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THERMAL COMFORT CONSIDERATIONS AND SPACE USE WITHIN RESIDENTIAL BUILDINGS IN IBADAN, NIGERIA.

Adewale Oluseyi Adunola and Kolawole Ajibola

Department of Architecture, Obafemi Awolowo University, Ile-Ife, Nigeria.

Corresponding Author's e mail- wadunola@yahoo.com

Abstract

Indoor thermal comfort is of utmost concern with respect to the use of residential accommodation spaces. A thermal comfort survey was conducted among residents of 528 buildings in 12 selected residential areas of Ibadan metropolis in Nigeria. The impact of the urban microclimate on the building spaces was found significant. Indoor comfort assessment varied according to the different building design typology. It was found that the differences in temperature between spaces in each of the buildings were within the range of 0.1 to 0.7 deg C. Residents exhibited thermal consideration in the use of spaces and utilized movement adaptive actions. The living room space was the most comfortable and most used space. There was very strong correlation between the most comfortable spaces, the most used spaces and first choice spaces voted by respondents. It was confirmed that pattern of use of spaces was related to the indoor comfort levels.

Keywords: adaptive action, residential design typology, space use, thermal comfort, urban microclimate.

Introduction

Buildings have functional purposes which are reflected in the types of spaces provided and their configuration. The utility of residential building spaces and the building design and configuration are interrelated components in the evaluation of the performance of the building. There are a number of factors to consider in examining the use of residential building spaces out of which are the user characteristics, the building design typology and the indoor thermal environment. The indoor thermal environment is constituted by the interaction of different factors of the climatic conditions and the building physical and spatial characteristics. The thermal comfort parameters within the building spaces provide an indication of the level of indoor thermal comfort. The residents provide an assessment of the indoor comfort based on their thermal experience within the spaces.

Variations would certainly occur in the distribution and intensity of the thermal comfort parameters from space to space and even within the spaces in a building. The variations are due to differing spatial characteristics due to factors relating to the building design, house type or typology and orientation as well as location and neighbourhood characteristics. The building type and typology are indicative of the design peculiarities.

The variation in the air temperature values within the spaces is indicative of variations in thermal comfort conditions. There have not been many findings concerning the thermal response of people to the indoor environment in Nigeria. According to Ogunsote and Prucnal-Ogunsote (2002), there is paucity of research findings that are based on African people and their indoor thermal experience. The indoor comfort levels in residential buildings in Ibadan as assessed by residents and their use of the spaces was evaluated in a survey with a view to determine the impact of thermal comfort on the functionality of building spaces in the residential design typologies.

Literature Review

The high level of activity, congestion and industrial processes in the cities within the tropical climate contribute to the buildup of heat. All these add to the discomfort experienced within the residential building spaces. The effect of high levels of temperature on the residents' comfort and use of spaces will affect the level of user satisfaction for the buildings. Though comfortable indoor environment is desirable for human activities, in Nigeria however, buildings are thermally uncomfortable for considerable periods. This may be due to poor design standards. Costa (1989) observed that studies of traditional buildings in Nigeria have laid too much emphasis on socio-cultural and economic factors to the neglect of environmental factors. Barozzi et al (1992) stated that there are constraints of extreme environmental conditions, limited financial resources and poor building technology manifesting in low standards of thermal comfort of buildings in many tropical developing countries. According to Givoni (1998), the urban climate and the building indoor climate are both parts of a climatological continuum. There is an operational regional natural climate which is modified at the urban scale by the structure of the town or city. This is further modified at the site scale by the individual building. Similarly, in each building endoclimate, there occurs a definition of different levels of spatial comfort. There is a variety of climatic effects on individuals, buildings and communities and thus architecture and climate have mutual influence.

The study of thermal comfort has taken a psychological dimension along with the initial physiological approach. Whereas the physiological concept laid the foundation for relating the physical parameters of an environment to the thermal state of the body physiology and health, the human subjective psychology gave insight into the human experience of thermal comfort (Fisk 1982; Frank et al 1999; Szokolay 2008). Fisk (1982) asserted that the psychological approach to the study of thermal comfort is more relevant because of the need to decipher the different levels of comfort within different environmental conditions. To buttress this, Frank et al (1999) and Lin et al (2010) also emphasized the role of subjective thermal comfort. The subject of thermal comfort has become more context specific in terms of the human respondent, the climate of the area and the spatial configuration of buildings. The fact that urban building spaces may present diversified thermal conditions due to the different spatio-structural elements means that the thermal comfort experienced by residents within most urban buildings is actually of an adaptive nature. People are certain to make use of the available spaces around them in response to the varying thermal environmental conditions within those diversities of spaces.

The characteristics of building users may actually take a role in the determination of their pattern of use of the room spaces. These characteristics include socio-economic, educational level, enlightenment and intellectual exposure, cultural and traditional values and background. All these affect the personality of building users which ultimately has a notable input in their behavioural tendencies. The behavioural tendencies have an expression in the adaptive actions taken within thermal environments. The adaptive nature of human thermal comfort has been expressed as being a means of extending the comfort conditions within spaces as occupants utilize the adaptive opportunities available to them. The adaptive principle states that if a change occurs such as to produce discomfort, people react in ways which tend to restore their comfort (Nicol and Humphreys 2002). The behavioral tendencies of building users as regards relocation within a space or from space to space as well as adjustments in clothing, posture and activity level all contribute to the attainment of adaptive thermal comfort. Movements within the building as necessary adaptive actions as well as user preferences for more comfortable conditions will contribute to the space use pattern for the residents.

Study Area

Ibadan metropolis, the study area, is located on latitude $7^{\circ}23'N$ and longitude $3^{\circ}55'E$ in the South-Western part of Nigeria (Fig. 1). The climate type is described as

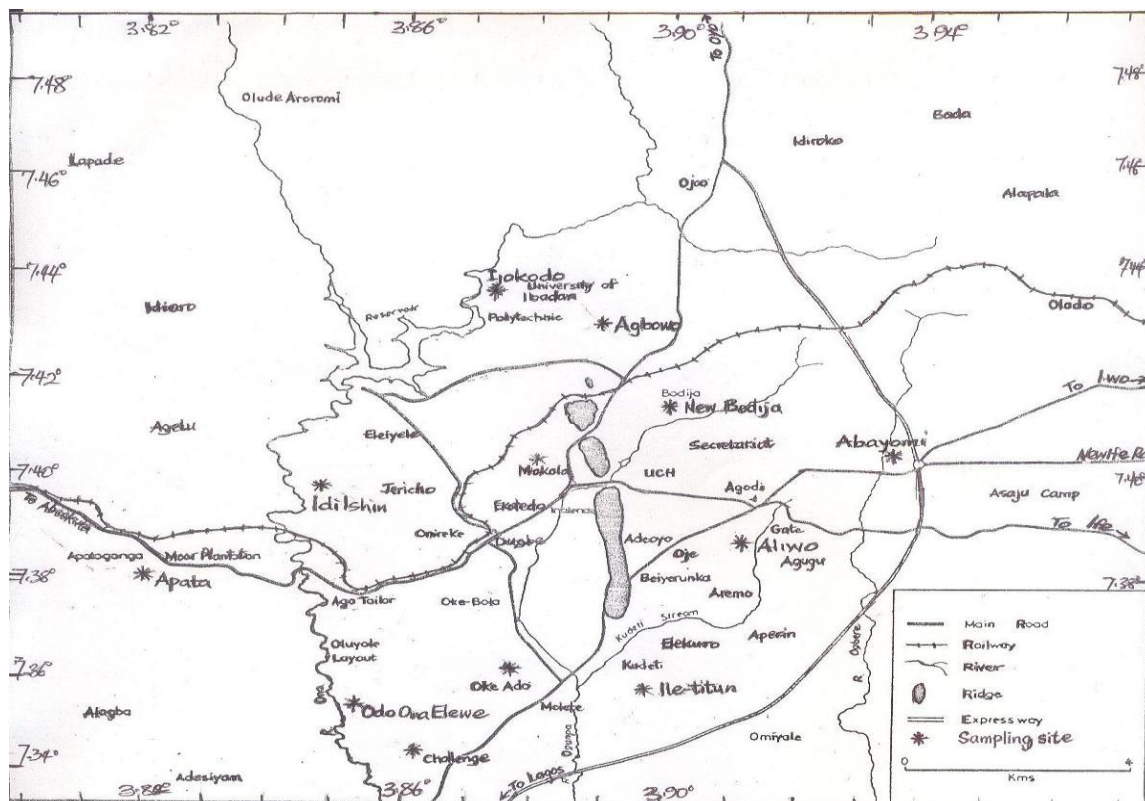


Figure 1: The site of Ibadan.

Source: Adapted from Ayeni (1994).

tropical wet and dry with a lengthy wet season. There are two broad seasonal patterns in Ibadan, namely the dry season (November to April) and the rainy season (May to October) according to Ideriah and Suleman (1989). The selected 12 neighbourhoods for the thermal comfort field survey were the following: Agbowo, Challenge, Aliwo, Mokola, Oke-Ado, Ile-titun and Apata (7 high density neighbourhoods); Abayomi, Ijokodo and Odo-Ona-Eluwe (3 medium density neighbourhoods); New Bodija and Idi-Ishin, (2 low-density neighbourhoods).

Methodology

A thermal comfort survey was conducted in Ibadan metropolis. Ten percent (twelve) of the 119 neighbourhoods identified from the metropolitan map were selected by stratified random sampling comprising two low, three medium and seven high densities. The number of houses in each of the neighbourhoods was estimated to be an average value of 885 based on data from National Bureau of Statistics (2008). A sample size of five percent of this gave 44 houses in each neighbourhood which were selected using systematic random sampling to give a total of 528 houses. An adult member of a household in each selected house was sampled for questionnaire administration. Indoor thermal comfort assessment was done by the respondents using the ASHRAE thermal sensation scale. Respondents also rated their respective building spaces according to use pattern and level of comfort for different periods of the day and their choice of spaces. They indicated their adaptive actions in their respective houses. Indoor and outdoor measurements of relevant climatic elements were done in representative buildings in the neighbourhoods. The weather measuring instruments used comprised the following: La Crosse Technology Instant Transmission Plus Weather Stations which offered immediate update of all outdoor and indoor climatic data measured from transmitters, Smart Sensor Intell Plus Instruments Electronic Anemometers and Multi-Thermo Digital Instruments. The survey was done in April 2010.

Research Findings

Relevant data was collected from the study and analyzed and the findings are hereby discussed in this section under the following sub-headings.

1. Characteristics of the Respondents

A total number of 528 respondents were surveyed in Ibadan metropolis. Out of this number, 271 were male (51.3%) and 257 were female (48.7%). 42.8% of the respondents' were of age 18-30 years, 45.6% were 31-54 years and 11.6% were 55 years and above. There were 171 owner occupiers (32.4%) and 357 tenants (67.6%) identified. With respect to highest educational level attained there were 30 respondents who had primary school education (5.7%), 185 had secondary school education (35%) and 271 had tertiary education (51.3%), 42 had postgraduate education (8%). Concerning their length of stay in their respective houses, 18% had stayed for 1-2 years, 54.7% had stayed for 3-10 years and 27.3% had stayed for over 10 years. The respondents' value judgments were therefore reliable.

2. Characteristics of the Buildings

The residential buildings considered were of diversified characteristics. However, majority of the buildings in Ibadan metropolis were naturally ventilated. The total number of residential buildings sampled was 528 with 88 located in 2 low density

neighbourhoods, 132 located in 3 medium density neighbourhoods and 308 located in 7 high density neighbourhoods. The residential building types consisted of 63 face-to-face bungalows (11.9%), 202 face-to-face storey buildings (38.3%), 107 bungalow flats (20.3%), 107 storey flats (20.3%) and 49 duplex buildings (9.3%). The face-to-face types are built such that rooms are lined up facing one another in two rows with a central

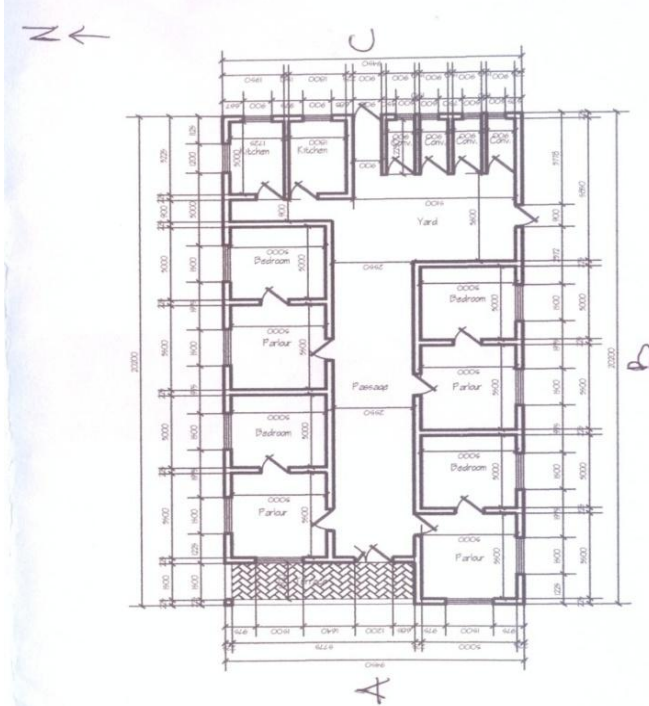


Figure 2: Floor plan of a vernacular face to face building in the study area.

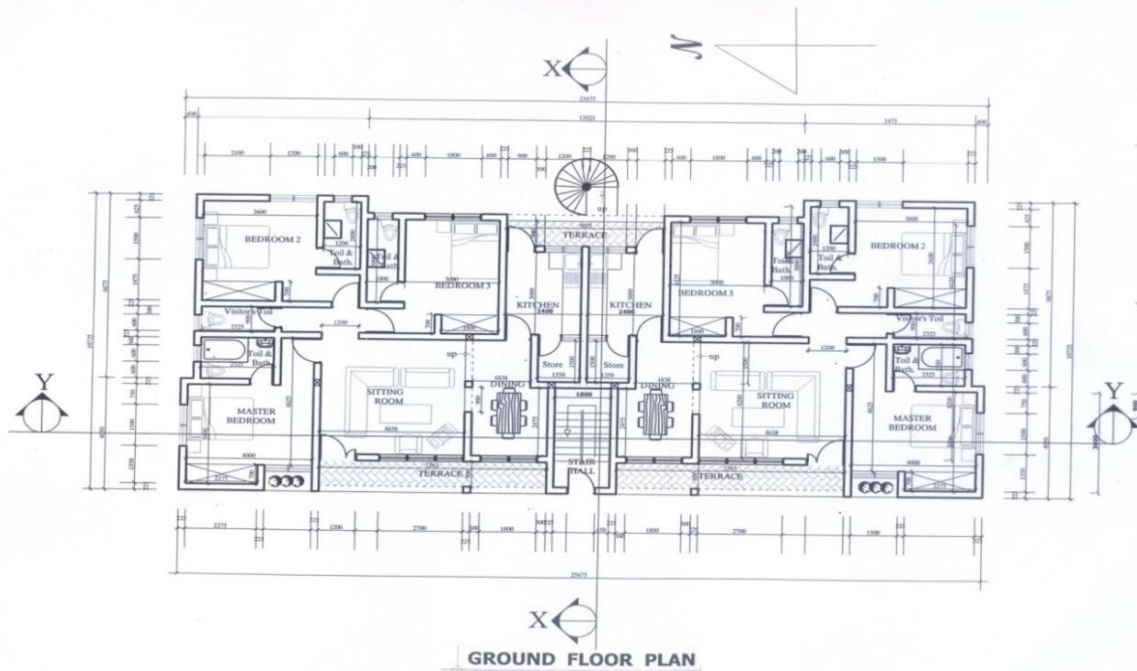


Figure 3: Floor plan of a contemporary block of flats in the study area

corridor space in-between. The storey classification are residential buildings with two or three floors. According to typology, there were 60 traditional buildings (11.4%), 237 vernacular buildings (44.9%) and 231 contemporary buildings (43.8%). Figs. 2 and 3 show the typical floor plans of a vernacular face to face building and a contemporary block of flats in the metropolis. Photographs of typical house types are shown in the Appendix.

3. Thermal Comfort Assessment of the House types

The mean comfort votes of respondent' thermal comfort assessments was categorized into building types. The analysis indicated that the duplex buildings were assessed as the most comfortable building type while the face to face storey buildings were assessed as the most uncomfortable building type during the afternoon period (Table 1). Results also implied that contemporary buildings were assessed as the most comfortable typology while vernacular buildings were assessed as the least comfortable typology (Table 2). The variations in the mean votes of thermal responses for the different building types implied that the different building types presented different indoor thermal conditions. The level of indoor comfort was reflected in the mean comfort vote values. From this it can be deduced that the diversity of building characteristics and location was influential on the thermal responses of the respondents.

Table 1: Assessment of the Mean Comfort Votes of Respondents by Building Type.

Building Type	Mean Comfort Vote
Face to face Bungalow	+1.387
Face to face Storey	+1.535
Flat Bungalow	+0.290
Flat Storey	+0.505
Duplex	-0.918

Source: Adunola (2011).

Table 2: Assessment of the Mean comfort votes of respondents by Typology.

Typology	Mean Comfort Vote
Traditional	+0.831
Vernacular	+1.574
Contemporary	+0.061

Source: Adunola (2011).

4. Measured Indoor Air Temperature Variation in the Building Spaces

The values of air temperatures were measured in the living and bedroom spaces of representative buildings in the neighbourhoods to provide information about temperature variations within the respective buildings. The measurement data for one of the buildings is presented in Table 3 to display typical variations. It was found that the differences in temperature considered from space to space in each of the buildings was only within the range of 0.1 to 0.7 deg C. It was also noted that values were sometimes similar for some adjacent spaces. The variations in air temperature, however slight, inferred that levels of

comfort would be different from space to space in each of the buildings. Similar buildings would also have about the same variation in the temperatures of spaces. It was also inferred that the difference in room temperatures from building to building would be in the same order or less within the same neighbourhood.

Table 3: Measured Values of Air Temperature for All Spaces in a Flat at Mokola.

Time	Outdoor temp (°C)	RH (%)	L (°C)	D (°C)	B ₁ (°C)	B ₂ (°C)	B ₃ (°C)
8	28.9	79	29.8	30.5	30.9	31.2	31.4
10	30.9	77	31.5	31.7	31.6	31.8	31.9
11	32.2	74	31.1	32.2	31.2	32.2	32.2
12	33.4	70	33.0	33.0	33.0	32.9	32.9
13	34.6	67	33.4	33.4	33.4	33.5	33.7
14	36.4	65	34.0	34.0	34.0	33.9	33.8
15	35.0	65	33.7	33.7	33.7	33.6	33.5
18	32	68	31.7	31.6	31.6	31.5	31.7
19	29.4	72	31.4	31.3	31.4	31.2	31.4

Legend: L = Temperature in Living, D = Temperature in Dining, B₁, B₂, B₃...B_N = Temperature in Bedrooms, Temperatures are in °C, R.H. is in %.

Source: Adunola (2011).

5. Respondents' Use and Choice of Spaces and the Most Comfortable Spaces

The respondents rated one of the spaces in their building as the most comfortable for each of the different periods of the day. They also indicated the space where they usually stayed at those periods. The analysis indicated similar results for the most comfortable spaces and the space where respondents stayed at the different periods of the day (Tables 4-11). From the results it was implied that the living room space was the most comfortable and most used space in majority of the buildings surveyed in the study. The bedroom and the verandah and balcony spaces were also indicated as most comfortable and most used spaces in significant percentages of the surveyed buildings. It could be implied from the results that there was remarkable agreement between the most comfortable space, the most used space and the first choice or preferred space as indicated by the respondents. The result agreed with the findings of Merghani (2004) that use patterns are related to comfort level of room spaces. Respondents voted in similar patterns through the four periods of the day with respect to space comfort, space use, space choice and preference. The substantial respondents' votes for the verandah or balcony space as most comfortable, most used and also most preferred or first choice space especially in the afternoon and evening periods implied the importance of these

semi-outdoor spaces in buildings with respect to indoor thermal comfort. The positive influence of semi-outdoor spaces on adaptive thermal comfort was clearly implied by this analysis which showed that many respondents used the verandah or balcony more than other spaces and considered it more comfortable than other spaces in the afternoon and evening periods.

Table 4: Respondents' votes for most used space in the morning by type of accommodation

Type of Accommodation occupied by respondent	Most used in the morning								Total
	Living	Dining	Family	Bedroom1	Bedroom2	Study	Balcony/Verandah	Kitchen	
Face to face bungalow	41	0	1	19	0	0	2	0	63
Face to face storey	126	0	0	67	1	0	6	1	201
Bungalow flat	45	0	4	53	1	3	0	1	107
Storey flat	50	1	4	47	2	1	1	1	107
Duplex	31	2	2	14	0	0	0	0	49
Total	293	3	11	200	4	4	9	3	527

Table 5: Respondents' votes for most comfortable space in the morning by type of accommodation

Type of Accommodation occupied by respondent	Most comfortable in the morning								Total
	Living	Dining	Family	Bedroom1	Bedroom2	Bedroom3	Study	Balcony/Verandah	
Face to face bungalow	42	1	0	17	0	1	0	1	62
Face to face storey	130	2	0	63	1	0	1	4	201
Bungalow flat	53	0	1	50	1	0	2	0	107
Storey flat	45	6	2	49	2	0	2	1	107
Duplex	23	2	5	18	1	0	0	0	49
Total	293	11	8	197	5	1	5	6	526

Table 6: Respondents' votes for most used space in the afternoon by type of accommodation

Type of Accommodation occupied by respondent	Most used in the afternoon									Total
	Living	Dining	Family	Bedroom1	Bedroom2	Bedroom3	Study	Balcony/Verandah	Kitchen	
Face to face bungalow	38	0	0	5	0	0	0	20	0	63
Face to face storey	111	0	7	5	0	1	1	76	0	201
Bungalow flat	67	1	0	11	2	1	1	20	3	106
Storey flat	74	0	1	14	3	0	1	14	0	107
Duplex	34	1	5	7	1	0	1	0	0	49
Total	324	2	13	42	6	2	4	130	3	526

Table 7: Respondents' votes for most comfortable space in the afternoon by type of accommodation

Type of Accommodation occupied by respondent	Most comfortable in the afternoon									Total
	Living	Dining	Family	Bedroom1	Bedroom2	Bedroom3	Study	Balcony/Verandah	Kitchen	
Face to face bungalow	43	1	0	7	0	0	0	11	0	62
Face to face storey	147	1	2	11	0	1	2	37	0	201
Bungalow flat	68	4	0	19	3	0	1	10	2	107
Storey flat	80	3	2	15	3	0	2	2	0	107
Duplex	31	0	4	13	1	0	0	0	0	49
Total	369	9	8	65	7	1	5	60	2	526

Table 8: Respondents' votes for most used space in the evening by type of accommodation

Type of Accommodation occupied by respondent	Most used in the evening										Total
	Living	Dining	Family	Bedroom1	Bedroom2	Bedroom3	Bedroom4	Study	Balcony/Verandah	Kitchen	
Face to face bungalow	31	0	0	3	0	0	0	0	29	0	63
Face to face storey	97	0	1	14	6	0	1	0	82	0	201
Bungalow flat	69	6	1	10	2	0	0	1	17	1	107
Storey flat	78	1	2	12	0	1	0	3	9	1	107
Duplex	37	0	11	1	0	0	0	0	0	0	49
Total	312	7	15	40	8	1	1	4	137	2	527

Table 9: Respondents' votes for most comfortable space in the evening by type of accommodation

Type of Accommodation occupied by respondent	Most comfortable in the evening							Total
	Living	Dining	Family	Bedroom1	Bedroom2	Study	Balcony/Verandah	
Face to face bungalow	35	0	1	8	0	0	19	63
Face to face storey	122	2	0	25	8	0	43	200
Bungalow flat	58	10	0	29	0	1	9	107
Storey flat	65	1	4	31	2	0	4	107
Duplex	34	0	9	6	0	0	0	49
Total	314	13	14	99	10	1	75	526

Table 10: Respondents' votes for most used space in the night by type of accommodation

Type of Accommodation occupied by respondent	Most used in the night								Total
	Living	Dining	Family	Bedroom1	Bedroom2	Bedroom3	Study	Balcony/Verandah	
Face to face bungalow	11	0	0	51	0	0	0	1	63
Face to face storey	46	1	0	141	2	0	0	12	202
Bungalow flat	9	0	1	92	0	1	3	1	107
Storey flat	15	1	2	81	4	2	0	2	107
Duplex	0	0	2	45	2	0	0	0	49
Total	81	2	5	410	8	3	3	16	528

Table 11: Respondents' votes for most comfortable space in the night by type of accommodation

Type of Accommodation occupied by respondent	Most comfortable in the night								Total
	Living	Dining	Family	Bedroom1	Bedroom2	Bedroom4	Study	Balcony/Verandah	
Face to face bungalow	16	1	0	45	0	0	0	1	63
Face to face storey	82	0	0	112	2	0	0	6	202
Bungalow flat	24	5	1	75	0	0	1	1	107
Storey flat	31	3	2	63	5	1	0	2	107
Duplex	3	2	0	44	0	0	0	0	49
Total	156	11	3	339	7	1	1	10	528

6. Correlation of Space Comfort, Space Use and Respondents' Choice

The statistical tool of correlation was used to examine if there was any association between residents' choice of room spaces and the thermal comfort level within the spaces with respect to the assessment of the most comfortable spaces at different times of the day. It was found that the space rated as the most comfortable in the morning by respondents had very strong correlation with the following: where respondents usually stayed in the morning ($r = 0.484$ at 0.000 level of significance (l.o.s.)), first choice of space in morning ($r = 0.508$ at 0.000 l.o.s.), second choice of space in morning ($r = -0.275$ at 0.000 l.o.s.). Also the space where respondents usually stayed in the morning had very strong correlations with the respondents' first choice of space in the morning ($r = 0.662$ at 0.000 l.o.s.) and the respondents' second choice of space ($r = -0.317$ at 0.000 l.o.s.).

It was found that the space rated as the most comfortable in the afternoon by the respondents had very strong correlation with the following: where respondents usually stayed in the afternoon ($r = 0.504$ at 0.000 l.o.s.), first choice of space in afternoon ($r = 0.519$ at 0.000 l.o.s.), second choice of space in afternoon ($r = -0.301$ at 0.000 l.o.s.), third choice of space in the afternoon ($r = -0.103$ at 0.018 l.o.s.). Also, the space where respondents usually stayed in the afternoon had very strong correlation with the

respondents' first choice of space in the afternoon ($r = 0.842$ at 0.000 l.o.s.), respondents' second choice of space in the afternoon ($r = -0.443$ at 0.000 l.o.s.) and respondents' third choice of space ($r = -0.143$ at 0.000 l.o.s.). Similar to afternoon results it was found that the space rated as the most comfortable in the evening by the respondents had very strong correlation with the following: where respondents usually stayed in the evening ($r = 0.580$ at 0.000 l.o.s.), first choice of space in evening ($r = 0.601$ at 0.000 l.o.s.), second choice of space in evening ($r = -0.330$ at 0.000 l.o.s.), third choice of space in evening ($r = -0.097$ at 0.026 l.o.s.). Also, the space where respondents usually stayed in the evening had very strong correlation with the respondents' first second choice of space in the evening ($r = 0.868$ at 0.000 l.o.s.), the respondents' second choice of space in the evening ($r = -0.472$ at 0.000 l.o.s.) and the respondents' third choice of space ($r = -0.174$ at 0.000 l.o.s.). It was also found that the space rated as the most comfortable in the night by the respondents had very strong correlation with where respondents usually stayed in the night ($r = 0.427$ at 0.000 l.o.s.) and the first choice of space in the night ($r = 0.410$ at 0.000 l.o.s.). Also the space where respondents usually stayed in the night had very strong correlation with the first choice of space in the night ($r = 0.404$ at 0.000 l.o.s.).

The above correlation confirmed the earlier results of frequency analysis of the respondents rating of most comfortable space, most usually used space and first choice space at different periods of the day. The strong correlation found between the considered spaces as voted by respondents were at very high levels of significance as indicated confirming the relationships. Room choice correlating with room comfort levels was also reported by studies in Heerwagen et al (1991) and Al-Azzawi (1996). The result of strong and significant correlation inferred that patterns of use of spaces related to comfort levels of room spaces as indicated by Merghani (2004). The lower correlation values for the second choice and third choice spaces as compared to the first choice space for respective periods distinctly indicated that reduced levels of preference for spaces was related to comfort levels. As indicated in the earlier analysis, the first choice space was generally the same space voted as the most comfortable space by the respondents.

7. Influence of Adaptive Actions of Respondents on Space Use

The respondents took adaptive actions to make themselves comfortable in the discomfort of the period considered according to the adaptive principle. Significant percentages of respondents utilized the movement adaptive actions (Table 12). In terms of movement actions of respondents, movement to the verandah, porch or courtyard was utilized most by respondents. This inferred that the verandah, porch and courtyard spaces offered better alternatives of comfort to the respondents compared to the other spaces and the outside. It was inferred from the results that residents moved from space to space and within spaces in relation to the thermal condition of the indoor spaces. This is a pointer to the impact movement adaptive actions made on space use. The observed and recorded adaptive movements of respondents suggested that thermal comfort considerations was utilized by respondents in the use of the building spaces.

Table 12: Movement adaptive actions taken by respondents

Adaptive action	Number of residents utilizing action	Percentage of residents utilizing action	Proportion of use as percentage of all Adaptive actions
Movement to verandah, balcony, porch	280	53.0	9.20
Sitting closer to window or fan	251	47.5	8.25
Movement to outside building	151	28.6	4.96
Movement to different position in room	143	27.1	4.70
Movement to another room	85	16.1	2.80

Source: Adunola (2011).

Conclusion

Indoor thermal comfort is of utmost concern with respect to the use of residential accommodation spaces. It was established that air temperature and the levels of comfort varied from space to space in each building and that pattern of use of spaces was related to the indoor comfort levels. The living room space was voted as the most comfortable and most used space by respondents. The substantial respondents' votes for the verandah or balcony space as most comfortable, most used and also most preferred or first choice space especially in the afternoon and evening periods implied the importance of these semi-outdoor spaces in buildings with respect to indoor thermal comfort. Movement adaptive actions within the residential buildings gave an insight to the influence of thermal comfort on space use. The functional utility of the building spaces has been found to be dependent on their thermal conditions.

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Appendix

Photographs of typical house types in Ibadan metropolis.



A face to face bungalow in the study area.



A face to face storey house in the study area.



A bungalow flat in the study area.



A storey flat in the study area.



A duplex in the study area.



A typical living room space.