# OCCUPANT'S THERMAL PERCEPTION IN MIXED-MODE OFFICE BUILDINGS OF THE TROPICAL CLIMATE

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**ABSTRACT:** *Thermal comfort and energy consumption in office buildings is a global critical concern. This study investigated this challenge in the Faculty of Environmental Technology, Abubakar Tafawa Balewa University, Bauchi-Nigeria. Through a field survey and physical environment measurements. The study explored occupant perceptions of thermal comfort and satisfaction. It evaluated the thermal comfort and satisfaction of occupants in a mixed-mode office building, focusing on potential discrepancies between perceived comfort and internationally recommended standards. Despite air temperatures falling outside the PMV model's comfort range, high thermal comfort, and satisfaction levels were reported by the respondents. These findings align with other studies in Nigeria, suggesting adaptation and acclimatization to local conditions. The study further examined the relationship between thermal comfort and occupant satisfaction. The result revealed a moderate positive association, suggesting increased thermal comfort leads to higher satisfaction among occupants. While thermal comfort explained 25% of the variance in satisfaction scores. Finally, the study suggests the localization of comfort standards, improved mixed-mode system performance, and encouraging evidence-based design interventions that will ultimately benefit both occupants and the environment.*

**KEYWORDS:** Thermal Comfort, Thermal Perception, Mixed-Mode Office, Energy Consumption


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## INTRODUCTION

Energy consumption in office buildings is rapidly increasing globally, as a result of occupant's thermal comfort requirements and climate change. Global warming and the excessive use of energy and natural resources threaten the sustainability of life on Earth. Providing a habitable indoor climate through cooling represents the most significant energy end-use in buildings (Williams *et al*., 2019; Gaffoor, *et al*., 2022). International Energy Agency (IEA) reports that the building sector is responsible for 38% of global energy consumption and nearly 40% of direct and indirect greenhouse gas ($CO_2$) emissions (IEA, 2022). Global carbon dioxide emissions attributed to space cooling have increased threefold from 1990 to 2016 amounting to 1,130 million tonnes (IEA, 2018). The Energy Information Administration (EIA) estimated a growth trend of 56.0% from 2014 to 2020. The analysis carried out by the US Energy Information Administration estimates that, by 2030, global energy consumption will have grown by over 70% (EIA, 2017). The latter shows that the increase in world energy consumption is considerable, and therefore, there is a need to focus on saving energy in the highest-demand sectors. Establishing an acceptable sufficient indoor climate without increasing energy use is one of the greatest world challenges in our contemporary time (Runa *et al.,* 2019).

Nigeria had an annual Gross Domestic Product (GDP) of 440.8 billion US dollars billion dollars in 2021 (National Bureau of Statistics (NBS), 2021), and has an average annual GDP growth rate of 3.46 % (NBS, 2023). Also, the Construction industry accounts for 16% of Nigeria's GDP (NBS, 2023). The implication of these growths in the economy, global warming, and population, will inevitably increase the demand for energy in the coming decades (IEA, 2021). The main function of a building is to provide and maintain a comfortable indoor environment with the lowest energy consumption (Šujanová et al., 2019). Energy efficiency as defined by the Environmental and Energy Study Institute (EESI) simply means using less energy to perform the same task by eliminating energy waste. Energy efficiency brings about a variety of benefits, among which are; reducing greenhouse gas emissions, reducing energy demand, and lowering costs for households and the economy (EESI, 2019). Several studies indicate that assuring adequate thermal comfort conditions inside buildings is essential not only for the health of the occupants but also in terms of productivity and efficiency (de Dear, 2015).

Mixed-mode buildings integrate natural and artificial ventilation systems to provide human thermal comfort and save energy (Chen, 2018). The basic concept of mixed-mode ventilation is to maintain satisfactory indoor environments by alternating between and combining natural and mechanical systems (Yan *et al*., 2015; Chen, 2018), depending on the operation. Mixed-mode ventilation is directly linked to sustainable solutions in buildings, allowing thermal variations where occupants can exercise control and meet their own needs (Alessi, 2015). Most office buildings in this study area operate under a mixed-mode system. Studies have also found the importance of people controlling their environment and established that in those situations, occupants became more satisfied with both their thermal conditions and the space they were in (Alessi, 2015; Hamza *et al*., 2022).

Thermal comfort is one of the most important aspects of the quality of the indoor environment and has thus gained a great deal of interest from many researchers (Chen, 2018). Thermal comfort is a subjective state of mind where people feel thermally comfortable within a given environment (Hamza *et al*., 2022). The most widely used definition describes thermal comfort as that condition of mind that expresses satisfaction with the thermal environment (ASHRAE


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55, 2017). Thermal comfort is subjective and therefore, the study of occupant's thermal perception is paramount in understanding their comfort and satisfaction. The design and construction of buildings are currently subject to a growing set of requirements concerning sustainability and energy efficiency (Castaño *et al*., 2018). Several studies indicate that assuring adequate thermal comfort conditions inside buildings is essential not only for the health of the occupants but also in terms of productivity and efficiency (de Dear, 2015).

Building energy efficiency guidelines for Nigeria (BEEG, 2017) declared that, globally, office buildings account for 50 – 60% of total electricity consumption, most of which goes to cooling systems (Adamu, Gillott, & Boukhanouf, 2019). This has called for the professionals of the building industry to aggressively face the critical challenge of reducing building energy demand (Zhang *et al*., 2022; Sun & Hong, 2017), through a robust utilization of energy-conscious ways of designing and constructing buildings, to counterbalance the universal energy deficit. The global advocacy for the reduction of buildings' energy consumption is largely due to the threats of climate change as contained in the 2030 agenda for sustainable development goals (United Nations, 2022). Research efforts concerning building energy consumption are steadily making progress by focusing more attention on thermal comfort and mixed-mode ventilation systems, which is a result of increased awareness of climate change (Rupp, Vasquez, & Lamberts, 2015).

The aforementioned formed the basis for conducting a field survey in the Faculty of Environmental Technology, Phase II, Abubakar Tafawa Balewa University, Bauchi- Nigeria to determine the building occupants' perception of thermal comfort, alongside, on-site physical environmental parameter measurements of indoor spaces. The main focus is to investigate the occupant's thermal comfort and satisfaction with a view to proper solutions that can have a considerable impact on the occupant's comfort and energy consumption.

**Statement of the Problem**

Indoor thermal comfort is essential for occupants' well-being, productivity, and efficiency. The tropical climate with its high temperatures and intense solar radiation is becoming hotter and drier, thus, providing indoor thermal comfort and reducing energy use in office buildings is becoming increasingly difficult. This has called for new ways of thinking and re-evaluation of the existing methods of tackling this problem, especially in Bauchi-Nigeria (Oluwafemi, 2010). It is commonly believed that warm indoor temperatures and the ensuing thermal discomfort result in decreased productivity/ performance and mental acuity (de Dear *et al.,* 2015). The quality of the indoor environment has an important role in providing thermal comfort and improving the productivity of the users, especially in office buildings (Hauge *et al*., 2011). Roelofsen (2002) suggests that indoor environmental quality (IEQ) is more important for the performance of office workers than job satisfaction and job stress. Occupants who experience even subclinical symptoms such as headache and fatigue because of poor indoor environmental quality are less likely to be comfortable and also less likely to be productive.

A successful thermal comfort design is one in which design for human thermal comfort is foreseen, planned, and carefully embedded in the design and operation intent (Runa *et al.,* 2019). However, there has been significant research carried out in the field of thermal comfort in many parts of the world, with different climatic indices depending on the climate. Research on thermal comfort is still in its infancy in Nigeria (Hamza et al., 2022; Efeoma, 2017). The pilot field study undertaken highlighted a clear need for further research into West African


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office building design, to explore how these office workspaces can be designed more efficiently to achieve thermal comfort, which can be best tested using a mixed-mode strategy (Ahadzie *et al.,* 2014). This was stressed further by Akande (2014) who said that throughout Nigeria, there have been few literature reports of field studies on indoor occupants' comfort and thermal environment. However, there is only little information available concerning occupant comfort and thermal environment in northern Nigeria. The aim is to support and complement a holistic building design approach by the inclusion of thermal comfort principles in their process (Hellwig *et al.,* 2019).

The research carried out by Nakano *et al.* (2004) shows that there are differences in the perception of the indoor environment by occupants of the same space and climate zone (de Dear & Brager, 2002). This study therefore attempts to fill the gaps highlighted above through evaluating the thermal perception of the occupants in the study area, as a complementary tool to an integrated design process within the context of this study.

### Aim and Objectives of the Study

This study aims to investigate the occupant's thermal perception in a mixed-mode office building of the Abubakar Tafawa Balewa University Bauchi, with a view to recommend solutions that can have a considerable impact on occupant's thermal comfort and the building's energy consumption.

### Objectives

i. To identify the thermal comfort parameters of occupants of the study area.

ii. To evaluate the occupant's thermal satisfaction with the study area

iii. To establish the relationship between occupants' thermal comfort and satisfaction in the study area.

## RESEARCH METHODOLOGY

Research Methodology is a way to systematically solve the research problem (Kothari, 2004). It may be understood as a science of studying how research is done scientifically. Researchers in the field of thermal comfort studies mostly employed field studies to determine thermal comfort in their respective areas of interest (de Dear *et al.,* 2012; Humphreys et *al.,* 2007). This study, therefore, adopts the field study approach. The subjective data obtained was processed using a quantitative method of data collection and analysis.

### Quantitative Research Approach

A quantitative research approach allows the researcher to observe and record the real signs of people's thermal comfort parameters (Wagner *et al.,* 2018). According to Groat, the quantitative research method is useful in dealing with precise and systematic measurement of verifiable quantities, such as climate data, and subjective thermal responses (Groat & Wang, 2013). The advantage of this research approach is that it allows a researcher to study the respondents in their familiar day-to-day environment, with their normal choice of clothing and activities (Nicol, 2012), keeping the researcher's intervention to a minimum. This has proved


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sufficient in providing unbiased research results. These qualities, therefore, encourage the authors to adopt this method so that sufficiently genuine results will be achieved. The study adopted a transverse field survey, employing questionnaires and physical measurements to collect the data required, as well as the researcher's observations during the field studies.

Table 1 shows the schematic flow of the research framework used in the conduct of this study.

Table 1: Research Framework

| S/N | Objectives | Methods | Instruments | Analysis |
|---|---|---|---|---|
| 01. | To identify the thermal comfort parameters of occupants of the study area. | Quantitative | Questionnaire | Descriptive |
| 02. | To evaluate the occupant's thermal satisfaction with the study area | Quantitative | Questionnaire | Descriptive |
| 03. | To establish the relationship between occupants' thermal comfort and satisfaction in the study area. | Quantitative | Questionnaire | Inferential |

Closed-ended questions were used to evaluate the thermal perception of office occupants in the study area. Part A of the questionnaire contains the demographic data of the respondent, while, part B contains general information on office space conditions. Parts C, D, E, and F of the questionnaire were designed to obtain information relating to respondents' subjective thermal comfort, thermal satisfaction, thermal sensation, and thermal preference using the right-here-right-now approach. Before any questionnaire was administered, consent was sought by the respondent who agreed to respond at that point in time. The idea of consent and the assessment type made it possible to retrieve all 30 questionnaires administered.

To determine the occupant's subjective thermal comfort vote, a six (6) points thermal comfort scale (1= very comfortable, 2= comfortable, 3= slightly comfortable, 4= slightly uncomfortable, 5= uncomfortable, and 6= very uncomfortable) was used (ASHRAE Standard 55, 2020). The respondent's thermal satisfaction votes were obtained to evaluate the occupant's satisfaction with their thermal environment. The thermal satisfaction scale adopted has seven (7) points scale; very satisfied (1), moderately satisfied (2), slightly satisfied (3), neutral (4), slightly dissatisfied (5), moderately dissatisfied (6), and very dissatisfied (7) adopted from (ASHRAE 55, 2017). The purpose of employing the thermal satisfaction scale was to allow every participant to respond freely to their level of satisfaction with the thermal environment.

**Study Area**

This study was conducted in Bauchi, Bauchi State, Nigeria and it is classified as the tropical savanna climatic region based on the Köppen-Geiger climate classification. Therefore, all climatic attributes of the tropical savanna climate in Nigeria were applied to this study. Bauchi is the headquarters of the Bauchi Local Government area of Bauchi State Nigeria. It is located on latitude $10^0 17^1$N and Longitude $09^0 49^1$ E. Bauchi state is located in North-Eastern Nigeria, it covers an area of 45,837 square kilometers. This study was a pilot test and was conducted in July 2021. During the study period, the maximum, minimum, and mean indoor operative


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temperature was 33.01$^{o}$C, 26.05$^{o}$C, and 29.30$^{o}$C respectively. The mean relative humidity was 63.74% with a maximum and minimum relative humidity of 73.04 and 54.01% respectively. The Accusense F900 air velocity instrument was used to measure the indoor air velocity at the time the respondents were attending the research questionnaire. The maximum air velocity recorded was 0.10m/s with 0.04 and 0.08m/s for minimum and mean air velocities respectively.

**Building Characteristics**

The study was conducted at the Faculty of Environmental Technology phase II, of the Abubakar Tafawa Balewa University, Bauchi-Nigeria. The building is a 4-storey structure accommodating 5 Departments. The complex operates under a mixed-mode ventilation system and has a daily regular occupants population. The building houses administrative offices, Drawing studios, computer laboratories, departmental libraries, seminar rooms, and lecture rooms. This study was limited to offices only. Figure 1 shows the approach view of the building.

***Figure 1: Faculty of Environmental Technology, Phase II***

## DATA PRESENTATION AND ANALYSIS

The questionnaire survey which evaluates the occupant's thermal perception was analysed using both descriptive and inferential statistical analysis with SPSS (Statistical Package for the Social Sciences) version 25. Data analysis on demographic records using frequency was presented.

Table 2 presents the summary of the respondent's demographic statistics. Descriptive analysis using frequency and percentage was carried out to explore the respondent's information.


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Table 2: Demographic Information of the Respondents

| | | Total (n= 30) Frequency | Percentage |
|---|---|---|---|
| Gender | Male | 27 | 90.0 |
| | Female | 3 | 10.0 |
| Age (Years) | 20 – 30 | 1 | 3.3 |
| | 31 – 40 | 23 | 76.7 |
| | 41 – 50 | 3 | 10.0 |
| | 50 and above | 3 | 10.0 |
| Years in Bauchi | < 6 months | 0 | 0.0 |
| | 6 months- 1 year | 0 | 0.0 |
| | 1 year and above | 30 | 100.0 |
| Educational background | Diploma | 2 | 6.7 |
| | Degree(s) | 28 | 93.3 |

Results from Table 2 established that there are more male respondents in the study accounting for 90%, while, female respondents constitute just 10%. The majority of the respondents are between the ages of 31- 40 years contributing 76.7% while the least percentage are between the ages of 20 – 30 years making 3.3%. The result reveals that 100% of the respondents had lived in the study area for one (1) year and above. Respondents educational background disclosed that 93.3% of the participants have a degree(s) and 6.7% of the respondents have a diploma.

### Subjective Thermal Perception

Thermal comfort is a subjective state of mind where people feel thermally comfortable within a given environment (Hamza *et al*., 2022). The need to study office occupant's thermal perception is paramount in a quest to improve the occupant's productivity and well-being. The survey questionnaire was designed to measure the constituents of respondents' subjective thermal perception; Thermal Comfort and Thermal Satisfaction.

### Thermal Comfort Votes

Research objective one (1) of this study intends to identify the thermal comfort parameters of occupants of the study area. In order to understand the respondent's thermal comfort, a six (6) point ASHRAE thermal comfort scale was used. The respondents were asked to indicate their thermal comfort with respect to sun protection, air temperature, relative humidity, air movement, and their current thermal comfort level in their offices. Table 3, presents the statistical summary of the respondent's thermal comfort votes.

Table 3: Cumulative Occupants Thermal Comfort Votes

| **Response** | Sun Protection | | Air Temperature | | Relative Humidity | | Air Movement | | Current comfort level | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Freq | (%) | Freq | (%) | Freq | (%) | Freq | (%) | Freq | (%) |
| Very comfortable | 4 | 13.3 | 4 | 13.3 | 2 | 6.7 | 4 | 13.3 | 5 | 16.7 |


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| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Comfortable | 13 | 43.3 | 12 | 40.0 | 14 | 46.7 | 17 | 56.7 | 20 | 66.7 |
| Slightly comfortable | 5 | 16.7 | 12 | 40.0 | 11 | 36.6 | 6 | 20.0 | 4 | 13.4 |
| Slightly uncomfortable | 6 | 20.0 | 2 | 6.7 | 3 | 10.0 | 2 | 6.7 | 1 | 3.3 |
| Uncomfortable | 2 | 6.7 | 0 | 0.0 | 0 | 0.0 | 1 | 3.3 | 0 | 0.0 |
| Very uncomfortable | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |

Table 3 presents data for all variables under occupant's thermal comfort based on descriptive statistics of the cumulative respondent's subjective thermal comfort votes in their offices. Frequency and percentage ranking were used and the following results were obtained. The Result indicates that 73.3% of the respondents were comfortable with sun protection in their offices, while, 26.7% were uncomfortable with sun protection in their offices at the time of this study. It further revealed that 93.3% were comfortable with air temperature in their office and 6.7% have recorded not being comfortable with sun protection in their offices. 90.0% have recorded comfortable with relative humidity in their offices, while, 10.0% have indicated not being comfortable with relative humidity in their offices. Also, 90.0% have marked comfortable with air movement in their offices during the study period, whereas, 10.0% have registered as not comfortable with air movement in their offices.

Finally, occupants were asked to indicate their general thermal comfort at the moment of the study. The result established that 96.7% of the respondents were thermally comfortable with their office environment, while, 3.3% of the respondents were not comfortable with the thermal environment in their respective offices. ASHRAE Standard 55 recommends that, where 80% of the respondents express being comfortable or satisfied with their giving environment, that space will be said to be comfortable or satisfied as the case may be. The findings of this study therefore reveal that the thermal environment of the respondents is comfortable although, the air temperature obtained during the study period falls outside the comfort range as postulated by the PMV model. This study has also aligned itself with many studies conducted in Nigeria, such as Efeoma (2017), who conducted a study on the influence of clothing on adaptive thermal comfort in Enugu, Nigeria. He found that 74.23% of the office occupants in his study area were comfortable with the thermal conditions surrounding their work environment. This implies that the thermal comfort of Nigerian office occupants is similar to and much unlike their Western counterparts. Understanding the occupant's thermal comfort perception is important in understanding the comfort requirements variations so that, environmental and personal controls can be designed to effectively accommodate the diverse needs of their occupants. This will undoubtedly determine the design direction of indoor environments of future buildings.

**Thermal Satisfaction Votes**

Research objective two (2) of this study seeks to evaluate the occupant's thermal satisfaction of the study area. The thermal satisfaction of office occupants was measured using 7- point scale (ASHRAE standard 55, 2017); Very satisfied (1) to very dissatisfied (7). The corresponding responses are presented in Table 4. Descriptive statistics based on frequency and percentage ranking were used to determine the level of influence on individual variables.


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Table 4: Cumulative Occupants Thermal Satisfaction Votes

| **Response** | Sun Protection | | Air Temperature | | Relative Humidity | | Air Movement | | Current satisfaction level | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Freq | (%) | Freq | (%) | Freq | (%) | Freq | (%) | Freq | (%) |
| Very satisfied | 10 | 33.3 | 8 | 26.7 | 2 | 6.7 | 6 | 20.0 | 6 | 20.0 |
| Moderately satisfied | 8 | 26.7 | 10 | 33.3 | 15 | 50.0 | 13 | 43.3 | 10 | 33.3 |
| Slightly satisfied | 3 | 10.0 | 9 | 30.0 | 9 | 30.0 | 7 | 23.4 | 6 | 20.0 |
| Neutral | 4 | 13.4 | 2 | 6.7 | 2 | 6.7 | 2 | 6.7 | 4 | 13.4 |
| Slightly dissatisfied | 3 | 10.0 | 0 | 0.0 | 1 | 3.3 | 1 | 3.3 | 2 | 6.7 |
| Moderately dissatisfied | 1 | 3.3 | 1 | 3.3 | 1 | 3.3 | 1 | 3.3 | 2 | 6.7 |
| Very dissatisfied | 1 | 3.3 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |

Table 4 presents data for occupants' thermal satisfaction variables based on frequency and percentage ratings of the cumulative occupants' thermal satisfaction votes in their respective offices. The Result revealed that 83.4% of the respondents were satisfied with sun protection in their offices, while, 16.6% indicated not satisfied with sun protection in their offices at the study time. The result further indicates that 96.7% of the respondents were satisfied with air temperature in their office, while, only about 3.3% have recorded not being satisfied with the air temperature in their offices. 93.4% have indicated satisfaction with relative humidity in their offices, while, 6.6% have indicated not being satisfied with relative humidity in their offices. Respondents' air movement satisfaction votes expressed that, 93.4% have marked satisfaction with air movement in their offices during the study period, whereas, 6.6% have registered as not satisfied with air movement in their offices. The respondent's current satisfaction level was recorded. The result established that 86.7% of the respondents were thermally satisfied with their office environment in the study area, whereas, 13.3% expressed not thermally satisfied with their thermal environment at the time of this study.

This result has complied with the provisions of ASHRAE Standard 55 (2017), that an environment is said to be thermally satisfied where more than 80% of the occupants are thermally satisfied with the given environment. The findings of this study have supported the declaration by Damiati *et al.* (2015) that, mixed-mode ventilated offices proved to be more advantageous over other ventilation systems as they provide higher office occupants' satisfaction and increase flexibility due to adaptive opportunities and control. The field survey conducted expressed thermal satisfaction at comfort temperatures above recommended international standards. This in the opinion of this study indicates that the occupants of the study area exhibit a high degree of acclimatization to higher temperatures than international standards recommendations. This demands the need for localization of standards to specific climates and geography. In agreement with these findings, Kim et al. (2019); Duan et al. (2022); Hamza et al. (2022); and Musa et al. (2022) indicated that occupants in mixed-mode buildings are more adaptive to varying environmental conditions, leading to higher satisfaction rates and potentially better comfort levels.


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### Relationship Between Thermal Comfort and Thermal Satisfaction

Research objective 3 desired to establish the relationship between occupants' thermal comfort and thermal satisfaction in the study area. Correlation analysis was conducted to identify the potential relationships between the variables, measure their strength, and also generate hypotheses. After careful evaluation, Table 5 presents the result of the correlation analysis between occupants' thermal comfort and occupants' thermal satisfaction during the study period.

Table 5: Correlation result between thermal comfort and thermal satisfaction

| | | Thermal Satisfaction |
|---|---|---|
| Thermal Comfort | Pearson Correlation | .504** |
| | Sig. (2-tailed) | .000 |
| | N | 152 |

**. Correlation is significant at the 0.01 level (2-tailed).

The correlation between occupants' thermal comfort and satisfaction suggests quite a strong relationship ($r = 0.504$, $p < 0.001$, $R^2 = 25\%$). This result implies that the more comfortable occupants feel in their offices, the more satisfied they become. From the above result, thermal comfort helps to explain 25% of the variance in respondents' scores on thermal satisfaction. The findings of this study have aligned with existing literature that highlights the importance of thermal comfort in workplace settings, where it positively impacts occupants' satisfaction, well-being, and productivity (Duan et al., 2022; Sakellaris et al., 2016). The study highlighted the important role thermal comfort plays in employee satisfaction. Investing in optimizing temperature, humidity, and air quality can significantly improve workplace well-being and productivity. This study provides valuable evidence for the significant role of thermal comfort in occupant satisfaction within the specific mixed-mode office environment. By understanding these relationships and considering individual needs, organizations can create more comfortable and satisfying workspaces, ultimately leading to improved employee well-being and potential performance benefits. Improving thermal comfort in buildings can therefore lead to enhanced occupant experiences and overall building performance.

## CONCLUSION

This study investigated the relationship between occupants' thermal comfort, thermal satisfaction, and energy consumption in office buildings within the Faculty of Environmental Technology, Phase II, Abubakar Tafawa Balewa University, Bauchi- Nigeria. By combining occupant surveys with physical environmental measurements, the study aimed to identify potential solutions for improving thermal comfort while minimizing energy consumption. The study investigated thermal comfort and occupant satisfaction in a mixed-mode office environment. It found a generally positive perception despite air temperatures outside the recommended comfort range. The study suggests that the majority of occupants were thermally comfortable and satisfied, exceeding the ASHRAE Standard 55 recommended threshold. The study further investigated the relationship between thermal comfort and occupant satisfaction in a mixed-mode office environment, finding a moderately strong positive correlation (r =


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0.504, $p < 0.001$). This aligns with existing research highlighting the importance of thermal comfort in workplaces.

## RECOMMENDATIONS

1. The study recommends the need for the development of localized comfort standards for Nigerian office buildings.
2. Mixed-mode office buildings need to be evaluated to analyse their effectiveness in maintaining comfort while minimizing energy use within the specific climate and building context.
3. To develop evidence-based design solutions and implement interventions that optimize thermal comfort, occupant satisfaction, and energy efficiency in mixed-mode office environments.

By addressing these recommendations, this study can contribute to creating more comfortable, sustainable, and adaptable office environments in Nigeria and similar climatic regions. It will contribute to creating truly healthy and sustainable work environments that benefit both occupants and the environment in the context of mixed-mode ventilation systems.

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