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# Assessment of building occupants' perception of indoor thermal comfort in Dhaka

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## Abstract

This study investigates the perceptions of occupants regarding thermal comfort in Dhaka, characterized by high temperatures and tropical wet and dry climate. The primary objectives are to identify factors influencing indoor thermal comfort and examine the effects of ventilation on occupants' health. Surveys were conducted in the living rooms of thirty residential units, measuring room temperature using thermometers and gathering occupant feedback. The findings reveal that building design factors, including form, orientation, the ratio of openings to floor area, landscaping, and fenestration, significantly influence average indoor temperatures. Poor ventilation and inadequate thermal comfort were linked to various health issues, including insomnia, fatigue, boredom, headaches, reduced cognitive alertness, and asthma. These conditions highlight the pressing need for improved building designs to mitigate adverse health effects and promote well-being. The study recommends involving building professionals in the planning, design, and construction processes to incorporate effective strategies such as optimal building orientation, appropriate ratios of openings to floor area, and enhanced landscaping. These measures can improve ventilation and maintain comfortable indoor temperatures, ensuring healthier living environments for urban residents. Addressing these factors is essential for creating thermally comfortable residential spaces in Dhaka, where climatic challenges demand tailored architectural and environmental interventions.

**Keywords:** Indoor Comfort; Buildings; Hazards; Temperature; Ventilation; Health and well-being

## 1. Introduction

Buildings are designed to provide environments conducive to human habitation, work, or recreation, adapting to local climates to ensure occupant comfort (Zainazlan, Mohammed & Shahrizam, 2007). Achieving thermal comfort is essential, particularly in regions like Nigeria, where global warming and climate change pose significant challenges to maintaining the human body's ideal temperature of 37°C (98.6°F). Dissatisfaction with the thermal environment can negatively impact health, productivity, and overall satisfaction (Nicol & Humphrey, 2004).

The American Society of Heating, Refrigeration, and Air-conditioning Engineers (ASHRAE, 2004) defines thermal comfort as "that condition of mind which expresses satisfaction with the thermal environment." According to ISO (2005) and ASHRAE standards, a thermal environment is considered acceptable when 80% of occupants report being comfortable. Achieving this state requires balancing environmental factors and human adaptation, with the optimal temperature range for comfort typically lying between 15°C (59°F) and 30°C (86°F) (Wikipedia, 2017).

Despite the importance of thermal comfort, studies in Nigeria reveal that poor building designs and insufficient use of climate-adaptive methods have led to increased reliance on energy-intensive air-conditioning systems (Michael, Richard & Gerald, 2015). Research by Ogbonna and Harris (2007), Akande and Adebamowo (2010), and others

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highlights the urgent need for innovative strategies to enhance thermal comfort in residential buildings. This is particularly critical as residential buildings contribute significantly to energy consumption, accounting for nearly one-third of fossil fuel use globally (Taleghani et al., 2013).

Designers and architects face the dual challenge of creating and maintaining safe, healthy indoor environments while reducing energy consumption. Most people spend approximately 90% of their time indoors, underscoring the importance of healthy housing that ensures sanitary comfort, social well-being, and an enhanced quality of life (Klepeis et al., 2011; Çeter, Alkan & Turhan, 2021; Boulemaredj & Haridi, 2022; Slipek et al., 2017; Al Horr et al., 2016). Buildings must integrate local bioclimatic principles to enhance living standards and provide optimal thermal comfort tailored to specific climates (Samuel et al., 2017; Hailu, Gelan & Girma, 2021; Akande & Adebamowo, 2010).

Numerous field studies across various climate zones highlight the adverse effects of extreme temperatures on thermal comfort in residential buildings. Research conducted in moderate climates (Lomas & Kane, 2013), tropical climates (Nicol, 2004; Al-Tamimi, Fadzil & Harun, 2011), and hot and humid climates (Akande & Adebamowo, 2010; Adaji, Watkins & Adler, 2015) reveals that elevated indoor temperatures significantly reduce occupant comfort. Interestingly, an in-situ study in a hot and dry climate found that older buildings offered better thermal comfort than newer constructions, further emphasizing the value of traditional design principles (Ealiwa et al., 2001).

Thermal comfort is influenced by the interplay of environmental and bodily factors. This dynamic has been well-documented by studies utilizing ASHRAE models (Lomas & Kane, 2013; Adekunle & Nikolopoulou, 2014) and adaptive thermal standards (Nicol, 2004; Humphreys, Rijal & Nicol, 2013). The findings consistently demonstrate the importance of climate-adaptive designs in achieving optimal comfort. Additional research by Toy and Kántor (2017) and Haruna, Muhammad & Oraegbune (2018) further supports the need for sustainable solutions to address the challenges posed by extreme climates.

However, thermal performance of residential buildings in Dhaka City has garnered significant research interest due to the city's tropical climate and rapid urbanization. Various studies highlight the factors influencing indoor thermal comfort, such as building orientation, insulation quality, and ventilation strategies. For instance, Ahmed et al. (2014) reported that most urban apartments in Dhaka suffer from inadequate natural ventilation, leading to notable thermal discomfort throughout the year. Similarly, Safiuddin et al. (2016) emphasized that insufficient insulation in walls and roofs exacerbates indoor heat retention during summer and heat loss during winter. Rahman et al. (2018) further noted that poor building design increases reliance on mechanical cooling systems, driving up energy consumption and costs for residents.

To better understand the factors influencing indoor thermal comfort in Dhaka, assessing occupants' perceptions is essential. This approach provides critical insights into how residents experience and manage thermal conditions within their homes. Collecting data on occupants' comfort levels, adaptive behaviors, and feedback on building performance can help guide more effective design and policy decisions.

### 1.1. Aims and Objectives

To analyze the perception of indoor thermal comfort among building occupants in Dhaka, focusing on the interplay of temperature, ventilation, and building-related hazards to develop strategies for improving indoor environmental quality.

- Evaluate how building occupants perceive indoor temperature and ventilation in relation to their comfort levels.
- Analyze the impact of ventilation, temperature fluctuations, and building design on indoor thermal comfort.
- Develop strategies to improve thermal comfort by addressing ventilation, temperature control, and potential hazards in building design.

### 1.2. Literature Review

**Table 1** literature based

| Study | Authors | Year | Research Focus | Methodology | Key Findings | Location | Relevance to Dhaka |
|---|---|---|---|---|---|---|---|
| Thermal Comfort and Adaptive Behavior | Nicol et al. | 2004 | Adaptive thermal comfort standards | Field study, surveys | Adaptive comfort is region-specific; occupants can adjust expectations based on local climate | Multiple locations | Provides a framework for adaptive comfort, relevant to tropical climates |
| Indoor Thermal Comfort in Residential Buildings | Ahmed et al. | 2014 | Thermal comfort in Dhaka apartments | Questionnaire, thermal measurements | Poor natural ventilation and insulation lead to discomfort; need for passive strategies | Dhaka, Bangladesh | Direct relevance to Dhaka residential buildings |
| Thermal Comfort in Hot and Dry Climates | Ealiwa et al. | 2001 | Traditional building designs for thermal comfort | Case study, field measurements | Traditional designs outperform newer ones in hot climates due to better passive cooling | Hot and dry climates | Relevant for improving Dhaka's traditional building approaches |
| Thermal Comfort and Energy Efficiency | Taleghani et al. | 2013 | Energy efficiency in buildings | Simulation, case study | Integrating passive cooling and ventilation enhances comfort and reduces energy consumption | Various regions | Could inform strategies for improving energy efficiency and comfort in Dhaka |
| Impact of Thermal Comfort on Health and Productivity | Al Horr et al. | 2016 | Effect of thermal comfort on health/productivity | Surveys, field study | Poor thermal comfort leads to reduced productivity and health issues | Offices | Useful for understanding broader implications of thermal discomfort in buildings |
| Influence of Natural Ventilation on Thermal Comfort | Rahman et al. | 2018 | Natural ventilation and thermal comfort in Dhaka | Field study, occupant surveys | Lack of natural ventilation in urban apartments leads to discomfort; passive design strategies recommended | Dhaka, Bangladesh | Directly relevant to Dhaka's urban environment |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Thermal Sensation and Building Occupants' Perceptions | Humphreys et al. | 2013 | Occupant perceptions of indoor comfort | Field surveys, statistical analysis | Occupants adapt their thermal comfort expectations based on seasonal changes and building design | Various climates | Supports adaptive comfort models for Dhaka's tropical climate |
| Assessment of Thermal Comfort in Modern and Traditional Buildings | Akande & Adebamowo | 2010 | Thermal comfort in Nigerian buildings | Surveys, field measurements | Traditional buildings provide better comfort in extreme heat compared to modern ones | Nigeria | |

## 2. Materials and Method

This study employed a mixed-method approach, combining post-occupancy surveys and field measurements to assess indoor thermal comfort. Surveys were conducted in May 2022, during the peak temperature period characterized by hot, dry weather both day and night. Room temperatures in the living rooms of 15 residential buildings were measured at 6:00 AM, 2:00 PM, and 10:00 PM using thermometers. These measurements were analyzed and presented in charts (Figure 1) and tables. Data on building design, construction materials, and other structural details were collected to evaluate their impact on indoor temperature. A questionnaire divided into two sections was used: Section A gathered background information (e.g., building age, occupancy status, and number of occupants), while Section B focused on factors influencing thermal comfort, identified through literature review. The results, including temperature data and related variables, were analyzed using descriptive statistics and presented in tables and charts.

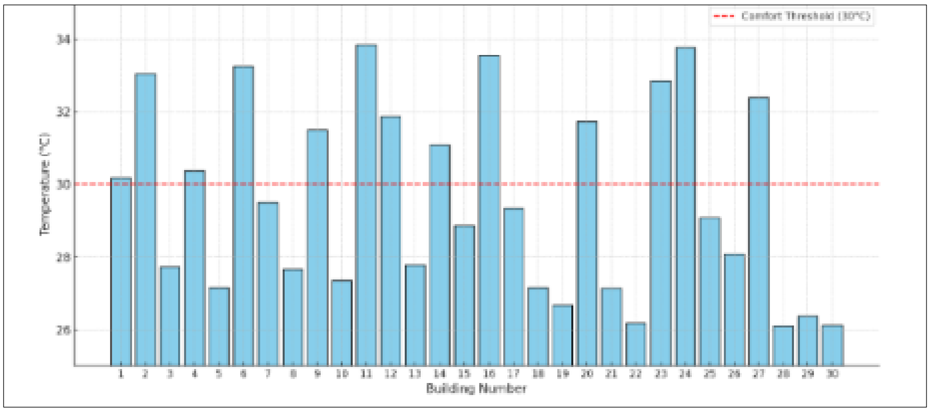


**Figure 1** May room temperature of residential building Floor plan of the investigated flat (Source: Authors, 2022)

## 3. Results and Discussion

The results shows buildings numbered 19 to 30, shown in Figure 1, are over 20 years old and make up 40% of the surveyed structures. These buildings have an average temperature of 31.58 °C, as presented in Table 2. According to the Health and Safety Executive (HSE, 2022), thermal comfort in buildings is influenced by environmental factors, such as air temperature, radiant temperature, air velocity, and humidity, along with personal factors like clothing and metabolic heat. Of these, air temperature is the most commonly used indicator due to its simplicity of measurement and relevance to occupants.

**Table 2** Age of Buildings and Average Temperature

| Age of Building (Years) | Building Numbers | Frequency | Percentage (%) | Average Temperature (°C) |
|---|---|---|---|---|
| Less than 5 | 1 to 4 | 4 | 15.3 | 31.6 |
| 5 – 10 | 5 to 7 | 3 | 10 | 32.47 |
| 11 – 15 | 8 to 12 | 5 | 14.7 | 31.24 |
| 16 – 20 | 13 to 18 | 6 | 20 | 30.55 |
| Above 20 | 19 to 30 | 12 | 40 | 32.04 |
| Total | - | 30 | 100 | - |

It is observed that 50% of the surveyed residential buildings accommodate more than six occupants, as shown in Table 2. Additionally, 20% of the buildings have fewer than five occupants residing in them.

**Table 3** Number of Occupants in a Building

| No. of Occupants | Frequency | Percentage (%) |
|---|---|---|
| Less than 5 | 6 | 20 |
| 5–8 | 9 | 30 |
| More than 6 | 15 | 50 |
| Total | 30 | 100 |

The majority of occupants (60%) are owner-occupiers, whose homes have a collective average temperature of 30.46 °C. In contrast, 40% of the occupants are tenants, with a higher collective average temperature of 30.18 °C. This difference in temperature can be attributed to tenants' shorter occupancy periods, which often limit modifications for better thermal comfort.

**Table 4** Status of Building Occupants

| Status of Occupants | Building No. | Frequency | Percentage (%) | Average Temperature (°C) |
|---|---|---|---|---|
| Tenants | 1 to 12 | 12 | 40 | 30.46 |
| Owner-Occupiers | 13 to 30 | 18 | 60 | 30.18 |
| Total | 30 | 30 | 100 | |

Irregularly shaped buildings account for 61.38% of the surveyed structures and have the lowest average temperature of 30.54 °C, suggesting better thermal comfort. In comparison, square-shaped buildings, comprising 20%, experience the highest average temperature of 31.81 °C. Rectangular buildings, making up 18.62%, follow closely with an average temperature of 31.78 °C. These findings suggest that irregular forms promote better ventilation, while square and rectangular forms hinder it.

**Table 5** Forms of Buildings

| Form of Building | Building No. | Frequency | Percentage (%) | Average Temperature (°C) |
|---|---|---|---|---|
| Irregular | 1–16, 21–23 | 19 | 61.38 | 30.54 |
| Rectangular | 17–20 | 5 | 16.67 | 31.81 |
| Square | 24–30 | 6 | 20 | 31.78 |
| Total | 30 | 30 | 100 | |

The orientation of the surveyed buildings significantly affects their thermal performance. About 63.47% of the buildings have their length facing the east-west direction, resulting in a collective average temperature of 33 °C due to increased solar exposure. In contrast, 36.53% have their length oriented in the north-south direction, yielding a lower average temperature of 29.27 °C. To minimize heat gain, the longer side of buildings should face the north-south direction, and the shorter side should face the east-west direction.

**Table 6** Building Orientation

| Orientation of Building | Building No. | Frequency | Percentage (%) | Average Temperature (°C) |
|---|---|---|---|---|
| Length facing north-south | 4,5,6,10,13,17,20,22,23,28 | 10 | 36.53 | 29.2 7 |
| Length facing east-west | 1–3,7–9,11–12,14,15,16,18,19,21,24,26,27,29,30 | 20 | 63.47 | 33 |
| Total | 30 | 30 | 100 | |

Table 6 highlights the impact of window fenestration on indoor temperatures. Buildings with 15–20% of their floor area allocated to window openings represent 50% of the surveyed structures and have the lowest average temperature of 29.74 °C. Conversely, 16.67% of buildings with less than 10% floor area as window openings record the highest average temperature of 32.29 °C.

**Table 7** Building Temperature Variations Based on Window Size, Orientation, and Distribution

| Category | Details |
|---|---|
| Buildings with Largest Window Openings | - Buildings with 15–20% of the floor area as window openings represent 50% of the surveyed buildings. |
| | - Record the lowest average indoor temperature: 29.74°C, indicating the cooling effect of larger, well-placed fenestrations. |
| Buildings with Smallest Window Openings | - Buildings with less than 10% of the floor area allocated to windows represent 16.67% of the surveyed buildings. |
| | - Record the highest average indoor temperature: 33.89°C, highlighting the limited cooling effect of smaller fenestrations. |
| Directional Analysis | - North-South facing windows: Average temperature of 33.04°C across all floor area categories. |
| | - East-West facing windows: Record the highest average temperature: 34.62°C, likely due to increased solar exposure. |
| | - Windows in three directions: Show a reduced average temperature of 32.24°C due to better ventilation potential. |
| | - Windows in four directions: Perform best with the lowest average temperature: 30.08°C, benefiting from maximum cross-ventilation. |

Regarding window orientation, 40% of buildings feature fenestration on all sides and achieve the lowest average temperature of 28.08°C. On the other hand, buildings with windows facing only the east-west direction account for 20% and have the highest average temperature of 32.62°C.

Buildings with larger window dimensions (1200mm x 1200mm) exhibit lower average temperatures (31.23 °C) compared to those with smaller dimensions (33 °C for windows smaller than 1200mm x 800mm). Similarly, larger doors (1200mm x 2100mm) are associated with lower average temperatures (31.67 °C) than smaller ones (33 °C).

**Table 8** Dimension of External Building Fenestration

| Fenestration Type | Dimension (mm) | Frequency | Percentage (%) | Average Temperature (°C) |
|---|---|---|---|---|
| Windows | 1200mm x 1200mm | 15 | 50 | 31.23 |
| | < 1200mm x 1200mm | 10 | 33.33 | 31.64 |
| | 1200mm x 800mm | 3 | 10 | 32.27 |
| | < 1200mm x 800mm | 2 | 6.67 | 33 |
| Doors | 900mm x 2100mm | 3 | 10 | 33 |
| | 1200mm x 2100mm | 27 | 90 | 31.67 |

Buildings with walls made of concrete blocks represent 90% of the surveyed structures, with an average temperature of 33°C, significantly higher than the 29.1°C recorded for buildings constructed with burnt bricks (10%). This difference arises because concrete conducts heat more effectively than bricks, transferring heat indoors.

**Table 9** Wall Materials

| Material | Frequency | Percentage (%) | Average Temperature (°C) |
|---|---|---|---|
| Concrete Blocks | 27 | 90 | 33 |
| Burnt Bricks | 3 | 10 | 29.1 |

Buildings with landscaped surroundings, including features such as grass, trees, and concrete interlocks, exhibit lower average temperatures (29.30°C) compared to those without any landscaping (32.24°C).

**Table 10** Landscape Provision

| Landscape Provision | Frequency | Percentage (%) | Average Temperature (°C) |
|---|---|---|---|
| No Landscape Provided | 7 | 43.33 | 32.24 |
| Natural Ventilation & Landscape | 23 | 57.67 | 29.3 |

Mechanical ventilation also plays a critical role in reducing indoor temperatures. Buildings equipped with both fans and air conditioners achieve the lowest average temperature (26.54°C), followed by those with only air conditioners (30.83°C) and fans (32.01°C). Buildings without any ventilation system experience the highest average temperature (34.33°C).

**Table 11** Types of Mechanical Ventilation Provided

| Mechanical Ventilation Type | Frequency | Percentage (%) | Average Temperature (°C) |
|---|---|---|---|
| Electric Fans Only | 15 | 50 | 32.01 |
| Air Conditioners Only | 7 | 23.33 | 30.83 |
| Fans and Air Conditioners | 5 | 16.67 | 26.54 |
| None | 3 | 10 | 34.33 |

The effects of inadequate ventilation on the health of occupants are summarized in Table 12. The results reveal that 80% of residential building occupants (8 out of 10) face the dual challenge of high temperatures and insomnia (difficulty sleeping) due to poor ventilation. Fatigue and boredom rank as the second most common impact, affecting 70% of occupants (7 out of 10).

Headaches, reduced arousal, depression, anxiety, psychological distress, and respiratory issues such as asthma collectively affect 50% of occupants (5 out of 10). These findings underscore the critical health implications of insufficient ventilation in residential buildings.

**Table 12** Health Effects of Inadequate Ventilation

| Health Effect | Frequency | Total Buildings | Ratio of Affected Buildings |
|---|---|---|---|
| Unpleasant smell | 12 | 30 | 2:5 (30%) |
| High temperature | 27 | 30 | 8:10 (80%) |
| Headache and poor arousal | 18 | 30 | 3:5 (60%) |
| Fatigue and boredom | 24 | 30 | 8:10 (80%) |
| Depression and anxiety | 18 | 30 | 3:5 (60%) |
| Insomnia | 27 | 30 | 8:10 (80%) |
| Psychological distress | 18 | 30 | 3:5 (60%) |
| Acute respiratory issues (e.g., asthma) | 12 | 30 | 2:5 (30%) |
| Stroke and cardiovascular abnormalities | Not specified | Not specified | Not specified |
| Acute left ventricular failure and right ventricular dilation | Not specified | Not specified | Not specified |

## 4. Conclusions and Recommendation

This study provides valuable insights into the factors influencing indoor thermal comfort in residential buildings in Dhaka. The findings highlight the critical role of building design, orientation, fenestration, materials, and ventilation systems in regulating indoor temperatures and ensuring occupant comfort. Older buildings, irregularly shaped structures, and those with natural ventilation and landscaped surroundings demonstrate better thermal performance. Conversely, buildings with inadequate ventilation, poor orientation, and smaller or less effective fenestration experience higher indoor temperatures and related health issues.

The study also underscores the significant impact of mechanical ventilation systems, with the combination of fans and air conditioners proving most effective in reducing indoor temperatures. Additionally, buildings constructed with heat-conductive materials like concrete blocks and those lacking landscaping exhibit poorer thermal performance.

Health implications of inadequate ventilation, such as insomnia, fatigue, and respiratory problems, are significant and call for immediate attention. These findings emphasize the need for improved building designs that prioritize natural ventilation, optimal orientation, and appropriate material selection to enhance thermal comfort. Future efforts should focus on integrating these strategies into urban planning and building codes to ensure sustainable and healthier living environments for the residents of Dhaka.

## Compliance with ethical standards

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The author(s) declare that there are no competing interests.

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