)	Far away (> 50 m)	
High F	122	65	25	212
% of R	57.5	30.7	11.8	100.0
% of C	52.8	33.2	43.9	43.8
Low F	38	45	17	100
% of R	38.0	45.0	17.0	100.0
% of C	16.5	23.0	29.8	20.7
Medium F	71	86	15	172
% of R	41.3	50.0	8.7	100.0
% of C	30.7	43.9	26.3	35.5
Total F	**321**	**196**	**57**	**484**
% of R	**47.7**	**40.5**	**11.8**	**100.0**
% of C	**100.0**	**100.0**	**100.0**	**100.0**

F = Frequency, % of R= Percentage of Row, % of C= Percentage of Column
($\chi^2 = 20.847$, df = 4, $p < 0.05 = 0.000$)

3.2.4 Physical Activity of the Respondent in the last One hour

The reported level of metabolic activity shows no significant variation by density ($\chi^2 = 9.614$, $p = 0.142$). "Moderate work" was the most common activity in all groups (Table 5). This finding reinforces that differences in thermal perception (seen in later tables) are more likely due to environmental conditions than to significant disparities in occupants' metabolic heat production at the time of assessment (ASHRAE, 2020).

Table 5: Physical Activity in the last One hour

Residential Density	Physical Activity in the last One hour				Total
	Rest	Light work	Moderate work	Hard work	
High F	35	59	88	30	212
% of R	16.5	27.8	41.5	14.2	100.0
% of C	50.0	21.0	41.1	53.6	43.8
Low F	16	28	51	5	100
% of R	16.0	28.0	51.0	5.0	100.0
% of C	22.9	19.4	23.8	8.9	20.7

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Medium	F	19	57	75	21	172
	% of R	11.0	33.1	43.6	12.2	100.0
	% of C	27.1	39.6	35.0	37.5	35.5
Total	**F**	**70**	**144**	**214**	**56**	**484**
	% of R	**14.5**	**29.8**	**44.2**	**11.6**	**100.0**
	% of C	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

F = Frequency, % of R= Percentage of Row, % of C= Percentage of Column
($\chi^2 = 9.614$, df = 6, $p > 0.05 = 0.142$)

3.2.5 Colour of Curtains on Windows

The colour of curtains, which affects solar heat gain and daylight penetration, shows no significant association with density ($\chi^2 = 5.420$, $p = 0.247$). Table 6 indicates a fairly even distribution between "Bright", "Dull", and "Dark" colours across all areas. This suggests curtain colour choice is not a density-specific adaptation strategy but may be driven more by interior décor preferences (Bellia et al., 2013).

Table 6: Colour of Curtains on Windows

Residential Density		Colour of Curtains on Windows			Total
		Bright	Dull	Dark	
High	F	76	83	52	211
	% of R	36.0	39.3	24.6	100.0
	% of C	40.9	46.4	44.4	43.8
Low	F	45	38	17	100
	% of R	45.0	38.0	17.0	100.0
	% of C	24.2	21.2	14.5	20.7
Medium	F	65	58	48	171
	% of R	38.0	33.9	28.1	100.0
	% of C	34.9	32.4	41.0	35.5
Total	**F**	**186**	**179**	**117**	**482**
	% of R	**38.6**	**37.1**	**24.3**	**100.0**
	% of C	**100.0**	**100.0**	**100.0**	**100.0**

F = Frequency, % of R= Percentage of Row, % of C= Percentage of Column
($\chi^2 = 5.420$, df = 4, $p > 0.05 = 0.247$)

3.2.6 Texture of Curtain Material on Window

In contrast to colour, the texture/weight of the curtain material shows a significant association ($\chi^2 = 19.357$, $p = 0.001$). Table 7 is striking: "Heavy" curtains are used by 20.3 % of High-density residents, compared to only 8.0 % in Low-density and 7.6 % in Medium-density. This strongly suggests that high-density residents are more likely to employ thicker window dressings, potentially for enhanced privacy, light blockage, or as a barrier against external noise and heat a direct behavioural adaptation to the dense urban context (Ghisi and Tinker, 2005).

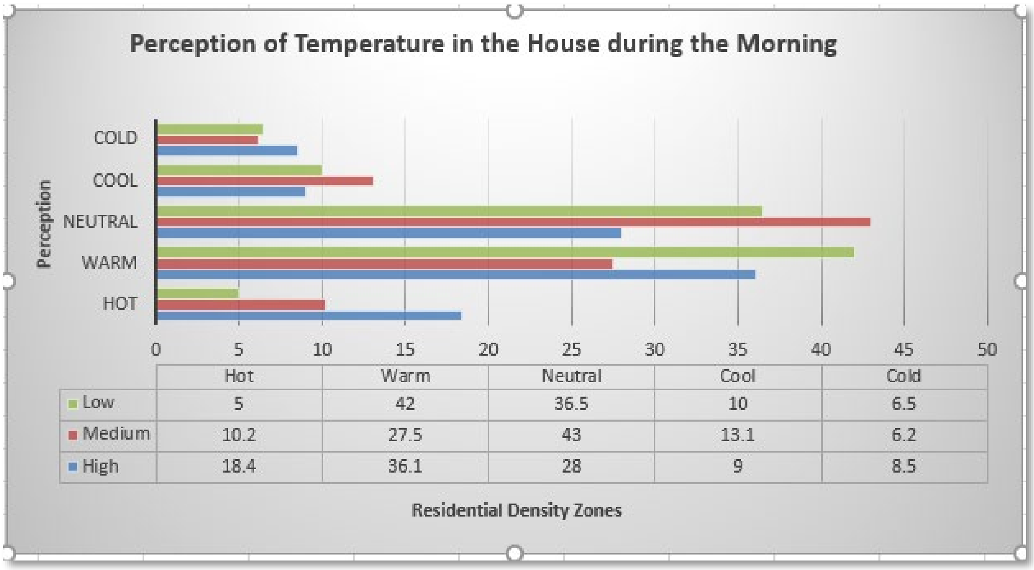
Table 7: Texture of Curtain Material on Window

Residential Density		Texture of Curtain Material on Window			Total
		Light	Medium	Heavy	
High	F	55	114	43	212
	% of R	25.9	53.8	20.3	100.0
	% of C	37.4	41.8	67.2	43.8
Low	F	39	53	8	100
	% of R	39.0	53.0	8.0	100.0
	% of C	26.5	19.4	12.5	20.7
Medium	F	53	106	13	172
	% of R	30.8	61.6	7.6	100.0
	% of C	36.1	38.8	20.3	35.5
Total	**F**	**147**	**273**	**64**	**484**
	% of R	**30.4**	**56.4**	**13.2**	**100.0**
	% of C	**100.0**	**100.0**	**100.0**	**100.0**

F = Frequency, % of R= Percentage of Row, % of C= Percentage of Column
($\chi^2 = 19.357$, df = 4, $p < 0.05 = 0.001$)

3.2.7 Perception of Temperature in the House during the Morning

Figure 12 reveals a highly significant and dramatic association ($\chi^2 = 53.074$, $p = 0.000$). The thermal experience diverges sharply by density. High-density residents report the most extreme perceptions: 18.4 % feel "Hot" in the morning (compared to 6.0 % in Low and 3.5 % in Medium), and they also constitute 90.0 % of all "Cold" responses. This bimodal pattern in high-density areas could indicate poor thermal uniformity, with some units overheating rapidly from morning sun while others remain in deep shade. Low-density residents report no "Cold" feelings, with the highest proportion feeling "Warm" (42.0 %). Medium-density residents cluster around "Neutral" (43.0 %). This underscores how urban morphology and microclimate create distinct thermal zones (Erell et al., 2011).

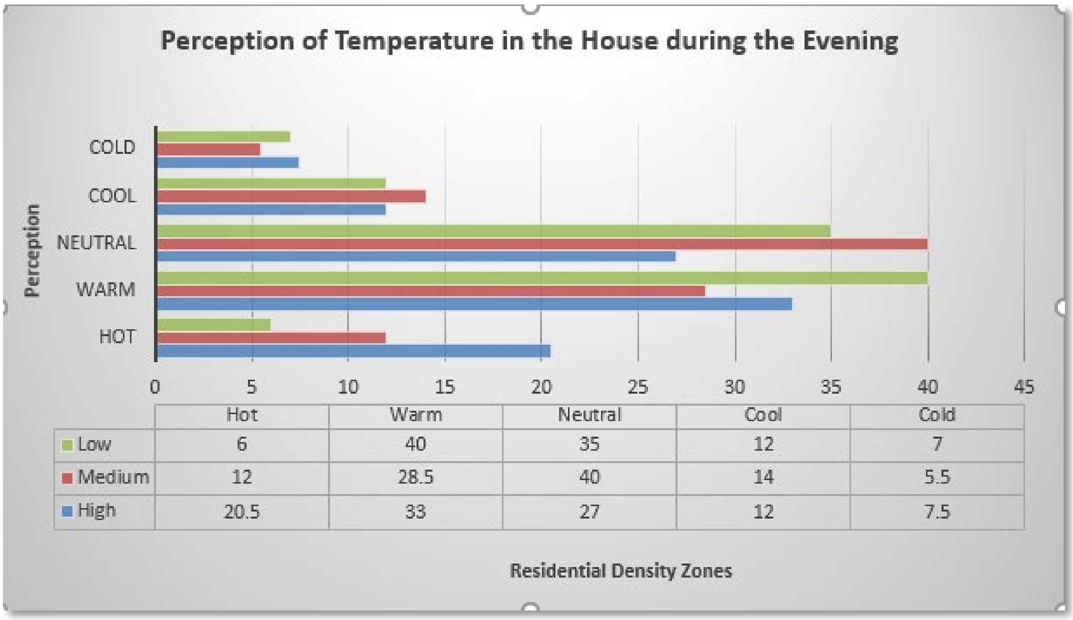


	Hot	Warm	Neutral	Cool	Cold
🟩 Low	5	42	36.5	10	6.5
🟥 Medium	10.2	27.5	43	13.1	6.2
🟦 High	18.4	36.1	28	9	8.5

Figure 12: Residents perception of morning temperature in their various houses.

3.2.8 Perception of Temperature in the House during the Evening

The evening pattern in Figure 13 is even more pronounced ($\chi^2 = 68.199$, $p = 0.000$). Nearly half (46.9 %) of High-density residents feel "Warm", with an additional 18.5 % feeling "Hot". This starkly contrasts with Medium-density, where 45.9 % feel "Neutral". This provides direct perceptual evidence of the Urban Heat Island (UHI) effect, where built-up areas retain solar heat long into the evening (Santamouris, 2014).



	Hot	Warm	Neutral	Cool	Cold
🟩 Low	6	40	35	12	7
🟥 Medium	12	28.5	40	14	5.5
🟦 High	20.5	33	27	12	7.5

Figure 13: Residents perception of morning temperature in their various houses.

3.2.9 Level of Humidity in the House during the Day and Night

Tables 8 & 9 described Level of Humidity in the House (Day & Night). For daytime humidity (Table 8), no significant association was found ($p = 0.147$), with about half of all respondents in each group feeling conditions are "Neither humid nor dry". However, night-time humidity (Table 9 shows a significant

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association ($\chi^2 = 20.407$, $p = 0.009$). Medium-density residents report the highest perception of being "Very humid" at night (4.7 %). This could relate to specific local ventilation patterns or landscaping, suggesting that the UHI is not solely a dry heat phenomenon but can interact with humidity (Rizwan et al., 2008).

Table 8: Level of Humidity in the House during the Day

Residential Density		**Level of Humidity in the House during the Day**					**Total**
		Very humid	**Humid**	**Very dry**	**Dry**	**Neither humid nor dry**	
High	F	2	37	35	41	97	212
	% of R	0.9	17.5	16.5	19.3	45.8	100.0
	% of C	66.7	42.0	53.8	46.1	40.6	43.8
Low	F	0	12	16	17	55	100
	% of R	0.0	12.0	16.0	17.0	55.0	100.0
	% of C	0.0	13.6	24.6	19.1	23.0	20.7
Medium	F	1	39	14	31	87	172
	% of R	0.6	22.7	8.1	18.0	50.6	100.0
	% of C	33.3	44.3	21.5	34.8	36.4	35.5
Total	**F**	**3**	**88**	**65**	**89**	**239**	**484**
	% of R	**0.6**	**18.2**	**13.4**	**18.4**	**49.4**	**100.0**
	% of C	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

F = Frequency, % of R= Percentage of Row, % of C= Percentage of Column
($\chi^2 = 12.104$, df = 8, $p > 0.05 = 0.147$)

Table 9: Level of Humidity in the House during the Night

Residential Density		**Level of Humidity in the House during the Night**					**Total**
		Very humid	**Humid**	**Very dry**	**Dry**	**Neither humid nor dry**	
High	F	1	56	17	32	106	212
	% of R	0.5	26.4	8.0	15.1	50.0	100.0
	% of C	10.0	42.4	45.9	43.2	45.9	43.8
Low	F	1	17	9	17	56	100
	% of R	1.0	17.0	9.0	17.0	56.0	100.0
	% of C	10.0	12.9	24.3	23.0	24.2	20.7
Medium	F	8	59	11	25	69	172
	% of R	4.7	34.3	6.4	14.5	40.1	100.0
	% of C	80.0	44.7	29.7	33.8	29.9	35.5
Total	**F**	**10**	**132**	**37**	**74**	**231**	**484**
	% of R	**2.1**	**27.3**	**7.6**	**15.3**	**47.7**	**100.0**
	% of C	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

F = Frequency, % of R= Percentage of Row, % of C= Percentage of Column
($\chi^2 = 20.407$, df = 8, $p < 0.05 = 0.009$)

3.2.10 Time of Thermally feeling comfortable in the House

Table 10 on comfort timing shows a highly significant association ($\chi^2 = 37.329$, $p = 0.000$). It reveals divergent "comfort schedules": High-density residents most often feel comfortable in the Morning (35.8 %). Medium-density residents feel most comfortable at Night (37.8 %). Low-density residents are more evenly split. This aligns perfectly with the temperature perception data: High-density areas become uncomfortable by evening due to heat accumulation, making mornings the preferred time. Medium-density areas, which cool down more effectively at night, find that period most comfortable (Gaitani et al., 2007).

Table 10: Time of Thermally feeling comfortable in the House

Residential Density		**Time of Thermally feeling comfortable in the House**				**Total**
		Night	**Evening**	**Afternoon**	**Morning**	
High	F	36	59	41	76	212
	% of R	17.0	27.8	19.3	35.8	100.0
	% of C	30.3	56.7	46.1	44.2	43.8
Low	F	18	17	29	36	100
	% of R	18.0	17.0	29.0	36.0	100.0
	% of C	15.1	16.3	32.6	20.9	20.7
Medium	F	65	28	19	60	172
	% of R	37.8	16.3	11.0	34.9	100.0
	% of C	54.6	26.9	21.3	34.9	35.5
Total	**F**	**119**	**104**	**89**	**172**	**484**
	% of R	**24.6**	**21.5**	**18.4**	**35.5**	**100.0**
	% of C	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

F = Frequency, % of R= Percentage of Row, % of C= Percentage of Column
(χ^2 = 37.329, df = 6, $p < 0.05$ = 0.000)

3.2.11 Blowing of Air in the House during the Day and Night

Tables 11 and 12 contain the analysis of the Blowing of Air in the House (Day & Night). Daytime air movement (Table 11) shows no significant density-based difference (p = 0.826), with most reporting air blows "moderately" or "well". However, night-time air movement (Table 12) is highly significantly associated with density (χ^2 = 46.770, p = 0.000). A concerning 5.2 % of High-density residents report air "Does not blow at all" at night, compared to 0 % in Low and 0.6 % in Medium. This critical lack of night-time ventilation in high-density settings, likely due to security-driven window closure, traps heat and severely limits a key passive cooling strategy, exacerbating discomfort (Hong and Lin, 2015).

Table 11: Blowing of Air in the House during the Day

Residential Density		**Blowing of Air in the House during the Day**					**Total**
		Does not blow at all	**Blows occasionally**	**Blows moderately**	**Blows well**	**Blows too much**	
High	F	5	13	78	71	45	212
	% of R	2.4	6.1	36.8	33.5	21.2	100.0
	% of C	55.6	46.4	44.1	41.0	46.4	43.8
Low	F	1	5	36	43	15	100
	% of R	1.0	5.0	36.0	43.0	15.0	100.0
	% of C	11.1	17.9	20.3	24.9	15.5	20.7
Medium	F	3	10	63	59	37	172
	% of R	1.7	5.8	36.6	34.3	21.5	100.0
	% of C	33.3	35.7	35.6	34.1	38.1	35.5
Total	**F**	**9**	**28**	**177**	**173**	**97**	**484**
	% of R	**1.9**	**5.8**	**36.6**	**35.7**	**20.0**	**100.0**
	% of C	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

F = Frequency, % of R= Percentage of Row, % of C= Percentage of Column
(χ^2 = 4.333, df = 8, $p > 0.05$ = 0.826)

Table 12: Blowing of Air in the House during the Night

Residential Density		**Blowing of Air in the House during the Night**					**Total**
		Does not blow at all	**Blows occasionally**	**Blows moderately**	**Blows well**	**Blows too much**	
High	F	11	28	61	88	24	212
	% of R	5.2	13.2	28.8	41.5	11.3	100.0
	% of C	91.7	93.3	37.7	38.9	44.4	43.8
Low	F	0	2	35	53	10	100
	% of R	0.0	2.0	35.0	53.0	10.0	100.0
	% of C	0.0	6.7	21.6	23.5	18.5	20.7

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Residential Density	Blowing of Air in the House during the Night					Total
	Does not blow at all	Blows occasionally	Blows moderately	Blows well	Blows too much	
Medium F	1	0	66	85	20	172
% of R	0.6	0.0	38.4	49.4	11.6	100.0
% of C	8.3	0.0	40.7	37.6	37.0	35.5
Total F	**12**	**30**	**162**	**226**	**54**	**484**
% of R	**2.5**	**6.2**	**33.5**	**46.7**	**11.2**	**100.0**
% of C	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

F = Frequency, % of R= Percentage of Row, % of C= Percentage of Column
(χ^2 = 46.770, df = 8, p < 0.05 = 0.000)

3.2.12 Freshness of the Air in the House

The perception of air freshness is significantly associated with density (χ^2 = 25.931, p = 0.001). Table 13 shows that High-density residents have the highest reports of "Stale" air (3.8 %) and the lowest combined "Fairly/Very Fresh" percentage (56.1 %). Medium-density residents report the highest air freshness (70.2 % combined). This aligns with Park and Chang, (2021) findings which points to potential issues with indoor air quality and inadequate ventilation in dense urban settings, possibly due to infiltration of pollutants or reduced air exchange rates.

Table 13: Freshness of the Air in the House

Residential Density	Freshness of the Air in the House					Total
	Stale	Not fresh	Fresh	Fairly fresh	Very fresh	
High F	8	19	66	64	55	212
% of R	3.8	9.0	31.1	30.2	25.9	100.0
% of C	80.0	38.8	48.9	35.6	50.0	43.8
Low F	2	16	32	34	16	100
% of R	2.0	16.0	32.0	34.0	16.0	100.0
% of C	20.0	32.7	23.7	18.9	14.5	20.7
Medium F	0	14	37	82	39	172
% of R	0.0	8.1	21.5	47.7	22.7	100.0
% of C	0.0	28.6	27.4	45.6	35.5	35.5
Total F	**10**	**49**	**135**	**180**	**110**	**484**
% of R	**2.1**	**10.1**	**27.9**	**37.2**	**22.7**	**100.0**
% of C	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

F = Frequency, % of R= Percentage of Row, % of C= Percentage of Column
(χ^2 = 25.931, df = 8, p < 0.05 = 0.001)

3.2.13 Level of Lighting in the House without use of Artificial Lighting

Access to natural light is strongly density-dependent (χ^2 = 58.374, p = 0.000). Table 14 shows Low-density residents enjoy the best natural lighting, with 78.0 % reporting "Bright" or "Very Bright" conditions. High-density residents are less positive, with 47.6 % reporting "Bright" light. Medium-density residents report the highest level of "Neither bright nor dim" lighting (41.9 %), suggesting a more diffuse or moderate light condition. This confirms that building proximity in high-density areas and potentially deeper floor plans limit daylight penetration as espoused by Dubois, (2001).

Table 14: Level of Lighting in the House without use of Artificial Lighting

Residential Density	Level of Lighting in the House without use of Artificial Lighting					Total
	Very dim	Dim	Neither bright nor dim	Bright	Very bright	
High F	5	31	43	101	32	212
% of R	2.4	14.6	20.3	47.6	15.1	100.0
% of C	83.3	77.5	31.9	49.0	33.0	43.8
Low F	0	2	20	55	23	100
% of R	0.0	2.0	20.0	55.0	23.0	100.0

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Residential Density	Level of Lighting in the House without use of Artificial Lighting					Total
	Very dim	Dim	Neither bright nor dim	Bright	Very bright	
% of C	0.0	5.0	14.8	26.7	23.7	20.7
Medium F	1	7	72	50	42	172
% of R	0.6	4.1	41.9	29.1	24.4	100.0
% of C	16.7	17.5	53.3	24.3	43.3	35.5
Total F	**6**	**40**	**135**	**206**	**97**	**484**
% of R	**1.2**	**8.3**	**27.9**	**42.6**	**20.0**	**100.0**
% of C	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

F = Frequency, % of R= Percentage of Row, % of C= Percentage of Column
($\chi^2 = 58.374$, df = 8, $p < 0.05 = 0.000$)

3.3 Rating of Importance Level of Bioclimatic Performance

This section analyses residents' ratings of key bioclimatic performance factors in residential buildings across Ilorin Metropolis to determine their relative importance in evaluating bioclimatic design. Respondents assessed seven factors thermal comfort, ventilation, air quality, visual comfort, light intensity, acoustic comfort, and noise level using a five-point Likert scale ranging from "Not Important at All" to "Very Important." The results aggregate responses from high-, medium-, and low-density areas (n = 484).

Table 15 presents the consolidated rating distribution, while Table 16 shows the overall importance levels using Summation of Weighted Values (SWV), Mean Weighted Values (MWV), and ranking.

Table 15: Rating of Bioclimatic Performance by the Respondents

Bioclimatic Factor	Not Important at All	Not Important	Neither	Important	Very Important	Total
Thermal Comfort	4 (0.8 %)	5 (1.0 %)	77 (15.9 %)	203 (41.9 %)	195 (40.3 %)	484
Ventilation	1 (0.2 %)	19 (3.9 %)	108 (22.3 %)	215 (44.4 %)	141 (29.1 %)	484
Air Quality	3 (0.6 %)	22 (4.5 %)	122 (25.2 %)	183 (37.8 %)	154 (31.8 %)	484
Visual Comfort	3 (0.6 %)	42 (8.7 %)	104 (21.5 %)	176 (36.4 %)	159 (32.9 %)	484
Light Intensity	7 (1.4%)	47 (9.7%)	95 (19.6%)	206 (42.6 %)	129 (26.7 %)	484
Acoustic Comfort	23 (4.8 %)	35 (7.2 %)	112 (23.1 %)	177 (36.6 %)	137 (28.3 %)	484
Noise Level	8 (1.7 %)	62 (12.8 %)	142 (29.3 %)	144 (29.8 %)	128 (26.4 %)	484

Table 16: Overall Level of Importance (Ranked)

S/N	Bioclimatic Performance	Ranking					NR (f)	SWV	MWV	Rank
		5	4	3	2	1				
1	Thermal Comfort	975	812	231	10	4	484	2032	**4.1983**	1
2	Ventilation	705	860	324	38	1	484	1928	**3.9835**	4
3	Air Quality	770	732	366	44	3	484	1915	**3.9566**	5
4	Visual Comfort	795	704	312	84	3	484	1897	**3.9194**	6
5	Light Intensity	645	824	385	94	7	484	1966	**4.062**	3
6	Acoustic Comfort	685	708	336	70	23	484	1822	**3.7645**	7
7	Noise Level	840	576	426	124	8	484	1974	**4.0785**	2

SWV = Summation Weighted Values, MWV = Mean Weighted Values,
NR = Number of Response (Frequency)

This indicates that residents in Ilorin Metropolis attach high importance to bioclimatic performance factors, with most responses concentrated in the "Important" and "Very Important" categories. Thermal comfort ranked highest (MWV = 4.1983), with over 82% rating it as important or very important, reflecting the strong influence of the hot climate on building performance perception. Noise level ranked second (MWV = 4.0785), followed by light intensity (MWV = 4.0620), indicating the significance of acoustic and visual conditions in residential satisfaction.

Ventilation and air quality occupied mid-level positions but remained highly valued, while acoustic comfort ranked lowest (MWV = 3.7645), though still above the neutral threshold.

Overall, thermal and noise-related factors are the dominant determinants of residents' evaluation of bioclimatic design, with visual and air-quality factors playing important but comparatively secondary roles.

4.0 Conclusion

This study examined the factors influencing residents' evaluation of bioclimatic design in residential buildings in Ilorin Metropolis, highlighting the significant role of residential density in shaping environmental perception. The findings reveal that thermal comfort is the most critical determinant of residents' evaluation, reflecting the influence of the hot tropical climate. Noise level and light intensity also ranked highly, confirming the importance of acoustic and visual conditions in overall residential satisfaction. High-density areas were associated with greater heat retention, reduced night-time ventilation, and lower perceived air freshness, indicating the impact of urban morphology and microclimatic conditions on building performance.

The results underscore the need for climate-responsive planning and architectural strategies, particularly in densely built neighbourhoods. Improving building orientation, spacing, and ventilation design, enhancing passive cooling measures, optimizing daylighting, and incorporating noise mitigation strategies are essential for improving residential comfort. Integrating bioclimatic performance considerations into planning regulations and housing design guidelines will promote more sustainable and context-responsive residential development in Ilorin Metropolis.

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