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Examining Relationship between Indoor Thermals and Visual Environment of Educational Institute: A Case Study of Engineering University, Main Campus Lahore

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Abstract: *In today's world, people tend to spend a substantial amount of their time in an indoor environment. The productivity and well-being of building inhabitants are greatly impacted by the quality of the indoor environment. Indoor quality and comfort depend upon various aspects like thermal comfort, visual environment, and acoustic and air quality. The main campus of Engineering University was selected for this study, and data was obtained from the campus to analyze the indoor thermal and visual environment for the winter. The physical, environmental, and personal factors for indoor thermal and lighting parameters of visual assessment were monitored. A sample size of nighty eight students was selected for the study by applying probability and snowball sampling techniques. The study was conducted by utilizing the occupant's survey and asses the findings on the standards established by the international organization, i.e., ASHRAE-55. Results indicate that occupant's response towards visual comfort is positive, while indoor thermal quality deviates from a set of standards established by the organization. Major sources of discomfort in the indoor environment, specifically in winter, are moving air and poor working of the heating mechanism. Thus, smart control sensors should be integrated to regulate the quality standards, occupancy sensors, BAC (Building et al.) systems, and lighting control systems that allow individuals to adjust according to their comfort range. Regulates the follow-up feedback from occupants yearly to maintain and improve the indoor thermal and visual comfort of the campus. The study examined the interventions and underlined the influence of indoor thermal and visual comfort on students learning outcomes in higher education contexts. A comprehensive study of each department should also be conducted to highlight problematic areas based on the study's parameters.*

Key Words: Indoor Thermal Comfort, Visual Environment, Educational Institute, ASHRAE-55

Introduction

Thermal comfort is about senses and feelings. The ASHRAE (American Society of Heating, Refrigerating and Air Conditioning Engineers) defines it as the condition of mind which expresses satisfaction with the surrounding environment of the occupants. In modern societies, people spend approximately 20 hours per day in an indoor environment. The indoor environment has a significant impact on student's health, holistic well-being, and efficiency. Generally, the assessment includes examining indoor environmental quality (IEQ), which highlights the four environmental factors like thermal, indoor air quality, acoustical, and visual that combined collectively influence human perception (Palella, 2021) about being comfortable in current environmental settings. However, assessing comfort remains one of the most significant factors influencing ecology and building sustainability (Bin, 2021).

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Literature indicates that buildings account for nearly 40% of global energy consumption, with educational buildings being among the highest consumers. This emphasizes the need to enhance energy efficiency in educational buildings without compromising comfort. From this perspective, enhancing the overall performance of educational buildings is crucial due to the interconnection between comfort and functionality. Educational facilities are designed to provide an optimal setting for learning in which students can effectively acquire knowledge and skills. In the context of educational buildings, which exhibit variable spatial usage, diverse social and geographical surroundings, and cultural characteristics, achieving thermal comfort has gained substantial attention from scholars, given that students spend approximately 30% of their time in classrooms, the classroom environment has a direct impact on their physical and mental health, as well as their learning performance and concentration (Riaz et al., 2023). Therefore, indoor thermal and visual comfort is of worldwide importance. Indoor Thermal comfort and visual environment are two important factors that affect the health, well-being, and productivity of occupants in buildings. For example, Research indicates that individuals who are exposed to thermal discomfort are more likely to experience fatigue, headaches, stress, dehydration, dizziness, loss of consciousness and difficulty concentrating. People who are exposed to poor visual conditions are also more likely to experience fatigue and eye strain.

Additionally, Indoor thermal comfort and visual environment also play a role in energy efficiency. Buildings, for example that are constructed to maximize natural light while minimizing heat loss and gain might consume less energy to heat and cool. Over the last two decades, extensive research has continuously proven a relationship between Indoor Environmental Quality (IEQ) and occupant performance, health, and attitudes. On the other hand, Visual Comfort is the main tool for designing a living environment. 75–90% of the information which a person perceives visually is obtained from their surroundings (Dolnikova & Katunsky, 2019). Both aspects are important to consider a suitable, comfortable learning environment for the students. The thermal environment in educational facilities, including university libraries, influences students' productivity, consistency, comfort, and well-being (Disci et al., 2023).

Globally, keen attention is paid to the subject of indoor thermal comfort and visual environment standards, and laws are formulated on particular aspects. Educational buildings are considered unique types of buildings due to their function and usage. According to the U.S. Department of Education, students spend an average of 1195 hours in the Classroom each year. In the educational buildings of developing countries like Pakistan, keen attention is given only to the physical aspects of buildings, which include aesthetics, structure and design. Factors related to the comfort of the user are neglected. Like other university around the global the students of Pakistani universities also face problems related to indoor comfort factors.

Hence, these situations have adverse effects on the health of occupants. Many universities and institutes in Pakistan evaluate their efficiency yearly through surveys, but feedback related to thermal or visual comfort is not taken into account. Thermal comfort assessment cannot be evaluated without students' perception of their thermal comfort. Thus, the study highlighted the factors that affect the thermal and visual comfort of occupants and their perception of thermal comfort assessment. The goal of this research is to evaluate indoor thermal comfort and visual environment in educational institutes. The research will achieve the following objectives:

- i To evaluate the impact of the Physical Environment on Learning Outcomes
- ii To test whether the indoor environment is lower than the outdoor environment
- iii To evaluate the impact of the building plan on the thermal comfort of the user
- iv To Formulate the recommended model

Literature Review

According to the scientific literature, there are several indicators that can be used to analyze the human comfort environment, but the differentiation between health and comfort indicators can be ambiguous. While studying the impact of the thermal environment in relationship to indicators, only five are standardized: Wet Bulb Globe Temperature (WBGT), required clothing insulation (IREQ), Predicted Heat Strain (PHS), and Predicted Mean Vote (PMV) and Predicted Percentage of Dissatisfied (PPD) for thermal comfort (Palella, 2021). Conversely, for the assessment of the visual environment, no specific indicators have been designed, and they are only associated with inadequate lighting exposure. Instead, similar indicators are utilized to identify inadequate light exposure and to evaluate visual comfort. Furthermore, only certain indicators (e.g., PMV, PPD, etc.) can stand alone as they integrate various physical parameters, offering comprehensive insights into human perception of a particular environmental factor.

A field study of thermal comfort for educational buildings was carried out in university classrooms across New South Wales, Australia, to evaluate or enhance students' comfort zones in the provided circumstances. The study aimed to determine both the thermal neutral and preferred temperatures by employing a combination of subjective and objective approaches. (Alghamdi et al., 2023) chooses the field study comprising measurements of indoor thermal comfort parameters using instruments (objective approach) and questionnaire surveys (subjective method) in three distinct University of Newcastle classrooms. Another field survey was conducted at the University de la Costa, in the Colombian region, with a concern to study the perception and acceptability of thermal comfort among the students in the classroom (Balbis-Morejón et al., 2020). A subjective approach was adopted by collaborating with the adaptive, the adaptive-variable, and the standard or Fanger thermal models to evaluate indoor and outdoor comforts. This method allowed for a comprehensive assessment by incorporating human feedback and personal experiences. By integrating these models, the study could capture a wider range of comfort perceptions and provide a more nuanced understanding of how different factors influence thermal comfort in various environments. This blend of models also facilitated a more accurate representation of occupant comfort, considering both theoretical and experiential perspectives.

(Ionta, 2021) says that vision is the main entrance for environmental input in the human brain. Visual comfort is defined as a "subjective condition of visual well-being induced by the visual environment (Dolnikova & Katunsky, 2019).

The visual environment plays a crucial role in shaping our experiences and well-being. From lighting to non-lighting features, these elements significantly impact our comfort, satisfaction, and overall functioning, particularly in settings like educational institutes.

A study conducted in the U.S. examines how different indoor settings in educational facilities may influence students' learning capabilities. The study delves into the impact of visual surroundings on student achievement, considering various metrics mentioned in the standard. These metrics include Horizontal Sight Angle, Outside Distance of View, and Number of View Layers, alongside traditional measures of daylight and electric lighting, emphasizing factors such as light availability and glare (Kuhlenengel et al., 2012). In China, another study related to the visual comfort of an educational institute was conducted, which highlighted the parameters of the visual environment in general. Research linked particular visual environmental factors or interventions related to the health outcomes of children. Most areas are concentrated on the topics of lights and access to nature. The assessment tools used for the study were interventional and experimental studies and comparing them with the Public Health Practice Project (EPHPP) standard (Meng et al., 2023). According to the study, Visual environmental characteristics can be divided into five categories: Lights, Access to nature, Windows, Aesthetics and spatial Arrangements.

Hence, several studies have been done in many countries like Australia, China, Spain, the U.S., and Colombia to assess indoor thermals and visual comfort. But Pakistan lacks in such a research field. Thus, this study will fill the gap between the literature and help universities; by focusing on this under-researched area, the study aims to contribute to the global understanding of thermal comfort and offer practical recommendations for improving campus environments. The findings will help universities in Pakistan to better quantify and address students' comfort needs, leading to enhanced learning environments and potentially influencing future building design and management practices.

Methodology

The research methodology opted for in the study is based on both objective and subjective methods, as evidenced by the literature. Data is analyzed in SPSS and Excel, and the final simulation of results is developed with the help of the CBE tool. For the assessment of the visual environment, the Likert scale is used, and results are analyzed with the help of SPSS and Excel.

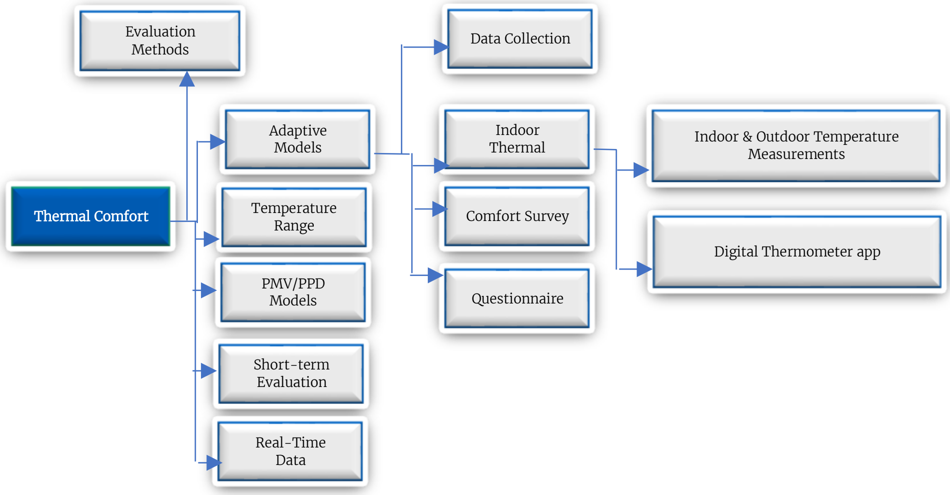
This research selects the University of Engineering and Technology (UET) Lahore Main Campus as a case study due to its confluence of prestigious reputation, focus on engineering and technology, and potential for in-depth exploration along with historic excellence. UET also serves as a cultural and learning hub for students as it provides a rich environment in which to study various aspects of research practices and technological advancements. Nestled in the bustling city of Lahore, the University of Engineering and Technology (UET) Lahore stands as a beacon of academic excellence in Pakistan. Situated amidst the vibrant streets and historical landmarks of Lahore. UET Main Campus is situated in the northern part of Lahore on historic G.T. Road near magnificent Shalimar Gardens.

To assess the indoor thermal of campus six parameters are selected these includes four environmental and two personal parameters for visual comfort five factors from literature were selected. A questionnaire regarding the comfort level of students in Classroom was developed and data collected related to the occupants' perception about comfort.

For the study of thermal and visual comfort, the research used both qualitative and quantitative approaches for data collection from the case study area (UET main campus). Thermal comfort scales formulated by studying ASHRAE-55. Thermal comfort scales are used to collect subjective data on thermal comfort quickly and easily. The Questionnaire was divided into three sections, first section includes the basic information of the respondents, while section two investigates the thermal comfort perception of respondent and last section enquire about the visual perception of respondents.

Figure 1

Data evaluation and collection methods flow chart



Results & Discussions

Data was organized and then analyzed in Spss, and the final simulation was presented in the CBE tool for assessment of the current state of thermal comfort. As the study focuses on students, a sample size of 98 was collected from all over the campus by using Google Forms. Results show that 56% of male and 44% of female students participated in the study. The findings will shed light on the thermal sensation experienced by occupants in the winter season. The majority reported that indoor university campuses effectively fulfil the thermal comfort needs of their occupants in winter-based survey results. Based on the CBE tool, PMV and PPD show a higher percentage of dissatisfaction.

However, occupants of the main campus were simultaneously exposed to all parameters during surveys. Satisfaction level was measured by asking people to rate their comfort level on the ASHRAE scale of thermal comfort assessment, which recommends that overall evaluation of the indoor parameter based on the individual physical factors any index to combine Table 1 shows the higher percentages of responses from database.

Table 1

Perception of occupants about thermal comfort state

S. No	Description	Occupants' Perception	Percentage
1	Current state of thermal comfort	Indifferent	58%
2	Satisfaction level of indoor temperature	Satisfied	50%
3	Activity level	Relaxed/seated	35%
4	Humidity	Satisfied	64%
5	Air Movement	Satisfied	51%
6	Clothing insulation	Light to medium	25%

The subjective data have been summarized and evaluated on the objective scale with the help of the CBE thermal comfort assessment software and comply it with ASHRAE 55 – 2023. Three operative temperatures with the highest activity range are calculated, and the average range for PMV and PPD is calculated. Results of the analysis are shown in the table 4.2.

Table 2

Measured and calculated parameters from CBE

Predicted Mean Vote	Predicted % dissatisfied	Cooling Effect	Air Speed (m/s)	Standard Effective Temperature
PMV	PPD	CE	VR	SET
-1.39	45%	Cool	0.2	20.8°C
-3.60	100%	Cold	0.3	13.4°C
-2.52	94%	Cold	0.2	17.1°C

Source: CBE assessment tool simulation

Figure 1

Indicates the operative temperature is 12 °C with humidity of 30%

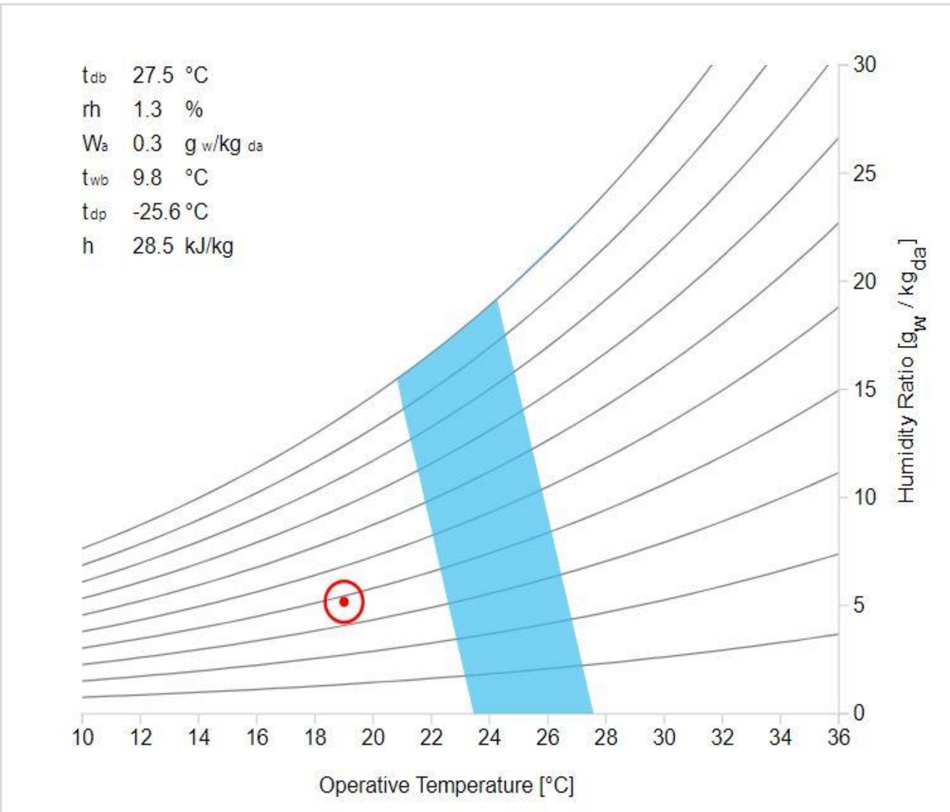


Figure 2

Indicates the operative temperature is 18 °C with humidity of 30%

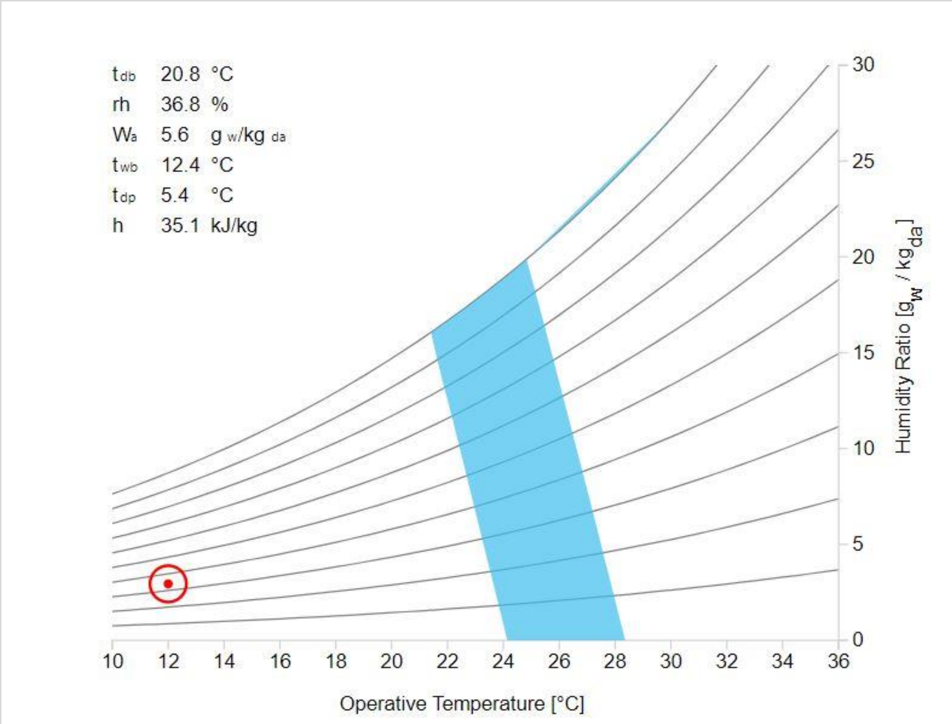
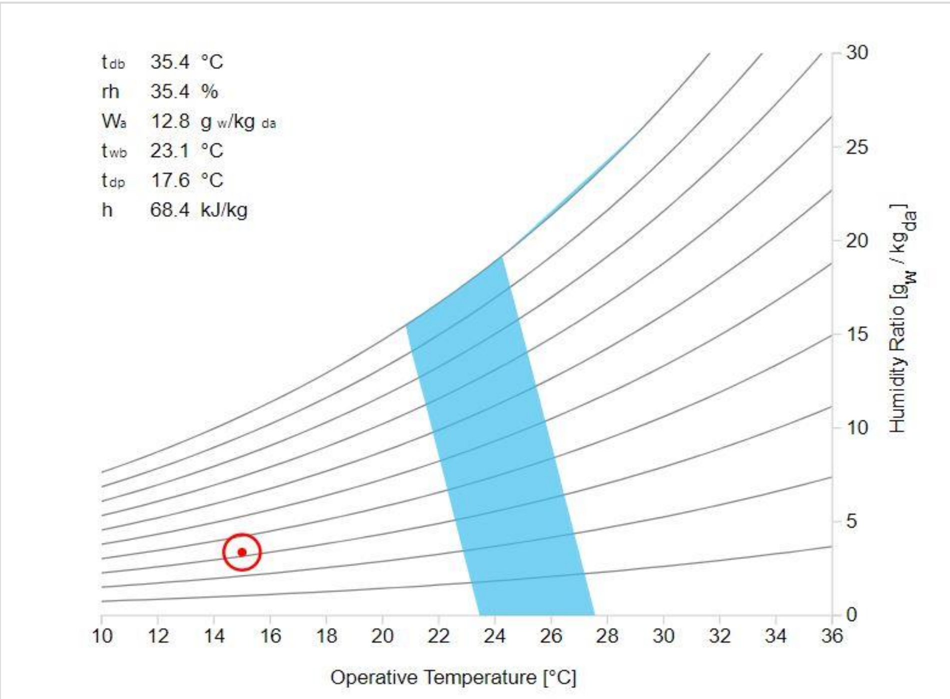


Figure 3

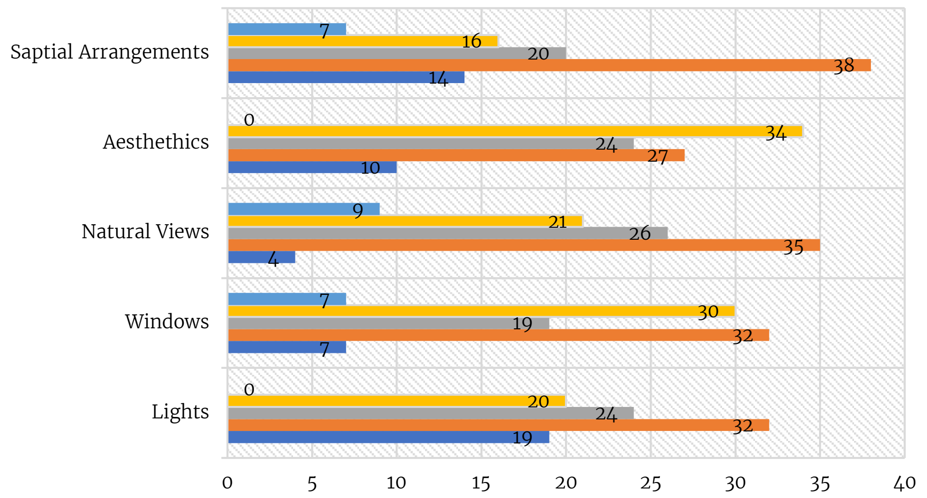
Indicates the operative temperature 15°C with humidity 30%



The recorded values for the PMV and PPD are not in compliance with the ASHRAE 55 standard. The comfort range for PMV is between -0.5 and +0.5; Table 2 shows the deviation from the standard with colder sensations and thermal discomfort. Similarly, PPD is in the acceptable range of 20% in ASHRAE 55 and Table 2. Results are not in favor of the thermal comfort range. The collected data for the assessment of the visual environment have been evaluated using the selected parameter from literature about human perception based on the objectives of the study. Respondents were asked to rate their current level of comfort with visual perception on the Likert scale in accordance with visual environment acceptance.

Figure 4

Visual environment parameters



	Lights	Windows	Natural Views	Aesthethics	Saptial Arrangements
V.Dissatisfied	0	7	9	0	7
Dissatisfied	20	30	21	34	16
Indifferent	24	19	26	24	20
Satisfied	32	32	35	27	38
V.Satisfied	19	7	4	10	14

The results from the data are shown in Figure 4.4 and trends are shown graphically. Graph illustrated that people are satisfied with visual environment of university campus while few respondents say they are dissatisfied in terms of spatial arrangements and colors.

Conclusion

Evaluating the quality of indoor thermal comfort and visual environment is crucial for providing a healthy, focused, and productive environment for students on university campuses. Thermal comfort, which refers to the state of thermal sensations where occupants feel neither too hot nor too cold, and visual comfort, which is related to the illumination sensations and the ability to view things clearly without strain and glare, are both important factors. By assessing these aspects, universities can play a valuable role in energy efficiency and optimize the building operation, design and maintenance action plan. The following the main conclusions are drawn:

i. Indoor thermal and visual comfort significantly impacts students' well-being and productivity. The physical parameters of the indoor environment are closely linked to positive learning outcomes. By analyzing feedback from respondents, this study identifies the number of satisfied occupants and explores the reasons for dissatisfaction and sources of discomfort.
ii. Respondents have identified several factors causing discomfort in indoor thermal and visual comfort. Major issues include inadequate air movement and ineffective heating and cooling systems. While the majority are satisfied with visual comfort, a few reported that solar radiation leads to discomfort during peak hours.
iii. In terms of indoor air quality, results show that responses range from indifferent to satisfied. Moreover, most of the respondents used dense clothing insulation, such as sweaters and coats, with a light to medium activity rate during the field survey.
iv. Regarding the thermal and physical aspects of the classrooms, most of the buildings are well-insulated and utilize solar control systems. The departmental layouts follow a traditional design, featuring corridors and courtyards surrounded by rectangular classrooms. The courtyards are landscaped with deciduous trees and plants, which contribute to maintaining a controlled and well-ventilated indoor thermal environment.

v. The visual environment of the university campus fosters positive and productive learning outcomes. Illumination and use of interior elements like the colour of classroom walls, surfaces, furniture, and physical appearance of the Classroom are the key elements to quantify the visual performance of the indoors. Neutral and warm colours are used in the interior with a blend of landscaping and artificial lighting. A significant number of respondents are satisfied with the visual environment of the university, but few pointed causes of discomfort, like the glare effect during a sunny day or the dark surface appearance.

To conclude this discussion, it was found from the results that the overall rating scale of indoor thermal and visual comfort of the campus with the ASHRAE 55 benchmark deviates. This discrepancy highlights the need to understand the underlying causes of discomfort and the variations in comfort factors. By identifying these issues, the findings provided valuable insights into specific areas for improvement and helped in developing more effective strategies to enhance comfort. Addressing these variations can lead to better alignment with established standards, ultimately improving the overall quality of the campus environment for students and staff.

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