VERTICAL DENSIFICATION AND INDOOR COMFORT: A PERCEIVED INDOOR ENVIRONMENTAL QUALITY ASSESSMENT OF GROUND-FLOOR LIVING SPACES IN SWARNA PLACE, COLOMBO

SENARATHNA M.S.M.[1]* & HETTIARACHCHI A.A.[2]
[1, 2]Faculty of Architecture, University of Moratuwa, Sri Lanka
[1]*sachini.senarathna20@gmail.com*, [2]*anishkah@uo.lk*

Abstract: This study investigates the Perceived Indoor Environmental Quality (PIEQ) in ground-floor living spaces within Swarna Place, a low-income incremental vertical housing settlement in Colombo, Sri Lanka. It evaluates four core environmental parameters: thermal quality, acoustic quality, air quality, and visual quality with lighting: using a validated questionnaire structure adapted from widely applied assessment scales to suit the socio-spatial context of multifunctional ground-floor living rooms. The research focuses on four development stages (Stages 01, 03, 05, and 07) observed during long-term settlement evolution. Findings from 60 surveyed households indicate a steady decline in perceived indoor comfort across stages, particularly in thermal and air quality aspects. This decline is closely linked to spatial densification, enclosed facades, and reduced natural light and ventilation due to vertical expansion. The study highlights the critical need to maintain environmental quality during housing transformation and suggests practical design measures for future low-income vertical housing developments. These findings contribute to broader discussions on residential experience, adaptive space use, and sustainable indoor environments in high-density urban communities.

Keywords: *Perceived Indoor Environmental Quality (PIEQ), Incremental Housing Development, Ground-Floor Living Spaces, Low-Income Settlements, Vertical Densification*

1. Introduction

This unregulated vertical growth directly compromises regulatory principles like the provision of 'space around buildings'. As dwellings expand upward (Stage 01 to Stage 07), the construction often reduces original setbacks and increases plot coverage. This vertical layering and enclosed façade design lead to significant degradation on the ground floor by casting persistent shadows and restricting pathways for natural airflow and cross-ventilation. These spatial compromises are a critical source of the declining thermal and visual comfort observed.

This study explores Perceived Indoor Environmental Quality (PIEQ) within ground-floor living spaces across four representative stages of vertical development in Swarna Place, a low-income housing settlement in Colombo, Sri Lanka. By focusing on the ground-floor living space; a multifunctional space for relaxation, dining, studying, and social interaction; the research highlights how vertical expansion affects indoor comfort and livability over time.

1.1 INCREMENTAL VERTICAL HOUSING IN SOUTH ASIA

Incremental housing, as conceptualized by Turner (1976) and later supported by Boonyabancha (2005), is a bottom-up approach where families expand their homes progressively in response to evolving needs, economic capacity, and available resources. While this method promotes affordability, ownership, and flexibility, it also introduces significant challenges-especially when vertical expansion replaces horizontal growth in dense urban areas. In such scenarios, design decisions are often made by residents with limited technical guidance, leading to reduced airflow, inadequate lighting, and spatial fragmentation (Rashid, 2019; Gifford, 2007). Moreover, without adequate planning and support, incremental vertical development can result in poorly constructed multi-story dwellings that lack essential services and infrastructure, effectively transforming into vertical slums. This phenomenon has been observed in various contexts, where the absence of regulatory oversight and support mechanisms has led to the deterioration of living conditions in vertically expanded housing (Franklin, 2018).

1.2 RESEARCH PROBLEM AND JUSTIFICATION OF THE STUDY

In many rapidly urbanizing contexts, especially across the Global South, state-led housing initiatives for low-income communities have encountered long-term sustainability challenges. While these developments may initially address issues of shelter and ownership, numerous studies have documented their decline into degraded, overcrowded, and undermaintained environments over time sometimes transforming into the very "vertical slums" they aimed to replace (UN-Habitat, 2016). This is particularly evident in Sri Lanka, where urban regeneration schemes often relocate communities into

*Corresponding author: Tel: +94 773459658 Email Address: sachini.senarathna20@gmail.com
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high-rise structures that lack alignment with the cultural, spatial, and functional preferences of residents. As a result, occupants may abandon or sublet these units, returning to familiar informal settings or modifying their new homes in unintended ways.

Amidst these limitations, incremental self-built housing continues to be a preferred and pragmatic alternative among urban poor communities. (Turner, 1976) In settlements like Swarna Place, residents expand their homes vertically as their economic capacity and family needs evolve. However, these additions are typically constructed without technical guidance or environmental performance considerations, which raises concerns about ventilation, lighting, noise control, and overall indoor comfort (Wong & Huang, 2004; Dovey & King, 2011). Despite the spatial transformation and upward mobility symbolized by vertical growth, the lived quality of these environments; particularly on ground floors; may deteriorate due to reduced airflow, poor daylight penetration, and increasing compartmentalization.

Although previous studies have examined physical conditions or satisfaction levels within public housing (e.g., Mohit et al., 2010; Warakapitiya et al., 2024), few have critically explored how residents themselves perceive indoor environmental quality across different stages of vertical self-build expansion. This gap becomes more significant when considering that ground-floor living rooms serve as the most intensively used, multifunctional spaces in these dwellings; accommodating rest, socialization, cooking, work, and leisure. As such, a nuanced, resident-centered understanding of indoor environmental quality is essential to inform housing design, regulation, and retrofitting strategies that support both comfort and sustainability.

1.3 RESEARCH GAP AND RELEVANCE

While many studies have examined Indoor Environmental Quality (IEQ) in residential buildings, particularly through thermal, acoustic, air, and visual parameters (Frontczak & Wargocki, 2011; Vischer, 2007), most rely on objective measurements within formal housing contexts. However, research using perceived evaluations; especially in incrementally developed, user-led housing; remains scarce. Post-occupancy evaluation (POE) is increasingly used to assess comfort, yet its application in self-built, informal vertical settlements is limited. These environments often lack professional design input, making resident feedback essential for understanding comfort and functionality. Ground-floor living spaces, being the most occupied and multifunctional spaces, are particularly vulnerable to reduced light, airflow, and acoustic performance as buildings expand vertically. Perceived Indoor Environmental Quality (PIEQ); which includes thermal quality, acoustic quality, air quality, and visual quality with lighting quality (Brink et al., 2020)- offers a valuable framework for assessing lived experience in such spaces. Despite this, few studies have focused on how vertical densification affects PIEQ at the ground-floor level, where conditions are poorest. This study addresses that gap by applying a context-specific PIEQ assessment across four vertical housing stages in Swarna Place, Colombo. A context-specific PIEQ assessment involves tailoring the standard subjective evaluation tools which typically focus on formalized settings to accurately capture the lived experience and behavioral adaptations within a unique architectural and socio-economic environment. For this study, the PIEQ framework was specifically adapted to account for the characteristics of the Sri Lankan low-income settlement, including passive climate responsiveness (e.g., natural airflow), the influence of household-driven modifications (e.g., staircases, partition walls), and local behaviors (e.g., use of gas cookers, incense, and curtains)

1.4 OBJECTIVES OF THE RESEARCH

This study aims to critically explore the spatial and perceptual implications of incremental vertical development on indoor environmental conditions in low-income housing. Recognising the multifunctional role of ground-floor living rooms; often the most socially and spatially active zones in such dwellings: the research investigates how progressive densification alters residents' environmental experiences.

Specifically, the research seeks to:

- Examine the interplay between spatial evolution and perceived indoor environmental quality (PIEQ) in ground-floor living spaces across selected stages of vertical housing transformation.
- Assess resident perceptions of thermal comfort, acoustic quality, air quality, and visual comfort through an adapted evaluation framework suited to the unique architectural and socio-economic context of Swarna Place.
- Identify patterns of environmental degradation or improvement attributable to architectural interventions such as added floors, enclosed façades, and internal reconfigurations.
- Generate evidence-based insights for future participatory housing strategies that prioritize environmental quality alongside incremental flexibility.
- Reinforce the value of resident-informed feedback mechanisms in evaluating indoor comfort in contexts where conventional building performance assessments are limited or impractical.

1.5 SCOPE AND LIMITATIONS

This study focuses exclusively on ground-floor living spaces in a single low-income housing settlement; Swarna Place, Colombo; due to their multifunctional role, accessibility, and ethical suitability. Data were collected from 60 households representing four incremental stages (Stages 01, 03, 05, and 07), based on clearly distinguishable construction and spatial features. The study employs an adapted version of the PIEQ framework (Brink et al., 2020), modified for cultural and architectural relevance. The research is limited by several factors: it excludes upper floors, private rooms, and transitional zones; does not cover all seven development stages; and relies solely on perceived resident feedback without physical measurements. Photographic documentation was restricted at the residents' request, with greater reliance on **on-**site sketches. These constraints mean that while the findings provide valuable insights into perceived comfort in vertically densified low-income housing, they are context-specific and not broadly generalizable. Future studies should include instrumental measurements, wider spatial coverage, and comparative multi-site analysis for broader applicability.

Figure1: Incremental development of housing unit.
(Note: Each stage includes multiple subtypes, but one representative house is illustrated here to reflect the typical incremental transformation. Adapted from "The Impact of Incremental Vertical Housing Development on Quality of Space and Residential Environmental Satisfaction: A Case Study of Swarna Place, Colombo, Sri Lanka," by M. S. M. Senarathna and A. A. Hettiarachchi, 2025, Proceedings of the 13th World Construction Symposium, pp. 1356–1368. Copyright 2025 by CIOB..)

2. Literature Review

2.1 PERCEIVED INDOOR ENVIRONMENTAL QUALITY (PIEQ): DEFINITIONS AND FRAMEWORKS

Perceived Indoor Environmental Quality (PIEQ) refers to occupants' subjective evaluation of indoor comfort based on environmental parameters such as thermal conditions, air quality, acoustic performance, and visual comfort (Brink et al., 2020; Frontczak & Wargocki, 2011). These parameters significantly influence physical health, psychological well-being, and productivity in residential settings (Geng et al., 2019). Brink et al. (2020) emphasize the importance of incorporating occupant feedback to assess indoor environments, particularly in participatory housing contexts where traditional comfort metrics may not fully capture experiential realities. The approach is often used in Post-Occupancy Evaluation (POE), which gauges user satisfaction through structured surveys and feedback mechanisms (Preiser & Vischer, 2005).

In low-income housing environments, perceived comfort is particularly relevant due to the absence of standardized climate control systems, increased reliance on passive design features, and resident-led architectural modifications. While physical measurements of environmental quality are common in laboratory or institutional settings, subjective perception studies offer a valuable lens into lived experience, especially in under-regulated or informally developed housing types (Nix et al., 2015; Ilesanmi, 2010).

2.2 INDOOR ENVIRONMENTAL QUALITY IN LOW-INCOME AND INCREMENTAL HOUSING

Numerous studies have addressed environmental quality in public housing and slum upgrading projects. For example, Mohit et al. (2010) found that resident satisfaction in Malaysian low-cost housing was strongly linked to air flow and daylighting. Similarly, Gifford (2007) emphasized the psychological burdens associated with poor acoustic insulation and ventilation in high-rise environments. In India, Nix et al. (2015) documented significant deficits in thermal and air quality performance in informal Delhi settlements, attributing them to compact layouts and unplanned modifications. These findings underscore that indoor quality parameters often deteriorate as vertical layering and densification increase.

Boonyabancha (2005) and Bredenoord & van Lindert (2010) argue that while incremental growth supports affordability and ownership, it often leads to regulatory gaps and compromised spatial standards. This is particularly true in self-built vertical housing where resident modifications are driven by necessity rather than design expertise (Franklin, 2018). In such scenarios, ground-floor units typically receive less daylight and ventilation due to shading from upper floors and enclosed façades (Warakapitiya et al., 2024), compromising comfort and livability.

2.3 GROUND-FLOOR LIVING SPACES AS CRITICAL ZONES FOR COMFORT ASSESSMENT

Ground-floor living rooms serve as the primary spatial nucleus in low-income homes, especially in South Asian contexts where indoor–outdoor thresholds are blurred (Rashid, 2019). These spaces are multifunctional; used for socializing, dining, sleeping, and working and experience the highest occupancy rates throughout the day (Warakapitiya et al., 2024; Samaratunga & O'Hare, 2015). However, as houses increment vertically, the introduction of staircases, partition walls, and balconies often restrict airflow, reduce visual access, and increase reverberated noise levels on the ground floor (Geng et al., 2019). Despite their importance, these living zones are rarely the focus of environmental quality evaluations. (Jiboye, 2010) Moreover, the ethical and logistical ease of accessing shared living rooms, as opposed to private bedrooms, makes them more suitable for research-based assessment (Jiboye, 2010). The use of PIEQ frameworks in such spaces offers a rich understanding of perceived comfort trends over time and across housing stages.

2.4 ADAPTATION OF PIEQ FRAMEWORKS IN INFORMAL HOUSING CONTEXTS
While frameworks like that of Brink et al. (2020) have been widely validated in office, school, and formal housing environments, their application in informal or semi-formal housing is still limited. However, several scholars have emphasized the importance of adapting such frameworks to context (Frontczak & Wargocki, 2011; Schweiker et al., 2020). In low-income urban settlements, where architectural evolution is largely user-led, standard scales may overlook cultural nuances and behavioral adaptations. For example, Rashid (2019) noted that families in Dhaka modify ventilation patterns by rearranging furniture and windows daily; practices not captured by conventional measurement tools.

Hence, the adaptation of the Brink et al. (2020) PIEQ questionnaire in the present study; customized for ground-floor living spaces in Swarna Place; addresses a critical methodological gap by tailoring the standard parameters to account for the Sri Lankan climate, the specific building typology, and unique socio-spatial behaviors (e.g., use of gas cookers, curtains, and partitions) prevalent in incremental low-income settlements. It also supports recent calls for incorporating resident perspectives in performance assessment (Preiser & Vischer, 2005; Schweiker et al., 2020).

3. Research Methodology

3.1 RESEARCH APPROACH
This study adopted a mixed-methods approach with a primary emphasis on quantitative perceptual data. The objective was to assess the Perceived Indoor Environmental Quality (PIEQ) in ground-floor living rooms of low-income housing that had incrementally developed vertically. PIEQ, as outlined by Brink et al. (2020), comprises four key four parameters. The research was designed to adapt this validated framework (Brink et al., 2020) to suit the socio-spatial characteristics of Sri Lankan low-income settlements, where passive climate responsiveness and household-driven modifications are common.

3.2 CASE STUDY SELECTION: SWARNA PLACE
Swarna Place in Colombo, Sri Lanka, was selected as a representative case of incremental vertical housing. It showcases a spectrum of spatial transformations, from single-story homes to multi-story (up to four-story) extensions, making it ideal for evaluating PIEQ across diverse housing forms. Based on earlier field observations and spatial mapping conducted during a previous study, seven development stages were identified. This study selected four fully developed and functionally distinct stages; Stage 01, 03, 05, and 07; for detailed assessment. Other stages were excluded due to incomplete construction or transitional forms.

3.3 DATA COLLECTION
The research focused exclusively on ground-floor living rooms, which serve as the primary multifunctional and socially active zones in these homes. Due to ethical concerns and spatial diversity in upper floors, bedrooms and private spaces were excluded. Data were collected from 60 households (15 per stage) using a context-adapted PIEQ questionnaire developed from Brink et al. (2020). The questionnaire included 20 items (5 per parameter) rated on a 5-point Likert scale (1 = Very Poor, 5 = Excellent). Prior to deployment, the questionnaire was reviewed for linguistic and cultural appropriateness and translated into Sinhala.

3.4 QUESTIONNAIRE DEVELOPMENT AND ADAPTATION
While the original PIEQ framework offers a standardized structure, modifications were introduced to account for the Sri Lankan climate, building typology, and the unique spatial behavior in low-income settlements.

- Visual comfort questions were rephrased to include curtain usage and partition walls.
- Air quality questions acknowledged the use of gas cookers, incense sticks, and indoor moisture.
- Acoustic quality items considered both vertical (between floors) and horizontal (shared wall) transmission.
- Thermal comfort items factored in natural airflow, orientation, and fan/AC dependency.

Table 1: Adaptation of the PIEQ Framework (Brink et al., 2020) for Swarna Place

PIEQ Parameter	**Modification Introduced (Adapted Item)**	**Reasoning for Adaptation (Context-Specific)**
	Visual Comfort	Questions rephrased to include **curtain usage and partition walls**.
Air Quality	Questions acknowledged the use of **gas cookers, incense sticks, and indoor moisture**.	These are specific localized indoor air pollution sources prevalent in Sri Lankan low-income homes that influence perceived air freshness.

Acoustic Quality	Items considered both **vertical (between floors)** and **horizontal (shared wall) transmission**.	Vertical expansion introduces new noise transfer challenges (footsteps from above), and dense settlements mean horizontal noise through shared walls is also critical.
Thermal Comfort	Items factored in **natural airflow, orientation, and fan/AC dependency**.	These homes lack standardized climate control; reliance on passive features (airflow/orientation) and mechanical aids (fans/AC) is the primary determinant of perceived comfort.

3.5 DATA ANALYSIS

Responses were coded and entered into a spreadsheet for stage-wise analysis. For each parameter, average scores were calculated and then converted into percentage scores for comparative visualization. Responses were coded and entered into a spreadsheet for stage-wise analysis. For each parameter, average scores were calculated and then converted into percentage scores for comparative visualization. These results were further supported by site sketches, on-ground observations, and researcher notes from walkthroughs, which provided the qualitative context necessary to interpret the quantitative trends (e.g., linking low thermal scores to observed fan usage and blocked openings) and to explain the spatial mechanisms behind the perceived comfort decline.

Below is a summary of average percentage scores per PIEQ parameter across the four stages:

Table 2: percentages of PIEQ parameters

PIEQ Parameter	Stage 01	Stage 03	Stage 05	Stage 07
Thermal Quality	80%	60%	58%	44%
Acoustic Quality	72%	60%	60%	58%
Air Quality	68%	66%	70%	74%
Visual Comfort	86%	48%	48%	48%
PIEQ	76.5%	58.5%	59.0%	56.0%

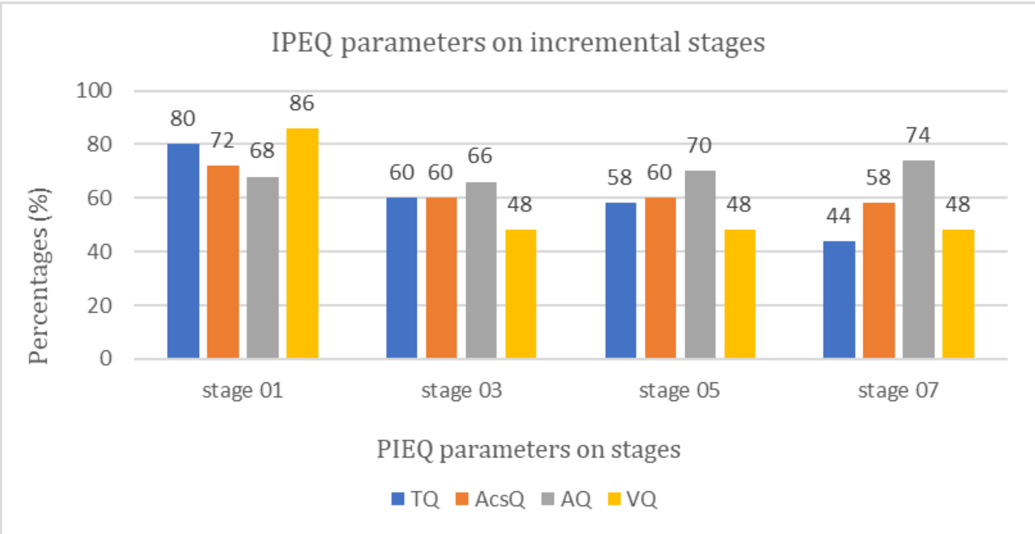

Figure 2: PIEQ parameters on incremental stages

4. Findings

This study examined how vertical incremental development affects Perceived Indoor Environmental Quality (PIEQ) in ground-floor living rooms across four selected stages of Swarna Place. The analysis focused on four environmental parameters as mentioned earlier; Thermal Quality, Acoustic Quality, Air Quality, and Visual Comfort including lighting quality and revealed critical differences in how residents experience comfort as densification increases.

4.1 THERMAL QUALITY

Thermal comfort recorded the most significant decline across stages, decreasing from 80% in Stage 01 to 44% in Stage 07. Stage 01 homes benefit from open layouts, minimal internal partitions, and optimal cross-ventilation through operable windows and roof openings. As buildings evolve vertically, internal barriers and enclosed staircases obstruct natural airflow, making the interiors increasingly hot and stuffy. Furthermore, the shadows cast by the added upper stories severely restrict daylight and passive solar gain on the ground floor, leading to reduced visual comfort and higher temperatures. This finding reflects Gifford's (2007) conclusion that dense vertical environments often lack the passive cooling required for occupant comfort in tropical climates. Residents in later stages increasingly rely on fans or mechanical cooling, shifting away from passive strategies. Residents in later stages increasingly rely on fans or mechanical cooling, shifting away from passive strategies because the internal barriers, enclosed facades, and upper-story shadows obstruct the natural airflow required for comfort in tropical climates. This increased dependence on mechanical systems also signals a rise in household energy usage over time.

4.2 ACOUSTIC QUALITY

Acoustic quality decreased moderately from 72% in Stage 01 to 58% in Stage 07. In the earliest stage, open plans and greater separation between units allow ambient sounds to dissipate. However, with vertical layering and increased internal partitions, noise; especially from footsteps and conversations above; transmits more directly between floors. The compact stacking of homes and thinner floor slabs in later stages result in less sound insulation; this physical compromise aligns with Rashid (2019)'s observation that resident-driven vertical expansions often overlook acoustic buffering, thereby contributing to discomfort and stress, particularly in communal ground-floor spaces.

4.3 AIR QUALITY

Unlike other parameters, air quality showed a slight upward trend from 68% in Stage 01 to 74% in Stage 07. This surprising result suggests that vertical development may enhance containment and isolation of cooking-related fumes and odors through better compartmentalization. In Stage 01, open layouts allow kitchen smells and dust to circulate freely. In contrast, later stages include internal partitions and doors that help reduce the spread of indoor pollutants. However, the improvement may not necessarily indicate healthier indoor air, as these spaces are also increasingly sealed, raising the risk of stagnant air and reduced ventilation.

4.4 VISUAL COMFORT AND LIGHTING QUALITY

Visual comfort declined sharply from 86% in Stage 01 to 48% in later stages. In Stage 01, the use of transparent roof sheets, large windows, and shallow room depths allows for maximum daylight penetration. However, vertical expansion introduces staircases, solid upper floors, and deeper room configurations that limit natural light. The reduced window area and orientation challenges further contribute to low visual comfort, especially in compact ground-floor units of Stage 07. This confirms previous observations by Warakapitiya et al. (2024) that vertical densification without design regulation diminishes access to natural lighting in low-income urban homes.

4.5 OVERALL PIEQ TREND

As shown in Table 01 and figure 03, the overall PIEQ score declines from 76.5% in Stage 01 to 56.0% in Stage 07. Although air quality improves slightly, this is outweighed by consistent declines in thermal, acoustic, and visual comfort. The steepest fall occurs between Stage 01 and Stage 03, coinciding with the transition from single-story to double-story dwellings. The findings highlight how the passive comfort advantages of early stages are gradually lost in the absence of technical guidance and formal design intervention. The passive comfort advantages of Stage 01, which are lost in later stages, include optimal cross-ventilation due to open layouts and maximum daylight penetration through large openings and transparent roof sheets.

This degradation in PIEQ illustrates a major concern in informal, architect-less vertical housing: residents prioritize expansion and spatial function over environmental performance, resulting in compromised comfort, particularly in heavily used ground-floor living rooms. These rooms; essential to everyday life; become the most vulnerable to poor design adaptations.

Table 2: Highlighted findings on stages

Subtopic / PIEQ Parameter	Stage 01	Stage 03	Stage 05	Stage 07
Lighting Availability	Ample openings with transparent roof sheets provide maximum daylight.	Openings reduced due to added walls; outdoor short walls, partial obstruction of light.	Few openings left; heavy reliance on artificial lighting	Natural light severely limited by structural columns.
Ventilation Methods	Natural cross-ventilation through open layouts and large windows roof and open doors.	Reduced airflow due to partitions; fans used more frequently.	Stuffy air; mechanical cooling needed for comfort like fans.	Minimal airflow; sealed interiors with blocked openings. (This describes the severe deterioration of ventilation and air quality in the ground-floor living spaces of the maximum vertically expanded homes. This condition results from the loss of

				natural cross-ventilation due to structural additions, internal compartmentalization, and residents enclosing original openings for security and privacy)
Perceived Temperature Comfort	Generally comfortable due to natural airflow and minimal enclosure.	Slight discomfort in warmer months due to reduced airflow.	Hot and enclosed feel; thermal discomfort common.	Most uncomfortable; temperature regulation hard without AC.
Thermal Regulation Systems	Passive design with no HVAC; fans used occasionally.	Fans widely used; design shifts toward mechanical ventilation.	Increased fan/AC use; energy usage rises.	Mechanical systems essential; 2 homes with full HVAC.
Noise Transfer from Upper Floors	Low noise due to absence of upper floors and minimal barriers.	Noticeable sound from upper floors; thin walls transmit noise.	High noise; enclosed spaces amplify sounds.	Muffled but persistent sounds from upper levels and echo sounds.
Privacy & Acoustic Buffering	Open plan supports high auditory privacy through spatial openness.	New barriers affect privacy; increased echo	Compromised acoustic privacy due to compact design.	Rigid layout offers limited sound isolation.
Natural vs Artificial Air Flow	Smooth flow; residents can open windows/doors freely	Natural air flow partially blocked by vertical additions.	Airflow poor; most living rooms are sealed and less-circulating.	Very low level of passive ventilation; relies sometimes on HVAC.
Odor Dispersion & Containment	Odor spreads but is quickly dispelled due to open airflow	Odor containment improved; barriers reduce spread	Odors localized but linger due to poor exhaust.	Odors trapped indoors; no outlet airflow.
Daylight Penetration	High daylight penetration; artificial lights rarely needed during day.	Daylight availability drops; reliance on bulbs increases.	Low daylight; artificial lighting dominates	Artificial light replaces most natural lighting.
Artificial Lighting Dependence	Low dependency; lights used only after dark.	Moderate reliance especially in enclosed spaces	High reliance due to poor natural access.	Very high dependency; lighting on all day with decorative light features.

5. Discussion

5.1 THE SPATIAL CONSEQUENCES OF VERTICAL DENSIFICATION

The progression from single-story to four-story housing at Swarna Place reveals a clear shift in spatial logic. The early-stage dwellings maintained open layouts with adaptable, multifunctional spaces on the ground floor. These conditions enhanced not only the usability of the space but also the perceived thermal and visual quality. However, in later stages, the construction of staircases, intermediate walls, and façade reinforcements significantly limited spatial permeability and daylight access. As Rashid (2019) and Warakapitiya et al. (2024) noted in similar South Asian contexts, such densification tends to compromise spatial efficiency in exchange for structural security or privacy. This compromise disproportionately impacts ground-floor living rooms; the most active and socially significant spaces.

5.2 PERCEPTION VS. PERFORMANCE: AIR QUALITY AND COMPLEXITY

One unexpected trend emerged in relation to air quality: Stage 01 did not receive the highest ratings. While openness allowed for ventilation, it also meant that smoke, cooking odours, and dust freely circulated due to the absence of spatial zoning. In contrast, some later-stage homes achieved slightly higher perceived air quality, owing to better containment of pollutants within more enclosed kitchen areas. However, without mechanical ventilation or passive stack solutions, these spaces still lacked effective airflow. This finding underscores the need to evaluate not only spatial openness but also the functional arrangement of activities (such as cooking), aligning with insights from Frontczak & Wargocki (2011) on context-sensitive PIEQ measurement.

5.3 PSYCHOLOGICAL AND SOCIAL COMFORT IN SHARED SPACES

The emotional and social roles of ground-floor living spaces cannot be understated. These rooms serve as the heart of daily interaction, family cohesion, and social identity (Kaitilla, 1993; Mohit et al., 2010). As their quality degrades through vertical densification, residents report a subtle psychological discomfort even if they have more private rooms or updated façades.

The reduction of daylight, visual connectivity, and spatial fluidity erodes the experiential richness of the home. Gifford's (2007) work on high-rise discomfort is echoed here: not in tower blocks, but in incremental vertical housing, where height and enclosure gradually alienate inhabitants from their surroundings.

5.4 RECOMMENDATIONS FOR FUTURE PRACTICE

Given these challenges, several actionable recommendations emerge:

- Design Guidelines for Vertical Infill: Authorities and architects should provide flexible, low-cost design templates to guide residents in expanding upward while retaining passive environmental performance. Staircases, in particular, must be integrated in ways that preserve cross-ventilation and daylight.
- Prioritising Ground Floor Usability: Since the ground floor remains the most multifunctional and occupied area, design efforts should prioritise its openness, accessibility, and ventilation perhaps through courtyard insertions, high sill windows, or double-height voids.
- Integrating Participatory Post-Occupancy Evaluation: Resident feedback, as captured through PIEQ, must inform future public housing upgrades. Tools adapted from Brink et al. (2020) and similar frameworks can institutionalise feedback loops within low-income housing development.
- Policy Support for Environmentally Sensitive Incrementalism: Local authorities should incorporate PIEQ targets into housing regulation frameworks. Allowing flexibility in self-built housing must not come at the cost of spatial and environmental health.

6. Conclusion

This study has demonstrated that vertical housing expansion, while enabling density and ownership, brings significant environmental and spatial compromises when executed without design oversight. Using a context-adapted PIEQ questionnaire, the research has highlighted how the most socially vibrant and multifunctional spaces; ground-floor living rooms; become environmentally vulnerable over time.

Despite physical upgrades in materials and vertical height, the perceived indoor environmental quality consistently declined from Stage 01 to Stage 07, especially in thermal comfort and visual access. The findings reinforce that resident well-being is not determined solely by quantity of space or structural completion, but by spatial logic, environmental performance, and human experience.

By giving voice to occupant perceptions and focusing on the quality of shared living areas, this study contributes to a more inclusive and responsive housing discourse in the Global South. Future approaches must bridge the gap between autonomy and support; ensuring that as housing grows, so too does livability.

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