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The Influence of Passive Design Strategies on Users' Comfort in Academic Libraries in Delta State, Nigeria

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Abstract The implementation of passive design strategies significantly affects user comfort and satisfaction. However, research on the implementation of passive design strategies in academic libraries, particularly in Nigeria, remains limited. Thus, the research paper focuses on passive design strategies and how they affect user comfort in three academic libraries in Delta State, Nigeria: Delta State University (DELSU), Petroleum Training Institute (PTI), and College of Education, Warri. The structured questionnaire was administered to 315 students and staff members with emphasis on natural light, ventilation, flexibility of space, and airflow. The results of the SPSS analysis indicated that window seating comfort (mean = 4.03), spatial flexibility (mean = 3.91), and natural lighting (mean = 3.84) had the highest satisfaction levels, whereas satisfaction with air-condition-free ventilation (mean = 3.15) ranked lowest. Spatial layout, airflow, lighting, and comfort strongly correlated with each other in relation to Spearman correlation ($\rho > 0.4$, $p < 0.01$). Spatial flexibility ($\beta = 0.402$), sunlight control ($\beta = 0.337$), and artificial lighting ($\beta = 0.213$) were found to define user comfort most significantly, with 53 percent variance (Adjusted $R^2 = 0.530$) using CATREG regressive probability analysis. These findings highlight the role of adaptive layouts, effective daylighting, and hybrid ventilation in increasing user comfort and lead to sustainable library design since they reinforce degrees of flexibility in the building as recommended in the local climate.

Keywords Academic Libraries, Natural Lighting, Passive Design Strategies, User Comfort, Ventilation

1. Introduction

Assuring a user's comfort in the tropical areas of Nigeria represents a major challenge because of high temperatures and inconsistent electricity supply. Also, bioclimatic architecture represents a sustainable method that uses natural factors, such as sunlight and wind, to control climate factors, including heat management, daylight, and ventilation [1]. Key passive design approaches consist of building direction and using natural ventilation while utilizing thermal mass and placing external shading elements [2]. Together with other research studies, passive design methods have been shown to effectively improve comfort levels in Nigerian libraries.

The significance of passive design continues to rise in countries such as Nigeria because energy remains expensive and irregular. Such passive measures create dual benefits by decreasing the building's reliance on artificial power consumption while advancing sustainable energy systems. The implementation of such integrated techniques demonstrates remarkable potential for reducing energy consumption and enhancing building effectiveness within hot-humid climate zones [3] [4].

Research on passive strategies in educational facilities, particularly academic libraries, remains scarce even though users' comfort directly influences their productivity and satisfaction levels. The interior environmental quality issues leading to substandard ventilation and lighting continue to severely affect Nigerian university libraries, according to Olasupo et al. [5]. Research supports that user satisfaction strongly improves when environmental conditions receive better attention [6].

Mohammadpourkarbasi et al. [7] found that while passive design strategies like natural ventilation can support thermal comfort in tropical library buildings, their effectiveness is often limited by architectural constraints and lack of retrofit-friendly infrastructure, showing that performance issues stem more from structural and operational limitations than from the passive strategies themselves.

Delta State faces a tropical environment in the southern region of Nigeria because of its constant hot temperatures throughout the year. Yearly temperature statistics in Asaba stand at 26.8 ℃, with daily temperatures spanning between 19.4 ℃ and 31.7 ℃ [8]. Warm and light-comfortable libraries require passive design strategies to create them.

This research is aimed at examining The Influence of Passive Design Strategies on Users' Comfort in Academic Libraries in Delta State, Nigeria. It analyzes passive building methods as factors that affect comfort perception among users of academic libraries throughout Delta State. The research analyzes the effects that ventilation systems create with natural lighting and shading components for thermal sensation, visual comfort, and general environmental performance. Two questions direct the research;

1) How do passive design strategies (e.g., natural lighting, ventilation) influence users' comfort in academic libraries in Delta State, Nigeria?
2) To what extent do passive design elements predict users' comfort in selected academic libraries in Delta State, Nigeria?

Particularly, the paper:

(1) Determines the satisfaction of users with passive design features;
(2) Studies the correlation between passive methods and the levels of comfort.
(3) Identifies the factors that are major predictors of comfort in general.
(4) Determines the most important visual, thermal and spatial comfort determinants.

The initiative will help achieve the SDG Goal 7 (Affordable and Clean Energy) and Goal 11 (Sustainable Cities and Communities) through the utilisation of green eco-friendly education policy for building.

2. Literature Review

2.1. Theoretical Framework

2.1.1. Bioclimatic Design Theory

The science of bioclimatic design promotes building strategies to operate in harmony with the local temperature and climate to minimize the heating and cooling requirements as well as the associated mechanical energy consumption, thus promoting comfort in the building interior. Historically, passive design was used in ancient civilizations like the Egyptians and Greeks, who used solar orientation, thermal mass, and natural ventilation for a comfortable climate [9]. However, Olgyay and Olgyay [10] in Design with Climate, conceptualized this theory formally, where they mentioned climate-responsive architecture as a sustainable design means.

More recent research confirms that it is still relevant today. By showing how passive building features such as cross-ventilation and solar orientation can enhance energy efficiency and resilience, Sánchez-Montes et al. [11] proved that in the case of Mexican housing, passive building features performed better than all the active energy efforts. According to Toroxel and Silva [12], vernacular passive strategies play a significant role in meeting climate-neutral targets set by the EU due to the consumption of less intense emissions of greenhouse gases.

In Denmark, the Sneglehusene Housing project incorporates solar heating, rainwater collection, and locally acceptable materials in a way that helps maintain comfort levels without excessive use of mechanical interventions [13]. Equally, Yunitsyna & Sadrija [14] observed that Trombe walls and other advanced forms of insulation saved energy consumption in residential buildings of Albania, and Krmpot et al. [15] identified how passive solar-based approaches and natural ventilation aspects enhanced indoor conditions in Serbia. These works confirm that bioclimatic design has long-lasting values in producing environmentally conscious buildings.

2.1.2. Thermal Comfort Theory

Thermal Comfort Theory explains the environmental conditions in which occupants feel environmentally comfortable and contented. The theory reached a peak with the Predicted Mean Vote (PMV) and Predicted Percentage Dissatisfied (PPD) indices, developed by Fanger (1970), which take into consideration variables such as temperature of the air and air humidity, speed of the air, and mean radiant temperature. Both indices formed the basis for the development of energy-efficient spaces without compromising the users' comfort and remain relevant to date in comparison and improvement of thermal comfort models [16].

Over time, the theory has been converted into adaptive comfort models, considering occupants' behavioral and physiological adaptation, especially in naturally-ventilated buildings. Feriadi and Wong [17] demonstrated that naturally ventilated residential buildings in Indonesia can achieve thermal comfort in hot and humid climates, primarily through adaptive behaviors such as increased air movement and occupant-controlled ventilation. On the same note, Awad & Desouki [18] discovered that shading and cross-ventilation were the most relevant passive design strategies in minimizing the use of HVAC in the Egyptian arid climate. The same concept is proposed in the ASHRAE Global Thermal Comfort Database II, which showed that strategies of adaptive comfort could be implemented in various climatic ranges [19]. In addition, Fan, He, & Liao [20] further found that the passive approaches can be improved by feeding in real-time information and machine learning to improve thermal comfort and minimise energy consumption.

2.1.3. Indoor Environmental Quality (IEQ) Perspective

The principles of bioclimatic design and thermal comfort are interlinked with the broader concept of Indoor Environmental Quality (IEQ), which encompasses thermal, visual, acoustic, and spatial comfort. Recent studies on educational and public buildings emphasize that natural lighting, airflow, and spatial flexibility are vital for both occupant satisfaction and performance [6] [30]. The traits required in libraries, especially, are conducive to long attention and energy conservation. Hence, this model informs the process of choosing passive building features as pivotal determinants of shaping user comfort in academic libraries, i.e., daylighting, natural ventilation, shading, and flexible layouts.

2.2. Impact of Passive Design Strategies on Indoor Environmental Quality and User Comfort in Libraries

Passive design strategies in library applications now play a critical role in advancing both indoor environmental quality (IEQ) and user comfort. Combining natural lighting with ventilation and thermal regulation through acoustic control creates energy-efficient facilities that enable user concentration and enhanced wellness but do not require extensive mechanical support.

Natural lighting is an essential strategy because researchers identify its dual value in enhancing user satisfaction while reducing energy consumption [21]. According to recent studies, an East Jakarta library achieved satisfactory reading illumination of 548 lux with shading devices while surpassing the minimum standard of 300 lux [22]. Visual comfort achieved through this intervention supported higher productivity levels. Kajjoba [23] continued this research by showing that properly aligned corridors and greenways improved daylight assessment and heat stress reduction. The studies demonstrate that controlled daylighting implementation leads to substantial thermal improvements and visual comfort for library spaces.

Properly managing natural ventilation with lighting ensures acceptable air quality and thermal conditions. Passive ventilation worked effectively throughout low-occupancy conditions, yet its effectiveness failed to sustain elevated occupancies and triggered the need for additional mechanical ventilation systems [24]. According to their findings, the implementation of wind-driven and stack-driven ventilation techniques in Nigerian educational buildings resulted in a temperature reduction of up to 3 ℃, particularly for high-floor areas [25].

The hybrid ventilation systems demonstrated their value for comfort maintenance, especially in hot, humid Nigerian conditions. How libraries are designed spatially affects building comfort and air circulation. Indoor spaces with access to daylight, flexible furniture, and visual transparency turned out to be preferred by users [26].

Professional analysis showed that open, transparent designs in libraries created various user actions and social relations in Helsinki libraries [27]. As shown in the research, where spatial elements of design fit well with one another, there is an improvement in the functioning of library spaces. The research found that the passive methods, such as shading the elements, locating the position of the buildings and using the thermal mass, can give impressive relief of thermal discomfort. A study showed that installing triple-glazed windows combined with appropriate ventilation cut discomfort hours in half through seasonal adjustments [28].

Deficient ventilation in lecture spaces produced discomfort which affected student cognition. Additionally, psychological elements can be incorporated by proving that student moods influence thermal comfort evaluations, thus demanding design approaches which recognise physiological and emotional human responses [29] [30].

Another aspect of the comfort of a building user is noise control. The control of noise represents a major concern during library construction. The fundamental requirement for a peaceful study area includes establishing passive acoustic management systems. Their research found that library settings are frequently interrupted by adjacent spaces and external noise, so they suggested implementing sound-absorbing materials and zone-planning strategies [31]. Library users who experienced improved user concentration and reduced distractions came from facilities implementing passive noise reduction methods [32].

Passive design approaches applied strategically lead to substantial enhancements in the library's internal environment quality and better user satisfaction, as documented in the research literature. Looked at independently, these strategies yield benefits for IEQ enhancement, yet their beneficial outcomes require successful implementation that links them with building occupancy data, spatial usage patterns, and user psychological responses.

2.3. User Perception and Satisfaction with Passive Design Elements in Public and Educational Spaces

Assessing user satisfaction and perception of passive design elements proves essential when designing educational and public areas that support comfort while enhancing well-being and productivity. The design features, including natural ventilation, lighting, thermal control mechanisms, and a natural setting, impact how users connect with their spaces, specifically when learning occurs in facilities that receive numerous users, like libraries.

A high level of visual comfort is essential in determining user satisfaction with the environment. The positioning of studio windows plays a greater role than their dimensions in determining daylight quality, in examined university studios, since eastward-orientated windows generate peak-time illumination for students' indoor artificial lighting because passive lighting requirements frequently fall short, which matches library conditions [33].

Passive design elements, including layout patterns, circulation routes, and office seating systems, affect user satisfaction, which signifies similar impacts on educational spaces that provide stress relief and enhanced comfort [34]. Ezema and Ajanaku [35] discovered that Nigerian churches experienced satisfactory comfort through passive systems like natural lighting and ventilation but required active maintenance to achieve steady satisfaction. The findings suggest different strategies should be used within educational facilities.

Academic buildings of two Nigerian universities achieved satisfactory natural ventilation levels, as confirmed by Sholanke [36], through improved window design. Light penetration through windows and indoor air quality needed improvement, specifically in Covenant University's office spaces, to achieve better user satisfaction with passive building techniques.

The interior comfort built environment directly relates to ventilation quality standards. Perceptions of stale air and discomfort occurred in homes mainly due to insufficient cross-ventilation, even with limited ventilation. Both performance and air exchange quality matter for passive systems because presence alone does not satisfy the requirements [37] [38].

Passive design techniques establish effects on both productivity and mental well-being apart from physical comfort. User satisfaction improved at a Peruvian educational center due to green roofs and energy-efficient design elements [39]. Furthermore, research has demonstrated that passive building design reduces stress and promotes productivity standards, which are important for educational facilities, including libraries [34].

The students at the University of Surabaya revealed their liking for open spaces with flexible floor plans and multi-purpose areas, which emphasises the importance of responsive design in libraries. The paper by Aisjah [40] points toward how smell interacts with emotions, thus demonstrating the importance of scent design to strengthen visual and acoustic library strategies [41].

It has been confirmed that perceptual clarity, combined with acoustic tranquillity, functions as a primary user engagement driver, boosting user interaction for indoor and outdoor settings through proper spatial passive design. Active olfactory design is vital for libraries because users display different patterns in silent reading zones, collaborative areas, and transitional spaces [42].

Contextual differences also shape satisfaction. Climate patterns together with cultural norms have defined comfort expectations in Nigerian churches. Also, further research proved that children developed stronger attachments to kindergarten environments through passive natural exposure features, which suggests that libraries should also cater to cultural and age-specific needs [35] [43].

Users who spend long periods of time or come for short durations in a space generally expect different arrangements from each other. The assessment of comfort between library staff who remain permanently and visitors who come and go demonstrates the requirement for libraries to adapt their design to effectively fulfil the needs of both groups. Public spaces receive a stronger impact from their identity and functionality than from comfort or access. This underlines the importance of designing libraries that offer thermal and visual comfort and foster a sense of belonging and usability [44] [45].

Furthermore, users in naturally ventilated classrooms adapt their behavior to remain comfortable despite high-temperature conditions. Findings reveal that well-conceived passive systems bring better thermal, acoustic, and visual comfort that result in a high level of satisfaction and efficiency in energy consumption [46] [47].

3. Methods

3.1. Research Design and Period

The research period spanned from December 2024 through January 2025. It serves as part of a larger project evaluating passive design strategies on Delta State academic library user's comfort in Nigeria. The research gathered data through a cross-sectional analytical survey design from selected libraries, enabling the analysis of relationships between passive design features and user comfort.

3.2. Study Area and Library Description

The study was carried out in three academic libraries in Delta State of Nigeria, and they are the Petroleum Training Institute (PTI) Library, Delta State University (DELSU) Library, and the College of Education (COE) Library, Warri. These libraries were chosen for their high user capacity (≥1,500 seats) and architectural features that incorporate natural ventilation and open layouts, making them suitable for evaluating passive design strategies in a hot-humid climate.

3.2.1. Petroleum Training Institute (PTI) Library, Effurun

The PTI Library is a two-storey, narrow, lengthwise building oriented along the east-west axis, with most windows facing north and south to optimize cross-ventilation and minimize direct solar gain. On the ground floor (Figure 1), the main entrance leads to the reception with lockers opposite; an e-library occupies the southeast, while printing/stationery sits to the southwest. A north-side service band contains admin, conference, and the head librarian's office, with a shared toilet and the staircase at the northeast. The first floor (Figure 2) is dominated by a deep open study area along the south façade, backed by closed study and reference rooms on the north side, again served by the same stair/toilet core. Although cross-ventilation is achieved in the main study areas, offices lack adequate airflow. Minimal shading elements and sparse vegetation reduce passive cooling efficiency, while thermal mass from hollow sandcrete walls contributes to internal temperature regulation. However, the absence of advanced glazing, light shelves, or skylights limits daylight penetration and glare control [48].

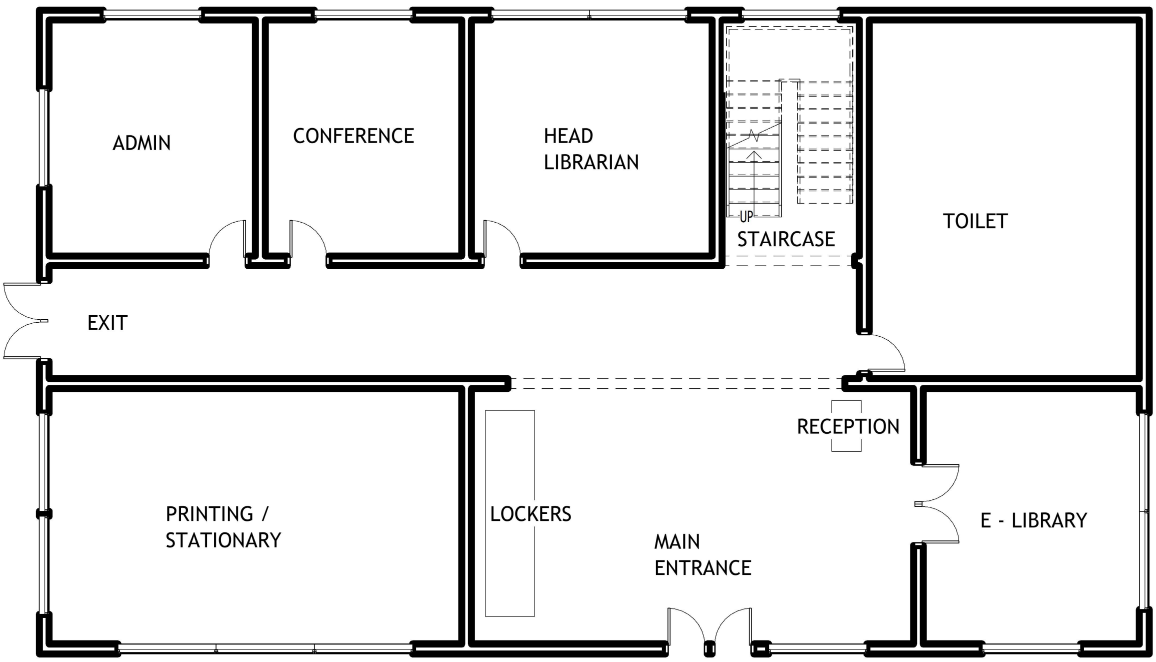

Figure 1. Ground floor plan of Petroleum Training Institute Library (Source: Authors fieldwork)

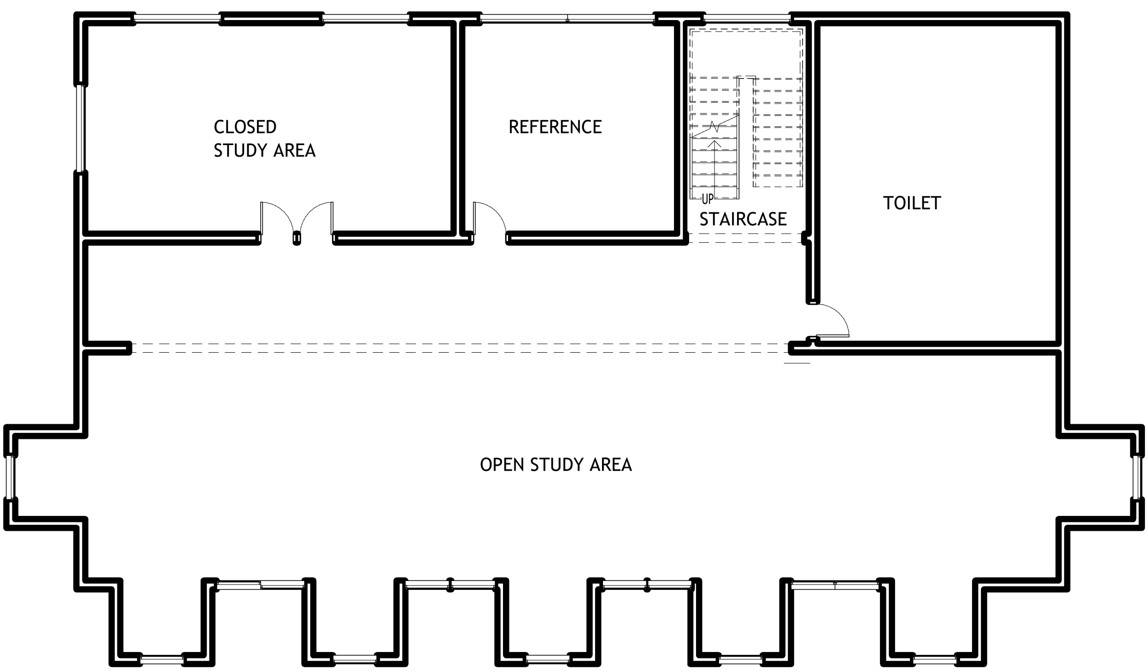

Figure 2. First floor plan of Petroleum Training Institute Library (Source: Authors fieldwork)

3.2.2. Delta State University (DELSU) Library, Abraka

Completed in 2022, DELSU Library is a modern, three-storey rectangular structure that accommodates up to 4,500 users. On the ground floor (Figure 3), the south entry opens to the central reception/security; open study spaces are in the west and east wings, administrative rooms (with the librarian's office) sit east near one elevator, lockers lie at the entrance, and toilets are at the north central. The first floor (Figure 4) has a large central circulation hall with study areas continuing in both wings. Special Collection occupies the space opposite the elevator in the southeast, and the toilets remain in the exact location in the north. The fact that both sets of plans present a single-corridor, mostly single-aspect solution constrains cross-ventilation even where high-level windows are included. The building features extensive glazing via full-length curtain walls, which enhance daylighting but also increase heat gain due to insufficient shading and inadequate roof overhangs. Study areas are spacious and well-lit, while collaborative and administrative spaces are distributed across the floors. Although the building incorporates high-level windows for ventilation, it lacks cross-flow ventilation in key zones. Vegetation on-site is sparse, and there is no courtyard integration, reducing natural cooling potential [48].

3.2.3. College of Education (COE) Library, Warri

The COE Library is a two-storey L-shaped building formed by two slender wings, strategically oriented along the east-west axis to enhance airflow. On the ground floor (Figure 5), a central reception with waiting/bag check-in sits at the junction of the wings; a run of administrative offices and the head librarian’s office lines the north spine, with the staircase and toilet just beyond. Large general study areas occupy the east wing and the projecting west wing, enabling cross-ventilation through opposing openings. The study spaces are cross-ventilated, but the design uses short perimeter windows that limit natural lighting, resulting in poorly lit lobbies and staircases. Passive shading is insufficient, with no window overhangs or advanced solar control elements. Vegetation is limited to shrubs around the site, offering minimal cooling or noise reduction. The walls, made of hollow sandcrete blocks, provide good thermal mass but lack insulation.

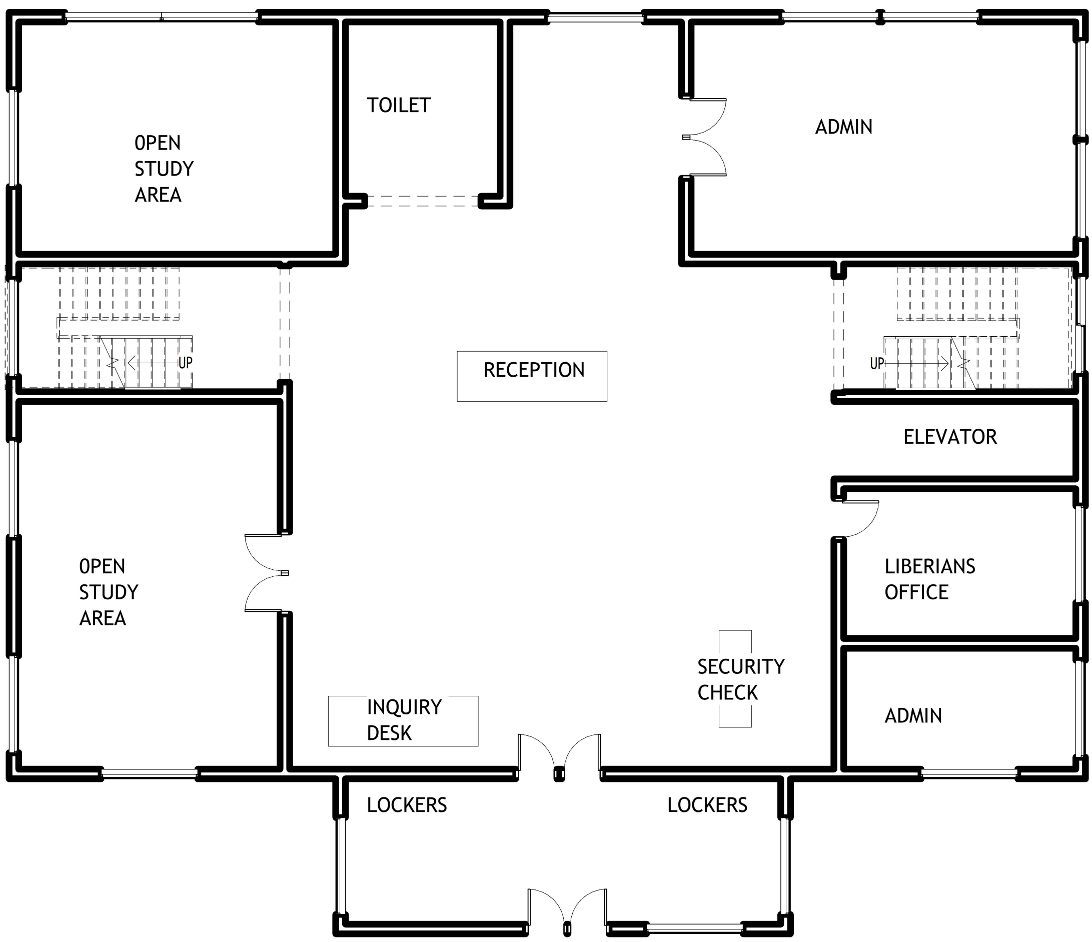

Figure 3. Ground floor plan of Delta State University (DELSU) Library (Source: Authors fieldwork)

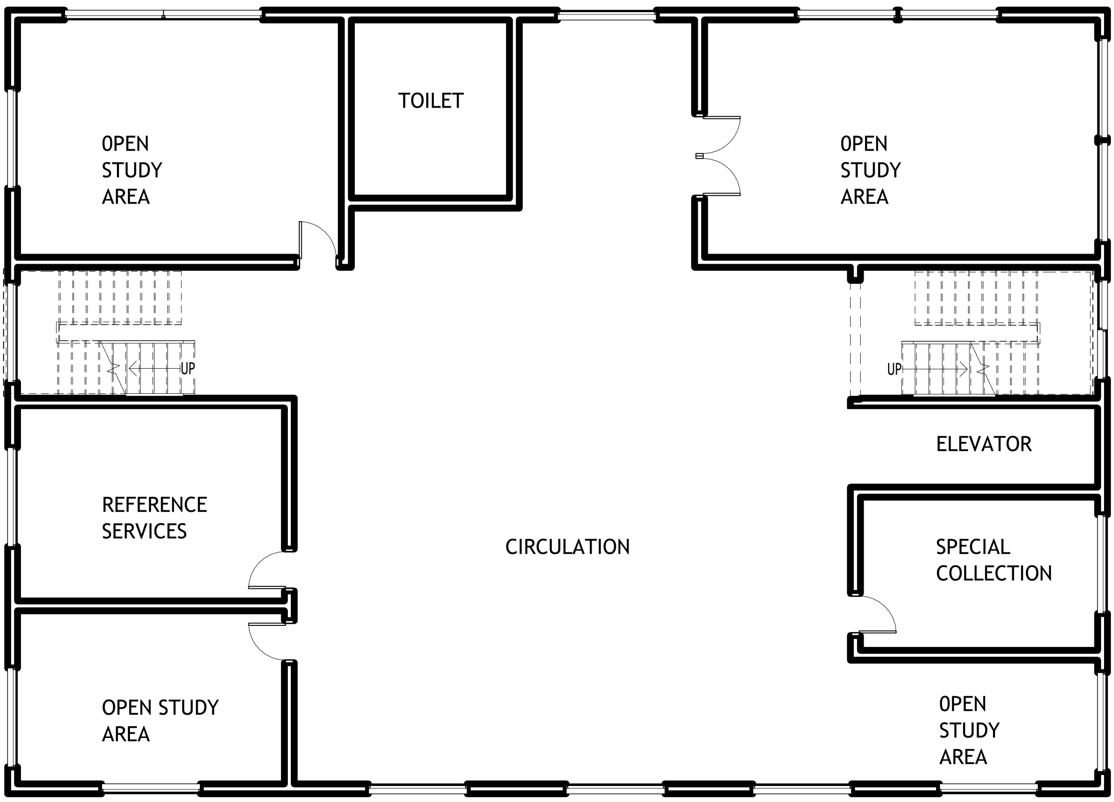

Figure 4. First floor plan of Delta State University (DELSU) (Source: Authors fieldwork)

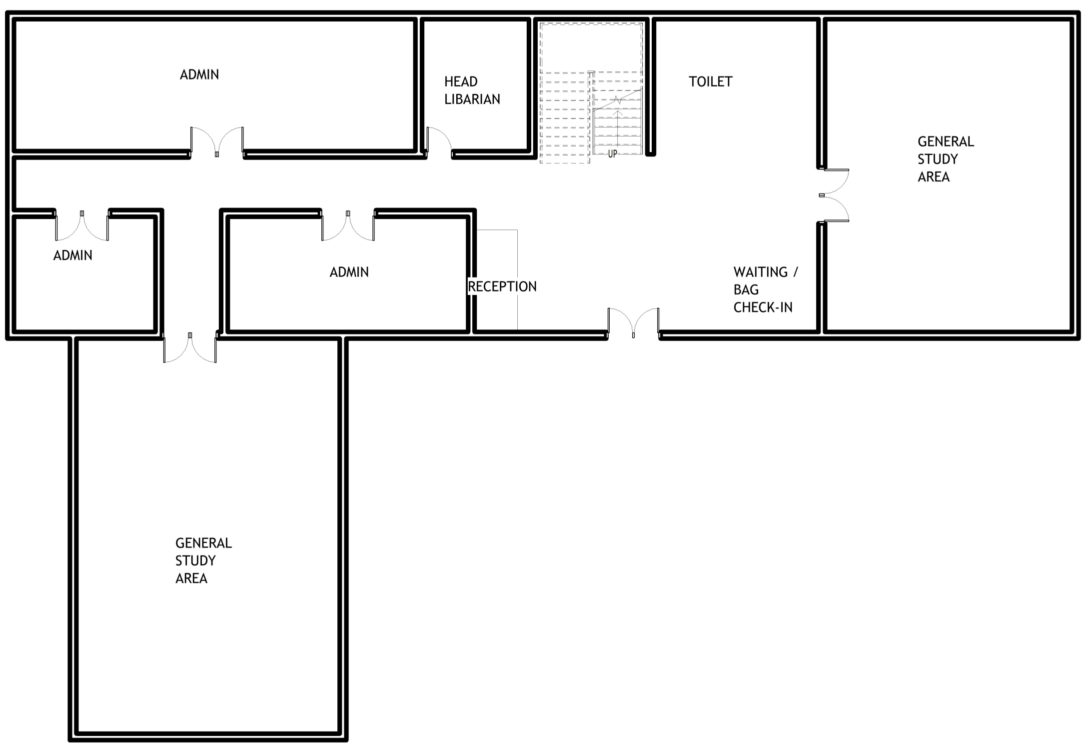

Figure 5. Ground floor plan of College of Education (COE) Library (Source: Authors fieldwork)

These descriptions highlight that while each library incorporates some passive strategies (e.g., orientation and cross-ventilation), there is an underutilization of shading, vegetation, and advanced daylighting features, which reduces overall thermal and visual comfort [48].

3.3. Participants and Sampling

The study population comprised students and academic staff in the two facilities at the time of conducting the study, who were willing to take part. 350 questionnaires were sent out, and after cleaning up the questionnaires, 315 returned questionnaires met the criteria of the analysis procedures. The researchers conducted convenience sampling of subjects while restricting participation to people from those institutions who visited the libraries during the previous thirty days. As shown in Table 1, nearly half of the respondents were from DELSU (45.7%), while PTI and COE contributed roughly a quarter each (26.7% and 27.6%).

Table 1. Academic Libraries investigated

Academic Library	Location	Frequency (n)	Percentage (%)
Delta State University (DELSU) Library	Abraka	144	45.7%
Petroleum Training Institute (PTI) Library	Effurun	84	26.7%
College of Education (COE) Library	Warri	87	27.6%
Total	—	315	100.0%

3.4. Questionnaire Development

The data collection instrument used a structured self-administered questionnaire that contained three sections about socio-demographic information. It covered both passive design feature adequacy and comfort rating scales. The research tool used a 5-point Likert format in which respondents provided their answers.

The questionnaire was developed from existing studies on passive design strategies, indoor environmental quality, and user comfort in educational buildings [6] [36] [39] [41] [48].

It comprised three sections: Section A captured socio-demographic information; Section B assessed the adequacy of passive design features (e.g., natural lighting, ventilation, shading devices, greenery, and spatial flexibility); and Section C focused on users' comfort levels, including visual, thermal, and acoustic comfort, as well as collaborative spaces and noise levels.

A 5-point Likert scale (1 = Strongly Inadequate, 5 = Strongly Adequate) was adopted for Sections B and C. To ensure content validity and clarity, the questionnaire was reviewed and validated by two senior experts in architecture and building science, who provided feedback on the structure, relevance, and wording of items, which was incorporated into the final version.

3.5. Data Processing and Analysis

The completed questionnaires were entered into Excel and analyzed using IBM SPSS. The study relied on frequencies, means, and standard deviations as ways of elaborating the participant reactions. Spearman rank-order correlation yielded the results of the passive design attributes and the indicators of comfort and CATREG was set as an estimating model or prediction of the comfort levels.

The Cronbach alpha was used to determine reliability. The significance level was $p < 0.05$. The research minimised bias by first allowing anonymous participation, administering the survey at different times, and keeping all procedures uniform.

3.6. Ethical Considerations

Ethical clearance from appropriate institutions enabled the participants freedom to accept or decline the study while granting consent upon question submission. All stored data remained secure, and researchers utilised them exclusively for academic work.

4. Results

4.1. Users' Perceived Adequacy of Passive Design Strategies and Comfort

The analysis of how passive design elements affect academic library user comfort starts with a description of the respondents' demographic information. A total of 69.2% of respondents identified as female among the 150 participants, while 80.0% fell within the age bracket of 16–25 years old (see Table 2). Participants with tertiary qualifications amounted to 58.1% of the group, followed by 22.2% who had completed postgraduate studies. Library users typically made sporadic visits, according to 48.3% of respondents, and 20.6% of users frequented the library spaces.

Table 2. Socio-demographic Characteristics of Respondents

Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	97	30.8%
	Female	218	69.2%
Age group	Below 16 years	41	13.0%
	16-25 years	252	80.0%
	26-35 years	8	2.5%
	36-45 years	11	3.5%
	46-55 years	3	1.0%
	55 years above	0	0.0%
Educational Qualification	Primary	2	0.6%
	Secondary	60	19.0%
	Tertiary	183	58.1%
	Postgraduate	70	22.2%
Frequency of Visit to the Library	Never	0	0
	Rarely	98	31.1%
	Occasionally	152	48.3%
	Frequently	65	20.6%

Table 3. Users' Perceived Adequacy of Passive Design Strategies in Academic Libraries

Passive Design Strategies	1	2	3	4	5	No. of responses	Std. Deviation	Mean	Rank
Comfort of sitting near the windows.	6 (1.9)	16 (5.1)	56 (17.8)	122 (38.7)	115 (36.5)	315	0.959	4.03	1st
Spatial flexibility and circulation within the library.	14 (4.4)	9 (2.9)	65 (20.6)	129 (41.0)	98 (31.1)	315	1.014	3.91	2nd
Natural light in the library during the day.	2 (0.6)	16 (5.1)	71 (22.5)	168 (53.3)	58 (18.4)	315	0.804	3.84	3rd
Overall comfort of the library's design.	11 (3.5)	26 (8.3)	74 (23.5)	136 (43.2)	68 (21.6)	315	1.007	3.71	4th
Design for natural light and fresh air.	9 (2.9)	23 (7.3)	93 (29.5)	127 (40.3)	63 (20.0)	315	0.970	3.67	5th
Cooling effect of greenery around the library.	6 (1.9)	28 (8.9)	95 (30.2)	132 (41.9)	54 (17.1)	315	0.932	3.63	6th
Effectiveness of shading devices in reducing glare and cooling.	7 (2.2)	34 (10.8)	110 (34.9)	129 (41.0)	35 (11.1)	315	0.908	3.48	7th
Airflow throughout the library.	11 (3.5)	34 (10.8)	109 (34.6)	122 (38.7)	39 (12.4)	315	0.961	3.46	8th
Presence of greenery around or near the library.	21 (6.7)	43 (13.7)	93 (29.5)	114 (36.2)	44 (14.0)	315	1.091	3.37	9th
Presence of shading devices (blinds, trees, overhangs).	21 (6.7)	60 (19.0)	111 (35.2)	89 (28.3)	34 (10.8)	315	1.070	3.17	10th
Ventilation without air conditioning.	26 (8.3)	50 (15.9)	126 (40.0)	77 (24.4)	36 (11.4)	315	1.083	3.15	11th

The ratings from users concerning passive design features in the library presented in Table 3 demonstrate how different elements affect overall comfort perception. Users strongly preferred seating near windows due to its comfort level (mean = 4.03) and rated this aspect as Adequate or Strongly Adequate for more than three-quarters.

Spacious design and circulation received similar user appreciation (mean = 3.91) because users admired flexible and easily accessible architectural features. Feedback about natural daylight exposure highlighted its essential position in creating comfortable visual and thermal conditions (mean = 3.84). Ventilation without air conditioning received the lowest evaluation (mean = 3.15) among the participants, resulting in an 11.4% rating. It was strongly inadequate, thereby showing a need for better ventilation solutions.

A high percentage of users (36.5% and 38.7%) rated sitting positions by windows as Strongly Adequate and Adequate, respectively, based on the recorded mean score of 4.03. The respondents were highly satisfied with spatial flexibility and circulation, rated 3.91, and natural light during the day received 3.84 points. The rating of ventilation without air conditioning surfaces is the weakest option (3.15), while 11.4% of users indicated it as strongly inadequate, which shows a clear requirement for enhanced ventilation solutions.

Users ranked sound isolation between collaborative zones and quiet areas as the fourth most important factor (mean = 3.70), demonstrating that they found it acceptable but experienced some issues with acoustics, as shown in Table 4. General noise comfort and fresh air quality assessments reached moderate levels according to user ratings (mean = 3.67 and 3.66). Users gave moderate ratings regarding their experiences with lighting and thermal control of study tables and windows and temperature regulation (mean = 3.63, mean = 3.59, mean = 3.44, respectively). Long-term seating comfort (mean=3.41), together with group space support (mean=3.28) and workspace availability (mean=3.14), received the lowest satisfaction ratings from users, according to the study data.

Table 4. Users' Perceived Comfort Characteristics in Academic Libraries

Users' comfort characteristics	1	2	3	4	5	Number of responses	Std. Deviation	Mean	Rank
Adequacy of quiet spaces for focused work.	11 (3.5)	16 (5.1)	60 (19.0)	143 (45.4)	85 (27.0)	315	0.982	3.87	1st
Lighting from windows for reading and studying.	12 (3.8)	10 (3.2)	86 (27.3)	131 (41.6)	76 (24.1)	315	0.971	3.79	2nd
Effectiveness of noise reduction from outside traffic.	20 (6.3)	22 (7.0)	54 (17.1)	139 (44.1)	80 (25.4)	315	1.104	3.75	3rd
Noise isolation between collaborative and quiet spaces.	18 (5.7)	23 (7.3)	73 (23.2)	124 (39.4)	77 (24.4)	315	1.092	3.70	4th
Overall noise comfort for studying.	14 (4.4)	28 (8.9)	76 (24.1)	128 (40.6)	69 (21.9)	315	1.053	3.67	5th
Freshness and comfort of air in the library.	5 (1.6)	39 (12.4)	81 (25.7)	123 (39.0)	67 (21.3)	315	0.998	3.66	6th
Comfort of study tables.	14 (4.4)	35 (11.1)	84 (26.7)	101 (32.1)	81 (25.7)	315	1.113	3.63	7th
Functionality of artificial lights in the library.	15 (4.8)	33 (10.5)	76 (24.1)	123 (39.0)	68 (21.6)	315	1.080	3.62	8th
Sunlight control to avoid glare.	18 (5.7)	32 (10.2)	77 (24.4)	121 (38.4)	67 (21.3)	315	1.103	3.59	9th
Temperature control in the library.	20 (6.3)	18 (5.7)	119 (37.8)	119 (37.8)	39 (12.4)	315	0.996	3.44	10th
Comfort of chairs for long-term sitting.	28 (8.9)	37 (11.7)	85 (27.0)	108 (34.3)	57 (18.1)	315	1.173	3.41	11th
Supportiveness of collaborative spaces for group work.	24 (7.6)	33 (10.5)	118 (37.5)	111 (35.2)	29 (9.2)	315	1.027	3.28	12th
Availability of collaborative workspaces.	27 (8.6)	61 (19.4)	108 (34.3)	80 (25.4)	39 (12.4)	315	1.127	3.14	13th

4.2. Correlation Analysis (Spearman's Rank Correlation)

Spearman's rank-order correlation was applied to determine the direction and strength of the relationship between passive design strategies in academic libraries and users' perceptions of comfort. This study examined which design components produced meaningful statistical relationships with typical comfort variables. The analysis included only statistically significant relationships with p-values below 0.01, so the researchers could minimise potential random outcomes.

The evaluation results presented in Table 5 demonstrated different strong relevant associations between outlined variables. Spatial flexibility and circulation within the library create a high comfort level in library spaces ($\rho = 0.560$, $p < 0.01$) along with the overall comfort of the library's design. Results show that the relationship between temperature control and overall comfort reached statistical significance ($\rho = 0.502$, $p < 0.01$) while airflow directly influenced air freshness ($\rho = 0.485$, $p < 0.01$), which underlines how temperature and ventilation affect indoor comfort.

Other notable findings included strong correlations between temperature control, both artificial lighting and natural light from windows, for reading and study activities ($\rho = 0.461$, $p < 0.01$).

Temperature control in the library ($\rho = 0.460$, $p < 0.01$), implies that thermal comfort is perceived in conjunction with adequate lighting conditions. Additionally, design for natural light and fresh air was positively associated with airflow ($\rho = 0.445$, $p < 0.01$) and air freshness ($\rho = 0.443$, $p < 0.01$).

4.3. Regression Analysis (CATREG)

A Categorical Regression (CATREG) was conducted to assess how selected passive design strategies predict users' overall comfort in academic libraries, with overall comfort of the library's design (DCM) as the dependent variable. The independent variables—spatial flexibility (SPC), temperature control (TMP), airflow (AFL), freshness of air (AIR1), artificial lighting (ART), sunlight control (SUN), and design for natural light and fresh air (DSA)—were selected based on strong and significant correlations ($\rho > 0.4$, $p < 0.01$). As shown in Table 6, the model was statistically significant ($F = 21.828$, $p = 0.000$) with an Adjusted R^2 of 0.530, meaning that 53% of the variation in overall comfort can be explained by these seven passive design elements. The Apparent Prediction Error = 0.445 ($\approx 1 - R^2$) indicates about 44.5% of variance is not captured, and the Multiple R = 0.745 shows a strong association between observed and model-predicted comfort scores, consistent with a well-fitting model. This highlights that factors such as spatial layout, lighting quality, and ventilation collectively shape more than half of the perceived comfort in the libraries studied.

As shown in Table 7, spatial flexibility ($\beta = 0.402$) had the strongest positive effect, followed by sunlight control ($\beta = 0.337$) and artificial lighting ($\beta = 0.213$). Freshness of air (AIR1) had a significant negative effect, suggesting ventilation systems may be inadequate or poorly maintained. In contrast, temperature control (TMP) and design for natural light (DSA) were not statistically significant, implying that users value layout and lighting conditions over temperature settings. These results underscore the critical roles of spatial flexibility, effective daylight management, and reliable artificial lighting in shaping user comfort in academic libraries.

Table 5. Top Correlation Coefficients Between Passive Design Strategies and Overall User Comfort (Spearman's ρ)

Variable one	Variable two	Spearman's ρ
Spatial flexibility and circulation within the library	Overall comfort of the library's design	0.560
Overall comfort of the library's design	Temperature control in the library	0.502
Airflow throughout the library	Freshness and comfort of air in the library	0.485
Temperature control in the library	Functionality of artificial lights in the library	0.461
Lighting from windows for reading and studying	Temperature control in the library	0.460
Functionality of artificial lights in the library	Sunlight control to avoid glare	0.474
Temperature control in the library	Sunlight control to avoid glare	0.394
Design for natural light and fresh air	Airflow throughout the library	0.445
Design for natural light and fresh air	Freshness and comfort of air in the library	0.443
Spatial flexibility and circulation within the library	Temperature control in the library	0.412

Table 6. Summary of Categorical Regression Results

Model Statistic	Value
Multiple R	0.745
R Square	0.555
Adjusted R Square	0.530
Apparent Prediction Error	0.445
F-value (from ANOVA)	21.828
Significance (p-value)	0.000
Dependent Variable	Overall comfort of the library's design (DCM)
Predictors	Spatial flexibility and circulation, Sunlight control to avoid glare, Functionality of artificial lights, Airflow throughout the library, Freshness and comfort of air, design for natural light and fresh air, Temperature control in the library

Table 7. Standardized Coefficients of Predictors

Predictor (Label)	Variable Name	Standardized Beta (β)	F	Sig. (p-value)	Significance
SPC	Spatial flexibility and circulation	0.402	21.366	< 0.001	Significant
SUN	Sunlight control to avoid glare	0.337	3.843	0.010	Significant
ART	Functionality of artificial lights	0.213	4.438	0.005	Significant
AFL	Airflow throughout the library	0.161	2.958	0.033	Significant
AIR1	Freshness and comfort of air	–0.195	5.999	0.003	Significant
DSA	Design for natural light and fresh air	0.089	0.535	0.586	Not significant
TMP	Temperature control in the library	0.012	0.008	0.929	Not significant

5. Discussion

This research aimed to study how passive design strategies affect user comfort in academic libraries across different locations throughout Delta State in Nigeria. Academic libraries located in Abraka, Effurun, and Warri function under the hot-humid climate zone of southern Nigeria, which requires immediate attention regarding thermal comfort, daylight control, and ventilation because of high temperatures, humidity, and unstable power supply.

To address the initial research question, this research investigates user comfort perceptions regarding passive design features in academic libraries throughout Delta State. Users found the most satisfaction in three features: window seat location comfort, flexible spaces and daylight coming through windows. The research findings align with those of Pan et al. [26] and Sholanke [36], showing passive design elements suitable for Delta State users who benefit from daylight access for lighting needs and spatial adaptability for comfort improvement [13].

Using ventilation without air conditioning and shading devices obtained unfavorable ratings compared to other strategies. The unsatisfactory ratings show existing architectural and operational constraints in library buildings rather than passive design flaws. Although passive strategies like natural ventilation and shading are valuable in theory, Mohammadpourkarbasi et al. [7] found that their effectiveness in tropical library buildings is often compromised by outdated infrastructure and limited resources, underscoring that performance issues stem more from architectural and operational constraints than from the strategies themselves. The fundamental structure of these buildings did not prioritise passive performance during their initial design phase. At the same time, their current condition displays restricted ventilation paths and blocked windows, and layout setups obstruct airflow and daylight entrance.

The findings show that Delta State libraries need specialized upgrade projects to optimize the present-day implementation of their sustainable design measures, especially those concerning airflow and shade utilisation.

Correlation analysis showed that passive management techniques connect substantially with user satisfaction levels. Users from Delta State chose spatial flexibility and circulation as the factors positively linked to overall comfort, with a correlation level of $\rho = 0.560$ [24]. The research supports architects and space planners to focus on designing libraries with open spaces, clear pathways, and adjustable furniture for improved user comfort in Delta State, Nigeria.

Lighting-related methods proved to be highly connected to comfort perceptions among users. The comfort ratings of users were directly affected by their experience with managing sunlight to reduce glare and their experience with controlled artificial lighting. This situation in Delta State highlights why combining high-quality shading devices with reliable artificial lighting is crucial since sunlight is harsh and the electrical supply remains inconsistent. These findings demonstrate practical value for two-mode lighting system retrofitting in existing libraries and regular upkeep of artificial and natural light sources.

The study revealed that adequate airflow inside the library positively impacts comfort levels because people need appropriate ventilation. The presence of ventilation features failed to produce beneficial results on comfort perception since indoor air freshness demonstrated an adverse relationship ($\beta = -0.195$). The presence of ventilation systems reveals ineffective operation since they work against measurements of environmental comfort and freshness. The research shows that ineffective maintenance techniques through blocked louvres or non-operable windows result in a failure of passive airflow benefits. Regular inspections with appropriate maintenance of natural ventilation systems should become routine practice to guarantee continuous effective airflow.

A Categorical Regression (CATREG) analysis answered the research question about passive design elements and user comfort. Statistical results of the model proved significance at $p < 0.001$ and revealed that the model could predict 53% of comfort levels, as shown in Table 6. The predictive power of passive strategies reaches a high level regarding user comfort in Delta State academic libraries.

Study environment comfort depends heavily on spatial flexibility and circulation, which proved to be the study's most significant factor ($\beta = 0.402$). Functional adaptability takes precedence over aesthetics in spatial design because it effectively enables the spaces to serve users' needs. The study shows sunlight control ($\beta = 0.337$), together with artificial lighting ($\beta = 0.213$), showed powerful predictive abilities in confirming the visual comfort importance for library use, similar to Ali [33]. Designers must include shading devices and lighting systems in the initial design plan and retrofitting projects to support light and climate conditions in Delta State.

Airflow received a positive association ($\beta = 0.161$) during the study, but the perceived freshness of air was linked to negative yet significant results. The study results imply that users receive ventilation benefits; however, their discomfort occurs because of stagnant air movements, possibly linked to inadequate ventilation exchange methods or filtration systems, which is verified by Gabel et al [37]. Based on these findings, passive design might not be sufficient until the building practices utilised over its operation and maintenance are similarly accomplished.

Temperature control systems and design measures regarding natural lighting and ventilation proved to be non-significant factors in this study. The weak and less obvious implementation of these principles within the studied library facilities can explain their lack of significance. These findings suggest that design developers should apply better integration techniques and user experience testing to achieve maximum impact.

These findings align strongly with Bioclimatic Design Theory, which promotes architectural responses that harmonize with local climatic conditions to enhance user comfort while reducing dependence on mechanical systems [28]. The significance of spatial flexibility and sunlight control affirms the role of adaptive and climate-sensitive layouts, consistent with findings from Mexico and Europe, where orientation and passive ventilation improved thermal regulation and energy performance [29,30]. Similarly, the lack of vegetation and shading elements in some of the libraries studied mirrors the limitations observed in other regions where passive cooling strategies were underutilized [31,32].

Moreover, the results support the Thermal Comfort Theory, particularly its adaptive framework, which recognizes the dynamic nature of thermal perception based on user expectations and environmental context [33]. The limited comfort reported in naturally ventilated zones echoes findings from Egypt and Indonesia, where passive design required enhancement to meet comfort benchmarks [34,35]. The prominence of artificial lighting and sunlight control further reflects principles from Fanger's PMV/PPD model, where visual and thermal parameters jointly affect perceived comfort [33].

These interpretations reinforce the theoretical understanding that passive design strategies, when spatially integrated and user-oriented, can substantially improve environmental comfort in hot-humid regions—especially when contextualised within adaptive comfort frameworks and supported by appropriate spatial planning.

The research conclusions demonstrate that passive design methods strongly affect comfort perception; however, their success in Delta State libraries depends on deliberate planning and necessary modifications followed by continuous maintenance. The study produces significant guidance for those who control educational facilities, builders, and government authorities who work to enhance library environments in hot climate areas.

6. Conclusions and Recommendation

This research studied user comfort levels in academic libraries of Delta State, Nigeria, which depended on passive design methods. Descriptive statistics, correlation analysis, and a categorical regression were utilized to determine significant natural ventilation characteristics that strongly influence the perception of the users in library environments in terms of comfort. Spatial flexibility and circulation inside the library proved to be the most influential factors in overall comfort perception, while sunlight control and artificial lighting followed second. The research confirms that planning spaces efficiently, combined with proper lighting systems, strengthens user comfort. Most users were satisfied with their library environment, yet features without air conditioning, limited seating comfort, and insufficient collaboration space received unfavorable feedback.

The findings have also indicated that the passive design approaches may be able to account for more than half of the difference in the levels of comfort, and this means that well-designed and well-considered passive features are a critical constituent of the well-being of users, especially in the hot-humid environments of Delta State. The research found that due to poor implementation and negligence, the strategies are often impaired, with factors like ventilation and the freshness of air, among others. Such observations point to the fact that there is a need to encourage a closer integration of design and more effective operational management of the passive systems in the academic libraries.

Based on these findings, several recommendations are proposed. To begin with, there must be better spatial organization that nurtures more open and flexible spatial layouts that facilitate ease of movement and individual and group study-based activities. Enhancing lighting conditions is also critical; this includes integrating effective shading devices with functional artificial lighting to ensure consistent visual comfort regardless of external conditions. Ventilation systems should be upgraded or maintained regularly to promote adequate airflow, particularly in libraries that operate without air conditioning. Attention should also be given to furniture ergonomics and the availability of collaborative work zones to support prolonged use and engagement. Lastly, continuous user feedback and periodic assessment of passive features should be institutionalized to guide facility upgrades and inform responsive design strategies.

While the study provides valuable insights, it is not without limitations. To begin with, self-reported user experiences were used in the research, which could be driven by subjective perception and time variations. Second, the assessment was conducted in only three libraries within Delta State, limiting the generalizability of findings across Nigeria or West Africa.

Future studies could adopt a longitudinal or mixed-method approach to capture seasonal variations in comfort perception and evaluate passive performance across time. Expanding the geographic scope to include libraries in other climate zones would enhance the applicability of findings. Also, the correlation of objective measurements of the environment, i.e. temperature, humidity, daylight, with user feedback would provide additional insights into the effectiveness of passive design.

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