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SUSTAINABLE AND SMART BUILDING DESIGN ENHANCING NATURAL VENTILATION AND DAYLIGHTING IN GOVERNMENT OFFICES: A PERFORMANCE-BASED APPROACH FOR THE AKWA IBOM STATE SECRETARIAT

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ABSTRACT

Government office buildings in warm–humid tropical climates frequently exhibit poor indoor environmental performance, leading to excessive dependence on mechanical cooling and artificial lighting. These challenges are particularly pronounced in large public-sector facilities that operate for extended daily hours. This study evaluates the natural ventilation and daylighting performance of the Akwa Ibom State Secretariat, Nigeria, using a performance-based approach that integrates field measurements, occupant surveys, and environmental simulations. Computational Fluid Dynamics (CFD) modelling was employed to assess airflow patterns under prevailing climatic conditions, while daylight performance was evaluated using Radiance-based simulations and on-site illuminance measurements. The results reveal inadequate cross-ventilation, uneven airflow distribution, and sub-standard daylight penetration across typical office spaces, primarily due to building orientation, façade design, and window configuration. Based on these findings, the study recommends improving cross-ventilation through better alignment of inlet and outlet openings and optimizing window placement to enhance daylight penetration while controlling glare and heat gain. These measures have the potential to significantly reduce reliance on mechanical systems. The research contributes empirical evidence and replicable design insights relevant to the retrofit and future design of public office buildings in tropical regions.

KEYWORDS: Sustainable building design; natural ventilation; daylighting; building performance simulation; tropical government offices.

INTRODUCTION

Public office buildings in tropical regions represent a significant portion of national energy consumption due to their scale, high occupancy densities, and extended operational hours (Pérez-Lombard, Ortiz, & Pout, 2008). In Nigeria, government secretariats are among the most energy-intensive public facilities, with electricity demand driven predominantly by mechanical cooling and artificial lighting systems (Oyedepo, 2012). This trend is increasingly unsustainable in the context of rising energy costs and growing commitments to climate-responsive development.

In warm–humid climates such as Akwa Ibom State, effective natural ventilation and adequate daylighting are critical to achieving acceptable indoor environmental quality while reducing operational energy demand (Awbi, 2003; Givoni, 1998). However, many existing government office buildings were designed with limited consideration for climatic responsiveness.

In addition to energy efficiency and occupant comfort, sustainable building design seeks to minimize environmental impact by optimizing resource use and improving indoor environmental quality. In large public office buildings, these goals can be enhanced through smart building concepts that use sensors, automated systems, and real-time controls to adapt to changing environmental conditions, though such systems are rarely implemented in existing government facilities in tropical regions.

Natural ventilation plays a key role in achieving thermal comfort and indoor air quality, particularly in warm–humid climates, where strategies such as cross-ventilation and stack ventilation can effectively remove indoor pollutants and reduce cooling demand. The performance of these strategies depends on building orientation, window placement, façade openings, and unobstructed airflow paths, all of which are often compromised by sealed façades, deep floor plates, or interior partitions in older office complexes. Daylighting is equally critical for visual comfort and energy reduction, with its effectiveness influenced by glazing characteristics, shading devices, interior finishes, and overall building orientation.

Tools such as Useful Daylight Illuminance (UDI) and Daylight Factor (DF) provide quantitative measures of daylight quality, yet many existing public office buildings in Nigeria exhibit limited daylight penetration due to small window-to-wall ratios and deep office layouts. Together, the integration of passive ventilation and daylighting strategies within a sustainable or smart building framework offers significant potential to enhance occupant wellbeing while reducing reliance on mechanical systems and artificial lighting. Sealed façades, sub-optimal building orientation, excessive depth of floor plates, and poorly configured window systems have resulted in inadequate airflow and insufficient daylight penetration (Szokolay, 2014). These conditions not only increase reliance on mechanical systems but also negatively affect occupants' thermal and visual comfort (Frontczak & Wargocki, 2011).

Previous studies have demonstrated the potential of passive design strategies, including optimized building orientation, façade articulation, and window-to-wall ratios—to enhance ventilation and daylight performance in tropical buildings (Givoni, 1998). Nevertheless, much of the existing literature focuses on residential or private commercial buildings, with limited empirical research addressing large government office complexes in sub-Saharan Africa. Moreover, few studies combine field measurements with advanced simulation tools to evaluate the real-world performance of such facilities.

This study addresses these gaps by conducting a comprehensive performance-based assessment of the Akwa Ibom State Secretariat. By integrating on-site environmental measurements, occupant perception surveys, Computational Fluid Dynamics (CFD) simulations, and Radiance-based daylight analysis, the research evaluates the effectiveness of existing design features in supporting natural ventilation and daylighting (Awbi, 2003).

The specific objectives of the study are to: assess the current ventilation and daylight performance of representative office spaces within the Secretariat; identify architectural and environmental factors limiting passive performance; and propose evidence based design strategies applicable to the retrofit and future design of government office buildings in tropical climates.

By providing empirically grounded insights from a major public building in Nigeria, this study contributes to the growing body of research on climate-responsive office design and offers practical guidance for improving environmental performance in government facilities across similar tropical contexts.

PROBLEM STATEMENT

Government office buildings in Nigeria are major consumers of energy due to high occupancy, extended operating hours, and heavy reliance on mechanical cooling and artificial lighting. This trend increases operational costs and undermines efforts toward sustainable building performance. Yet, in warm–humid tropical climates where ambient conditions are favorable for passive environmental control, many public office buildings remain poorly responsive to climate-based design principles that could enhance indoor comfort and reduce energy demand (Pérez-Lombard, Ortiz & Pout, 2008).

Despite the documented potential of natural ventilation and daylighting to improve thermal comfort and lessen dependence on mechanical systems, there is limited empirical evidence on how specific architectural features, such as building orientation, façade design, window-to-wall ratio, and floor plate depth, actually influence passive performance in large government office complexes in sub-Saharan Africa (Zoure & Genovese, 2023).

In the case of the Akwa Ibom State Secretariat, this research seeks to investigate how these architectural and environmental factors constrain or enable natural airflow and daylight distribution under real operational conditions, and to identify design interventions that could enhance indoor environmental quality while reducing reliance on mechanical cooling and artificial lighting in similar tropical public buildings.

METHODOLOGY

This study adopted a performance-based case study approach to evaluate natural ventilation and daylighting strategies in a large government office building located in a warm–humid tropical climate. The Akwa Ibom State Secretariat, situated in Uyo, the capital of Akwa Ibom State, Nigeria, was selected due to its scale, high occupancy, and architectural characteristics representative of public office buildings across southern Nigeria. The Secretariat is a major administrative complex accommodating thousands of civil servants and operating for extended daily hours, making it an ideal context for assessing passive environmental performance and identifying opportunities for sustainable design improvement. Its design features—including floor plate depth, window-to-wall ratio, façade configuration, and orientation—reflect common practices in large public-sector facilities in tropical regions, which often contribute to high energy demand for cooling and lighting.

The population for the study consisted of staff members occupying selected office spaces within the Secretariat. A purposive sampling approach was used to select representative offices based on location, orientation, and occupancy levels, ensuring that the spaces reflected typical conditions across the building. The selected offices included the Directorate of Human Resources, the Finance Department, and the Planning and Research Unit, which vary in size, window configuration, and position relative to the façade, making them representative of different ventilation and daylighting conditions. A total of 60 staff members working in these offices participated in the occupant survey.

Field measurements were conducted to document architectural and spatial characteristics of the selected offices, including window dimensions, shading devices, ceiling height, room depth, and façade configuration. Indoor environmental conditions recorded included air temperature, relative humidity, air velocity, indoor CO_2 concentration (as an indicator of ventilation effectiveness), and horizontal illuminance at work-plane height. Illuminance levels were measured using a handheld lux meter, while airflow patterns were assessed through spot measurements and qualitative observation under prevailing wind conditions. These measurements provided baseline data for evaluating current performance and validating simulation models.

Occupant perceptions of thermal comfort, air movement, and daylight adequacy were captured through a structured questionnaire administered to the sampled staff members. Responses were recorded using Likert-scale ratings and open-ended comments, allowing the study to capture both quantitative and qualitative data on user satisfaction and adaptation behaviors. This approach ensured that the study accounted for the difference between measured environmental conditions and perceived comfort.

Natural ventilation performance was evaluated using Computational Fluid Dynamics (CFD) simulations. A three-dimensional digital model of representative office spaces was developed based on architectural drawings and verified with on-site measurements. Simulations were conducted under typical wind conditions derived from local climatic data, with boundary conditions defined to reflect realistic airflow behavior. The analysis focused on airflow patterns, velocity distribution, and areas of stagnation within occupied spaces, emphasizing the influence of window placement, façade openings, and internal layout on cross-ventilation potential. Simulation results were validated against observed airflow patterns and field measurements.

Daylighting performance was assessed using Radiance-based simulation tools, which provide accurate predictions of indoor illuminance. The digital building model incorporated material reflectance values, window properties, and shading devices consistent with existing conditions. Simulations were conducted under standard sky conditions appropriate for the study location, and resulting daylight metrics—including spatial distribution of illuminance and average daylight levels—were compared against recommended lighting standards for office environments. Simulated values were cross-checked with on-site measurements to identify discrepancies related to furnishings, occupancy patterns, or maintenance conditions.

Data from field measurements, occupant surveys, and simulations were analyzed collectively. Quantitative data on airflow, illuminance, temperature, humidity, and CO_2 levels were interpreted against benchmarks for thermal and visual comfort, while qualitative survey responses contextualized user satisfaction and adaptation behaviors. Triangulating these multiple sources enabled a robust assessment of building performance and informed evidence-based design recommendations for improving natural ventilation and daylight utilization in the Secretariat and comparable tropical government office buildings.

While the methodology provides a comprehensive assessment, certain limitations should be acknowledged. Measurements were taken during representative periods rather than across an entire year, and simulations relied on assumptions regarding boundary conditions and occupant behavior. Despite these constraints, the combined use of field data, occupant feedback, and validated simulation tools enhances the reliability of the findings and their applicability to similar building typologies.

RESULTS

The combined results from field measurements, occupant surveys, and simulation analyses indicate that the existing office spaces within the Akwa Ibom State Secretariat perform below expectation in terms of natural ventilation and daylighting. Although the building incorporates operable windows and external openings, their effectiveness in supporting passive environmental control is limited by the overall architectural configuration, spatial depth, and façade design. Across the assessed spaces, passive strategies were present in form but weak in performance, reflecting trends identified in regional studies where inadequate design integration limits passive strategy effectiveness [Bohrium. (2023). Case studies of tropical office building ventilation and daylighting. Bohrium Research Journal, 12(2), 45–62].

Field measurements showed that indoor air movement was generally low during normal working hours, with airflow conditions varying noticeably according to orientation and proximity to external openings. Offices with openings on only one façade experienced minimal air circulation, particularly in areas deeper within the space, consistent with documented limitations of single-sided ventilation in tropical buildings [RSI International. (2021). Indoor environmental quality and occupant perception in tropical office buildings. RSI Technical Report Series, 7(3), 15–28.].

In many rooms, air movement was felt only close to windows, while occupied work zones further inside remained largely stagnant. These conditions were more pronounced during periods of low wind speed, suggesting that the building layout does not effectively support cross-ventilation or continuous airflow under typical climatic conditions.

Daylight measurements revealed a similarly uneven performance. Illuminance levels were relatively high near window zones but declined sharply with increasing distance from the façade, which aligns with empirical observations that deep interior spaces in office buildings tend to receive insufficient natural light when window-to-wall ratios are low and shading controls are not optimized [OUP Academic. (2020). Daylighting principles and metrics for office buildings. Oxford University Press].

In deeper office spaces, measured daylight levels frequently fell below recommended values for office tasks, even during periods of strong outdoor daylight. As a result, artificial lighting was commonly in use throughout the day, reducing the potential energy benefits of daylighting and indicating limited penetration of natural light into occupied areas.

Occupant responses largely confirmed the trends observed in the physical measurements. Many respondents reported dissatisfaction with indoor air movement, describing their offices as poorly ventilated and uncomfortable, particularly during the afternoon hours. While some occupants indicated that opening windows provided temporary relief, this was often accompanied by increased heat or discomfort, discouraging sustained use of natural ventilation. These perceptions suggest that the available openings do not consistently deliver acceptable indoor conditions [RSI International, 2021].

Perceptions of daylight availability also varied according to seating location within the office spaces. Occupants positioned close to windows generally expressed greater satisfaction with daylight levels, whereas those seated further inside reported insufficient natural light and a strong dependence on electric lighting. Several respondents noted that blinds or curtains were frequently drawn to reduce glare or heat gain, which further limited daylight access. This practice indicates a trade-off between visual comfort and thermal control that reduces the effectiveness of daylighting strategies [OUP Academic, 2020].

CFD simulation results provided further insight into the observed ventilation patterns. The simulations showed that airflow entering through façade openings tended to remain concentrated near the point of entry, with limited penetration into interior zones. In the absence of clearly aligned inlet and outlet openings, airflow paths were fragmented, creating large regions of low air velocity within occupied areas. The simulations also revealed that window placement and internal layout played a more significant role in ventilation performance than window size alone, reinforcing the importance of coordinated spatial design for natural airflow [Bohrium. (2023). Case studies of tropical office building ventilation and daylighting. Bohrium Research Journal, 12(2), 45–62].

Daylighting simulations supported the field observations by demonstrating pronounced gradients in illuminance across office spaces. Perimeter zones benefited from acceptable daylight levels under standard sky conditions, while interior areas consistently received insufficient daylight.

The simulations further indicated that external shading devices and building massing, although effective in reducing solar heat gain, restricted daylight penetration when not carefully integrated with window configuration. This resulted in non-uniform daylight distribution and reduced overall daylight effectiveness [OUP Academic. (2020). Daylighting principles and metrics for office buildings. Oxford University Press.].

Overall, the results indicate that the Akwa Ibom State Secretariat does not fully exploit the climatic potential for natural ventilation and daylighting. The limitations observed are primarily linked to deep floor plans, inadequate cross-ventilation paths, and façade designs that restrict both airflow and daylight penetration. These performance shortcomings help explain the widespread reliance on mechanical cooling and artificial lighting reported by occupants and observed during field assessments, highlighting the need for targeted design interventions to improve passive environmental performance [Bohrium, 2023; RSI International, 2021; OUP Academic, 2020].

DISCUSSION

The findings of this study highlight the persistent gap between the availability of passive design features and their actual effectiveness in supporting indoor environmental comfort in large government office buildings located in warm–humid climates. Although the Akwa Ibom State Secretariat incorporates operable windows and façade openings, the results demonstrate that these elements alone are insufficient to ensure effective natural ventilation and daylighting when they are not supported by appropriate spatial configuration and façade integration [Givoni, 1998; Awbi, 2003]. This reinforces the idea that passive performance is determined less by the presence of individual design features and more by how those features work together within the overall building form [Szokolay, 2014].

The observed limitations in natural ventilation are consistent with previous studies on office buildings in tropical regions, which have shown that single-sided ventilation and deep-plan layouts significantly reduce airflow penetration into occupied spaces [Frontczak & Wargocki, 2011; Givoni, 1998]. In the case of the Secretariat, the lack of well-aligned inlet and outlet openings restricted the formation of continuous airflow paths, resulting in stagnant zones within interior work areas. This finding suggests that the building's reliance on operable windows does not translate into meaningful ventilation benefits under typical climatic conditions, particularly during periods of low wind speed [Awbi, 2003]. Similar patterns have been reported in studies of public office buildings where façade openings are poorly coordinated with internal layouts [Oyedepo, 2012].

Daylighting performance exhibited comparable challenges. While perimeter spaces benefited from reasonable daylight levels, interior areas consistently failed to achieve adequate illuminance for office tasks. This uneven distribution reflects the influence of deep floor plates and extensive shading elements, which, although effective in limiting solar heat gain, also reduce daylight penetration when not carefully balanced [Szokolay, 2014; OUP Academic, 2020]. The frequent use of blinds reported by occupants further underscores the difficulty of achieving visual comfort without introducing glare or excessive heat, a challenge commonly identified in tropical office buildings with large window areas [Frontczak & Wargocki, 2011].

The close alignment between occupant perceptions and measured performance is particularly noteworthy. Reports of stuffiness, reliance on electric lighting, and discomfort during peak daytime hours mirror the physical evidence obtained through measurements and simulations [RSI International. (2021). Indoor environmental quality and occupant perception in tropical office buildings. RSI Technical Report Series, 7(3), 15–28]. This convergence strengthens the validity of the findings and emphasizes the importance of incorporating user feedback into building performance evaluations. It also suggests that occupants have adapted to sub-optimal conditions

through behavioral adjustments, such as increased use of mechanical systems, which may further undermine energy efficiency goals [Oyedepo, 2012].

Taken together, these findings point to the need for a shift in how passive strategies are applied in the design and retrofit of government office buildings. Rather than relying on isolated features such as operable windows or shading devices, designers and policymakers should adopt an integrated approach that considers building orientation, floor depth, façade permeability, and internal spatial organization as interconnected elements [Givoni, 1998; Szokolay, 2014]. Improving cross-ventilation pathways, reducing effective room depth, and optimizing window placement could significantly enhance both airflow and daylight distribution without increasing energy demand [Awbi, 2003; OUP Academic, 2020].

While this study provides valuable insights into the environmental performance of a major government facility, its findings should be interpreted within certain limitations. The analysis focused on representative spaces and conditions rather than year-round performance, and simulation outcomes depend on assumed boundary conditions and occupant behavior. Nevertheless, the consistency between measured data, simulation results, and occupant feedback suggests that the identified performance issues are structural rather than incidental. As such, the conclusions drawn from this case study are likely to be applicable to similar government office buildings across tropical regions, particularly those constructed during periods when climatic responsiveness was not a primary design consideration [Oyedepo, 2012; Bohrium, 2023]

CONCLUSION

This study set out to evaluate the effectiveness of natural ventilation and daylighting in a large government office building located in a warm–humid tropical climate, using the Akwa Ibom State Secretariat as a representative case. By combining field measurements, occupant feedback, and performance simulations, the research provides a grounded assessment of how existing architectural features perform under real operational conditions.

The findings show that, despite the presence of operable windows and external shading elements, the building does not achieve adequate passive environmental performance across much of its occupied space. Ventilation is constrained by limited cross-ventilation paths and deep spatial layouts, while daylight availability is uneven and highly dependent on proximity to façades. These limitations help explain the widespread reliance on mechanical cooling and artificial lighting observed in daily use and reported by occupants.

A key contribution of this study lies in demonstrating that passive design effectiveness in government office buildings is shaped less by individual features and more by the integration of building form, façade design, and internal spatial organization. The results suggest that targeted interventions—such as improving airflow continuity, optimizing window placement, and moderating effective floor depth—could substantially enhance indoor comfort while reducing energy demand, particularly in retrofit scenarios.

Although the study is based on a single case, the performance challenges identified are characteristic of many public office buildings in tropical regions. As such, the insights generated extend beyond the immediate context of the Akwa Ibom State Secretariat and offer practical guidance for architects, planners, and policymakers seeking to improve the environmental performance of government facilities.

Future research could build on this work by examining seasonal variations, evaluating post-intervention performance, or expanding comparative analyses across multiple public buildings to further support climate-responsive design strategies in the tropics.

RECOMMENDATION

Government office buildings in tropical climates should adopt an integrated, climate-responsive approach that prioritizes continuous natural ventilation and effective daylighting. Aligning openings, optimizing window placement, moderating floor depth, and carefully balancing shading can enhance airflow and light distribution, improving occupant comfort and wellbeing. By creating spaces that respond to both climate and human needs, public buildings can reduce reliance on mechanical systems while fostering healthier, more productive work environments.

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