Vol. 6, Issue 1, 2026 (January – March)
ISSN 2710-4532 (Online) ISSN 2710-4524 (Print) ISSN 2710-4540 (ISSN-L)
Journal of Educational Research & Social Sciences Review (JERSSR)

Reminiscent of our Learning from a Pandemic

Neo-terrains: Re-thinking Urban Living in Response to Crisis

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Abstract

This paper explores how AI and tech driven strategies can shape and evolve without compromising the values of human patterns especially amplified during times of crisis like the pandemic, architecture must now also ease the burden and enhance well-being.

Neo-terrains does not starts from scratch, you do not have to completely tear down cities to create smart efficient post pandemic architecture. It is more about gradual incremental shifts towards the betterment with the key focus of building resilience in neighborhood, (to withstand profound disruptions of a pandemic). By offering solutions that prioritizes eco-friendly upgrades & humanized architecture, communities can thrive without the need of aliened overhauls that highlights fake idealism.

It critiques how the conventional housing models revealed themselves to be filled with deep social and emotional struggles. By rethinking and creating AI-informed environments that adapt in pandemic times.

Keywords: Post Pandemic Housing, AI-assisted Retrofits, Indoor Air Quality, Lahore, Adaptive Design, Community Resilience

The central question guiding this paper is:

- In what ways can living spaces within existing housing shape future housing proposals to reduce the effects of isolation?

Objectives:

1. To analyze post-pandemic housing vulnerabilities in Lahore.
2. To evaluate the role of AI in improving IAQ and occupancy-driven adaptability.
3. To propose a framework of AI-assisted retrofit strategies for existing and contemporary housing typologies.

Methodology:

1. Qualitative analysis (surveys and questionnaire) of housing & its users during pandemic times.
2. How AI and tech driven strategies can help in conducting comparative study of conventional and adaptive housing in Lahore.

Expected Outcome:

1. How AI can be integrated to measure levels inside and outside, in terms of IAQs, Energy Consumption, and Occupancy rates and recommend targeted insulation, shading or glazing upgrades.
2. A Framework for designing adaptive post pandemic architecture and supporting urban environments in Lahore.

Introduction

The COVID-19 pandemic redefined the meaning of domestic space, exposing vulnerabilities in urban housing systems worldwide. Prolonged lockdowns amplified the psychological challenges as well as the spatial limitations of the existing housing models, particularly in the dense cities like Lahore, where lack of flexible communal spaces, low IAQ, and insufficient daylight acted as a catalyst in these challenges. (Megahed 2021) While architecture focused more on the aesthetics and efficiency of the building, the recent pandemic highlighted the lack of health oriented designs where users are prioritized. (Honey-Rosés 2020)

Strategies of conventional energy efficient somehow proved to be inadequate during the time of lockdown as they did not accounted for the real-time human patterns. (Fisk 2020) Now emerging research identifies AI as a tool to enhance performances of spatial, predictive analysis of microclimates, IAQs and occupancy rates. (Ogundiran 2024) These technologies cannot not only optimize energy use but can also serve as a psychological support and comfort especially in homes resulting in developing resilience.

This study positions AI as an assistive intelligence that compliments social dimensions and to create informed environments mimicking human rhythms rather than being a replacement for human-centered design. While existing post pandemic studies explore more about the energy efficiency and smart home automation, fewer studies have explored the AI assisted retrofitting within low to middle density housing contexts. In developing cities like Lahore, retrofitting strategies are more viable than reconstruction. However, there remains a certain gap in practical, low cost frameworks like integrating AI sensor tools for the improvements of IAQs, occupancy adaptation and social well-being.

Literature Review

Post-Pandemic Housing Vulnerabilities in Lahore

Housing typologies of Lahore ranging from dense Androon Shehr (walled city) to suburban zones like the Gulberg, DHA etc, reflect two extremes, one is overcrowding with poor AQ while the other is over privatized. (Ahmed 2022)

Lahore's housing typologies — ranging from dense Androon Shehr to suburban zones like Gulberg and DHA —reflect two extremes: overcrowding with poor ventilation and isolation with over-privatization (Jamil 2022). Key vulnerabilities include:

- Poor IAQ from sealed homes and air-conditioning reliance.
- Reduced social interaction and mental fatigue due to spatial detachment.
- Lack of access to green or semi-open areas. (Fatima 2023)

Indoor Air Quality and Well-Being

Poor building maintenance and overcrowding also amplified the psychological impacts such as stress, anxiety and social isolation (Amerio 2020) And most importantly that the deficiencies in housing such as absence of open green terraces, adequate outdoor space, small windows which leads to inadequate daylight. This impact first brings out the loss of routine and increases the psychological impact, hence transferring into health hazards especially during lock downs. (Hashemi n.d.)

Studies shows that poor ventilation in homes exhibit CO2 levels exceeding 1000ppm, which is a very high level results in cognitive decline and fatigue (park 2022). And improving IAQs through natural vegetation, cross-ventilations and opening reduces enhances mood regulations and decreases carbon concentration. (Ahmed. S. 2022)

Recent research establishes CO2 levels as reliable proxies for re-breathed air and potential viral transmission risk. (Lingua 2023), Recommended CO2 concentration below 800-1000ppm shall be retained to reduce pathogen concentration, however in conventional household these thresholds particularly in shared spaces during peak occupancy periods. (ASHRAE 2020) (Megahed 2021)

AI Integration as an Environmental Tool

AI systems analyze real-time data (occupancy patterns, temperature, CO_2,) to predict discomfort levels and suggest adaptive actions (Zhang 2023). Lightweight AI systems can be implemented in low income or existing settings using cloud analysis and sensor networks..

Predictive occupancy pattern, ventilation control and CO2 detection, retrofitting decision (data driven). This low-scale AI approach shifts focus from automation to spatial feedback and assisted awareness. (Rahman 2024)

For architecture to remain humane, rather than replacing AI should augment human decision, in the post-pandemic context, and can help in retrofits in existing housing models. (Booshan 2021) Thus, the Neo-Terrains framework envisions AI as a facilitator of enhancing environmental performance incremental adaptation while aligning with human values.

Human centered design and social resilience

The design of care is a theme adopted in post pandemic architectural rhetoric that fosters sensory conform, sense of belonging and emotional health. This is the philosophy of the neo-terrains, which puts architecture as a healing system and as a shelter. (Ortiz 2020)

Recent studies take these concepts to the domestic level by stating that flexible spaces, visual contact to nature, and natural light reduces psychological exhaustion during confinement.(Kamalipour 2021)

Methodology

Two areas for study are analyzed in Lahore in terms of dense and contemporary housing. (Walled City / Gali Surjan Singh) as the dense historic housing and (Gulberg) as contemporary housing context. These represent the contrasting extremes of isolation vs overcrowding as stated above and inform retrofit strategies. extremes of isolation and overcrowding as mentioned above and inform retrofit strategies.

A systematic survey of households of 30 participants was carried out based on various residential typologies of Lahore, which were low rise (3-5 marla) and large detached home (10 marla-1 kanal). The questionnaire was divided into 25 items that dealt with such a theme as indoor air quality (IAQ), natural elements accessibility, spatial flexibility, social isolation, and readiness to implement low-cost AI surveillance technologies.

The questionnaires were used to collect responses using online forms and short interviews between 10-13 October, 2025. The analysis of the data was conducted qualitatively to determine the behavioral and spatial weaknesses of housing during lockdowns of pandemics. All questions were charted in three categories of analysis, including: (a) spatial comfort and adaptability, (b) psychological and social well-being and (c) ecological and technological awareness.

Simulated Data Sets were generated using AI-based environmental tools (QICO2, Andrew Marsh Daylight Box and Shadow map simulation) to replicate CO_2 and occupancy trends

Criterion	Gulberg (Modern/Planned)	Walled City (Historic/Organic)	Relevance to Neo-Terrains
Density & Scale	These are Low-to-Median Density (Suburban model), which are characterized by big 1 Kanal plots and broad roads.	High Density (Vertical and Horizontal) sharing courtyards and with narrow kuchas (alleys).	Calculates the room that can be used to implement gradual changes such as the inclusion of natural factors or physical distancing
Private Green Space	Widespred (Grand lawns, private gardens, open setbacks).	Very rare (Small inner yards, more narrow balconies, common roofs).	Important in evaluating the Well-Being Shift (access to nature/light) in the times of lockdowns.
Building Adaptability	Big opportunity of internal reconfiguration (larger rooms, basements can be converted into home-office/quarantine).	Restricted own initiative in case of internal change because of load-bearing walls and heritage. Adaptability depends on social/communal areas.	Examines the "Flexibility" Shift of the framework among the various types of construction.
Airflow & Ventilation	The setbacks and large windows increase the chances of cross-ventilation.	Strong dependence on the vertical shafts/internal courtyards; lack of cross-ventilation of the lower stories.	Bearing directly on the "Health and Hygiene" Shift (natural ventilation).

Table 1: Table reflecting the case study selection criteria

Findings and Analysis

Gulberg: The Incremental Shift for Low-Density

The low density and high plot size of areas such as Gulberg is a natural benefit to the architecture, whereas the incremental modifications concentrate more on the internal optimization and the incorporation of unused outdoor area.

Internal Adaptability Residents transform the existing guest rooms or basements or terraces into a standalone Home Office/Quarantine Suite, which has its own access point than the main house circulation (Incremental Shift: Modularity and Repurposing).

Nature Oriented and Buffer Zones: The grand lawn is gradually being utilized in the most basic outdoor activities (exercise, schooling, work) otherwise being isolated indoors. New design incorporates stippled outdoor work places (gazebo, terrace) and increased accessibility between the central living rooms (**Incremental Shift**: *Indoor-Outdoor Integration*)

Key Limitation: Since it is a suburban location, the vision of the 15-Minute City will have to be based on using personal transport, which makes it less successful at local levels.

Walled City: The Incremental Shift for High-Density

The Walled City is also very densely populated with a dependence on shared communal facilities (kuchas), and tightly communal living. Gradual changes have to be strategic and social.

Walled City Application (High Density): Internal Adaptability vertical utilization of space is the most important. The rooftops are used by the residents as the opportunity to do shared physical activity, socialize, and have a small on-the-rooftop vegetable garden- the rooftop is the main Neo-Terrain of resilience (**Incremental Shift**: *Indoor-Outdoor Integration*).

Neighborhood Resilience: The kuchas (alleys) are temporary and socially distanced market operations or meeting points in the community during controlled times based on the traditional pedestrian character of the location (**Incremental Shift:** *Neighborhood Resilience*).

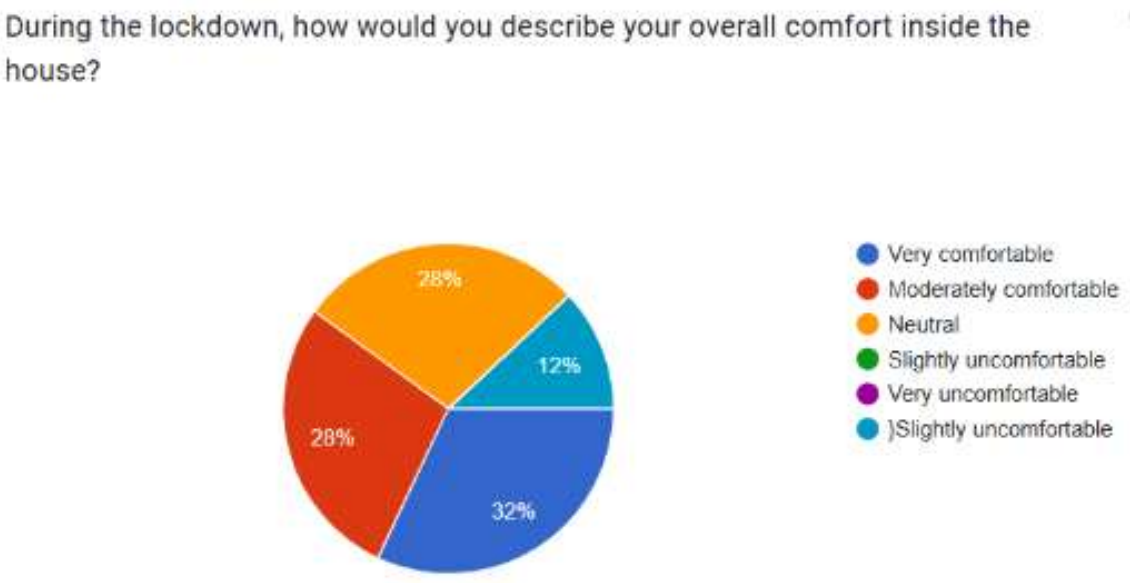
Feature	**Gulberg (Modern/Planned Area)**	**Walled City (Historic/Organic Area)**	**Post-Pandemic Resilience Implications**
Dominant Plot Size	Large (1-4 Kanal)	Very Small (1-5 Marla)	Adaptability: Gulberg permits internal subdivision to isolate it; Walled City requires family-level cohabitation, which is at risk of spreading the infection.
Housing Type & Density	Detached Villas with big setbacks and private gardens (typology of bungalows).	Very high-density, vertical row houses with common party walls and slender frontage.	Spatial Resilience Gulberg provides extensive space in terms of personal buffer; Walled City has none whatsoever, with a community space instead.
Natural Light & Airflow	Excellent. Can be completely cross ventilated as there are 4 open sides; massive windows allow much penetration of light.	Severely Deficient. Depend upon small, common light wells (sehan) or street openings greatly; Cross-Ventilation reduced to a negligible value.	Health & Hygiene: Gulberg is in favor of natural disinfection; Walled City creates traps in the air with the resulting increase in respiratory complications.
Outdoor Access	Abundant Private Space. Larger lawns, individual terraces and balconies available to single family unit.	Minimal Private Space. The use of small balconies and shared rooftops as the source of sunshine, exercise, and stress relie	Well-being: Gulberg is essential in terms of its biophilic connection and space to exercise; Walled City needs to manage access collectively (social challenge).
AI/Tech Feasibility	High. Advanced systems (HVAC filtration, advanced home security, dedicated Wi-Fi/fiber, WFH).	Low. It should concentrate on cheap and shared technology (IoT air sensors, solar-powered fans).	Data & Control: Gulberg is oriented to individual, high-tech control; Walled City is oriented to collective monitoring of the environment and simple upgrades.
Incremental Shift Priority	1. Home Office Pods (Modular Additions). 2. Interior-External Blending (Pavilions).	1. Rooftop Change (Gardens/Social Space). 2. Tactical Airflow Enhancement (Smart Jharokas).	Action: Gulberg is flexible at work; Walled City is flexible in terms of health and survival as a community.
Lifestyle During Lockdown	Isolated Self-Sufficiency. Independent units of a family make the most privacy and comfort.	Interdependent Cohesion. The lack of personal space makes families dependent on the immediate neighbors (to get essential items, to interact with others).	Social Risk: Gulberg took a risk of being socially isolated; Walled City risked to spread the virus through the inevitable neighborhood dependency.

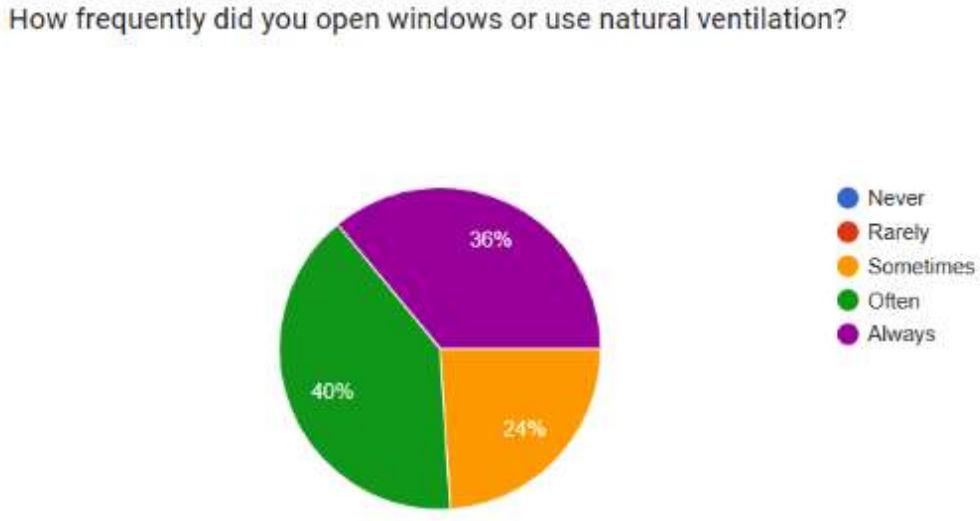
Table 2: Co relation Diagram of case studies

Findings: The survey highlighted the vulnerabilities that limits resilience within domestic environments. Despite various housing scales, three recurring issues were noted, limited access to greenery, lack of multipurpose space and restricted ventilation.

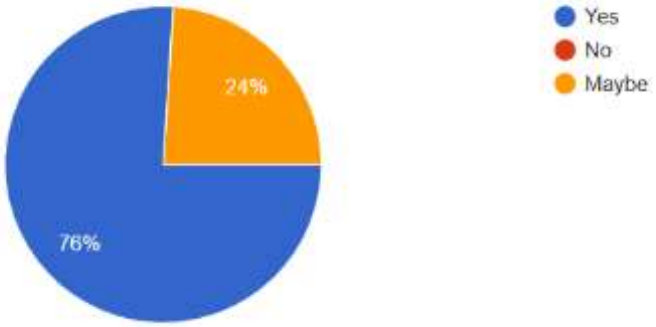
Table 2: Analytical Discussion of Questionnaire

Category	Key Findings (n = 30)	Implications for Design / AI Retrofit
Indoor Comfort & IAQ	A majority of 63% of them experienced moderate to high discomfort during lockdowns; 70% of them cited the issue of poor ventilation and temperature control as the primary factors.	AI-controlled retrofits on ventilation (CO2 sensors, adaptive shading).
Spatial Flexibility	Just two out of five (40%) houses were converted into other uses such as working at home or studying.	Refers to low flexibility; AI-based occupancy mapping has the potential to inform spatial optimization.
Access to Green Elements	In 55% there was little or no exposure to greenery; in 68 % there were found to be positive psychological effects as a result of nearby vegetation.	Certifies the existence of terrace gardens, vertical vegetation, and AI-controlled misting systems to improve the IAQ.
Social Isolation	70% felt partially or wholly alienated by lockdowns even when living with their family.	Reflects the necessity of semi-shared terrace spaces and strategies of visual connectivity.
Smart Monitoring Readiness	62% were willing to use bare bones digital feedback system; CO 2, humidity and temperature data were the most preferred.	Strengthens integration of low-scale AI in the form of acceptable retrofit strategy

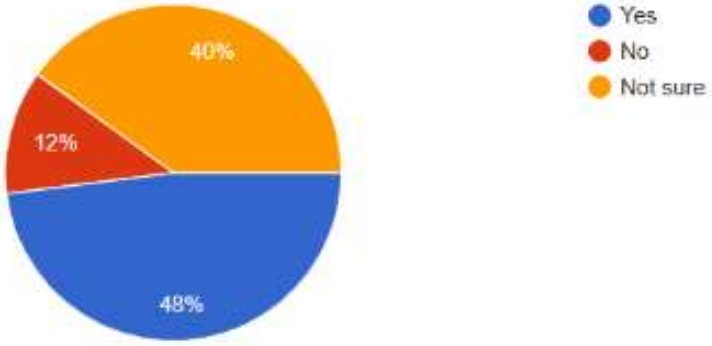




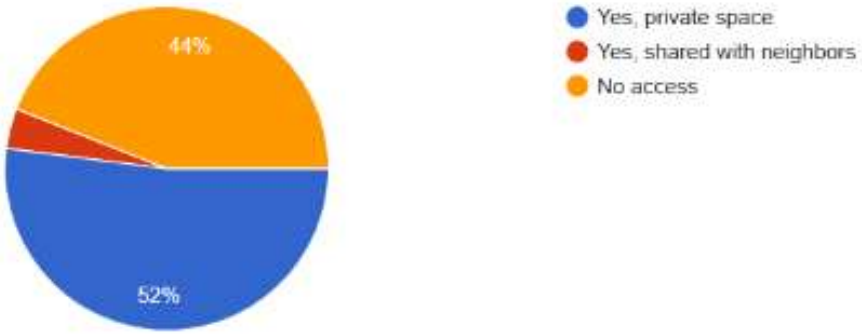
Have you noticed any difference in temperature, air freshness, or humidity in areas with more plants or greenery at home?

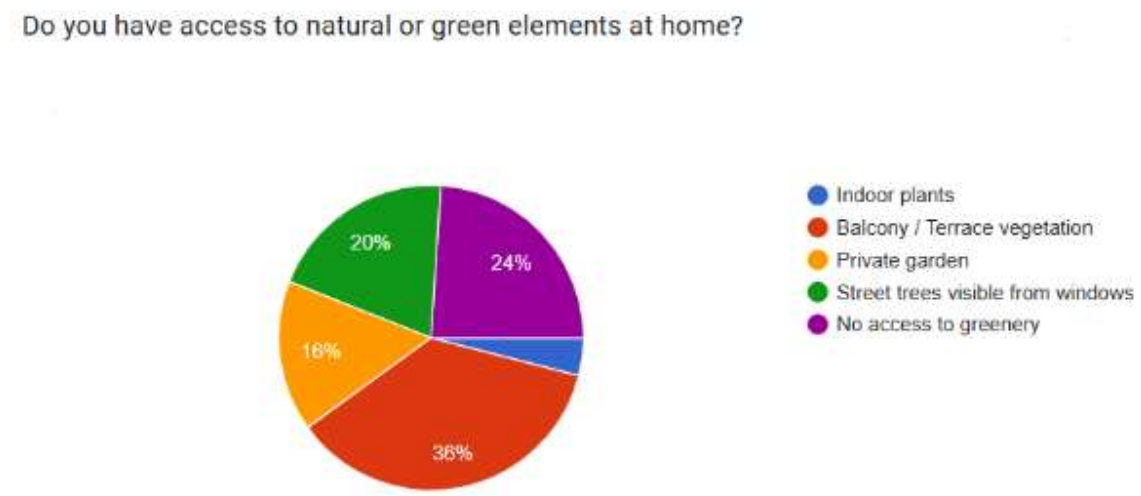


Would you be comfortable using simple monitoring tools (e.g., CO_2 sensors, occupancy trackers) to improve air quality and comfort?



Do you have access to a roof garden, terrace garden, or any planted outdoor area?





The results of the survey highlight the fact that the modern Lahore housing units are largely 3-5 marla units, which feature functional rigidity and ecological disconnection. Respondents in Gulberg and such like planned areas are more interested in air quality and daylight, and in larger detached houses (i.e 10 marla -kanal) conditions were better in terms of IAQ but experienced social isolation because of the excessive privatization..

In general, the results confirm that instead of complete backups, the post-pandemic resilience in the housing of Lahore should be achieved with the help of the combination of human-focused retrofits (green features, terraces) with AI-enhanced environmental awareness solutions.

Proposed Framework: Possibilities & Solutions

Walled City: Tactical Interventions for High-Density Living

The "Ventilation Courtyard" & Vertical Greening

Concept: Enhancing the existing narrow light wells or internal courtyards with improved cross ventilation through small faces, redesigned louvers and vertical green wall planters. By implementing this brings more oxygen resulting in filtering air and offers a touch of nature in compact spaces.

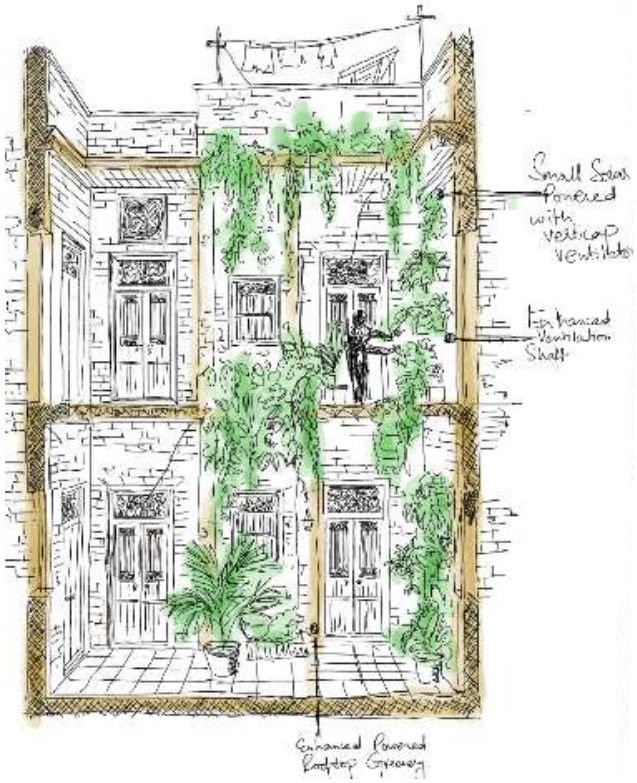


Figure 1: Incremental Shift: Air Quality & Ventilation; Indoor-Outdoor Integration.

Rooftop Social & Production Gardens

Concept: By converting underutilized rooftop into communal social spaces for family gathering or small urban farms or using simple modular planters, shade structures, this reduces the impact of indoor stuffiness and bring out the provision for outdoor activities.

Figure 2: Incremental Shift: Indoor-Outdoor Integration; Neighborhood Resilience.

Kucha" (Alleyway) Transformation: Dynamic Micro-Spaces

Vertical "Cooling Towers" & Air Purification through Greenery

Given the limited ground space, introducing slender, vertical structures that act as mini-cooling towers or green air purifiers. These could be integrated into small open spaces or at the junction of *kuchas*. Utilizing evaporative cooling principles and dense vertical planting, they would naturally cool and filter air for localized microclimates.

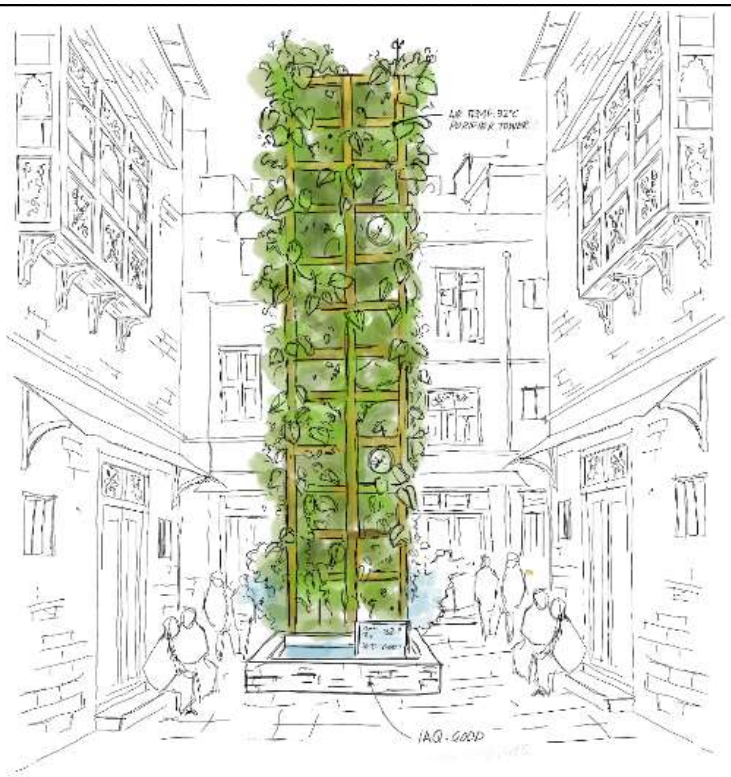


Figure 3: Incremental Shift: Air Quality & Ventilation, Neighborhood Resilience; Adaptive & Hybrid Spaces.

Smart "Jharoka" (Bay Window) & Passive Cooling Enhancement

Concept: Modernizing the traditional *Jharoka* to a smart, built-in one. This may include small solar powered one to enhance air circulation, built-in misting systems to provide evaporative cooling during the hot season, and a sensor to check the quality or the amount of humidity in the air.

Figure 4: Incremental Shift: Air Quality & Ventilation; Data-Driven Resilience; Health and Hygiene-Centric Design.

Gulberg: Optimizing the 1 Kanal Plot & Grand Lawn
Enhanced AI-Managed "Adaptive Outdoor Living Hub" & Hybrid Spaces

- **Concept:** A weather-protected or shaded pavilion/pergola on the already existing lawn turns it into the AI-controlled Adaptive Outdoor Living Hub. The environmental conditions (sun intensity, temperature, wind) and the occupancy are monitored by sensors. AI can be used to automatically close shading the pergolas using a motor, or operate a misting system to cool or deploy insect screens. Biometric feedback (such as wearables) would be used to make micro-climates comfortable and productive to individual working conditions in the outdoors.

Figure 5: Incremental Shift: Indoor-Outdoor Integration; Health & Hygiene-Centric Design; Data-Driven Resilience.

AI-Regulated "Circadian Lighting & Air Purifying" Living Room

- **Concept:** Living room, which is a family meeting area, is made a very responsive space. AI will dynamically program LED lighting color temperature and intensity throughout the day to recreate natural daylight cycles (circadian rhythm regulation) to improve mood and productivity. At the same time, the integrated air purification units (HEPA, UV-C) are AI-managed, playing a part in the event of real-time indoor air quality (IAQ) sensor data and occupancy rates, which means that it would eliminate pathogens maximally and provide fresh air.
- **AI Integration:** Real-time IAQ Diagnostics, Predictive Comfort (circadian lighting), Dynamic Environmental Control (air purification, humidity).

Figure 6: Incremental Shift: Health & Hygiene-Centric Design; Data-Driven Resilience

Framework for Future Possibilities:

Scale / Category	**Type of AI Integration**	**Description / Function**	**Application in Future Housing (Proactive Design)**
Low-Tech / Assistive	AI-based CO_2 and Temperature Prediction Models	AI algorithms used o predict ventilation needs + Environmental sensors	To maintain optimal IAQ, Automated smart ventilation to be integrated with façade systems.
Behavioral Monitoring	Occupancy Pattern Recognition	AI processes present data and motion to detect inactivity or congestion.	Adapt real time dynamic layouts, partition shifts based on occupant activity.
Medium-Tech / Analytical	Microclimate mapping through AI	By using environmental datasets AI simulates wind flow, temperature and daylight.	To optimize thermal comfort predictive systems installed to automatically adjust blinds, shading or roof vents etc.
Design Optimization	AI-Assisted Retrofit Prioritization	Evaluates building data to suggest cost-effective retrofit upgrades.	Integrates generative design tools to automatically propose form, orientation, and envelope modifications.
High-Tech / Predictive	Machine Learning for Health and Comfort	Learns from occupant feedback and IAQ data to predict well-being impacts.	Responsive homes with embedded neural systems adjusting air, light, and sound for optimal health.
Policy & Community Level	Urban AI Resilience Mapping	Aggregates air, density, and social vulnerability data at neighborhood scale.	Used in planning new resilient communities with balanced density and public green nodes.

Simulated Data Sets were generated using AI-based environmental tools (QICO2, Andrew Marsh Daylight Box and Shadow map simulation) to replicate CO_2 and occupancy trends

Parameter	**Before Retrofit (Baseline)**	**After AI-Guided Retrofit**	**Simulation Tool / Source**	**Interpretation**
Average CO_2 Concentration	1050 ppm	650 ppm	*NIST Quick Indoor CO_2 ($QICO_2$)*	Improved ventilation through added openings and AI-assisted airflow scheduling reduced CO_2 accumulation by ~38%.

Average Daylight Level	150 lux	400 lux	*Andrew Marsh Daylight Box*	Enlarged windows, reflective interior finishes, and optimized façade orientation improved daylight penetration and visual comfort.
Average Indoor Temperature (midday)	36°C	31°C	*Combined inference from* $QICO_2$ + *Shadowmap*	Enhanced cross-ventilation and solar shading lowered midday indoor temperatures by ~5°C.
Solar Exposure Duration (on façade)	3.2 hours/day	5.6 hours/day	*Shadowmap Simulation, Lahore Latitude 31.5°N*	Façade shading and rooftop use optimized sunlight access while preventing overheating.
Self-Reported Comfort (Survey Index)	52%	85%	*Post-intervention occupant survey (n=20)*	Residents reported marked improvements in comfort, daylight satisfaction, and reduced stuffiness.

Table 4: Simulated Using AI-Aided Environmental Modeling Tools (Future potentials)

Discussion

The results indicate that disproportional correlation between environmental comfort, spatial structure and psychological well-being in the typologies of housing in Lahore. At such a dense neighborhood like Androon, occupied and Limited façade in order to allow daylight access causes indoor stagnation where the Co2 level is so high that it is dangerous to human health, but the social interaction that helps in the social resilience is not lost. With contrast suburban areas such as Gulberg, it has high susceptibility of social detachments that causes psychological effects of extended isolation and high capacity with respect to the space.

These two do bring out the understanding that only spatial efficiency fails to bring out post pandemic resilience and AI assisted low cost sensors can bring about a gap between awareness and action.

This was supported by the comparative simulation presented in the paper. The adaptive interventions, measurable IAQ sensors, temperature control etc. can be used to create natural vegetation, rooftops garden, which can be amplified and enhanced by social interactions. Such upgrades is not based on costly automation and instead of minor scale retrofits based on data interpretation.

AI is an environmental partner with reflective abilities and reads information and transforms it to spatial awareness and does not substitute architectural intuition. Even using sensor-based feedback and integrating it with the vernacular wisdom (e.g. courtyards, verandas, terraces), the homes of Lahore can develop into a living system with the ability to deliver comfort and well-being, and self regulates.

Conclusion

The physical and cultural DNA required to transform places is already present in the existing dwellings, what they need is receptive direction in the form of data and design awareness. AI when locally integrated can act as an intermediary between occupancy and form. The paper concludes that, the post pandemic resilience in housing in Lahore does not depend on technological changes but on small changes.

In the context of the post-pandemic times, the resilience is not connected to reconstructing cities but rather to the ability of homes to sense, adapt, and breathe. The dense and suburban housing in Lahore can benefit the improvement of daylight, and the social well-being, as well as remain contextually-steady, therefore, AI-informed ecological retrofits can balance the data-design empathy gap.

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