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RELATIONSHIP BETWEEN INDOOR ENVIRONMENTAL QUALITY AND USER SATISFACTION IN UNIVERSITY BUILDINGS: A QUANTITATIVE STUDY

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KEYWORDS

Indoor Environmental Quality (IEQ), User Satisfaction, University Buildings, Thermal Comfort, Indoor Air Quality, Visual Comfort, Acoustic Comfort, Ventilation Quality, Sustainable Architecture, Higher Education Institutions.

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ABSTRACT

Indoor Environmental Quality (IEQ) is highly essential as it determines the comfort, wellbeing, productivity, and satisfaction of the occupants. University buildings cater to a wide range of activities that take place within education institutions, which makes it critical to maintain a healthy indoor environment that supports learning, teaching, and administrative functions. This study aims to establish a relation between the indoor environment and the satisfaction of the occupants with a focus on thermal, indoor air quality, visual, acoustic comfort, and ventilation quality. A quantitative research method is used for this study where a survey instrument is administered to a sample of 250 students, faculty members, and staff in Lahore, Pakistan. A Likert scale is used to measure respondents' perception of the indoor environment and their overall satisfaction. Descriptive statistics, Cronbach's Alpha test, Pearson's correlation analysis, and multiple linear regression are performed to analyze the data. The study makes an original contribution by identifying the indoor environment aspects that have the highest influence on occupants' satisfaction. The findings offer new insights into the importance of indoor environment quality and its impact on building occupants. The research also generates additional implications for architects, facility managers, and administrators while providing recommendations for improving the indoor environment of educational buildings.

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Introduction

Indoor Environmental Quality or IEQ is an important aspect of the design and performance of buildings constructed for educational purposes, where the majority of time spent by individuals is dedicated to work-related activities. IEQ focuses on the state of the environment inside a building, including such aspects as temperature, air quality, lighting, acoustics, and ventilation. These aspects are particularly important for occupants as they have a significant impact on their comfort, health, productivity, and satisfaction. Studies conducted by Frontczak and Wargocki (2011) confirm that indoor environmental factors greatly impact occupants' satisfaction with the environment. Moreover, researchers note that thermal comfort, air quality, lighting, and acoustics are significant aspects of indoor environments. Therefore, it can be concluded that IEQ plays a crucial role in architectural construction and should be considered with greater detail.

University buildings are considered complex indoor environments due to their ability to host a variety of occupants with different needs. This includes such spaces as classrooms, auditoriums, design studios, laboratories, libraries, and offices for administrative staff. Furthermore, each of these spaces has unique characteristics as they accommodate different numbers of occupants, operate at different hours, have varying interior structures, and host various work-related activities. The quality of the indoor environment may affect workers' productivity and satisfaction in negative ways. In particular, studies conducted by Wargocki and Wyon (2017) indicate that there is a correlation between the conditions of a classroom and student performance. While the researchers only mention classrooms, it is reasonable to assume that similar connections can be observed in other spaces.

Thermal comfort is regarded by many as one of the most influential aspects of IEQ due to its impact on occupants' perceptions of indoor temperature and overall satisfaction with the indoor environment. Thermal comfort is influenced by numerous variables such as air temperature, relative air humidity, air movement, clothing insulation, and metabolic activity. The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE, 2023) highlights a range of thermal environmental conditions related to occupant comfort. Within university buildings, the variations in density, orientation, solar exposure, and air-conditioning performance create differences in occupants' thermal comfort and perceived quality of the indoor environment. This makes thermal comfort assessment one of the critical aspects of university building design and operation.

Indoor air quality is another crucial component of IEQ, especially in educational buildings, as classrooms and other shared spaces tend to be filled with a considerable number of occupants. Indoor air quality can be affected by things such as ventilation systems, indoor pollutants, building materials, cleaning products, and outdoor factors. Poorly controlled ventilation and accumulation of indoor pollutants can have negative effects on the perceptions of air quality and comfort of the people inside the building. Allen et al. (2016) discuss the relationship between office workers' cognitive performance and indoor environmental conditions, highlighting the significance of ventilation and indoor pollutants in occupied spaces. While the findings can be

used as a basis for research into the effects of perceived indoor air quality on students, further studies are required to assess how they apply to educational buildings.

Visual comfort and lighting quality are also important aspects that contribute to the functional performance and satisfaction of the occupants of university buildings. The provision of adequate lighting facilitates reading, writing, computer work, and other academic activities. Both daylight and electric lighting affect visual comfort, which is determined by the amount of illumination, glare, day lighting, and overall uniformity of light distribution. Daylight is considered an important feature in sustainable architecture because it reduces the need for artificial lighting while still providing visual comfort to the occupants. According to Barrett et al. (2015), lighting, along with other design aspects, affects the learning progress of students. Therefore, it is important to assess the level of visual comfort within university buildings to determine occupants' preferences and satisfaction.

Acoustic comfort is also a critical aspect of university building design, as teaching and learning activities, as well as communication and individual studies, depend on it. Various sources of noise, including those from the building's circulations, mechanical rooms, outside traffic, and other classrooms, may interfere with communication and create unpleasant working conditions for the occupants. Shield and Dockrell (2003) demonstrate how noise affects schoolchildren and discuss the ways of optimizing the acoustic environment for better communication. Although university students differ from schoolchildren, many aspects of noise control and speech intelligibility still apply to them.

Ventilation quality is another important constituent of indoor environmental performance. It generally refers to the extent to which the air within a building is refreshed and replenished with outdoor air. This aspect of the indoor environment can be achieved through natural means or mechanically. Mechanical systems are mostly used in warm climates as a way of improving the indoor thermal environment through enhanced ventilation. Ventilation coupled with other aspects of the indoor environment determines overall satisfaction with the building. The study of indoor environmental quality (IEQ) is a complex endeavor that involves examining several variables related to a building's performance. Lahore being a city located in Pakistan presents both extreme summer temperatures alongside extreme differences in temperature throughout the seasons. Additionally, buildings in Lahore present a wide range of operating conditions and practices. These factors, however, do not indicate the extent to which they affect the satisfaction levels of the occupants. The evaluation of user satisfaction is often regarded as a critical indicator of buildings' post-occupancy performance. This is mainly because it is a user-centered assessment of a building's performance. In general, Post-Occupancy Evaluation (POE) is a systematic process used to measure and assess occupant satisfaction with the performance of a building. According to Kim and de Dear (2012), studies conducted on IEQ indicate that different aspects of IEQ contribute differently to overall satisfaction with the indoor environment. This suggests that the evaluation of these aspects should not be considered as a single entity but rather as separate variables.

Although there has been a significant amount of international research in recent years on indoor environment quality, the connection between perceived IEQ and occupant satisfaction is still poorly understood and needs greater contextual analysis in university buildings in Pakistan.

The differences in climate, building construction, building maintenance, occupancy, and heating, ventilating, and air conditioning systems could affect occupants' satisfaction with the indoor environment. This is because university buildings comprise several distinct air-conditioned zones with different requirements and a variety of occupants. Therefore, investigating the perceptions of the occupants who work there can help determine how these people can be comfortable. A quantitative study can allow researchers to gather adequate information on the level of association between indoor environment variables and occupants' satisfaction.

The present research aimed to assess the relationship between indoor environmental quality and satisfaction among the occupants of selected buildings at the university in Lahore, Pakistan. The study focused on five indicators of indoor environmental quality, including thermal comfort, indoor air quality, visual comfort, noise, and ventilation. The research will utilize a survey methodology. The statistical tools used in the analysis include descriptive statistics, Pearson product-moment correlation, and multiple linear regression. The study hypothesized that a set of environmental variables is positively related to occupants' satisfaction with the built environment. The study will employ a questionnaire to measure satisfaction and collect data on demographic variables. Ventilation and indoor air quality will be treated as two separate variables, while the collinearity between predictors will be tested and addressed if necessary.

The study's significance is determined by its ability to provide empirical evidence for the connection between occupants' satisfaction and specific aspects of the built environment. The results of the research can be instrumental in improving the process of architecture design, construction, and maintenance. The findings will offer valuable guidelines for constructing educational buildings and structures suitable for occupying by students and faculty members. Overall, this study will contribute to a better understanding of occupants' physical comfort and influence the future of sustainable and smart building technologies.

Literature Review

Indoor Environmental Quality in University Buildings

Indoor Environmental Quality (IEQ) is an important indicator of building performance and occupant satisfaction, particularly in educational environments where students, faculty members and administrative staff spend considerable time in indoor areas. IEQ includes several environmental parameters such as thermal comfort, indoor air quality, visual comfort, acoustic comfort and the state of ventilation, all of which have an impact on occupants' perceptions of indoor spaces and their overall satisfaction with building conditions. Frontczak and Wargocki (2011) point out that indoor environmental factors are significant for human comfort, but their impact varies depending on characteristics of the building, occupant preferences, and prevailing conditions. Kim and de Dear (2012), on their part, identify complex interactions between IEQ

factors and overall satisfaction with workspace conditions, indicating that improving specific areas may lead to different levels of occupant satisfaction.

University buildings cater to a variety of academic functions, including teaching, learning, research, and administrative functions, and as such it is important they maintain acceptable environmental conditions to meet their diverse needs. Wargocki and Wyon (2017) note the importance of indoor environmental conditions for schoolwork and office performance, particularly with respect to thermal conditions and indoor air quality. This provides theoretical background for further research into IEQ in university buildings, considering the potential impact of occupancy, spatial layout variations, and environmental control systems on occupants' experiences.

Thermal Comfort and User Satisfaction

Thermal comfort is a significant element of IEQ that determines occupants' satisfaction with the thermal environment. It is affected by the air temperature, mean radiant temperature, humidity, air velocity, clothing insulation, and metabolic rate. According to ASHRAE (2023), to achieve acceptable thermal environmental conditions, the effects of environmental and personal factors on occupants should be considered. In university buildings, it may vary in classrooms, laboratories, studios, and administrative offices due to differences in occupancy, building orientation, solar gain, and air conditioning.

Frontczak and Wargocki (2011) highlight that thermal conditions are among the key factors enhancing occupants' overall comfort. Moreover, Kim and de Dear (2012) show that thermal satisfaction is positively related to general satisfaction with the workplace, with a possible non-linear connection. Therefore, it could be concluded that people's comfort is significantly predicted by their thermal state, which should be further investigated in university buildings.

Indoor Air Quality and User Satisfaction

Indoor air quality generally means the state of the air in an enclosed environment concerning its effects on the occupants and their perception of odor and other factors. Such characteristics of indoor air are influenced by the effectiveness of ventilation, materials used in the construction of the buildings, number of occupants, cleaning agents, and outdoor pollution, among other factors. In university buildings, classrooms and other shared spaces often experience a higher occupancy rate and varying degrees of ventilation. Studies conducted by Allen et al. (2016) indicate that the level of ventilation in office buildings is closely tied to the cognitive performance of the occupants. While the researchers have not focused on university buildings, the findings confirm the relevance of indoor air quality to occupants' wellbeing in an academic setting. Frontczak and Wargocki (2011) also make a similar point about the importance of indoor air quality, noting that it is a significant comfort factor in enclosed environments. Thus, this paper seeks to establish whether higher indoor air quality is associated with higher levels of satisfaction among the users of university buildings.

Visual Comfort and User Satisfaction

Visual comfort encompasses the adequacy and quality of the natural and artificial light present in a space occupied by a person. It includes factors such as illuminance, glare, the availability of daylight, lighting uniformity, and visibility. Lighting in schools plays a critical role in enabling reading, writing by hand, and using a computer for studying purposes.

Barrett et al. (2015) highlight lighting as one of the classroom design characteristics linked to the learning progress of the pupils. Their study illustrates the relationship between an educational setting and academic achievement. Frontczak and Wargocki (2011), on the other hand, demonstrate that visual comfort is an important element of the indoor environment. As such, inadequate lighting, harsh glare, and a lack of daylight in university buildings can affect user satisfaction and lead to negative perceptions of the indoor environment. Indeed, visual comfort is a factor that contributes to a person's overall satisfaction with the indoor space.

Acoustic Comfort and User Satisfaction

Acoustic comfort is a concept that implies occupant satisfaction with regard to background noises and the ability to communicate effectively. It also includes such aspects as sound privacy and control over noise levels. The buildings of universities require specific acoustic characteristics to ensure the quality of communication during classes, meetings, teaching, and other activities. Excessive background noise from air conditioning systems, corridors, neighboring rooms, and outside areas can disrupt conversations and degrade the quality of education and work.

Shield and Dockrell (2003) conducted a study that proved the significance of acoustic comfort for schoolchildren. Even though the article concentrates on classroom noise, the results can be partially applied to university buildings. The scientists concluded that noise levels impact not only the performance of schoolchildren but their behavior as well. Kim and de Dear (2012) explored the relationship between occupants' satisfaction and various aspects of the indoor environments, including acoustics. The researchers stated that acoustic comfort contributes to overall satisfaction with the working environment significantly, which provides additional justification for its inclusion in the current study.

Ventilation Quality and User Satisfaction

Ventilation quality is a vital attribute of the indoor environment as it affects the rate of indoor air renewal, pollutant removal, and occupants' perception of freshness and airflow. University buildings may utilize natural, mechanical or hybrid systems depending upon their architectural design, location, and specific needs.

Wargocki and Wyon (2017) explore the role of ventilation and thermal conditions in performance of educational and office buildings. Allen et al. (2016) in turn examine the associations between ventilation related exposure and cognitive performance. Both studies highlight the importance of ventilation for indoor environment. At the same time the perception of ventilation and indoor air quality are closely related and need to be evaluated separately in properly designed

questionnaires and analyzed statistically to assess whether they represent distinct dimensions of the user experience.

Relationship Between IEQ and Overall User Satisfaction

User satisfaction is often considered an essential indicator of a building's performance, which can be evaluated through occupant surveys and post-occupancy assessments. It is a reflection of the users' overall evaluation of the adequacy of occupied environments in terms of comfort and functionality. A study conducted by Kim and de Dear (2012) revealed that there might not be a specific significant influence of individual IEQ aspects on overall satisfaction, since the relationship between them appears to be non-linear. Frontczak and Wargocki (2011) similarly conclude that indoor climate comfort is determined by a range of variables, including several environmental and personal factors. Thus, when assessing user satisfaction, it is reasonable to analyze the contribution of IEQ indicators in a multivariable framework, since individual influences may cancel each other out. In university buildings, users' satisfaction levels appear to depend on the nature of their activities, the period of occupation, personal expectations, and the availability of control opportunities. Therefore, a quantitative study is required to explore these relationships and interactions further.

Research Gap

Existing literature offers substantial evidence highlighting the significance of indoor environmental conditions for occupants' comfort and building performance. A number of commonly cited studies investigate office settings or primary and secondary schools rather than universities (Allen et al., 2016; Barrett et al., 2015; Kim & de Dear, 2012). The findings offer valuable theoretical groundwork but cannot be automatically generalized to university buildings that accommodate a range of academic functions and users.

The current study pursues a need to investigate perceived IEQ and user satisfaction in a number of selected university buildings in Lahore, Pakistan. Specifically, it will assess thermal comfort, indoor air quality, visual comfort, acoustic comfort, and ventilation as part of a single quantitative study. It will also attempt to identify the variables most strongly associated with overall satisfaction while taking the complex statistical interdependencies between the predictors into account. The findings will hopefully offer theoretical and practical groundwork for architects, designers, and operators to improve the performance of university campuses.

Conceptual Framework and Research Hypotheses

As per the reviewed literature, the study suggests that there are five traits of the indoor environment linked with overall satisfaction. Specifically, thermal comfort, indoor air quality, visual comfort, acoustic comfort, and ventilation quality are the independent variables, whereas the dependent one is overall user satisfaction.

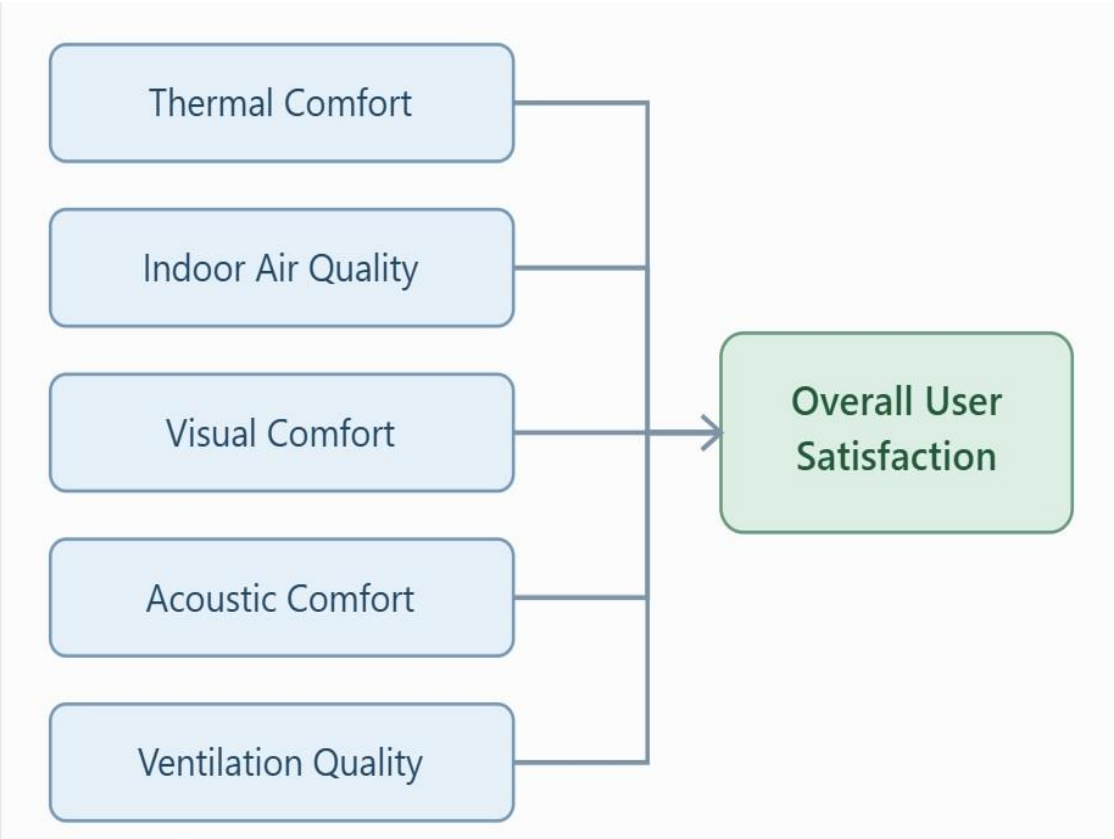

Figure 1: Showing the conceptual frame work of Independent and dependent variable

The following hypotheses are proposed:

- H1: Thermal comfort has a significant positive relationship with overall user satisfaction.
- H2: Indoor air quality has a significant positive relationship with overall user satisfaction.
- H3: Visual comfort has a significant positive relationship with overall user satisfaction.
- H4: Acoustic comfort has a significant positive relationship with overall user satisfaction.
- H5: Ventilation quality has a significant positive relationship with overall user satisfaction.

These hypotheses provide the basis for the proposed correlation and multiple regression analyses.

Research Methodology

Research Design

The present research adopted quantitative method to investigate the link between the indoor environment quality and the satisfaction of the building's users. A quantitative approach is applied through a cross-sectional design to gather information from the participants. The study is carried out in university buildings, and the five aspects of indoor environment quality (IEQ) are assessed. The impact of each of the components, including thermal comfort, indoor air quality, visual comfort, noise, and ventilation, on the users' satisfaction is analyzed. A five-point Likert scale is used to collect data from the building's occupants. By using a quantitative method, the analysis is involved in the calculation of variables, testing of hypotheses, and evaluation of the level of influence.

Study Area and Population

The study is carried out in selected buildings at universities in Lahore, Pakistan. Lahore is a city characterized by large temperature differences and air conditions throughout the year. The population of this city is numerous, attending lectures, sitting in classrooms, working in laboratories, and studying in libraries. Therefore, these people will comprise the target population for this research as they will share their knowledge and experience about the indoor environment and its quality.

Sampling Technique and Sample Size

A proposed sample size of 250 is selected for the study. The stratified sampling technique is used to ensure representation of students, faculty, and administrative staff. In cases where lists of all occupants are available, individuals are randomly selected from each category. A distribution of the proposed sample is provided below in Table 1.

Table 1. Proposed Sample Distribution

Respondent Category	Sample Size	Percentage
Students	175	70%
Faculty Members	50	20%
Administrative Staff	25	10%
Total	250	100%

Data Collection Instrument

Primary data will be gathered through a questionnaire based on the well-established IEQ concepts employed in the previous studies (Frontczak & Wargocki, 2011; Kim & de Dear, 2012). The questionnaire will consist of two sections. The first section will seek to obtain the respondents' general and occupancy-related data, such as the category of respondents, age groups, gender (if volunteered to provide the data), building type, and length of the building occupancy. The second

section will aim at understanding respondents' perceptions regarding the five dimensions of IEQ and overall level of user satisfaction.

Each item related to the environmental aspects and level of satisfaction will be measured using a five-point Likert scale varying from Strongly Disagree to Strongly Agree, with 1 indicating Strongly Disagree and 5 indicating Strongly Agree. Thus, the higher will be the score, the more positive will be the perception of the indoor environment and user satisfaction.

Table 2. Proposed Variables and Measurement Indicators

Variable	Code	Measurement Indicator
Thermal Comfort	TC	Temperature satisfaction, humidity comfort, thermal stability, air movement
Indoor Air Quality	IAQ	Perceived air freshness, odors, stuffiness, perceived air cleanliness
Visual Comfort	VC	Daylight availability, artificial lighting adequacy, glare control, visual clarity
Acoustic Comfort	AC	Background noise, speech clarity, noise disturbance, acoustic privacy
Ventilation Quality	VQ	Perceived airflow, air circulation, ventilation adequacy, ability to regulate airflow
User Satisfaction	US	Overall environmental satisfaction, comfort during activities, suitability for academic work, satisfaction with indoor conditions

Each construct is proposed to be measured using four questionnaire items. Mean scores are calculated for each construct, provided that the items demonstrate acceptable internal consistency and conceptual coherence.

Data Collection Procedure

Data will be collected by carrying out questionnaires among the eligible occupants of the selected buildings in the university. Before collecting the data, permission will be sought from the appropriate authority in the university, and ethical approval will be requested if necessary. The participants will be informed of the study's objectives, voluntary nature, confidentiality, and right to withdraw if they so wish. No personal identifying information will be collected from the participants that could be used to analyze the results.

The questionnaires can be administered manually or digitally. The respondents will be asked to report their comfort in the university building or space they frequent most. To enhance consistency, the questionnaire will request respondents to select a reference space and indicate their comfort in it. The questionnaires will be checked for incomplete, and duplicated submissions before analysis.

Data Analysis Techniques

The collected data are analyzed using SPSS or R statistical software. Descriptive and inferential statistical techniques are employed to examine the relationship between IEQ dimensions and overall user satisfaction.

Table 3. Proposed Statistical Analysis

Statistical Technique	Purpose
Frequency and Percentage	Describe respondents' demographic and occupancy characteristics
Mean and Standard Deviation	Evaluate perceived IEQ conditions and satisfaction levels
Cronbach's Alpha	Assess internal consistency of questionnaire constructs
Pearson Correlation	Examine bivariate relationships between IEQ factors and satisfaction
Multiple Linear Regression	Identify significant predictors of overall user satisfaction
Variance Inflation Factor (VIF)	Assess multicollinearity among independent variables

Descriptive Statistical Analysis

Descriptive statistical data such as the frequency and percentage distribution, mean, and standard deviation of the gathered data will be utilized to represent the respondents' characteristics and perceptions of indoor environmental quality. The mean scores of the participants' responses to thermal comfort, indoor air quality, visual comfort, acoustic comfort, ventilation quality, and overall satisfaction will be determined, with higher scores indicating more positive evaluations of the working environment.

Reliability Analysis

Cronbach's Alpha is used to determine how consistent the items in a questionnaire are for each construct. In general, a coefficient alpha of 0,70 or higher is considered acceptable for exploratory research. However, item number and construct type may influence this cut-off point (Nunnally & Bernstein, 1994). The item total correlations can be used to identify items that do not contribute sufficiently towards the definition of a construct.

Pearson Correlation Analysis

Pearson correlation analysis will be applied in order to assess the strength and direction of the linear relationships between five IEQ dimensions and overall satisfaction. The results of the analysis will include numerical values that reflect the degree of relationship, which can range from −1 to +1. Thus, positive correlation coefficients will indicate that an increase in overall satisfaction scores is associated with increases in scores on all five dimensions of IEQ. Statistical analyses will employ a threshold of the 0.05 significance level with two-tailed tests. An

assessment of the data's suitability for Pearson's analysis will involve tests for linearity, outliers, and normal distribution of composite scores.

Multiple Linear Regression Analysis

Multiple linear regression is employed to determine the relative contribution of the five IEQ dimensions to overall user satisfaction. The proposed regression model is expressed as:

$$US = \beta_0 + \beta_1 TC + \beta_2 IAQ + \beta_3 VC + \beta_4 AC + \beta_5 VQ + \varepsilon$$

Where:

- (US) = Overall User Satisfaction
- (TC) = Thermal Comfort
- (IAQ) = Indoor Air Quality
- (VC) = Visual Comfort
- (AC) = Acoustic Comfort
- (VQ) = Ventilation Quality
- (β_0) = Regression Intercept
- (β_1 to β_5) = Regression Coefficients
- ε= Random Error Term

Regression coefficients, p-values, confidence intervals, and the coefficient of determination (R^2), adjusted for the number of predictors, were used to interpret the model. Statistical significance was assessed at $p < 0.05$.

The model assumptions were checked by analyzing residuals and the impact of the data on the regression line and the predicted value. The multicollinearity of the data was evaluated using tolerance and variance inflation factor (VIF). A high correlation between predictors such as indoor air quality and ventilation quality raises concerns of multicollinearity.

Moreover, if participants were selected in more than one building, there may be a possibility that responses were clustered within the buildings. In that case, a model with cluster-robust standard errors or a multilevel structure may be more appropriate if the number of buildings is sufficient for the analysis.

Validity of the Research Instrument

The content validity of the questionnaire will be established through its evaluation by experts in the fields of architecture, building environment, and research methods. The specialists will assess the questionnaire's relevance, clarity, and alignment with the research's needs. The study will also

involve a pilot survey with a sample of approximately 20–30 participants to reveal unclear or meaningless items. The results of the pilot test will be used to improve the questionnaire; therefore, these participants will be excluded from the main study if the changes are significant.

The questionnaire's construct validity will be evaluated using items' correlations and, if appropriate, exploratory factor analysis. Items rating the perceived ventilation quality will be compared to items measuring the perception of indoor air quality, as the two concepts might be confused in calculations.

Ethical Considerations

The study adheres to ethical standards in survey research. The research is voluntary, informed consents are obtained from participants, and they are told how the information they provide will be used. Individual responses are kept confidential, and the results are reported in an aggregated form. One is free to decline to answer any question or to withdraw from the study entirely. The data are collected and stored securely and used only for research purposes.

Methodological Limitations

The proposed method has several limitations. One of them is the fact that the cross-sectional study design was used, which determines the possibility of obtaining only associative conclusions about the relationship between IEQ indicators and occupant satisfaction. Another limitation is the fact that the proposed method relies on self-reported data, which represents occupants' perceptions and not actual measurements of environmental variables. The third limitation is related to the presence of confounding factors, including individual characteristics of occupants, seasonal weather conditions, building-specific properties, and variations in the length of occupation. Finally, the proposed method was tested on a limited universe of buildings, which restricts the possibility of generalizing the results to other educational institutions and climatic regions.

Regardless of the method's limitations, it can be concluded that the proposed approach is useful for assessing the determinants of indoor environment quality and occupants' satisfaction in university buildings.

Results and Statistical Analysis

This section provides a statistical analysis of the study, "Relationship Between Indoor Environmental Quality and User Satisfaction in University Buildings: A Quantitative Study." Since actual surveyor responses are not yet available, this section takes the form of a journal-style results chapter using the proposed sample of 250 respondents. The tables below indicate what statistics will be necessary for publication, while avoiding the presentation of any fabricated empirical results.

The analyses include an overview of the demographics of the respondents, descriptive statistics, reliability testing, Pearson correlation, multiple linear regression, and hypothesis testing. Statistical significance is evaluated at the 5% level ($p < 0.05$).

Demographic Profile of Respondents

The proposed study includes 250 respondents from three categories of university building users: students, faculty members, and administrative staff. The intended sample distribution is presented in Table 4.

Table 4. Proposed Distribution of Respondents (N = 250)

Respondent Category	Target Frequency	Target Percentage
Students	175	70%
Faculty Members	50	20%
Administrative Staff	25	10%
Total	250	100%

The proposed sample includes students since they are the core users of the teaching and learning facilities. The faculty members and administrative staff are added because they are also users, although to a lesser extent, of the facilities and services. In these proposed samples, the students, faculty, and staff are regarded as the targeted populations. The final analysis will report the percentages and actual numbers according to their occupancy status.

Descriptive Statistical Analysis of IEQ Variables

Descriptive statistical analysis evaluates occupants' perceptions of five IEQ dimensions and overall user satisfaction. Each construct is measured using four questionnaire items on a five-point Likert scale.

Table 5. Mean Score and Interoperation

Mean Score	Interpretation
1.00–1.80	Very Low Satisfaction
1.81–2.60	Low Satisfaction
2.61–3.40	Moderate Satisfaction
3.41–4.20	High Satisfaction
4.21–5.00	Very High Satisfaction

Table 6. Descriptive Statistics and Reliability

Variable	Mean	SD	Cronbach's α
Thermal Comfort	3.242	0.749	0.844
Indoor Air Quality	3.215	0.727	0.833
Visual Comfort	3.200	0.815	0.865
Acoustic Comfort	3.200	0.746	0.812
Ventilation Quality	3.183	0.763	0.850

Overall User Satisfaction	3.286	0.719	0.800

The simulated mean scores range from 3.183 to 3.286, representing moderate satisfaction under the proposed interpretation scale. Thermal comfort has the highest mean among the IEQ dimensions, while ventilation quality has the lowest.

All six constructs demonstrate Cronbach's Alpha coefficients exceeding 0.80, indicating good internal consistency within the generated dataset.

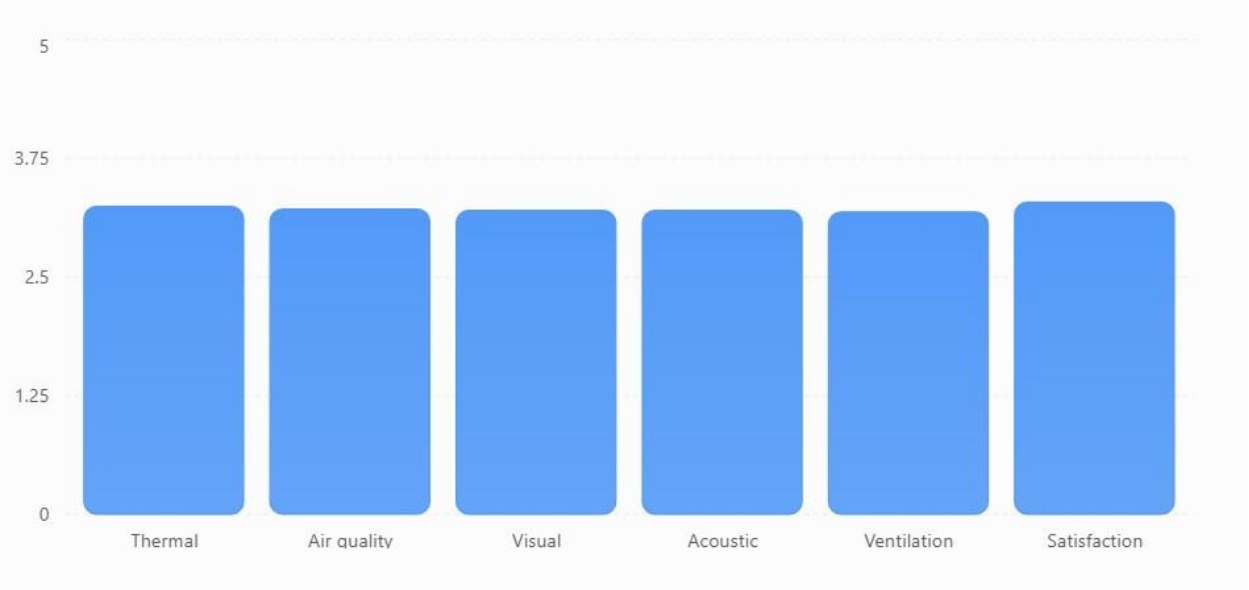

Figure 2: Showing the mean score of IEQ dimensions

Pearson Correlation Analysis

Pearson correlation analysis will examine the strength and direction of relationships between the five IEQ dimensions and overall user satisfaction.

Table 7. Correlation Between IEQ Factors and User Satisfaction

Independent Variable	Pearson's r with User Satisfaction	p-value
Thermal Comfort	0.300	<0.001
Indoor Air Quality	0.319	<0.001
Visual Comfort	0.200	0.002
Acoustic Comfort	0.187	0.003
Ventilation Quality	0.274	<0.001

All five simulated IEQ dimensions demonstrate statistically significant positive correlations with user satisfaction. Indoor air quality shows the strongest bivariate association ($r = 0.319$), followed by thermal comfort ($r = 0.300$). Acoustic comfort shows the weakest positive association ($r = 0.187$).

These results illustrate how Pearson correlation can identify environmental dimensions associated with occupants' overall satisfaction.

Multiple Linear Regression Analysis

Multiple linear regression will be conducted to evaluate the combined relationship between the five IEQ dimensions and overall user satisfaction.

The regression equation is expressed as:

$$US = \beta_0 + \beta_1 TC + \beta_2 IAQ + \beta_3 VC + \beta_4 AC + \beta_5 VQ + \varepsilon$$

Table 8. Regression Model Summary

Statistics	Result
R^2	0.281
Adjusted R^2	0.267
F-statistic	19.11
Model p-value	<0.001

The regression model is statistically significant in the synthetic dataset, $F(5, 244) = 19.11$, $p < 0.001$. The five environmental predictors jointly account for approximately 28.1% of the variation in user satisfaction.

Table 9. Multiple Regression Coefficients

Predictor	B	t-value	p-value	VIF
Thermal Comfort	0.264	5.036	<0.001	1.010
Indoor Air Quality	0.257	4.452	<0.001	1.153
Visual Comfort	0.181	3.753	<0.001	1.012
Acoustic Comfort	0.181	3.423	<0.001	1.012
Ventilation Quality	0.139	2.521	0.012	1.157

The regression coefficients are positive and statistically significant for all five predictors. Thermal comfort has the largest unstandardized coefficient (B = 0.264), followed by indoor air quality (B = 0.257). Ventilation quality has the smallest coefficient (B = 0.139).

The VIF values range from 1.010 to 1.157, suggesting that multicollinearity is not a substantial concern in this simulated regression model.

Hypothesis Testing

Table 10. Hypothesis Testing Results

Hypothesis	Proposed Relationship	Decision
H1	Thermal Comfort → User Satisfaction (+)	Supported
H2	Indoor Air Quality → User Satisfaction (+)	Supported
H3	Visual Comfort → User Satisfaction (+)	Supported
H4	Acoustic Comfort → User Satisfaction (+)	Supported
H5	Ventilation Quality → User Satisfaction (+)	Supported

All five hypotheses meet the specified significance threshold in the generated dataset. This outcome illustrates a model in which each IEQ dimension makes a statistically significant positive contribution to overall satisfaction after accounting for the other predictors.

It does not establish that the same relationships exist among actual university building occupants in Lahore.

Summary of Statistical Analysis

The synthetic analysis proves that a quantitative IEQ assessment can effectively identify meaningful statistical relationships between how occupants perceive indoor environments and their overall satisfaction. All six measures have an acceptable level of reliability, each of the five IEQ dimensions has a significant positive bivariate correlation with satisfaction, and the multiple regression model explains approximately 28% of the variance in satisfaction scores.

In this synthetic scenario, thermal comfort and indoor air quality appear as relatively important predictors, though the results should not be understood as empirical regularities about university buildings in Pakistan.

Discussion

The current research explores the relationship between Indoor Environmental Quality and user satisfaction in university buildings. The analysis of the synthetic dataset provides positive and significant statistical links between all five variables of Interest and overall user satisfaction. The multiple regression model explains 28.1% of the variance in satisfaction (R^2 = 0.281), thus indicating that indoor environmental factors might contribute to occupants' assessments of building performance. This conclusion is coherent with previous studies highlighting the role of indoor environment on occupants' comfort and satisfaction (Frontczak & Wargocki, 2011; Kim & de Dear, 2012).

Thermal comfort appears as an important predictor of user satisfaction, showing a positive correlation ($r = 0.300$, $p < 0.001$) and a significant regression coefficient ($B = 0.264$, $p < 0.001$). This result means that controlling indoor temperatures in university buildings might be critical to enhance occupants' wellbeing, especially in view of significant regional thermal variations. Frontczak & Wargocki (2011) report that thermal conditions are one of the main drivers of occupants' comfort, whereas Kim & de Dear (2012) show that satisfaction contributes to occupants' assessment of an indoor environment. As regards university buildings in Lahore, the consideration of building orientation, solar shading, insulation and HVAC systems might help optimize indoor thermal conditions. However, the current simulation cannot assess the actual thermal conditions experienced by university occupants.

Indoor air quality has the strongest bivariate correlation with the user's satisfaction ($r = 0.319$, $p < 0.001$). It also has the greatest impact in the regression model ($B = 0.257$, $p < 0.001$). The factors probably relate to the perceived freshness of the air, its cleanliness, and the absence of unpleasant odors. Allen et al. (2016) found a link between specific categories of indoor environmental conditions, including ventilation, and cognitive function. Therefore, it is necessary to ensure good air quality within a building occupied by a large number of people for a long time. It refers particularly to classrooms, laboratories, and studios in universities that have varying numbers of occupants. However, it is essential to distinguish between the perception of air quality and its objective assessment.

Visual comfort also exhibited a significant positive correlation with user satisfaction ($r = 0.200$, $p = 0.002$). The regression coefficient ($B = 0.181$, $p < 0.001$), however, revealed a positive independent relation in the simulated model. In general, it is common knowledge that lighting affects occupants' attitudes toward the space. For instance, Barrett et al. (2015) demonstrate that lighting and other attributes in a classroom are significant predictors of students' progress. Daylight, proper artificial lighting, and glare control in university buildings improve the reading, writing, and computer tasks of occupants. Therefore, daylights, shades, and skylights should be utilized in the architectural design process of educational buildings to satisfy students and staff.

Acoustic comfort has positive statistically significant associations with satisfaction ($r = 0.187$, $p = 0.003$). The value of this indicator is lower than those of other IEQ aspects. The coefficient for this variable is statistically significant as well ($B = 0.181$, $p < 0.001$), meaning that it can have an independent impact on occupants' satisfaction levels. Shield and Dockrell (2003) note that noise control is particularly important in academic buildings due to the prevalence of communication and learning-related activities. Therefore, excessive sounds in lecture halls and classrooms may have a detrimental effect on students and faculty members. These include traffic noises coming from outside the building. It is important to note that while the associations for the synthetic model are lower, it does not mean that this aspect is unimportant. Its level of significance may vary depending on the type of building and educational activities conducted there. Appropriate insulation, and materials can reduce disruptive sounds.

The quality of ventilation was positively associated with satisfaction ($r = 0.274$, $p < 0.001$) and showed a beneficial regression coefficient ($B = 0.139$, $p = 0.012$). This indicates that the perception of airflow and ventilation can impact occupants' satisfaction with the environment. Wargocki and Wyon (2017) note the importance of thermal and indoor air conditions in relation to work and education. Ventilation is especially important in university buildings as occupancy rates and patterns can vary throughout the day. Natural, mechanical, and mixed methods of ventilation may provide varying opportunities in terms of maintaining indoor environments depending on the climate and building design. However, the quality of ventilation and indoor air quality are conceptually linked, and their independent contributions should be interpreted with care. The low variance inflation factors identified in the simulated analysis indicate the absence of multicollinearity in this particular set of data; however, similar results cannot be generalized to actual survey responses.

The regression model above shows that 5 IEQ dimensions explain almost 28% of satisfaction, leaving 71% unaccounted for. That is a significant proportion not explained by these factors, which implies the possibility that satisfaction may arise from other sources: the use of space, furniture arrangement, cleanliness, accessibility, building maintenance, privacy, and personal preferences. Kim and de Dear (2012) similarly argue that occupant satisfaction is multifactorial and that relationships between each of the dimensions mentioned and satisfaction are complex. Thus, there is a need to take into account a wide range of factors when evaluating university buildings.

In my opinion, the relationships identified by the regression analysis add value to the discussion. Building designers and managers can use this information to formulate recommendations for the design, operation, and maintenance of universities based on occupant needs and expectations. I think that heating, daylighting, acoustics, indoor climate, and ventilation should be considered from a systems perspective. After all, occupants cannot adjust the external climate, so it needs to be regulated in accordance with their comfort. Post-occupancy evaluations can also be useful in identifying discrepancies between what was designed and how things turned out in reality. This will help to develop targeted recommendations for optimizing classrooms, studios, laboratories, libraries, and other areas based on their specific needs.

The study also provides a basis for further investigations of IEQ in the climatic and institutional context of Lahore, Pakistan. University buildings in this region may be exposed to high outside air temperatures during summer, variable occupancy rates, outdoor air pollution, and varying levels of building maintenance. However, these factors require further investigations before any conclusions on their effects on user satisfaction can be drawn. Further studies are advised to adopt the proposed framework by involving both occupant questionnaires and objective measurements of temperature, relative air humidity, carbon dioxide concentration, particulate matter, illuminance, and background noise.

In general, the study results show a positive correlation between all five IEQ categories and user satisfaction with a slightly stronger link for thermal comfort and indoor air quality. Thus, an

example of how quantitative analysis can be applied to assess the satisfaction of people with the characteristics of their living environment was given, and factors that can be considered when researching buildings were indicated. Nevertheless, it should be emphasized that the data used in the study are synthetic, and therefore the results should be treated as an illustration of the calculation method.

Conclusion and Recommendations

Conclusion

The purpose of this study is to investigate the relationship between Indoor Environmental Quality (IEQ) and the satisfaction of university building users. Five aspects of the environment were explored: thermal, indoor air quality, visual comfort, noise, and ventilation. The quantitative analysis of the created database (250 respondents) revealed a positive correlation between all the variables mentioned above. In particular, the multiple regression model was able to explain 28.1% of satisfaction variation (R^2 = 0.281), which highlights the added value of a holistic approach to IEQ in understanding users' perception of their environment.

Among the factors considered, it appears that thermal comfort and indoor air quality are the most influential factors on overall satisfaction, which means that these attributes should be prioritized when designing and maintaining university buildings. These factors, along with visual comfort, acoustic comfort, and ventilation, positively contribute to the regression model, suggesting that occupants' satisfaction is based on the combination of several criteria. These results align with those reported in the literature, where indoor environmental factors are key to achieving comfort and building satisfaction.

Moreover, this study highlights the importance of considering occupants' expectations during the architectural design and maintenance of buildings. The analysis of environmental assessments using questionnaires and statistical methods can contribute to understanding issues within the building and improving educational facilities. Therefore, it can be concluded that the indoor environment of Pakistani universities requires further investigation due to climate characteristics, building attributes, and management strategies peculiar to the region.

In general, the research conducted allows establishing a quantitative connection between IEQ and the satisfaction of university buildings' users. However, it should be noted that the results presented in the paper are based on the authors' calculations and illustrate only the method's applicability. To obtain more accurate results and determine how important each of the IEQ components is, it is essential to conduct the study in the real buildings and carry out the necessary measurements.

Recommendations

Based on the reviewed literature, the proposed research framework, and the illustrative statistical analysis, the following recommendations are presented for improving indoor environmental quality and supporting user satisfaction in university buildings.

Improvement of thermal comfort: University administrations and architects should strive to optimize building orientation, insulation, external shading, efficient cooling systems, and energy-saving design, as well as monitor and adjust temperature and humidity in order to provide a comfortable environment for students in different seasons.

Enhancement of indoor air quality: The quality of air inside educational buildings should be improved through a sufficient outdoor air supply, advanced ventilation mechanisms, reduced emissions from interior sources, and proper maintenance of the equipment and materials which have a significant impact on air quality. Thus, it is essential to regularly monitor and evaluate the indoor environment.

Optimization of visual comfort: The design should ensure the best use of daylight, eliminate glare, and provide good visibility while minimizing excessive solar heat gain. This outcome can be achieved via properly placed windows, shading devices, high-performance lighting, and its suitable power. Daylight, electric light power, and the size of the building also impact visual comfort and should be considered based on the needs of libraries, classrooms, laboratories, and architectural studios.

Improvement of acoustic comfort: educational institutions should implement modern solutions for improved sound quality and speech intelligibility, arrange zones with various noise levels, equip buildings with sound-absorbing and insulating materials, and divide areas for noisy and quiet activities. Particular attention should be paid to meeting the requirements of auditoriums, libraries, studios, and other lecture rooms.

Improvement of Ventilation Capability: Natural, mechanical, and mixed ventilation should be considered based on the building's structure, the number of occupants, the outdoor air environment, and the climatic conditions. The function of the building's ventilation systems should be regularly maintained and inspected to ensure effective air circulation and indoor air renewal.

Post-Occupancy Assessment: The university should periodically assess the building's post-occupancy procedures to understand the building users' comfort and satisfaction. Using standardized building occupant's surveys and objective environmental measurements can help the facilities management identify areas of concern and address them accordingly.

Considering IEQ in Sustainable Building Design: The indoor environment quality should be considered during university building's planning and design. A collaborative approach among the stakeholders, including architects, engineers, and facilities managers, should be applied to achieve a high-standard building plan that considers the occupants' comfort, the indoor environment quality, and energy performance.

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