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Thermal Indices Influence on Occupants’ Window Opening Behaviours: A Case of Ibadan and Ogbomoso, Oyo State, Nigeria

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ABSTRACT

Window opening operations are considered as one of the significant way of regulating indoor climate and maintaining thermal comfort in buildings, even when alternative active devices such as fans and air conditioners are available. This study investigates responses of occupants of the traditional core areas of Ibadan and Ogbomoso to thermal comfort conditions (thermal stress) through window opening behaviours. Climatic data of the two cities were subjected to Evans scale to predict their day and night thermal stress and questionnaires were administered to know how occupants respond to changing thermal conditions through window opening behaviours. Descriptive and inferential statistics were used in analysing the data. The study found the morning periods to be the most comfortable, the afternoon periods offer the most hot discomfort condition and cold discomfort is mostly experienced in the evening periods in both cities. Findings revealed that majority of occupants in both cities prefer to keep their windows opened in the morning and afternoon periods and an increase was observed in the numbers of occupants who prefer to keep their windows closed in the evening periods. This is an indication that building occupants in both cities actively respond to thermal stress using window opening operations. Results obtained from chi square analysis concluded that there is a significant relationship between occupants’ window opening behaviour and thermal conditions at different periods of the day in both cities. Recommendations were given on how to improve on window opening systems in the future.

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1. Introduction

The concept of comfort in buildings represents the state of building occupants’ satisfaction with the indoor environment [1]. Various scholars have studied the concept of Indoor comfort (IC) in buildings using different approaches and parameters. Among these are sound and acoustic comfort in buildings, light and visual comfort in buildings, ventilation and thermal comfort in buildings, moisture and humidity, odour, colour, ergonomics etc. While all these parameters as they affect human IC are all important, Authors [1-5] all established in their various studies that thermal comfort is of top priority to man. This is because it has a direct effect on occupants’ psychological wellbeing, health and welfare. Thermal comfort is said to be the state with which occupants’ expresses satisfaction with the indoor thermal condition (indoor temperature) of the environment [6].

Buildings must protect occupants against extreme temperatures because they have a direct consequence on occupants’ health and general wellbeing. Factors affecting indoor temperature include Outdoor temperature, Solar radiation, outdoor humidity level, wind velocity, mean radiant temperature-generated from bulbs and other equipments and appliances (mostly cooking appliances) in buildings etc. [7].

The outdoor thermal temperature can be best described in terms of Thermal (heat) Index (TI). According to National weather service [7], TI is a measure of perceived temperature derived from Ambient Outdoor temperature (AOT) and Outdoor Relative Humidity (ORH) used in calculating Thermal Stress (TS). Similarly, Author [4] submitted that TI is a measure of perceived TS imposed by external conditions which is derived from AOT and ORH; it is used to predict the optimal thermal environment needed for comfort in buildings. Simply put, TI is a measure of perceived range of outdoor temperature causing perceived hot and cold discomforts in buildings resulting from AOT and ORH.

Indoor thermal environment varies according to season, just as Indoor thermal comfort is relative to occupants i.e., it is a measure of the subjective feeling of occupants; meaning that a thermal condition that is said to be comfortable for an occupant may not be comfortable for the other. Author [6] put the comfortable limits for occupants condition at about 74-83°F (23-28°C) in the summer and 67-79°F (19-26°C) in the winter seasons.

Considering the climatic condition of Nigeria and other tropical regions which according to Author [6] is characterised by high temperature, high rainfall, high humidity and intense solar radiation, the effect of AOT is heat build-up in indoor spaces and the constant challenges are how to avoid heat from getting into the building and how to swiftly remove such once they get in [9-10]. High TS is hence a general threat to people in Nigeria and other tropical regions and a greater threat to those whose health, economic situation or social circumstances makes them vulnerable to exposure to high temperatures [7]. This has however caused occupants to adopt different measures of regulating their various spaces to suit their IC conditions. Among these is the use of active driven devices such as fans, air conditioners, humidifiers, ventilators, heaters etc. to dissipate heat and regulate Indoor environment mostly used by the rich and affluent [10].

However, these devices are heavily dependent on electricity and the fact that electricity supply in Nigeria is erratic and with very high costs implications makes them uneconomical and unaffordable for the poor who are mostly found in the traditional core areas of cities in Nigeria [9]. Occupants hence resolved to maintain IC by opening windows as a way of responding to high TS [1]. This can also be inferred from the studies of Author [11] who posited that the most common and economical way to control thermal comfort is through window openings and Author [12] who found window opening behaviour of occupants as the most economical and effective way of responding to TS and maintaining good IC. Understanding TI and TS of cities and how occupants respond to them through window opening operations would further assist architects and engineers in delivering buildings devoid of active driven mechanical devices while maintaining indoor comfort of occupants.

This study attempts to establish the thermal indices of Ibadan and Ogbo moso, both in Oyo state, Nigeria and to study the response and attitude of their building occupants to TS through window opening behaviours. The study specifically focuses on residents of the traditional core areas of the two cities that are adjudged by several scholars as being poor and vulnerable and hence cannot afford the cost and maintenance of active driven mechanical devices [13-14].

2. Study Areas

Ibadan lies on latitude 7 degrees, 23 minutes North and Longitude 3 degrees, 55 minutes East of the Greenwich Meridian and falls within the forest region of Nigeria while Ogbo moso is situated on latitude 8 degrees, 10 minutes North and longitude 4 degrees, 10 minutes East of the Greenwich Meridian and falls within the derived savannah region of Nigeria. Both cities are in Oyo state, South west Nigeria. Ibadan is the largest city in the state and Ogbo moso is the second largest [1].
Both cities fall within the warm humid climate like every other towns and cities in the South western part of the country. Hence, their climates are characterised by high temperature, high humidity, high rainfall and a relatively low wind velocity with their maximum temperature rising above 33 degrees and their humidity rising above 89 percent in some months \(^{[15]}\). However, both cities have variations in their microclimatic conditions because of their geographical uniqueness and their level of urbanization \(^{[1]}\).

![Figure 1](image1.jpg)

**Figure 1.** Showing the traditional core area of Ibadan.

*Source:* Google maps, 2020

3. Research Method

The data presented in this study were drawn from a larger research project designed to assess the indoor environmental quality of houses in selected cities in Oyo state, Nigeria. The study subjected 5 years climatic data of Ibadan and Ogbomoso to the Evans heat index scale to determine the day and night thermal stress of the two cities. The climatic data were between the periods of 2011 and 2015. In a study conducted by Authors \(^{[4]}\) in 2003, the Evans heat index scale and the Mahoney tables were adjudged to be the best method of calculating TI of any city, owing to their accuracy, low error of prediction and their ability to predict the day and night comfort conditions.

Questionnaire was used to collect data on the social-economic characteristics of occupants, their tenure status, length of stay in their various houses, their subjective feelings of thermal stress in their various houses at different times of the day (morning, afternoon and evening) and to determine their response and attitudes to TS through window opening operations and behaviours at those periods of the day.

Respondents are expected to express their subjective feeling to indoor temperature on a likert 5 point scale ranging from cool, cold, neutral, warm and hot at those periods of the day and were simply asked to indicate whether they prefer to open their windows or keep them closed anytime they are in their various spaces at those periods as a way of moderating the indoor climate.

Data obtained from the National bureau of statistics (NBS) \(^{[16]}\) indicated that a total number of 5,310 and 5,240 buildings are in the traditional core areas of Ibadan and Ogbomoso respectively. This data was a subset extracted from the broader research project earlier mentioned. 2.5% of buildings were studied in each of the cities and hence, 133 and 131 houses were sampled in Ibadan and Ogbomoso respectively. Summarily, a total of 249 buildings were sampled out of a population of 10,550 buildings. However, 131 questionnaires representing 98.5% were retrieved in Ibadan and 118 (90.1%) questionnaires were retrieved in Ogbomoso. A total of 249 (94.3%) questionnaires were retrieved and analysed. See table 1.

![Figure 2](image2.jpg)

**Figure 2.** Showing the traditional core area of Ogbomoso

*Source:* Google maps, 2020

| Study areas | No of buildings in the study areas (Population) | No of buildings studied (Sample) | No of questionnaires retrieved | Percentage of questionnaires retrieved |
|-------------|-----------------------------------------------|---------------------------------|-------------------------------|--------------------------------------|
| Ibadan      | 5,310                                         | 133                             | 131                           | 98.5                                 |
| Ogbomoso    | 5,240                                         | 131                             | 118                           | 90.1                                 |
| Total       | 10,550                                        | 264                             | 249                           | 94.3                                 |

Simple random sampling technique was adopted to select houses studied in each of the city. This was done after the areas had been divided into segments and houses in each segment have been numbered. An adult respondent of above 18 years was simply selected in a building to be studied.

Descriptive and inferential methods of analysis were employed to analyse the data. Chi-square was used to determine the relationship between respondents’ attitude to windows openings and periods of the day. Findings are discussed below.
4. Findings and Discussions

4.1 Evans Scale

As earlier mentioned, Author [4] in 2003 posited that the Evans heat index scale and the Mahoney tables were adjudged to be the best method of calculating TI of any city in Nigeria, owing to their accuracy, low error of prediction and their ability to predict the day and night comfort conditions. The Evans scale employs air temperature and relative humidity to predict the thermal stress [10]. See Table 2:

| Relative humidity (%) | Day comfort limits (°C) | Night comfort limits (°C) |
|-----------------------|-------------------------|---------------------------|
| 0-30                  | 29.5-32.5               | 27.5-29.5                 |
| 30-50                 | 28.5-30.5               | 26.5-29                   |
| 50-70                 | 27.5-29.5               | 26-28.5                   |
| 70-100                | 26-29                   | 25.5-28                   |

Source: Author [10]

Table 2. Comfort limits proposed by Evans

4.2 The Comfort Condition (Thermal stress) in Ibadan and Ogbomoso

Table 4. Climatic data of Ibadan

| Month  | Temp. °C (Max.) | Temp. °C (Min.) | Temp. °C Mean monthly | RH(AM) % | RH(PM) % | Rainfall (mm) | Radiation MJ/m²/day | Wind Speed(m/s) |
|--------|----------------|----------------|-----------------------|---------|---------|--------------|---------------------|-----------------|
| Jan    | 33.6           | 19.7           | 26.7                  | 78.8    | 28.0    | 1.3          | 14.2                | 0.98            |
| Feb    | 35.0           | 21.8           | 28.4                  | 93.7    | 30.2    | 12.8         | 15                  | 1.16            |
| March  | 34.6           | 23.1           | 28.9                  | 96.4    | 38.0    | 66.9         | 17.3                | 1.22            |
| April  | 33.1           | 23.2           | 27.0                  | 98.1    | 59.5    | 174.3        | 16.2                | 0.99            |
| May    | 31.6           | 22.3           | 27.0                  | 98.1    | 59.5    | 174.3        | 16.2                | 0.99            |
| June   | 30.0           | 21.8           | 25.9                  | 98.8    | 63.8    | 233.6        | 13.9                | 0.96            |
| July   | 28.1           | 21.5           | 24.8                  | 99.0    | 67.7    | 195.7        | 11.7                | 0.92            |
| August | 27.6           | 21.3           | 24.5                  | 99.6    | 72.4    | 109.7        | 12.8                | 0.87            |
| September | 29.2       | 21.5           | 25.4                  | 98.2    | 68.2    | 197.7        | 12.8                | 0.87            |
| October | 29.1          | 21.7           | 26.0                  | 98.1    | 60.8    | 187.9        | 13.3                | 0.83            |
| November | 31.9         | 22.6           | 27.3                  | 98.2    | 49.6    | 28.9         | 15.2                | 0.81            |
| December| 32.5           | 20.9           | 26.7                  | 95.6    | 35.4    | 1.2          | 13.5                | 0.78            |
| Average | 31.4           | 21.8           | 26.6                  | 96.0    | 52      | 14.2         | 0.98                |                |

Source: Author [10]

Table 5. Human Comfort condition (Thermal stress for Ibadan)

| Ibadan 2011-2015 | Jan | Feb | Mar | Apr | May | June | Jul | Aug | Sep | Oct | Nov | Dec |
|------------------|-----|-----|-----|-----|-----|------|-----|-----|-----|-----|-----|-----|
| Monthly Mean Max Temperature (°c) | 33.6 | 35.0 | 34.6 | 33.1 | 31.6 | 30.0 | 28.1 | 27.6 | 29.2 | 29.1 | 31.9 | 32.5 |
| Monthly Mean Min. Relative Humidity (%) | 28.0 | 30.2 | 38.0 | 51.1 | 59.5 | 63.8 | 67.7 | 72.4 | 68.2 | 60.8 | 49.6 | 35.4 |
| Day Thermal Stress | + | ++ | + | + | + | 0 | 0 | 0 | + | + | + | + |
| Monthly Mean Min Temperature (°c) | 19.7 | 21.8 | 23.1 | 23.2 | 22.3 | 21.8 | 21.5 | 21.3 | 21.5 | 21.7 | 22.6 | 20.9 |
| Monthly Mean Max. Relative Humidity (%) | 78.8 | 93.7 | 96.4 | 97.2 | 98.1 | 98.8 | 99.0 | 99.6 | 98.2 | 98.1 | 98.2 | 95.6 |
| Night Thermal Stress | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |

Source: Authors’ Analysis, 2020.
Table 6. Climatic data of Ogbomoso.

| Month     | Temp. °C (Max.) | Temp. °C (Min.) | Temp. °C Mean monthly | RH(AM) % | RH(PM) % | Rainfall (mm) | Radiation MJ/m²/day | Wind Speed (m/s) |
|-----------|----------------|----------------|-----------------------|----------|----------|---------------|---------------------|-----------------|
| Jan       | 35.5           | 19.6           | 26.6                  | 66.3     | 41.3     | 0.3           | 12.1                | 1.47            |
| Feb       | 34.8           | 20.5           | 27.7                  | 68.2     | 35.9     | 10.8          | 12.8                | 1.45            |
| March     | 34.6           | 22.6           | 28.6                  | 62.6     | 46       | 47.7          | 13.6                | 1.44            |
| April     | 33.1           | 22.2           | 27.7                  | 77.2     | 61       | 103.2         | 13.1                | 1.42            |
| May       | 32.0           | 22.2           | 27.1                  | 80.8     | 65.6     | 149.5         | 12.3                | 1.51            |
| June      | 30.9           | 21.8           | 26.4                  | 84.7     | 69.1     | 180.1         | 10.9                | 1.51            |
| July      | 29.3           | 21.5           | 25.4                  | 89.1     | 71.6     | 181.6         | 9.7                 | 1.49            |
| August    | 28.9           | 20.8           | 24.9                  | 84.8     | 73.6     | 141.3         | 8.9                 | 1.47            |
| September | 29.4           | 20.8           | 25.1                  | 87.3     | 71.6     | 222.6         | 9.5                 | 1.5             |
| October   | 31.3           | 19.6           | 25.5                  | 85.3     | 66.3     | 185.2         | 10.6                | 1.47            |
| November  | 33.0           | 20.5           | 26.8                  | 83.5     | 54.9     | 79.7          | 11.9                | 1.47            |
| December  | 33.2           | 18.7           | 26.0                  | 73.9     | 44.5     | 12.2          | 11.8                | 1.43            |
| Average   | 31.9           | 20.9           | 26.4                  | 78.6     | 58.5     | 11.4          | 1.47                |                 |

Source: Author [1]

Table 7. Human Comfort condition (Thermal stress for Ogbomoso)

| Month     | Night Thermal Stress | Day Thermal Stress | Night Thermal Stress | Day Thermal Stress |
|-----------|----------------------|--------------------|----------------------|--------------------|
| Jan       | ++                   | +                  | ++                   | +                  |
| Feb       | +                    | +                  | +                    | ++                 |
| March     | ++                   | +                  | ++                   | +                  |
| April     | +                    | ++                 | +                    | ++                 |
| May       | ++                   | +                  | ++                   | +                  |
| June      | ++                   | +                  | ++                   | +                  |
| July      | ++                   | +                  | ++                   | +                  |
| August    | +                    | +                  | ++                   | +                  |
| September | ++                   | +                  | ++                   | +                  |
| October   | ++                   | +                  | ++                   | +                  |
| November  | ++                   | +                  | ++                   | +                  |
| December  | ++                   | +                  | ++                   | +                  |
| Average   | ++                   | +                  | ++                   | +                  |

Source: Authors’ Analysis, 2020.

Analysis from the Evans heat index scale reveals that Ibadan witnesses a comfortable thermal condition during the day for four months which are: July, August, September and October. The city experiences hot discomfort throughout the rest of the months except February which presents a very hot discomfort condition. Cold discomfort is experienced at night throughout the year except January which presents a very cold discomfort condition.

The thermal condition of Ogbomoso is very different from that of Ibadan. Comfortable condition is experienced during the day in just one month which is August; the city experiences hot discomfort during the day throughout the rest of the months and even experiences a very hot discomfort condition in January. Cold discomfort is experienced at night for 5 months; these months are March, April, May, June and July. Very cold discomfort condition is experienced at night throughout the rest of the months.

4.3 Residents’ Social-economic Characteristics

Data obtained from field work revealed that 49.6% respondents in Ibadan are male while 50.4% are female. Similarly, 39.0% respondents in Ogbomoso are male while 60.2% are female (see table 8). Respondents’ age distribution in the study areas indicated that majority of the respondents in the two cities falls between the age ranges of 31-45 years. This age structure makes up 74.0% of the respondents in Ibadan and 45.8% of the respondents in Ogbomoso. Second to this are those that fall between the ages of 18-30 years with Ibadan having 15.3% and Ogbomoso having 26.3%.

Data also revealed that 90.1% respondents in Ibadan are married while only 9.9% are single. Also, 84.7% respondents in Ogbomoso are married while only 14.4% are single. Obtained data revealed that 71.8% of respondents in the traditional core of Ibadan either have no formal education or does not complete primary school, 15.3% completed primary school, 9.2% completed secondary school and only 3.8% have a tertiary education. Similarly, 91.5% respondents in Ogbomoso have either an incomplete primary education or no formal education at all, only 6.8% completed primary education and 1.7% has a secondary
Table 8. Residents socio-economic characteristic

| Cities       | Socio-economic characteristics | Attributes | Frequency (%) | Percentage (%) |
|--------------|---------------------------------|------------|--------------|---------------|
| Ibadan       | Sex                              | Male       | 65           | 49.6          |
|              |                                  | Female     | 66           | 50.4          |
|              | Total                            |            | 131          | 100           |
| Ogbomoso     | Male                             | 46         | 3.6          |
|              | Female                           | 71         | 60.2         |
|              | Total                            |            | 118          | 100           |
| Ibadan       | Age                              | 18 - 30 years | 20    | 15.3          |
|              |                                  | 31 - 45 years | 97    | 74.0          |
|              |                                  | 46 - 60 years | 04    | 3.1           |
|              |                                  | 61 - 70 years | 00    | 00            |
|              |                                  | 71 and above | 00    | 00            |
|              | Total                            |            | 131          | 100           |
| Ogbomoso     | Male                             | 29         | 25.2         |
|              | Female                           | 41         | 35.9         |
|              | Total                            |            | 118          | 100           |
| Ibadan       | Educational Status               | No formal education | 47    | 35.9          |
|              |                                  | Pry. Sch. Incomplete | 47   | 35.9          |
|              |                                  | Pry. Sch. Complete | 20   | 15.3          |
|              | Total                            |            | 131          | 100           |
| Ogbomoso     | No formal education              | 67         | 56.8         |
|              | Pry. Sch. Incomplete             | 41         | 34.7         |
|              | Pry. Sch. Complete               | 08         | 6.8          |
|              | Total                            |            | 118          | 100           |
| Ibadan       | Monthly Income                   | Below ₦18,000.00 | 97    | 74.0          |
|              |                                  | ₦18,000 - ₦25,000 | 25    | 21.2          |
|              |                                  | ₦25,100 - ₦40,000 | 02    | 1.7           |
|              |                                  | Total       | 131          | 100           |
| Ogbomoso     | No formal education              | 05         | 5.1          |
|              | Pry. Sch. Incomplete             | 06         | 5.1          |
|              | Pry. Sch. Complete               | 06         | 5.1          |
|              | Total                            |            | 118          | 100           |
| Ibadan       | Occupation                       | Student/Apprentice | 05    | 3.8           |
|              |                                  | Farmer      | 10          | 7.6           |
|              |                                  | Artisan     | 44          | 33.6          |
|              |                                  | Trading     | 44          | 33.6          |
|              | Total                            |            | 131          | 100           |
| Ogbomoso     | Civil Servant                    | 06          | 5.1          |
|              |                                  | Pensioners  | 00          | 00            |
|              |                                  | Clergy      | 01          | 0.8           |
|              | Total                            |            | 118          | 100           |
| Ibadan       | Marital Status                   | Single      | 13          | 9.9           |
|              |                                  | Married     | 118         | 90.1          |
|              | Total                            |            | 131          | 100           |
| Ogbomoso     | Single                           | 17          | 14.4         |
|              | Married                          | 100         | 84.7         |
|              | Total                            |            | 118          | 100           |

Source: Authors’ fieldwork.
school certificate and none of the respondents have a tertiary education.

Occupation distribution in the study areas revealed that majority of respondents in the two cities are either artisans or traders i.e., 33.6% and 33.6% respondents in Ibadan are artisans and traders respectively and 29.7% and 59.2% respondents in Ogbomoso are artisans and traders respectively. 20.6% respondents in Ibadan are civil servants, 7.6% are farmers and 3.8% are either students or an apprentice. 5.1% respondents in Ogbomoso are civil servants, another 5.1% are farmers and 5.1% are either students or serving as an apprentice.

Data gathered on the monthly income distribution of respondents in the two study areas indicated that 74.0% and 72.9% respondents in Ibadan and Ogbomoso respectively earn below 18,000 naira per month, this implies that they earn less than the minimum wage in Nigeria and hence lives in abject poverty [17]. This further justifies their inability to afford the cost of procurement, operating and maintenance of active driven mechanical devices used in achieving comfort in indoor spaces. 20.6% and 21.2 % respondents in Ibadan and Ogbomoso respectively earn between 18,000 and 25,000 naira per month. 5.3% respondents in Ibadan earn between 25,100 and 40,000 naira per month and no respondent earns above that in a month. However, in Ogbomoso, 1.7% respondents earn between 25,100 and 40,000 naira per month, 1.7% earns between 60,100 and 80,000 naira per month and 2.5% earn above 80,000 naira per month.

4.4 Respondents Tenure Status and Length of Stay

Data on the tenure status of respondents revealed that 21.4% of respondents in Ibadan are owners of their various houses, 38.2% lives in rented apartments and 39.7% houses freely. Similarly, 28.8% respondents in Ogbomoso are owners of their houses, 31.4% lives in rented apartments and 33.9% houses freely.

Data also revealed that 42.7 % respondents in Ibadan have lived in their various houses for between 2- 5 years, 33.6% have lived for between 6-10 years and 19.1 have stayed in their various houses for over 10 years. Similarly, 16.9% respondents in Ogbomoso have lived in their various houses for between 2- 5 years, 17.8% have lived for between 6-10 years and 56.8% have stayed in their various houses for over 10 years. This implies that 95.4% and 91.5% of respondents in Ibadan and Ogbomoso respectively have lived in their various houses for over two (2) years which makes them suitable for the study.

| Cities | Socio-economic characteristics | Attributes | Frequency (%) | Percentage (%) |
|--------|--------------------------------|------------|---------------|----------------|
| Ibadan | Owner Occupier                 | 28         | 21.4          |
|        | Renter                         | 50         | 38.2          |
|        | Free Houser                    | 52         | 39.7          |
|        | Others                         | 1          | 0.8           |
|        | Total                          | 131        | 100           |
|        | Owner Occupier                 | 34         | 28.8          |
| Ogbomoso| Renter                         | 37         | 31.4          |
|        | Free Houser                    | 40         | 33.9          |
|        | Others                         | 7          | 5.9           |
|        | Total                          | 118        | 100           |
|        | Less than 2 years              | 05         | 3.8           |
|        | 2 years - 5 years              | 56         | 42.7          |
|        | 6 years - 10 years             | 44         | 33.6          |
|        | Over 10 years                  | 25         | 19.1          |
|        | No Response                    | 01         | 0.8           |
|        | Total                          | 131        | 100           |
|        | Less than 2 years              | 10         | 8.5           |
|        | 2 years - 5 years              | 20         | 16.9          |
|        | 6 years - 10 years             | 21         | 17.8          |
|        | Over 10 years                  | 67         | 56.8          |
|        | Total                          | 118        | 100           |

Source: Authors field work.

4.5 Respondents' subjective Feelings of Thermal Stress in the Study Areas (Thermal Comfort Sensations)

The subjective feelings of respondents towards thermal stress in the two study areas at different times of the day (morning, afternoon and evening) were assessed on a likert 5 point scale ranging from cold, cool, Neutral, warm and hot. Data obtained in Ibadan indicated that 21.4% respondents feel cold in the morning, 11.5% feel cool, 64.1% feel comfortable, 2.3% feel warm and 0.8% feels hot. However, 2.3% feel cool in the afternoon, 9.2% feel comfortable, 44.3% feel warm and 44.3% feel hot while 37.4% feel cool in the evening, 45% feel comfortable, 16.8% feel warm and 0.8% feels hot.

Data obtained from Ogbomoso on the other hand indicated that no respondent feels cold discomfort in the morning, 15.3% feel cool, 38.1% feel comfortable, 25.4% feel warm and 21.2% feel hot discomfort. 2.5% respondent indicated that they feel cold discomfort in the afternoon, 0.8% feels cool, 1.7% feels comfortable, 0.8%
feels warm and 94.1% feel hot discomfort. 4.2% respondents also indicated that they feel cold discomfort in the evening, 40.7% feel cool, 18.6% feel comfortable, 19.5% feel warm and 16.9% feel cold discomfort.

It can be inferred from this result that while 64.1% respondents in Ibadan feel comfortable in the morning period, only 38.1% respondents feel comfortable in Ogbomoso. Whereas only 3.1% respondents feel either warm or hot in Ibadan in the morning, 46.6% respondents in Ogbomoso either feel warm or hot discomfort. Data obtained also revealed that while 9.2% respondents feel either warm or hot discomfort in Ibadan in the afternoon period as against 46.6% respondents in Ogbomoso, 88.6% respondents feel either warm or hot discomfort in Ibadan in the afternoon period as against 94.9% who feel either warm or cold discomfort in Ogbomoso. This period of the day however offers the greatest hot discomfort conditions in the two cities.

45% respondent indicated that they feel comfortable in Ibadan during the evening periods while only 18.6% feel comfortable in Ogbomoso. Similarly, while 17.6% respondents feel either warm or hot discomfort in Ibadan in the evening period, 36.4% feel either warm or hot discomfort in Ogbomoso.

This result has however shown that the climate of Ibadan is more comfortable than that of Ogbomoso and this is in line with the objective findings presented by the Evans scale.

### 4.6 Residents’ Response to Thermal Stress through Window Openings

Data obtained from the respondents attitudinal response to thermal stress at these periods of the day shows that 98.5% respondents in Ibadan prefer to leave their windows opened in the morning while 1.5% prefers to leave them closed. Similarly, 94.7% prefer to leave their windows opened in the afternoon as against the 5.3% that prefer leaving them closed and 74% prefer leaving them opened in the evening as against 26% who prefer leaving them closed.

However, 94.1% respondents in Ogbomoso prefer to leave their windows opened both in the morning and afternoon periods as against 5.9% who prefer closing their windows at both periods of the day. However, 66.9% respondents prefer leaving their windows opened in the evening as against 33.1% who prefer leaving them closed.

Chi-square analysis was used to determine whether there is a significant relationship between residents’ response to thermal stress through window openings and periods of the day or not. Result obtained indicated that their relationship is significant at 0.05 significant level in the two cities (χ² = 46.43, df = 2 and p value = 0.000 in Ibadan and χ² = 45.45, df = 2 and p value = 0.000 in Ogbomoso).

### Table 10. Residents subjective feelings of thermal stress in the study area at different periods of the day

| City   | Periods of the Day | Indoor Temperature Feeling |
|--------|-------------------|---------------------------|
|        |                   | Cold | Cool | comfortable | Warm | Hot | Total |
| Ibadan | Morning           | 28 (21.4) | 15 (11.5) | 84 (64.1) | 03 (2.3) | 01 (0.8) | 131 (100) |
|        | Afternoon         | 00 (00) | 03 (2.3) | 12 (9.2) | 58 (44.3) | 58 (44.3) | 131 (100) |
|        | Evening           | 00 (00) | 49 (37.4) | 59 (45.0) | 22 (16.8) | 01 (0.8) | 131 (100) |
| Ogbomoso| Morning          | 00 (00) | 18 (15.3) | 45 (38.1) | 30 (25.4) | 25 (21.2) | 118 (100) |
|        | Afternoon         | 03 (2.5) | 01 (0.8) | 02 (1.7) | 04 (0.8) | 111 (94.1) | 118 (100) |
|        | Evening           | 05 (4.2) | 48 (40.7) | 22 (18.6) | 23 (19.5) | 20 (16.9) | 118 (100) |

**Note:** Figures outside brackets represents frequencies; Figures in brackets represents percentages.

**Source:** Authors fieldwork.

### Table 11. Residents’ response and attitude to thermal stress through window openings for indoor comfort in the study areas

| Cities   | Window Opening conditions | Periods of the Day |
|----------|---------------------------|--------------------|
|          |                            | Morning Freq. (%)  | Afternoon Freq. (%) | Evening Freq. (%) |
| Ibadan   | Opened                    | 129 (98.5)         | 124 (94.7)         | 97 (74.0)         |
|          | Closed                    | 02 (1.5)           | 07 (5.3)           | 34 (26.0)         |
|          | Total                     | 131 (100)          | 131 (100)          | 131 (100)         |
| Ogbomoso | Opened                    | 111 (94.1)         | 111 (94.1)         | 79 (66.9)         |
|          | Closed                    | 07 (5.9)           | 07 (5.9)           | 39 (33.1)         |
|          | Total                     | 118(100)           | 118(100)           | 118(100)          |

**Note:** Figures outside brackets represents frequencies; Figures in brackets represents percentages.

**Source:** Authors fieldwork.
4. Conclusion

The results from the Evans scale revealed that hot or very hot discomfort is experienced in most of the months in the two cities (8 months in Ibadan and 11 months in Ogbomoso) and cold or very cold nights is experienced in the two cities throughout the year. Through the subjective assessment, the study found that occupants’ experiences a more comfortable condition in the morning periods in the two cities (64.1% and 38.1% in Ibadan and Ogbomoso respectively), the afternoon periods presents the highest hot discomfort condition in the two cities (88.3% and 94.9% in Ibadan and Ogbomoso respectively) and cold discomfort is mostly felt in the evening periods in the two cities (37.4% and 44.9% in Ibadan and Ogbomoso respectively). This result however aligns with the results of the Evans scale.

The study however realised that over 90% of occupants in the two cities prefer to keep their windows opened in the morning and afternoon periods when comfortable and hot discomfort conditions are mostly experienced and only less than 10% prefers keeping their windows closed during those periods. Findings also revealed that there is a rise in the number of occupants who prefer to keep their windows closed in the evening periods (26.0% and 33.1% in Ibadan and Ogbomoso respectively) and cold discomfort condition present the highest cold discomfort condition.

The outcome of the study has clearly shown that occupants in the two study areas respond actively to thermal stress in their various buildings by keeping their windows either opened or closed depending on the thermal condition of the environment and periods of the day. This is also in line with the results obtained from the chi-square analysis which found a significant relationship between residents’ response to thermal stress through window openings and periods of the day in the two cities.

The study has further proven that building occupants effectively use window openings to moderate indoor climates in achieving balanced thermal conditions and hence, the study is in line with the findings of Authors[11] and [12] who both found window opening behaviours of occupants as the most effective, efficient and economical way of achieving comfort in buildings. Architects should hence come to the awareness that window opening is one of the most effective ways IC can be maintained with or without active driven devices and should:

1. Concentrate more on window opening systems and designs vis-a-vis Type, number and sizes which would be capable of achieving comfort in their proposed design.
2. Ensure good window positions and orientations in order to maximize their effectiveness.
3. Take decisions on window designs right from design inception with special attention to construction and operation, details and specifications.

If possible, future researches should look further into the effect of privacy, persisting cultural practices, the organization of buildings in relation to density and use of thermal indices and window openings behaviours or operations in various places.

Abbreviations

The following is the list of abbreviations used in the study

IC - Indoor comfort
TI - Thermal (heat) Index
AOT - Ambient Outdoor temperature (°c)
ORH - Outdoor Relative Humidity (%)
TS - Thermal Stress

Conflict of Interest

The authors have not declared any conflict of interest.

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