Global Nexus Journal of Multidisciplinary Research (GNJMR)
www.globalnexusjournal.com.ng
p-ISSN: 3115-5847
e-ISSN: 3121-8318
September 2026, Vol. 1, No 3, pg 12-25

Evaluating Occupancy Patterns Affecting the Performance of Natural Ventilation Design Elements in Military Barracks: A Comparative Study in Plateau State, Nigeria

By

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Abstract

This study evaluates how occupancy patterns affect the performance of natural ventilation design elements in two army barracks located in contrasting microclimatic zones of Plateau State, Nigeria. A mixed-methods design was adopted, combining, physical building assessments, microclimate measurements and structured questionnaire survey administered to 245 respondents across the Maxwell Khobe Cantonment Barracks (MKCB) in Bassa Local Government Area (highland, ~1,200 m a.s.l.) and the 332 Artillery Regiment Barracks (ARB) in Shendam Local Government Area (lowland, ~300 m a.s.l.) to capture occupant perceptions of ventilation performance; physical building assessments documented design parameters at both sites; and microclimate measurements were triangulated with occupant perceptions. Multiple regression and Pearson correlation analyses were conducted to determine the predictive weight of occupancy patterns, design parameters, microclimate integration, and occupant comfort on natural ventilation performance. The regression model explained 80.6% of the variance in natural ventilation performance ($R^2 = 0.806$, $F = 50.82$, $p < 0.001$). Occupant comfort ($\beta = 1.008$) and occupancy pattern ($\beta = 0.871$) emerged as the strongest positive predictors, while microclimate integration returned a negative coefficient ($\beta = -0.585$), indicating that existing designs fail to adequately mitigate localised climate stressors. Strong positive correlations were found between occupancy pattern and occupant comfort ($r = 0.921$) and between occupancy pattern and natural ventilation performance ($r = 0.825$), and MKCB consistently outperformed ARB across all measured indicators, reflecting the joint influence of altitude, building typology, and occupant behaviour. The study concludes that occupant behaviour, beyond architectural design, is the dominant determinant of natural ventilation performance in military barracks and recommends that climate-responsive retrofitting strategies addressing both behavioural and technical dimensions be adopted to improve indoor environmental quality in Nigerian military housing and comparable sub-Saharan African contexts.

Keywords: Natural Ventilation; Occupancy Patterns; Military Barracks; Indoor Air Quality; Thermal Comfort; Climate-Responsive Design; Nigeria

1.0 INTRODUCTION

Military barracks face design pressures rarely encountered in civilian residential architecture: a regimented security framework limits occupant control of the building envelope, high occupancy densities intensify internal heat and pollutant loads, and prototype construction often misaligns buildings with their microclimates (Maiyaki et al., 2021). These tensions are especially acute in Nigeria, where most barrack stock dates to the colonial era and has not been substantially redesigned despite documented evidence of inadequate ventilation and declining occupant well-being (Onwubiko, 2019; Milala et al., 2021).

Natural ventilation which introduces and distributes outdoor air through purpose-built openings using wind pressure and thermal buoyancy, offers a low-cost, low-carbon route to improved indoor environmental quality (IEQ) in tropical and semi-tropical buildings (Atkinson, 2009; Cheng et al., 2022; Ibrahim et al., 2026). Its effectiveness depends not only on architectural parameters such as window size, placement, and building orientation, but also on occupant behaviour: how frequently windows are opened or closed, how furniture is arranged relative to airflow paths, and the degree to which security concerns override comfort considerations (Gou et al., 2018; Pourtangestani et al., 2024).

Plateau State, in Nigeria's middle belt at elevations of 1,200-1,829 m, has a temperate-dry highland climate with modest diurnal temperature ranges, low humidity, and distinct harmattan and rainy seasons that shape passive ventilation design (Gontul et al., 2007; Mobolade & Pourvahidi, 2020). The two study sites occupy markedly different positions within this climatic envelope: MKCB in the highland zone of Bassa LGA and ARB in the lowland zone of Shendam LGA, providing a natural quasi-experimental setting for isolating microclimate effects on ventilation performance while holding building typology broadly constant. Despite growing scholarly attention to natural ventilation in Nigerian residential buildings (Adunola, 2017; Okonkwo et al., 2022; Akubue, 2023; Basil et al., 2026), research specifically addressing military barracks remains scarce, and no published study has systematically examined occupancy patterns as a mediating variable between building design and ventilation performance in this building type. This paper addresses that gap through a comparative, mixed-methods investigation across MKCB and ARB.

1.1 Statement of the Problem

Nigerian military barracks are built to a single prototype design deployed nationwide irrespective of local microclimate, leaving occupants in hot lowland and cooler highland installations alike dependent on the same fixed windows and room geometries for thermal relief. Where this design fails to deliver adequate airflow, the consequence for the Nigerian Army is direct: degraded soldier welfare and morale (Maiyaki et al., 2021), impaired rest and recovery for personnel on demanding schedules, heightened heat-related health risks (Fobiri, 2023), and growing reliance on mechanical cooling that strains an already stretched defence budget (Onwubiko, 2019), all of which bear on troop readiness. Compounding this, occupant behaviour, particularly window operation shaped by security concerns (Donubari & Ideozu, 2019), interacts with these fixed designs in ways that can amplify or neutralise their intended performance, yet this interaction remains almost entirely unexamined in the military housing literature. It is this evidentiary gap that the present study addresses.

1.2 Objectives, Research Questions, and Hypotheses

The specific objectives of this study are to: (a) assess the occupancy patterns of residents at MKCB and ARB; (b) evaluate the design parameters influencing natural ventilation performance at both sites; (c) assess the extent of microclimate integration in the design of the two barracks; (d) determine the predictive relationship of occupancy patterns, design parameters, and microclimate integration on natural ventilation performance; and (e) compare natural ventilation performance between the highland (MKCB) and lowland (ARB) sites. Accordingly, the study addresses the following research question: to what degree do occupancy patterns, design parameters, and microclimate integration predict the performance of natural ventilation in military barracks, and how do these relationships differ across contrasting microclimatic zones? Two hypotheses, stated in the null form, guide the empirical analysis: H_1, occupancy patterns, design parameters, and microclimate integration do not significantly predict natural ventilation performance in military barracks; and H_2, there is no significant difference in natural ventilation performance between the highland (MKCB) and lowland (ARB) barracks.

2. LITERATURE REVIEW

2.1 Natural Ventilation in Tropical and Highland Climates

Natural ventilation is driven by two primary forces: wind pressure across building surfaces and stack effect, generated by temperature differentials between interior and exterior air (Atkinson, 2009; Shpak, 2023). In tropical and highland climates, the relative dominance of these forces shifts seasonally, requiring adaptive rather than static ventilation strategies. Causone (2016) demonstrated that the climatic potential for natural ventilation varies significantly with latitude, altitude, and seasonal wind regimes, while Brager and de Dear (2002) established that occupants apply adaptive strategies- adjusting clothing, activity levels, and window operation- that extend the acceptable comfort range well beyond steady-state model predictions.

Aflaki et al. (2015) identified window-to-wall ratio, facade orientation, and vertical ventilation shafts as the most influential facade parameters in tropical climates, while Loo et al. (2021) consolidated 92 studies and identified 78 configuration parameters affecting performance, with fenestration and courtyard/atrium voids the most researched. Li et al. (2024) found indoor temperature variations of up to 8.2°C within a single building due to facade-scale microclimate differences, underscoring the need to calibrate passive design to each facade's specific microclimate rather than regional data alone. Salvati and Kolokotroni (2023) similarly showed that ignoring urban heat island effects can underestimate cooling demand by up to 28%.

2.2 Occupancy Patterns and Ventilation Performance

The relationship between occupant behaviour and natural ventilation performance has attracted increasing scholarly attention since the mid-2000s, catalysed by evidence that buildings designed for natural ventilation frequently fail to meet their intended performance in use (Gou et al., 2018). Sharpe et al. (2015) surveyed 200 post-2009 airtight Scottish dwellings and found that trickle vents were ignored by 63% of occupants in bedrooms, with windows opened reactively for warmth, odour, or fresh air rather than as a deliberate strategy; measured CO_2 concentrations averaged 1,550-2,000 ppm, substantially exceeding the 1,000-ppm adequacy threshold, concluding that natural ventilation designs routinely fail without active occupant engagement. Pourtangestani et al. (2024) used probabilistic modelling of window operation schedules to show that stochastic 'probable behaviour' patterns boost annual air changes per hour (ACH) by 5–12% relative to deterministic patterns, with post-occupancy evaluation (POE) confirming design-behaviour mismatches as a primary source of underperformance. Consistent with this, Buonocore et al. (2025) found that Brazilian residents strongly prefer natural ventilation, driven primarily by routine and economics rather than environmental awareness, with indoor air velocity thresholds of $\geq$0.4 m/s identified as the key comfort condition for sustained adoption.

In military and institutional settings, security considerations are a documented barrier to window use. Donubari and Ideozu (2019) observed that soldiers in Nigerian barracks frequently close windows and louvres for security reasons, particularly overnight, creating stagnant indoor environments that persist into occupied periods due to thermal lag, aligning with Atkinson's (2009) observation that climate, security, and cultural criteria may collectively cause ventilation rates to fall well below design intent. High-density occupation increases internal heat and moisture loads, requiring proportionally higher ventilation rates to maintain acceptable IEQ (Etheridge & Sandberg, 1996). Zhang et al. (2024) demonstrated that household size predicts indoor CO_2 concentration and thermal discomfort in naturally ventilated dwellings, while Nasir and Abdullah (2025) showed that dormitory IAQ is directly affected by variation in occupancy levels.

2.3 Military Barracks Housing in Nigeria: Context and Challenges

Military barracks in Nigeria accommodate approximately 223,000 army personnel and their dependents as of 2022 (Premium Times & Agency Report, 2022). Their design history reflects a colonial structures of swish and timber with thatched roofs, while post-independence buildings shifted to block-andcement construction, frequently with louvre windows giving way to sliding and casement windows in renovation cycles (Abdurrahman, 1985; Maiyaki, 2019). This has architectural implications for ventilation: louvre windows permit airflow through approximately 95-100% of their open area and can be adjusted incrementally, while casement windows offer less flexible control (Atkinson, 2009).

Milala et al. (2021) found that while structural elements at Coral Barracks were rated fair, essential services such as roofs, kitchens, and toilets were rated poor. Oyeleke et al. (2021) similarly documented mixed conditions at Shadawanka Barracks, Bauchi. Despite substantial government investment including $54.4 million in rehabilitation between 2012 and 2014 (Onwubiko, 2019) and N63.1 billion budgeted for barrack construction in 2025 (Budget Office of the Federation, Nigeria, 2025), new and renovated barracks continue to rely on mechanical cooling that is unaffordable for many occupants and misaligned with Nigeria's 2021 Climate Change Act (Daudu & Idehen, 2024), making climate-responsive, occupant-centred ventilation design a practical imperative rather than merely an academic concern.

2.4 Research Gap

The foregoing review reveals three principal gaps. First, while the interaction between occupant behaviour and natural ventilation performance is increasingly documented in residential and office buildings (Sharpe et al., 2015; Pourtangestani et al., 2024), systematic investigation in military barracks where behavioural constraints are institutionally structured and security concerns add complexity, is inadequate. Second, existing Nigerian studies of passive ventilation (Adunola, 2017; Mba et al., 2022) focus on civilian building types and do not account for barracks-specific constraints. Third, Plateau State's temperate, low-humidity highland microclimate remains understudied relative to the hot-humid coastal climates that dominate the Nigerian ventilation literature. This study addresses all three gaps through a comparative, empirically grounded investigation.

3. METHODOLOGY

3.1 Research Design

A mixed-methods design was adopted, combining quantitative survey data with physical building assessments, microclimate measurements, and qualitative occupant feedback, consistent with established practice in built-environment research where architecture-climate-behaviour interactions resist mono-method investigation (Doyle et al., 2016; Akotia et al., 2024). The independent variables are occupancy patterns, design parameters, and integration of microclimate in building design; the dependent variable is natural ventilation performance, measured as a composite index of perceived airflow quality, air change effectiveness, and thermal comfort. Geographical location (highland versus lowland) functions as a moderating variable.

3.2 Study Area

The study encompasses two army installations in Plateau State, Nigeria (9°10′0″N, 9°45′0″E). MKCB is situated in Bassa LGA (9°56′00″N, 8°44′00″E) at approximately 1,200 m a.s.l., with a semi-temperate climate (mean temperatures 20–31°C, annual rainfall ~1,460 mm, April-October) and a pronounced harmattan from December to February. ARB is in Shendam ((or 8°52'43"N, 9°32'4"E) LGA at approximately 300 m a.s.l., with warmer conditions (exceeding 36°C) and annual rainfall of 1,000–1,450 mm. The ~900 m altitude contrast produces meaningfully different wind, humidity, and heat stress conditions, enabling a quasi-experimental comparison of how the same prototype building typology performs under different microclimates (Alfred et al., n.d.; Gontul et al., 2007).

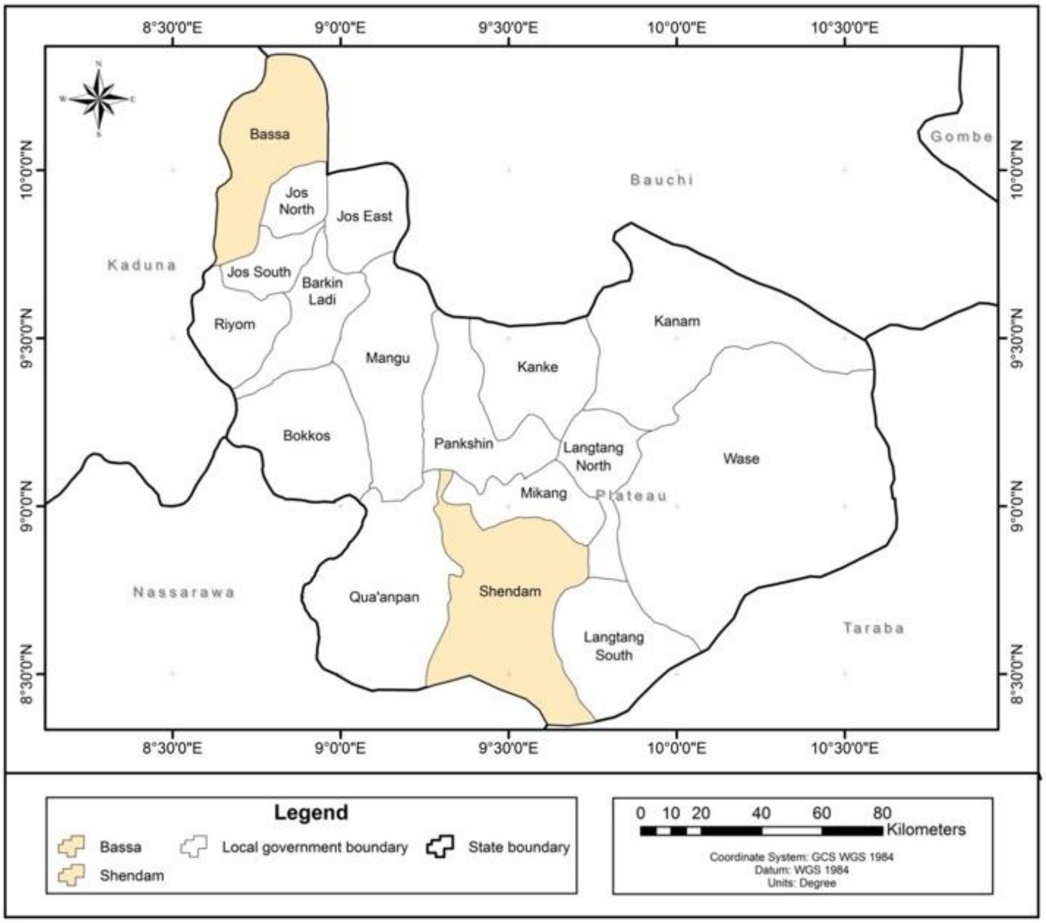

Figure 1: Map of Plateau State showing Bassa Local Government Area (MKCB, highland site) and Shendam Local Government Area (ARB, lowland site). Source: [GIS Laboratory, University of Jos, 2025].

3.3 Population and Sampling

The total population of housing units across the two barracks was 667 (MKCB: 469; ARB: 198), comprising four accommodation types: Married Officers' Quarters (MOQ), Single Officers' Quarters (SOQ), Senior Non-Commissioned Officers' Quarters (SNCOQ), and Corporals Below Quarters (CBQ). Sample size was calculated using Taro Yamane's formula at a 5% margin of error, yielding a required 250 units. Proportional stratified sampling ensured representation of all accommodation types and both sites, giving a final allocation of 170 units at MKCB and 75 at ARB. One questionnaire was administered per housing unit, addressed to the household head; 245 were retrieved complete, a response rate of 97.9%, aided by the regimented environment in which respondents were gathered periodically over one week.

3.4 Instruments and Data Collection

Data were collected through three instruments: a structured questionnaire organised in four schedules covering (a) natural ventilation design parameters, (b) occupant satisfaction with airflow, (c) integration of microclimate in building design, and (d) occupancy patterns, using five-point Likert scales adapted from ASHRAE Standard 55 protocols; local microclimate data from the University of Jos weather station supplemented by on-site digital thermometers and anemometers; and geospatial analysis using

Geographic Information Systems (GIS) and Global Positioning System (GPS) technology to document topographic, slope, and vegetation data relevant to airflow patterns at each site.

Content validity of the instrument was established through expert review by academics and practitioners in architecture and building physics prior to data collection. Instrument reliability was then assessed using Cronbach's alpha on pilot data from 54 respondents; the final alpha for the five main constructs was 0.707, exceeding the 0.70 threshold recommended by Field (2000).

3.5 Data Analysis

Quantitative data were analysed using the Statistical Package for the Social Sciences (SPSS). Descriptive statistics, including means and standard deviations, were computed for all variables. Pearson product-moment correlation analysis examined bivariate relationships among the five key constructs: Natural Ventilation Design performance (NVD), Integration of Microclimate (IM), Design Parameters (DP), Occupancy Pattern (OP), and Occupant Comfort (OC). Multiple linear regression was used to determine the unique predictive weight of each independent variable on NVD performance, with the Durbin-Watson statistic used to assess serial autocorrelation. Principal component analysis with Varimax rotation was conducted to identify underlying factor structures, and total variance explained was used to assess the dimensionality of the construct space.

4. RESULTS

4.1 Sample Profile

Of the 245 respondents, 69.4% were residents of MKCB and 30.6% of ARB, reflecting the proportional sampling frame; full demographic detail is presented in Table 1. Male household heads constituted 80.8% of the sample, consistent with the gender composition of the Nigerian Army, and the Corporals-Below Quarters (CBQ), the highest-density accommodation type, typically single-room or two-bedroom units in three-storey blocks of 10–12 units per floor, accounted for 53.1% of the sample.

Table 1. Demographic Profile of Respondents (n = 245)

Variable	Category	Frequency	Percentage (%)
Barrack	MKCB (Bassa)	170	69.4
	ARB (Shendam)	75	30.6
Rank	Lance Corporal	50	20.4
	Corporal	50	20.4
	Sergeant	45	18.5
	Staff Sergeant	50	20.4
	Warrant Officer	45	18.5
Household size	1 - 4 members	73	29.6
	5 - 9 members	104	42.6
	10 - 15 members	68	27.8
Duration of stay	1 - 5 years	54	22.2
	6 - 10 years	132	53.7
	11 - 15 years	36	14.8
	16 - 20 years	23	9.3
Accommodation status	Old building	159	64.8
	New building	45	18.5
	Renovated building	41	16.7

4.2 Comparative Analysis of Natural Ventilation Performance across Sites

Comparative Likert-scale means across the seven measured ventilation indicators are presented in Table 2.

Table 2. Comparative Likert-Scale Means by Barracks (1 = Very Poor; 5 = Excellent)

Variable	ARB (n=75)	MKCB (n=170)	Overall Mean
Quality of air	3.0	4.0	3.5
Condition of windows	2.5	4.5	3.5
Frequency of opening windows	3.0	4.0	3.5
Airflow obstacles present	4.0	2.0	3.0
Preference for additional features	4.5	3.5	4.0
Impact of airflow on comfort	3.5	4.5	4.0
Seasonal climate impact on ventilation	4.0	3.0	3.5

The condition of windows showed the greatest inter-site divergence (ARB: 2.5; MKCB: 4.5). Building assessments confirmed that ARB blocks rely heavily on louvre windows in poor repair, whereas MKCB retains better-maintained louvre windows in older accommodation, consistent with research showing louvre configurations enable airflow through 95-100% of their opening area (Atkinson, 2009), while newer MKCB blocks incorporate larger sliding and casement windows.

Plate 1: Old and renovated 'C' block of MKCB, Bassa LGA with louvre window and newly installed casement window respectively.

Plate 2: 'C' block ARB, Shendam with louvre windows.

Airflow obstacles scored markedly higher at ARB (4.0 vs 2.0 at MKCB), consistent with qualitative feedback that dense vegetation and furniture placement obstruct airflow at the lower-altitude, warmer site. Security concerns additionally drove window closure at ARB, where burglary-proofing and window nets are absent, leaving occupants reluctant to open windows overnight.

4.3 Descriptive Statistics for Study Variables

Descriptive statistics for the five primary constructs are presented in Table 3.

Table 3. Descriptive Statistics for Study Variables (n = 245)

Variable	Mean	Std. Deviation (SD)	Min	Max
Natural Ventilation Design (NVD)	40.56	7.87	16.00	61.00
Design Parameter (DP)	17.65	3.16	8.00	26.00
Occupancy Pattern (OP)	12.44	3.66	5.00	22.00
Occupant Comfort (OC)	12.57	3.48	4.00	21.00
Integration of Microclimate (IM)	10.17	2.34	4.00	18.00

The composite Natural Ventilation Design (NVD) performance score shows considerable variability across the sample, confirming that ventilation performance is not uniform even within the same prototype building type. Occupancy Pattern and Occupant Comfort record nearly identical means, anticipating the very high correlation found between these constructs, while Integration of Microclimate is the lowest-scoring variable, signaling that current building designs are perceived as poorly aligned with local climatic conditions.

4.4 Regression Analysis: Predictors of Natural Ventilation Performance

Results of the multiple regression analysis of predictors of natural ventilation design (NVD) performance are presented in Table 4.

Table 4. Multiple Regression Results: Predictors of Natural Ventilation Design Performance

Predictor	B	SE	β (Beta)	t	p
(Constant)	14.575	3.425	-	4.220	.000
Occupant Comfort (OC)	1.008	0.389	0.445	2.590	.013
Occupancy Pattern (OP)	0.871	0.364	0.405	2.391	.021
Design Parameter (DP)	0.477	0.188	0.191	2.533	.015
Integration of Microclimate (IM)	-0.585	0.245	-0.174	-2.389	.021

Model summary: R = 0.898; R^2 = 0.806; Adjusted R^2 = 0.790; F (4, 241) = 50.82; p < .001; Durbin-Watson = 0.766

The model was statistically significant ($F(4, 241) = 50.82$, $p < 0.001$) and explained 80.6% of the variance in NVD performance ($R^2 = 0.806$; Adjusted $R^2 = 0.790$). The Durbin-Watson statistic of 0.766

indicates some positive autocorrelation, expected given the nested nature of the data (housing units within barracks within sites). Occupant Comfort returned the highest coefficient (β = 0.445, p = 0.013), the strongest predictor of overall NVD performance; this is not circular, since the NVD composite captures objective indicators such as perceived air change rate and window condition, while Occupant Comfort measures subjective thermal satisfaction. Occupancy Pattern was the second-strongest predictor (β = 0.405, p = 0.021), confirming that occupant-environment interaction is a primary driver of ventilation effectiveness.

Design Parameter was positively associated with NVD performance (β = 0.191, p = 0.015), confirming that architectural features (window type, orientation, ceiling height) make a significant independent contribution, though smaller than the behavioural variables. Critically, Integration of Microclimate returned a negative coefficient (β = −0.174, p = 0.021): as local microclimatic stressors, primarily heat and humidity at the lower-altitude ARB, increase, the perceived effectiveness of existing ventilation designs decreases, evidence that current barrack designs fail to adequately mitigate the specific microclimate they inhabit.

4.5 Correlation Matrix

Pearson correlation coefficients among the five key constructs are presented in Table 5.

Table 5. Pearson Correlation Matrix

Variable	IM	DP	OP	OC	NVD
Integration Microclimate (IM)	1.000	.468**	-.245	-.070	-.174
Design Parameter (DP)	.468**	1.000	.069	.194	.224
Occupancy Pattern (OP)	-.245	.069	1.000	.921**	.825**
Occupant Comfort (OC)	-.070	.194	.921**	1.000	.868**
NV Design (NVD)	-.174	.224	.825**	.868**	1.000

*** Correlation significant at the 0.01 level (2-tailed).*

The matrix reveals a dominant human-centric cluster. The correlation between Occupancy Pattern and Occupant Comfort (r = 0.921) is the strongest relationship in the matrix, indicating that how residents interact with opening windows, arranging furniture, and regulating airflow is closely coupled to their experienced thermal comfort. Occupant Comfort and NVD performance (r = 0.868) and Occupancy Pattern and NVD performance (r = 0.825) are both very strong, confirming that active occupant engagement is a prerequisite for ventilation effectiveness. A moderate positive correlation between Design Parameter and Integration of Microclimate (r = 0.468) suggests that higher-quality architectural features are modestly associated with better perceived microclimate responsiveness, but that this architectural dimension is largely orthogonal to the behavioural cluster; Integration of Microclimate's negative bivariate correlation with NVD (r = −0.174) is consistent with the regression finding.

4.6 Factor Structure

Principal component analysis with Varimax rotation identified two components accounting for 85.88% of total variance. Component 1 (Human-Centric Dimension; 56.4% of variance) loaded strongly on Occupant Comfort (0.965), Occupancy Pattern (0.958), and NVD performance (0.950), confirming that these three constructs represent a coherent underlying dimension of occupant-mediated ventilation effectiveness. Component 2 (Technical-Architectural Dimension; 29.5% of variance) loaded on Integration of Microclimate (0.858) and Design Parameter (0.855), capturing the physical and design-related aspects of ventilation capacity. This structure provides theoretical justification for treating occupancy behaviour and architectural design as distinct but interacting influences on natural ventilation performance.

5. DISCUSSION OF FINDINGS/RESULTS

5.1 The Primacy of Occupant Behaviour

The most consequential finding of this study is the dominance of behavioural variables in predicting natural ventilation performance. Occupancy Pattern and Occupant Comfort jointly contributed 84.9% of explained variance across the two strongest regression coefficients, substantially outweighing Design Parameter. This hierarchy aligns with the growing consensus in ventilation science that architectural design creates potential for natural ventilation, but that occupant behaviour determines whether that potential is realised (Gou et al., 2018; Pourtangestani et al., 2024; Buonocore et al., 2025; Bhattacharjee et al., 2026).

5.2 Design Parameters and the Window Typology Transition

While behavioural variables dominate, Design Parameter nonetheless makes a statistically significant independent contribution to NVD performance ($\beta = 0.191$, $p = 0.015$), confirming that architectural decisions matter. The most salient design finding is the replacement of louvre windows with casement windows during renovation cycles: louvre windows, which dominated the original stock at both sites, allow continuous, adjustable airflow through approximately 95-100% of their open area and can be tilted to direct airflow (Atkinson, 2009), whereas casement windows offer only full-open or closed positions, with occupants reluctant to leave them open due to rain, security, and insect ingress. The significantly lower window condition scores at ARB, despite also being louvres (mean 2.5 vs 4.5 at MKCB), reflect poorer maintenance of ARB blocks.

5.3 Microclimate Integration

The negative regression coefficient for Integration of Microclimate ($\beta = -0.174$, $p = 0.021$) is the most theoretically significant finding of this study and reveals a critical gap. It indicates that as site-specific microclimatic stressors such as higher temperatures and humidity intensify at ARB's lowland location, the effectiveness of existing ventilation design in mitigating those stressors diminishes, reflecting the prototype construction model applied across Nigerian military barracks, in which identical building designs are deployed across substantially different climatic contexts without local adaptation.

The moderate positive correlation between Design Parameter and Integration of Microclimate ($r = 0.468$) offers a more encouraging signal: where design quality is higher, manifested in appropriate window types, adequate headroom, and favourable orientation, there is better perceived alignment with local climate. Investing in design quality improvements that address each site's specific microclimate such as adjustable louvre-type windows for cross-ventilation at ARB, taller internal spaces for stack effect, and screen walls for wind deflection could reduce the negative microclimate coefficient and improve overall ventilation performance.

5.4 Altitudinal Contrast of ARB vs MKCB

The systematic advantage of MKCB over ARB across all positive ventilation indicators cannot be attributed solely to microclimate. Building typology, construction status (more MKCB respondents occupied renovated or new structures with better-maintained windows), site topography (GIS slope analyses confirm better elevation gradients at MKCB), and screen walls and courtyard features in MKCB married officers' quarters all contribute, reflecting a real-world confound: military authorities have historically invested more heavily in the larger, strategically important MKCB, producing both a better microclimate and better-maintained buildings.

Qualitatively, MKCB respondents recorded benefits from shaded areas and cross-ventilating orientation during harmattan, with window operation constrained primarily by cold rather than security. At ARB, the dominant constraint was heat combined with security: residents opened windows by day but closed them at night, inverting the optimal strategy for stack-driven night-time flushing- a rational but counterproductive response that points to the need for design solutions that decouple security from ventilation, such as security screen grilles permitting full window opening without risk.

5.5 Implications for Design and Policy

The factor analytic results, separating a Human-Centric Dimension from a Technical-Architectural Dimension, provide a practical framework for intervention. Human-centric interventions—occupant education on nocturnal window opening, security-permeable screens in ARB blocks, and window-opening schedules aligned with roster patterns—are low-cost relative to architectural renovation and, given that this dimension accounts for 56.4% of total variance, potentially high-return. Technical-architectural interventions should focus on restoring louvre windows in renovated ARB blocks, increasing CBQ headroom to at least 3.0 m, and assessing building orientation against prevailing wind data before new construction; the current prototype model, deployed nationwide regardless of microclimate, should be replaced with separate highland and lowland design variants.

At the policy level, these findings support integrating natural ventilation performance standards into the Nigerian Army's barrack rehabilitation framework. Existing Presidential Committee on Barracks Rehabilitation allocations have not produced sustainable passive design outcomes (Onwubiko, 2019); redirecting a proportion of these resources towards climate-responsive design and occupant behaviour programmes represents a high-leverage use of public funds, consistent with Nigeria's Climate Change Act (2021).

6. CONCLUSION

This study provides the first systematic empirical analysis of occupancy patterns as determinants of natural ventilation performance in Nigerian military barracks, drawing on a comparative investigation across two installations in contrasting microclimatic zones of Plateau State. Occupant behaviour, operationalised as occupancy pattern and occupant comfort, is the dominant predictor of natural ventilation effectiveness, outweighing architectural design parameters and more than three times the magnitude of the microclimate integration coefficient; the regression model accounts for 80.6% of variance in natural ventilation performance. Architectural design nonetheless makes an independent, significant contribution, with the replacement of louvre windows by casement windows during renovation the most consequential design change, while the negative microclimate integration coefficient confirms that existing barrack designs fail to mitigate site-specific climate stressors. These findings extend an emerging body of evidence foregrounding occupant behaviour as a necessary but often underweighted determinant of natural ventilation effectiveness, with contextualised implications for military housing authorities in Nigeria and comparable sub-Saharan African settings seeking to improve indoor environmental quality without greater reliance on mechanical cooling. Limitations include the cross-sectional design, reliance on self-reported perception, and the confound between microclimate quality and investment history at the two sites; future research should integrate longitudinal, sensor-based monitoring alongside building performance simulation.

6.1 Recommendations

Based on these findings, military housing authorities should:

(a) retrofit security-permeable screens to enable overnight window use without compromising security;
(b) restore improved louvre-type windows in accommodation currently fitted with casements;
(c) ensure headroom to at least 3.0 m across barrack houses to support stack ventilation;
(d) develop site-specific design variants for highland and lowland microclimatic zones; and
(e) introduce occupant education programs on passive ventilation strategies.

Together, these measures address both the human-centric and technical-architectural dimensions of natural ventilation performance identified in this study.

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