

EVALUATING THERMAL COMFORT IN OFFICE BUILDINGS: A SUSTAINABILITY PERSPECTIVE

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Abstract

This study combines measured indoor environmental factors with occupant perceptions to examine thermal comfort conditions in faculty and staff offices at the University of Engineering and Technology (UET) in Lahore, Pakistan. 130 respondents from various departments were given a structured questionnaire that included the ASHRAE 7-point thermal feeling scale and categorical evaluations of productivity and health. Physical measures included room temperature, air velocity, and relative humidity. Despite typical interior temperatures (28.6°C) surpassing ASHRAE 55 summer standards, the results indicate that more than 80% of respondents assessed their thermal environment as satisfactory, indicating adaptive tolerance in the local climatic and cultural context. There were very minor effects on productivity, mostly in the late afternoon. The study's unique contribution is the way it combines quantitative building performance data with qualitative user feedback in the context of higher education in developing nations. This results in occupant-centered, evidence-based recommendations for campus building design, such as the necessity of centralized cooling and better ventilation throughout academic spaces.

INTRODUCTION

The psychological state of contentment with the thermal environment is known as thermal comfort, and it has a direct influence on the productivity, well-being, and health of building occupants. Thermal conditions have an impact on workplace efficiency and well-being in academic institutions where faculty and staff spend considerable amount of time in offices and workspaces. This study examines the thermal performance of campus buildings, with a particular focus on academic and administrative offices, in the Department of Architectural Engineering and

Design, University of Engineering and Technology (UET) Lahore, Pakistan.

Early Foundations and Adaptive Comfort Models:

Humphreys' (1994) groundbreaking research in Pakistan's Northwest Frontier Province established the groundwork for adaptive thermal comfort by demonstrating that occupants' tolerance for a broad temperature range is influenced by behaviour and natural ventilation rather than fixed set points. To support adaptive comfort

models over old fixed-temperature standards like ASHRAE 55, which were problematic in hot, humid, and semi-arid regions, Nicol et al. (1999) identified climate-specific comfort ranges across Pakistan's various zones (De Dear and Brager, 2002). The paradigm changes toward user-adaptive comfort, especially in naturally ventilated office buildings, has been aided by Humphreys, Nicol, and de Dear. According to recent reviews (Lamsal et al., 2023), office environments worldwide can safely have adaptive comfort temperature ranges between 17.6°C and 31.2°C. This allows for energy savings and increased occupant satisfaction, particularly in mixed-mode offices that use both natural ventilation and HVAC.

Occupant-Centred Research Including Productivity and Health:

Beyond temperature ranges, thermal comfort affects occupant health and productivity. Kaushik et al. (2019) demonstrate how reduced cognitive function and productivity losses are associated with heat discomfort in office settings. In a similar vein, Alajmi et al. (2015) discovered that increasing thermal comfort boosts productivity at work.

Utilizing the ASHRAE 7-point scale in conjunction with environmental monitoring (temperature, humidity, and air velocity), UET Lahore fills this occupant-centred gap in Pakistani academic offices by offering localized, culturally relevant insight into productivity impacts linked to thermal conditions. Pakistani researchers such as Riaz et al. (2023, 2025) highlighted occupant feedback and contextual factors in university buildings, linking thermal comfort to motivation and health effects. The importance of evaluating thermal comfort in residential settings, especially in colder climates, was emphasized by Iqbal et al. (2024).

Ventilation Strategies, Mixed-Mode Comfort, and Energy Efficiency:

Pakistan has conducted extensive research on the benefits of natural ventilation for improving thermal comfort and lowering energy use (Shaheen et al., 2016; Hafeez et al., 2017). In terms of energy consumption and perceived comfort, mixed-mode offices that permit occupant control and HVAC replenishment perform better than offices with only air conditioning (Saeed et al., 2024). Despite

being insufficiently used in many Pakistani structures, passive design elements such as orientation, shading, and insulation have been shown to save energy in hot climates (Glicksman et al., 1998; Mahar et al., 2018). Recent research has shown promise for workplace energy savings and occupant satisfaction with individualized comfort systems, like thermal chairs that allow for individual thermal control (Vesely et al., 2020). Although they are still in the initial stages of field applications, these methods deal with the irregular interior settings that are common in offices.

Research Gaps in Pakistani Academic Office

Contexts: Although residential and general office buildings are included in Pakistani thermal comfort research (Mahar et al., 2018; Kaushik et al., 2019), academic office settings are still not well studied. These areas have unique cultural settings that are rarely thoroughly examined, sporadic HVAC use, and occupant behavioural adjustments. By validating and expanding adaptive comfort theories, your research bridges this gap by combining quantifiable indoor environmental characteristics with occupant perceptions and productivity indicators in higher education offices in a developing nation. Decades of study have collectively shown that adaptive comfort is the best paradigm for office buildings in hot regions like Pakistan, with occupant-centred approaches being crucial for both productivity and health outcomes. The study's unique features include its emphasis on office settings in higher education, integration of objective and subjective data, and culturally aware validation of adaptive comfort frameworks. Taken together, these elements close a sizable gap in the local literature and offer practical suggestions for campus building design. The study evaluates the degree to which these areas satisfy thermal comfort standards by combining building performance data with occupant impressions. The information acquired is used to create occupant-centred building design standards that are specific to the local climate and culture. This work is innovative because it takes an integrated strategy, combining subjective comfort assessments using the ASHRAE thermal sensation scale with field data on architectural and environmental parameters in the neglected setting of higher education offices in a developing nation.

Materials and Methods

Using Google Forms, a structured questionnaire survey was created and distributed to UET Lahore's academic and administrative staff only, as illustrated in Fig. 1. A total of 130 legitimate answers were gathered. Three sections made up the survey instrument: Information about occupation and demographics (gender, age, type of clothes, degree of activity, length of stay, affiliation by birth). Features of the building and office (direction, construction time, kind of structure, floor level, office design, window condition, ventilation mode, and changeable parts). The ASHRAE 7-point thermal sensation scale (from -3 "cold" to +3 "hot") and categorical choices for productivity and health-related implications were used to measure thermal comfort perceptions and self-reported effects on health and productivity. Most respondents were

between the ages of 36 and 45, and 70% of the sample was male. Sixty-six percent were Lahore natives, and almost 88% had been in their current city for more than ten years. The majority stated that they mostly engaged in sedentary activities and wore light apparel to work. Most offices were situated on the ground level of five to fifteen-year-old brick structures, mainly facing west and south. Air conditioning was the main source of ventilation in closed-plan layouts, and windows were typically kept closed while the system was operating. According to perception data, 80% of those surveyed reported minimal heat discomfort at the time of the study, and stated productivity losses were comparatively infrequent, usually happening between 2:00 and 5:00 pm. Table 1 summarizes the information on the building and its occupants.



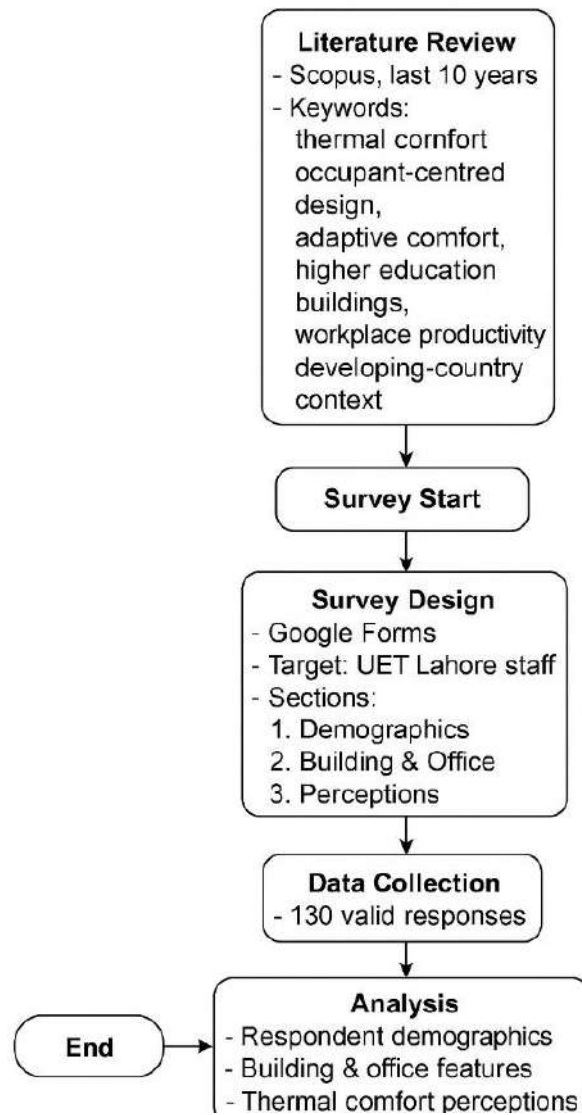


Figure 1: Methodology adopted for work

The Fig. 2 shows front view of buildings visited for questionnaire survey.



Figure 2 View of surveyed Departments at UET, Lahore

Table 1 Occupant Information and Building details.

OCCUPANTS INFORMATION IN %		BUILDING DETAILS IN %	
Gender	Response Time	Building Structure	Window Condition

Male 70 Female 30	Afternoon 61 Morning 17 Noon 22	Masonry 70 RCC 30	Close 89 Open 11
Affiliation By Birth	Clothing Type	Construction Period	Office Floor Level
Lahore 66 Other cities of Punjab 30 Other Provinces of Pakistan 4	Light 52 Medium 36 Heavy 12	>5-15 years 70 >16-25 years 19 >26-40 years 11	Ground Floor 58 First Floor 35 Second Floor 23
Age Group	Activity Level at the office hours	Office Layout	Adjustable Components
26> 35 47 36>45 29 46>60 23	Reclining 16 Sitting 48 Standing 18 Walking 18	Open 96 Closed 4	Blinds/Curtains 22 NA 41 Electric Fans 21 Windows/Doors 16
Duration of Stay	Discomfort Level at present.	Ventilation	Productivity Loss
<10- 25 years or more 88 <1-9 years 8 >1 year 4	No 80 Yes 20	Air conditioning 87 Natural ventilation 1 Hybrid 12	8:00 to 10:00 AM 10 11:00 to 1:00 PM 21 2:00 to 5:00 PM 69

Results, Analysis and Discussion

Thermal Comfort Assessment

According to survey results, many participants responded with "neutral" or "slightly comfortable" on the ASHRAE 7-point thermal sensation scale, indicating that they felt at ease in their workplaces. In terms of ASHRAE Standard 55 and ISO 7730, which require operating temperatures in the range of 23 to 26°C for summer circumstances in air-conditioned spaces, assuming light clothing and sedentary behaviour, this is in close accordance with the comfort zone. The majority of respondents thought their surroundings were satisfactory, even though the observed mean inside temperature of 28.6°C was somewhat higher than the upper limit of the ASHRAE-recommended summer range. According to this research, expectancies, cultural acclimatization, and adaptive comfort mechanisms might all be

crucial factors in how people perceive heat in the local climate.

Acceptability of Thermal Conditions

Many respondents rated their workspace's thermal conditions as adequate, according to general acceptance ratings. The widespread use of air conditioning in faculty offices, where windows are usually closed to preserve controlled indoor temperatures, is probably the reason for this elevated level of approval. However, microclimatic shifts may exist in buildings without centralized systems, especially on upper levels, where respondents reported slightly higher temperatures than in offices on the ground floor.

Physical Discomfort and Health Symptoms

Most of the participants reported no symptoms of Sick Building Syndrome (SBS), including physical discomfort. However, a small percentage did occasionally suffer from symptoms like headaches, fatigue, or eye discomfort, usually in places outside of air conditioning systems' direct coverage or in workplaces with inadequate ventilation. This result emphasizes the necessity of assessing ventilation efficiency in addition to temperature regulation, since both elements work together to influence perceived comfort and health consequences.

Impact on Productivity

Some respondents reported minor losses in productivity, especially between 2:00 and 5:00 pm, however the majority assessed their output as "normal." This decline may have been exacerbated by environmental factors like rising temperatures or decreased afternoon air flow, and it was accompanied by reports of exhaustion from the daily workload. It is significant to notice that there were inconsistent effects on productivity after departmental events or meetings, which may indicate that occupancy density and temporary heat loads could have an impact on comfort levels.

Based on measured velocities between 3 and 5 m/s, respondents assessed the airflow in the majority of offices as "acceptable." Values of 40–60% relative humidity fell within the ranges advised for indoor air quality and thermal comfort. However, based on qualitative input, the dispersion of airflow was not uniform across departments, with some offices having better air conditioning coverage than others.

Comparison with Standards and Literature

The results are in line with the occupant acceptability level of $\geq 80\%$ set by ASHRAE 55, which was met by the academic offices at UET Lahore. According to regional comfort studies conducted throughout South Asia, local acclimatization appears to be the reason the slightly higher mean interior temperature than recommended is accepted. This highlights the significance of contextual calibration when implementing international standards in climates in underdeveloped nations, where adaptive comfort models may better reflect occupant experiences.

Airflow Conditions

Comfort Level at Workspace: -

How did the respondents feel their comfort level at present in their workspace.

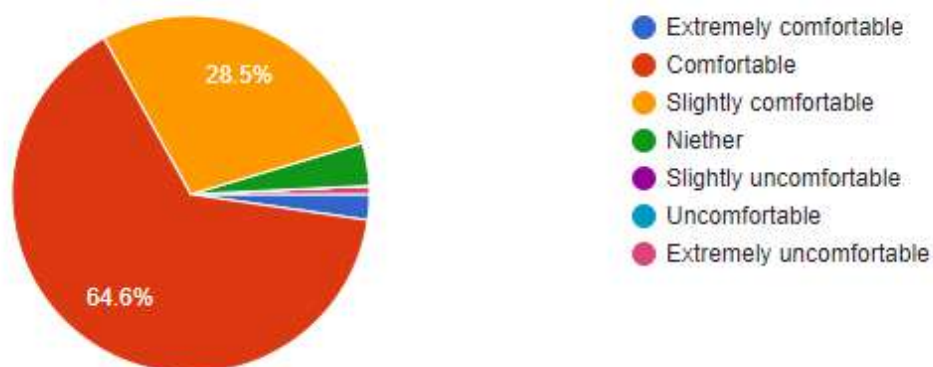


Figure 3 Comfort Level at Workspace

Fig. 3 shows that many faculty members are at ease in their jobs. Of those surveyed, 64.6% (red) said they felt "Comfortable." "Slightly

comfortable" was the response given by 28.5% (orange). Very few people chose "Neither"

(green), which is a neutral response, and "Extremely comfortable" (blue), which is a very

tiny percentage. Very few people chose "Slightly uncomfortable, Uncomfortable, or Extremely uncomfortable." The findings unequivocally demonstrate that most faculty members (more than 93%) are either completely or satisfied

with their working environment. Very few people said they were uncomfortable or neutral.

Feeling right-here right-now at workspace: -

Responses for the feelings of the faculty members at their workspace for coolness.

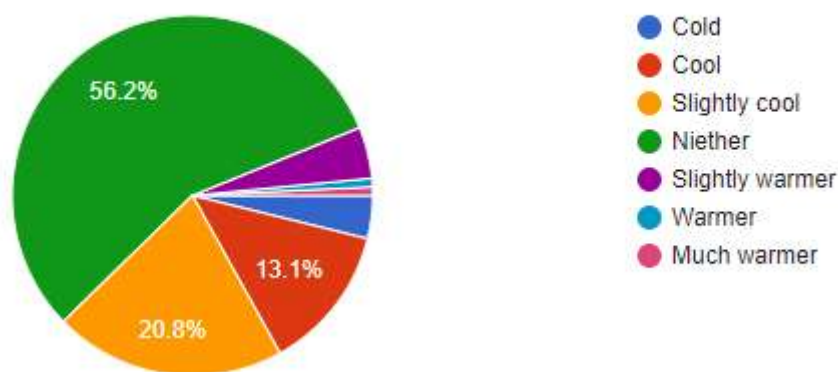


Figure 4: Feeling right know at Workspace

Most faculty members feel that they are unable to feel warm at work, as shown in Fig. 4. It indicates a comfortable interior temperature in offices. According to 56.2% (green) of respondents, they felt "Neither" about the workspace's temperature, which means they considered it either pleasant or neutral. "Slightly cool" was the response given by 20.8% (orange), indicating a noticeable but bearable coolness. 13.1% (red) said they felt "Cool," which some people could find a little uncomfortable. A lower percentage experienced warmth: Some responders said it was a little

warmer (purple). Very few are warmer (pale blue). Much warmer (pink)—an exceedingly small proportion. Additionally, a small percentage said they felt "Cold" (dark blue). Moreover, half of the faculty members believe the temperature is pleasant and neutral. Around one-third find the atmosphere on the colder side, while only an exceedingly small fraction experience it as warmer.

Acceptable level of thermal comfort at workspace: -

The general acceptability of the thermal comfort of the faculty members at their workspace.

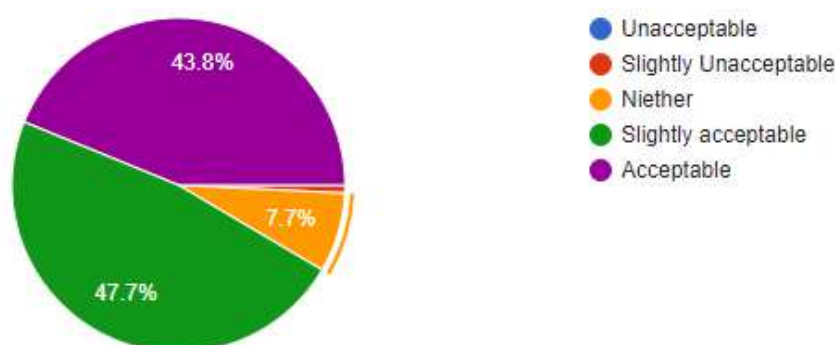


Figure 5: Acceptable level of thermal comfort

at Workspace

47.7% (green) of respondents thought the workstation temperature was "slightly acceptable," as seen in Fig. 5. 43.8% (purple) thought it was "Acceptable," indicating a generally favourable opinion. 7.7% (orange) gave the neutral response "Neither." Few people (blue/red) gave it an "Unacceptable" or "Slightly Unacceptable" rating; their percentage in the chart is insignificant. Accordingly, most faculty members (more than 91%) think that the

temperature at their workplace is either suitable or at least marginally acceptable. Just a small percentage indicated displeasure or indifference.

Any physical discomfort in The Building: -

Do the faculty members feel any physical symptoms of discomfort in the building.

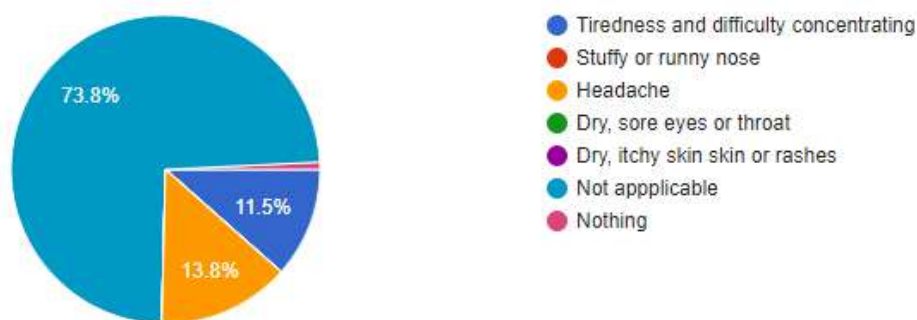


Figure6: Physical discomfort in The Building

73.8% (cyan) of respondents indicated in Fig. 6 that they did not encounter any symptoms associated with the workplace environment, meaning "Not applicable." 13.8% (orange) mentioned they had headaches. 11.5% (dark blue) said they were exhausted and had trouble focusing. Other symptoms (such as a painful throat, dry or itchy skin, or a stuffy nose) were chosen in very tiny percentages and were hardly noticeable on the chart. The findings demonstrate that the majority of faculty members—three-fourths—did not

experience any health problems as a result of their working conditions. Nonetheless, a small percentage of respondents had symptoms including headaches (13.8%) and fatigue/difficulty focusing (11.5%), which might be related to interior environmental elements like ventilation, lighting, or air quality.

Productivity level affected by the Thermal comfort: -

Does the thermal comfort ever effect the faculty members productivity at any time.

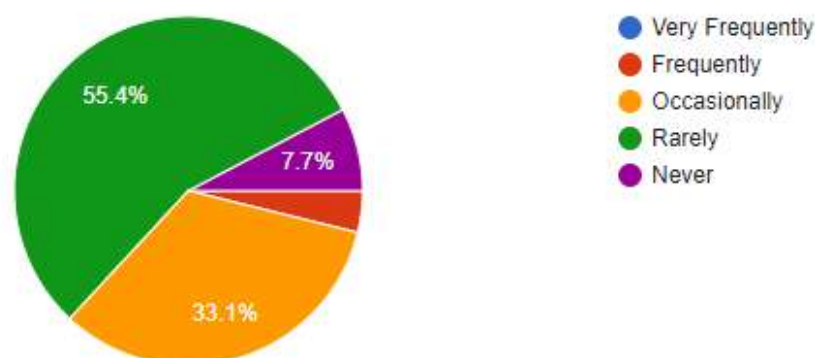
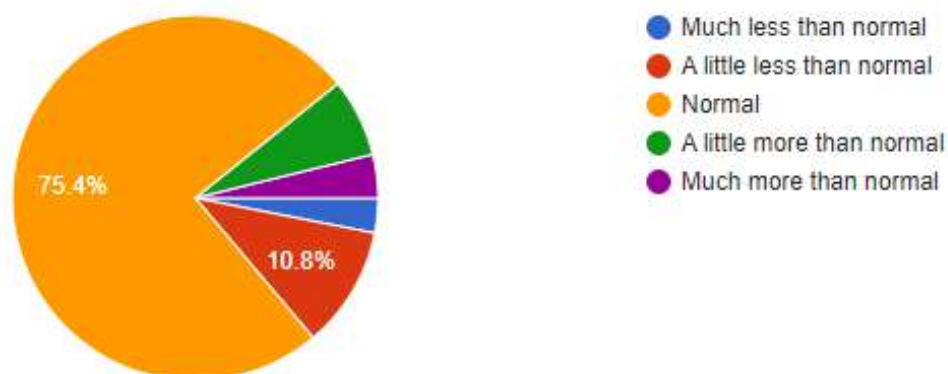


Figure 7: Productivity level affected by the Thermal comfort

This Fig. 7 shows that the productivity level of mostly faculty members is rarely affected (during the time 2-5 pm) because of tiredness of entire day. And productivity level of some members affected occasionally (after meetings, events).

Rate of productivity at your space: -

How the faculty members rate their overall productivity at their space.

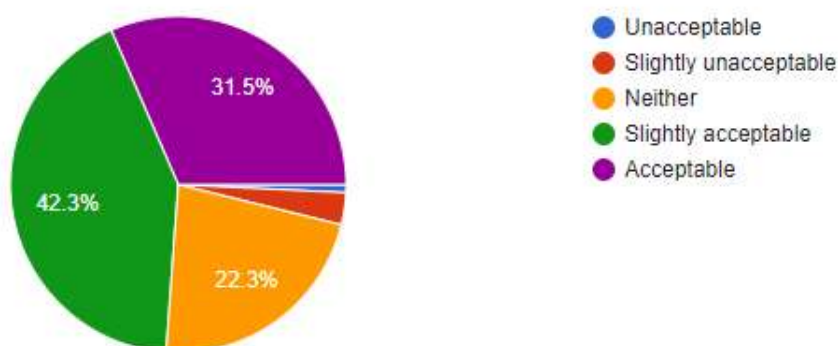
**Figure 8: Rate of productivity at your space**

According to Fig. 8, 75.4% (orange) of respondents reported their productivity was "Normal." A little less than normal" was indicated by 10.8% (red). Few respondents claimed that they were "much less than normal" (blue), while only a small proportion said that they were "a little more than normal" (green). The purple phrase "much more than normal" refers to little. In their existing workplace, most faculty members (more than three-fourths) believe that their productivity is unchanged and

at regular levels. While just a tiny percentage claim lower or higher productivity than usual, a smaller fraction (about 11%) thinks that productivity is decreased. The productivity rate of mostly faculty members at their offices is normal.

Airflow at the workspace: -

How does the airflow in the department/workspace rate according to the faculty members.

**Figure9: Airflow at the workspace**

According to Fig. 9, 42.3% of respondents (green) thought the conditions were "slightly acceptable." They were rated as "Acceptable" by

31.5% (purple). The neutral response "Neither" was given by 22.3% (orange). Very tiny proportions selected: "Slightly unacceptable" (red) - a minimal percentage, "Unacceptable" (blue) - insignificant. Most respondents (almost 74%) had a good opinion of the workplace environment, finding it to be either acceptable or marginally acceptable. Only a tiny percentage thought it was objectionable, while about one-fifth was neutral. Most offices had adequate air flow.

Physical Measurements: -

The average indoor temperature reading taken as 28.6 measured in degree Celsius in the offices of the respondent faculty members. Air velocity in most offices was between 3-5 m/s. Humidity of most offices of the faculty was between 40-60 %.

Occupant Experience Analysis at UET Lahore

Many employees (approximately 33) chose "Comfortable" as their most common response in Fig. 10, indicating that they are comfortable with the thermal environment. "Slightly Comfortable" (around twenty-five individuals) is the second most popular response, indicating that many people feel content but not entirely at ease. The replies to "Slightly Uncomfortable" and "Extremely Comfortable" were comparable (approximately thirteen persons each), suggesting some variation in individual preferences. "Neither" was selected by a smaller group (about eight persons), indicating that they are neutral. Few respondents said that they were "Uncomfortable" (4 individuals) or "Extremely Uncomfortable" (3 people), indicating that discontent is uncommon.

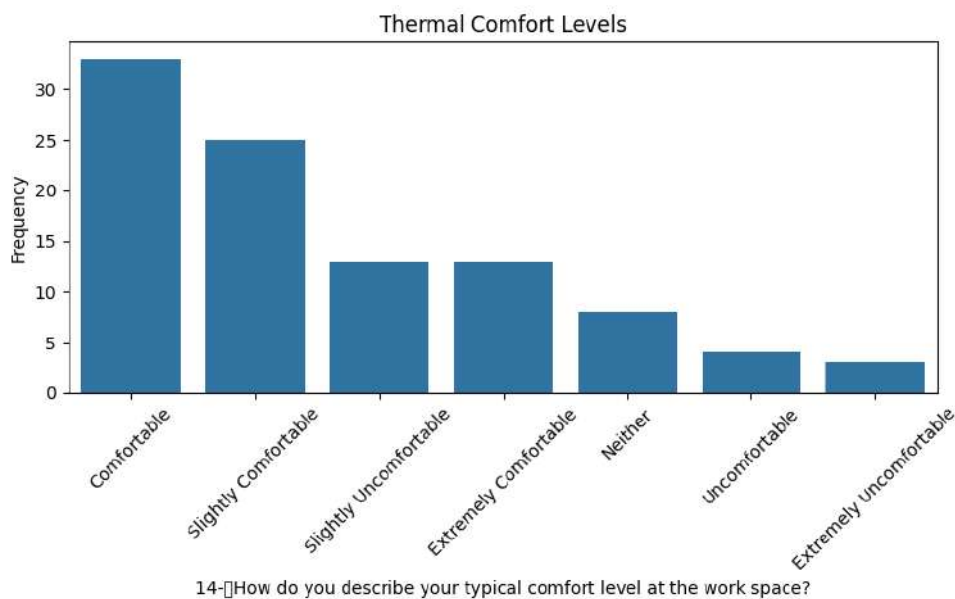


Figure 10: Thermal Comfort Trends

Only a small percentage of respondents reported actual pain, with the majority falling somewhere on the pleasant end of the spectrum. This implies that, although some people continue to have problems that could require attention (whether because of personal preferences, office location, or temperature sensitivity), the thermal conditions at work are typically well-managed.

Productivity Ratings

Fig. 11 displays the results of a questionnaire on workplace productivity assessments. About twenty-five respondents chose "Normal" as their most popular response, indicating that many workers believe their output is neither abnormally high nor poor. With about twenty-three respondents, "A little less than normal" is

the second most common response, indicating that some workers believe that their output is hampered. According to the responses "A little more than normal" (20 people) and "Much more than normal" (18 people), a sizable percentage of workers believe that their

workplace occasionally increases their productivity. "Much less than normal" was the response given by the smallest group (13 individuals), indicating that they felt noticeably less productive at work.



Figure 11: Productivity Ratings

Most workers consider their productivity to be typical or about normal, while significant numbers indicate productivity that is greater than average. A sizable portion, nevertheless, report feeling less productive than usual, which may indicate issues with environmental

variables, task management, or distractions (related to thermal comfort, as seen in the preceding chart). Most said they were either normal or below normal in terms of production. A significant decrease in productivity was reported by several responders, which was frequently linked to discomfort or symptoms of SBS.

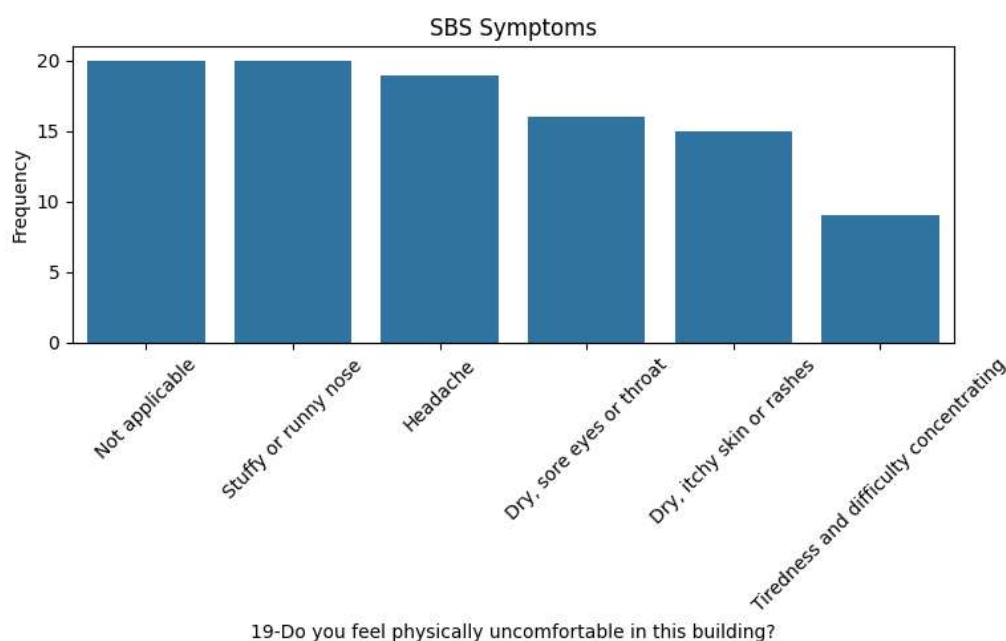


Figure 12: Sick Building Syndrome (SBS) Symptoms

The findings of a survey on symptoms of Sick Building Syndrome (SBS) at work are displayed in Fig. 12. The interpretation is as follows: "Not applicable" and "Stuffy or runny nose" are the most common answers (20 each). This indicates that a large number of workers either do not suffer any physical discomfort or mostly deal with respiratory problems. About nineteen individuals report having headaches, which suggests that working circumstances may occasionally be a contributing factor in pain. Moderately frequent reports of dry, itchy skin or rashes (15 individuals) and dry, painful eyes or throat (16 people) may be related to humidity levels or indoor air quality. "Tiredness and difficulty concentrating" (9 persons) is the least prevalent but still noteworthy; it can also be linked to inadequate lighting, thermal comfort, or air circulation.

Even if a substantial number of workers say they are not uncomfortable, many nonetheless have skin, respiratory, or concentration-related issues. This might indicate problems with humidity, ventilation, or

air contaminants in the interior environment. Although many residents did not report any physical pain, many did describe symptoms like fatigue and headaches, particularly in buildings with limited ventilation or poor airflow.

SDGs Mapping:

As shown in Fig. 13 SDGs are mapped with research work.

SDG 3: Good Health and Well-being: By evaluating and improving thermal comfort, you reduce health symptoms (e.g., headaches, tiredness, concentration issues) and promote physical and mental well-being in workplaces.

SDG 7: Affordable and Clean Energy: Optimizing thermal comfort often involves energy-efficient HVAC systems, natural ventilation, and passive design strategies, reducing reliance on non-renewable energy sources.

SDG 8: Decent Work and Economic Growth: Improved comfort boosts productivity and reduces absenteeism, contributing to healthier, more effective workplaces and better economic performance.

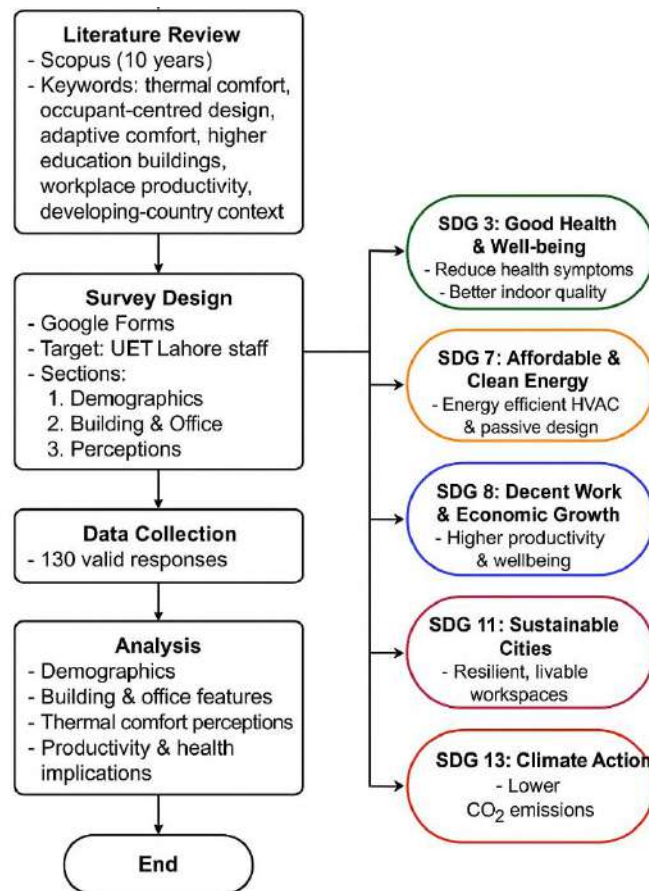


Figure 13: SDGs mapping with survey design

SDG 9: Industry, Innovation, and Infrastructure:

Promotes sustainable building technologies and innovative design approaches to achieve better indoor environments.

SDG 11: Sustainable Cities and Communities:

Creating sustainable and resilient office environments enhances urban sustainability, making cities more liveable.

SDG 12: Responsible Consumption and Production:

Efficient use of energy and sustainable building design practices minimize resource consumption while maintaining comfort.

SDG 13: Climate Action: Energy-efficient thermal comfort strategies reduce greenhouse gas emissions, directly contributing to climate change mitigation.

This research contributes most strongly to SDG 3 (Health & Well-being), SDG 7 (Clean Energy), SDG 8 (Decent Work), and SDG 11 (Sustainable Cities), while also aligning with SDG 12 (Responsible Consumption) and SDG 13 (Climate Action).

Conclusion and Recommendations

This study integrated measured indoor environmental parameters with occupant perceptions to evaluate the thermal comfort of academic and staff offices at the University of Engineering and Technology (UET) Lahore. The outcomes demonstrate that most respondents thought their workstations were thermally comfortable, with acceptability ratings that either met or surpassed the ASHRAE Standard 55 baseline of 80%. Most occupants agreed that the mean measured interior temperature of 28.6°C to be acceptable, despite it being slightly higher than the normal suggested summer range for air-

conditioned facilities. This is due to cultural acclimatization and adaptation expectancies in the local environment. With recorded air velocity of 3–5 m/s and relative humidity of 40–60%, most offices had airflow and humidity levels within advised comfort criteria.

Only a small percentage of respondents mentioned symptoms of Sick Building Syndrome, especially in places with inadequate ventilation or without air conditioning. Overall, productivity effects were negligible, but they tended to manifest in the late afternoon and were associated with both slight temperature rises and cumulative weariness. Regarding architectural attributes, a recurring pattern was noted: orientation indicated higher heat exposure. Classrooms and laboratories frequently lack mechanical cooling, even though most offices have air conditioning. Therefore, the following recommendations are based on the preceding conclusion:

Centralized Cooling Systems: To guarantee consistent thermal comfort in all work and learning areas, including classrooms and labs, departmental installation of central air conditioning systems is advised. **Ventilation Optimization:** To solve localized airflow inadequacies, especially in workplaces on upper floors and spaces with closed layouts, review and enhance air distribution patterns.

Adaptive Comfort Integration: Building operations may use adaptive comfort techniques to save energy consumption while preserving occupant satisfaction, given the study's findings on tolerance for higher interior temperatures. **Zonal Thermal Management:** Using zoned control systems, zone thermal management enables precise temperature and airflow modifications based on building orientation, floor level, and occupancy density. **Health Monitoring and IAQ Checks:** To guarantee the long-term health and well-being of occupants, conduct routine indoor air quality tests and keep an eye on complaints pertaining to SBS. This research contributes most strongly to SDG 3 (Health & Well-being), SDG 7 (Clean Energy), SDG 8 (Decent Work), and SDG 11 (Sustainable Cities), while also aligning with SDG 12 (Responsible Consumption) and SDG 13 (Climate Action).

UET Lahore can improve the total indoor environmental quality of its campus facilities, decrease productivity losses, and enhance employee well-being by coordinating building operations and design initiatives with occupant-centred comfort requirements. These findings add to the body of information for creating user-centred, climate-responsive thermal comfort guidelines in higher education institutions with comparable climatic and cultural settings.

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Authorship Credit

All authors contributed equally to the completion of the manuscript.

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Geo location information

Lahore, Punjab, Pakistan

Declaration of Conflicting Interests

The Author(s) declares that there is no conflict of interest.

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