Spatial Assessment of Urban Growth and Air Quality Across Three Major Pakistani Cities Using Multi-Criteria GIS

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Abstract

Rapid urbanization in Pakistan has led to urban densification that increase the environment to deterioration and the gap in the living standard between different areas to get wider. Lahore, Islamabad, and Rawalpindi, the three major metropolitan centers of the country, show very different patterns of urban growth ranging from very compact to planned low, density development. This paper presents a multi, criteria GIS, based spatial assessment to analyze these cities concerning land use change, urban density, vegetation loss, and ambient air quality. The research employs satellite images of Sentinel and Landsat, supervised classification, NDVI, and AQI data to track urban expansion and its environmental impact. Lahore represents a typical example, urban growth there is without any control. The city is continually expanding outward, with air quality hotspots remaining where AQI is more than 200. Thus, the people of Lahore breathe highly polluted air every day. However, Rawalpindi's urbanization pattern is polar opposite to that of Lahore. It is less continuous and more scattered, densification is happening very fast and, in most cases, it is unplanned, with air pollution being concentrated around those areas where commercial activities take place. Meanwhile, Islamabad is maintaining lower building density and stable vegetation cover. The quality of its air is still fairly good; however, pollution is gradually increasing. The study pinpoints a very obvious pattern: the disappearance of vegetation goes hand in hand with rapid urban sprawl, and air quality gets worse. The conclusions here are calling for the radical change of the system. Planning the cities should not be a mere task of guesswork whereby planners would need a variety of data from the field to make the right decision. It is time they utilized geospatial data, invested in green infrastructure, and enforced zoning laws that consider air quality. Taking such measures is absolutely necessary if the big

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cities of Pakistan are to expand in a way that is not detrimental to human health and nature.

Keywords: urbanization, air quality, GIS, Spatial assessment

Introduction

Urbanization at a rapid pace in Pakistan is the major reason for its changes in land use, population distribution, and environmental sustainability that make it one of the fastest urbanizing regions of South Asia. More than one, third of the population of Pakistan is currently living in urban areas, and this proportion is expected to increase dramatically over the next few decades. The huge increase has worsened problems related to unplanned expansion, congestion, environmental degradation, and air pollution, which are especially severe in major cities. Lahore, Rawalpindi, and Islamabad are the examples of different urban forms and planning histories. Lahore, a dense city that naturally evolved over time, has extended its horizontal sprawl, overburdened its infrastructure, and made a significant reduction in parks and green spaces. Rawalpindi, which is a combination of planned and unplanned development, has fragmented neighborhoods, poor infrastructure, and decreasing green areas. The capital of the country, Islamabad, was built to be a low, density, green city with wide roads and open spaces, but the spread of the city, the increased use of cars, and the underutilization of land have, in a way, made the originally efficient design less so.

In these cities, air pollution has become the primary environmental problem that needs to be solved. During the worst seasons, Lahore is almost always among the cities with the most polluted air in the world; Rawalpindi suffers pollution hotspots locally as a result of mixed land, use patterns; and despite its extensive vegetation buffers, Islamabad's air quality is getting worse due to the increase in traffic in the region and pollution being brought from other areas. To tackle these environmental and social issues, it is necessary to understand intricately how urban growth patterns, population density, and land, use changes affect environmental quality.

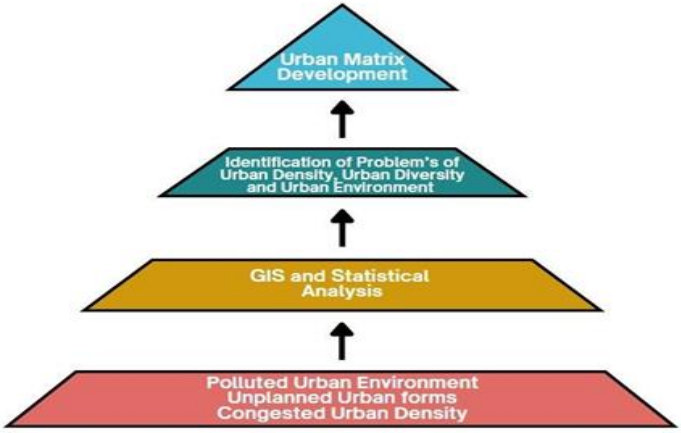
Urban development is large influenced by the three interrelated factors of urban diversity, density, and the environment that are closely connected with each other. Urban diversity that refers to a mix of land uses, building types, social groups, and economic activities is probably the major factor that makes cities vibrant, resilient, and inclusive. Indeed, urban diversity if

planned properly, can fuel local economies, facilitate social interaction, and improve the provision of services. However, if the management of urban diversity is mishandled, the existing infrastructure will be overstrained and living standards will drop.

The issue of how many people, buildings, or activities there are in a certain area (urban density) is very crucial in determining the most efficient use of resources, reduction of emissions, and promotion of public transport. Without good planning, densely populated areas, however, may become too crowded, the environment may be degraded and social inequalities may deepen.Green are very necessary for cities since they not only help in cooling the cities but also clean the air, provide habitat for animals, and the mental and social health of people as well.The combination of these elements is absolutely a must if we want to build cities that can live on and are able to bounce back from problems.

Figure 1

Conceptual Framework



This research work presents a diagram (Figure 1) that demonstrates the interrelations of city diversity, density, and the environment through a GIS approach with numerous factors. Firstly, the framework revolves around the changes in land use, building density, and vegetation health measurement with the help of spatial analysis and statistical models. Besides that, it also keeps track of the air quality in Lahore, Rawalpindi, and Islamabad. The system through analyzing the correlation of urban features with

environmental happenings, identifies overcrowding, uncontrolled growth, and the loss of green area as the chief problems. Besides that, it also suggests the city planning solutions to these issues. This orderly, data, focused method of working is an excellent way to bring to light the links between population distribution, urban morphology, and sustainability. It makes a solid case for research, based urban planning that enhances the livability, resilience, and eco, friendliness of cities.

Literature Review

Urban development depends heavily on the interplay of three major factors: Urban diversity, density, and environment. These, in turn, regulate sustainability and livability. Diversity can be seen as a mixture of use of land, types of buildings, social groups, and economic activities that, according to Mehta (2025), contribute largely to a city's vibrancy, resilience, and inclusiveness. In mixed, use neighborhoods, local economies, social cohesion, and the access to services get strengthened, which is proved by several studies (Bardhan et al., 2015; Yoshimura et al., 2022). However, if diversity is not properly managed, it might result in the predominance of commercial activities, unfair competitions, and even overloading of the infrastructures. The outward appearance of a city also plays a role in determining its energy usage and climate changes adjusting capacities since the height, density, and the general shape of buildings are what matter the most to the environmental efficiency, especially in regions with high temperatures (Cheshmehzangi & Li, 2020; Shareef, 2021). The influx of people from different parts of the world is another factor that increases the diversity of cities and demands the creation of more inclusive plans as well as the provision of equal services if social cohesion is to be maintained (Pisarevskaya et al., 2022; Xu et al., 2020). Besides this, the combination of social, cultural, and ecological factors with green infrastructure will open the way for the preservation of the biodiversity, ecological balance, and finally, the urban sustainability (Glišić et al., 2021; Savchenko & Borodina, 2017).

Urban density, which can be described as the focusing of people, buildings, or activities in a certain area, is one of the main elements of sustainable urban planning. Such places can achieve the fullest use of resources; thus, the necessity for private cars is almost eliminated, and the emission of greenhouse gases per person declines accordingly (Dodman, 2009). In contrast, the mere existence of these districts without good

preparation can result in an amplification of the traffic jams, the degradation of the environment, and the appearance of social inequities (Bramley & Power, 2009; Chen & Felkner, 2020). The areas where the surfaces have been highly modified are usually the places where the environmental consequences such as the rising of the surface runoff and the risk of floods get stronger (Wijayawardana et al., 2023). To effectively execute the idea of dense cities, planners have to consider various crucial factors that encompass compactness with mixed land use, green infrastructures, and easily accessible services as well as with the maintenance of the living standard, and resilience (Jabareen, 2006; McFarlane, 2016). The examined examples of the dense urban forms in New York, Barcelona, and Shanghai elucidate that such urban compactness can be eco, friendly if technically supported by the sufficient infrastructure, social inclusion, and environmental planning (Dong et al., 2019; Resch et al., 2016; Su et al., 2021).

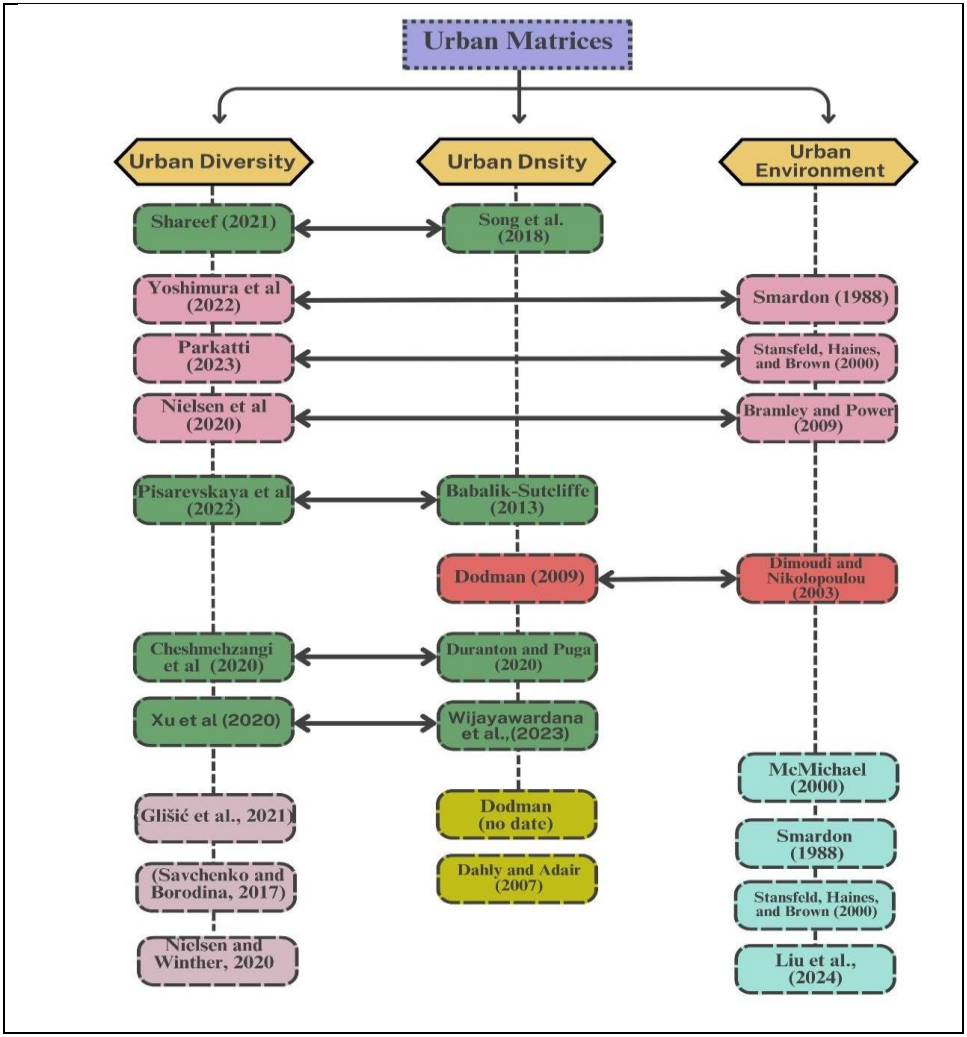
Green infrastructure, such as clean, air parks, vegetated areas, and public spaces, which can be a part of the urban environment, is highly significant in combating the climate crisis and improving the residents' mental and physical health. These factors mitigate the effects of the urban heat island phenomenon, enhance the air quality and serve as a habitat for various species in this way, and they also create social and psychological health from a positive interaction between nature and human (Smardon, 1988; Stansfeld et al., 2000). Rapid city expansion usually fails to take into account major factors, thus it increases the risk of climate change and the social tension of the city (Ahmadian et al., 2019; Liu et al., 2024). Digitally duplicated cities along with some other innovative technologies empower urban planners to deploy green infrastructure in a way that yields high environmental and social benefits. Singapore demonstrates the way of sustaining and intensifying the urban forest in tightly packed neighborhoods. Vertical gardens, urban farms, and open areas of Singapore provide excellent solutions for balancing city growth, environmental preservation, and residents' welfare.

The Literature Map (Figure 2) indicates the connections between the urban variety, concentration, and environmental quality. These elements are wrapped around each other and influence the level of sustainability and livability of the cities. Areas that are properly designed can help to flourish diversity which in turn becomes a source of economic development and

social integration. Density that is well managed can result in energy efficiency being enhanced and carbon emissions being reduced. Green or blue infrastructure is a sure way to environmental sustainability and can also contribute to general public health.City planning of this kind which is holistic and supported by data, and that recognizes the interactions among these factors is needed to create urban spaces that are socially, environmentally, and economically sustainable and also people, centered.

Figure 2

Literature Map



Literature map illustrating the interrelationships between urban diversity, density, and environmental quality, showing how planned diversity fosters economic growth and social cohesion, managed density enhances resource efficiency and reduces emissions, and green infrastructure supports environmental resilience and social well-being, collectively promoting sustainable and livable cities.

Methods

Research Approach

The qualitative part is a series of interviews with experts and public surveys that aim to understand social, economic, and environmental factors influencing urban development. Urban planners, architects, and policymakers as experts responding to the questions provided their perceptions of the issues in planning and gave suggestions for strategic solutions. While residents talked about infrastructure, green spaces, and air quality and shared their knowledge.

The quantitative part is about statistical and GIS, based spatial mapping analysis to show the patterns of urban growth, land use, and environmental metrics. That combination extends the study's range to fully understand urbanization dynamics and their effect on the development of sustainable cities.

Research Design and Sampling

The study's research design has been carefully planned and is suitable for its objectives. The sampling methods are; judgmental sampling for professionals and stratified random sampling for residents. The selection of professionals was done on the basis of their knowledge and experience in urban planning and environmental management, which made them the most suitable people to provide valuable ideas. Regarding the general public, the division of demographic characteristics at the city level helped in the formation of different social, geographic, and economic groups. This mixed sampling method deals with the technical side and uncovers community, level experiences.

Data Collection

Data collection methods included primary, secondary, and spatial data sources. Primary data were obtained through structured questionnaires containing both open, and close, ended questions which focused on urban

forms, population density, infrastructure, environmental challenges, and policy perceptions. Secondary data comprised of literature reviews, international case studies, and sustainability benchmarks which provided context to the findings. Spatial data were derived from high, resolution satellite imagery (Landsat/Sentinel) and were further analyzed through supervised classification (Maximum Likelihood and SVM) in GIS software (ArcGIS/QGIS) to delineate land use/land cover (LULC) into four classes: built, up areas, vegetation, water bodies, and barren land. Ground truthing and accuracy assessment were used to confirm the identifications.

Figure 4
Urban Density of Islamabad

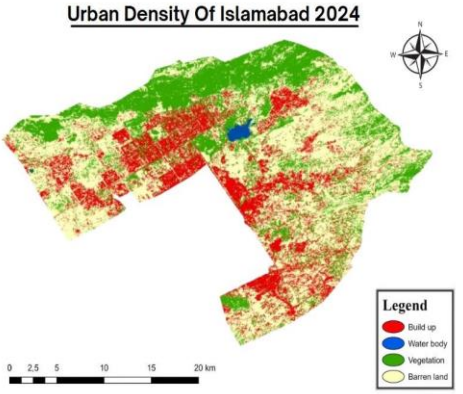


Figure 5
Urban Density of Lahore

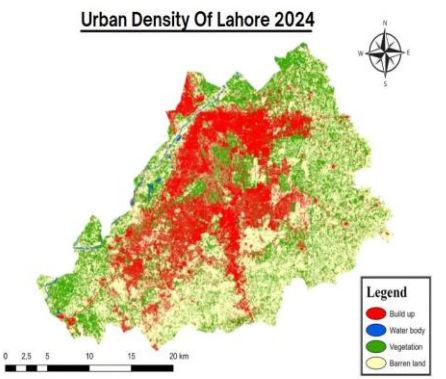


Figure 6
Urban Density of Rawalpindi

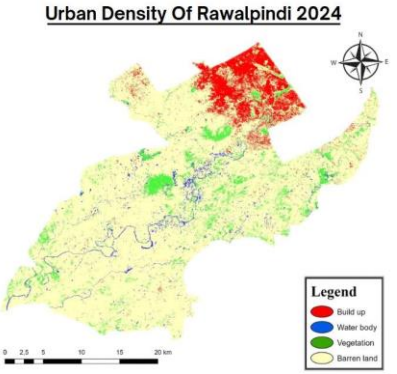


Figure 7
AQI Map of Islamabad

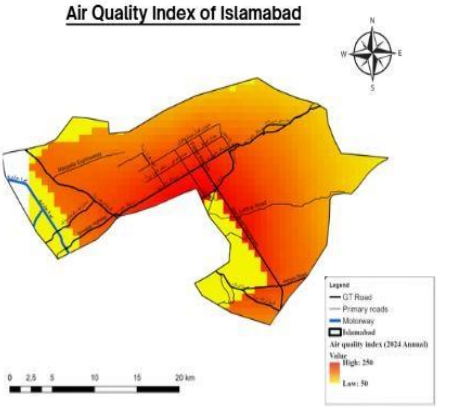


Figure 8
AQI Map of Lahore

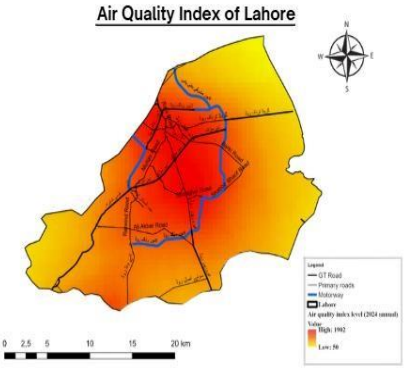
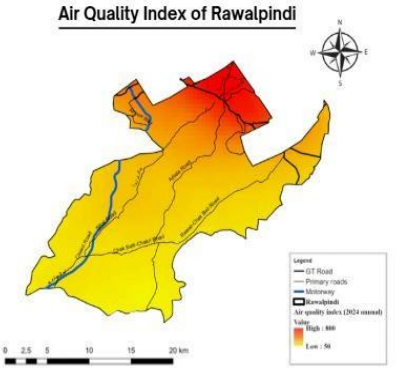


Figure 9
AQI of Rawalpindi



Urban density mapping indicates a fast urban sprawl of the central and southeastern districts of Islamabad and loss of vegetative cover due to it. Lahore has dense centrally located zones and industrial areas, which lack green spaces but the peripheral areas have the vacant lands, which will probably be used for the future development. The northern and northeastern parts of Rawalpindi show the scattered urban sprawl and the green belts as well as the barren lands along the city boundaries.

Environmental mapping using the Air Quality Index (AQI) data reveals that there is a very strong relationship between urban density and pollution. In the case of Lahore, the central areas such as Mall Road and Anarkali are characterized with extremely high AQI (~190) whereas lower levels (~50, 300) are observed in peripheries. The same trend is also seen in Islamabad where the central sectors including Faizabad, G, 9, and Murree Road are associated with high AQI (~250), whereas the peripheral green areas are having better air quality (~50, 100). Similarly, in Rawalpindi, the northern areas along GT Road are having AQI more than 200 whereas the southwestern regions are moderate (<100) and this is because of the presence of the vegetation, low development, and hydrological features such as Leh Nullah.

Data Analysis

In order to understand the factors that affect urban density and the environment, we first looked at quantitative survey data using descriptive, correlation, and regression methods to find trends, relationships, and

predictors. GIS, based analyses displayed the spatial patterns of population dispersal, land use changes, and environmental hotspots. Our comparison of the three cities revealed not only the shared problems but also the unique characteristics that can be used to develop city, specific sustainable planning strategies. The combination of statistical and spatial analyses has given us a comprehensive, data, driven insight into urbanization which can be used to guide policy and planning decisions.

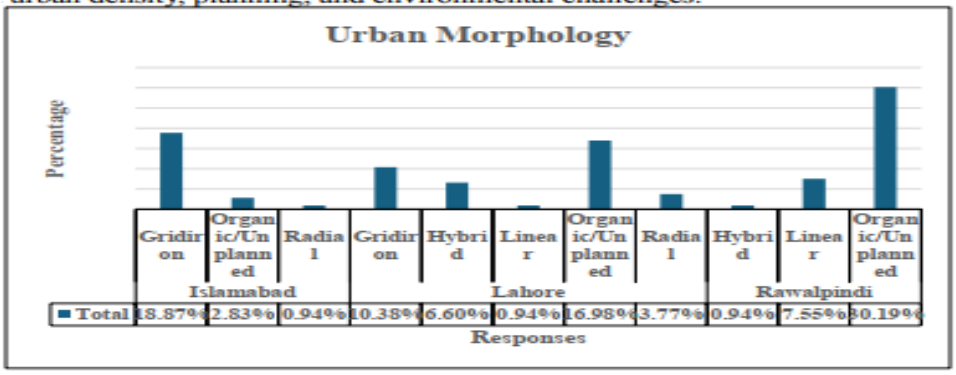
Results and Discussion

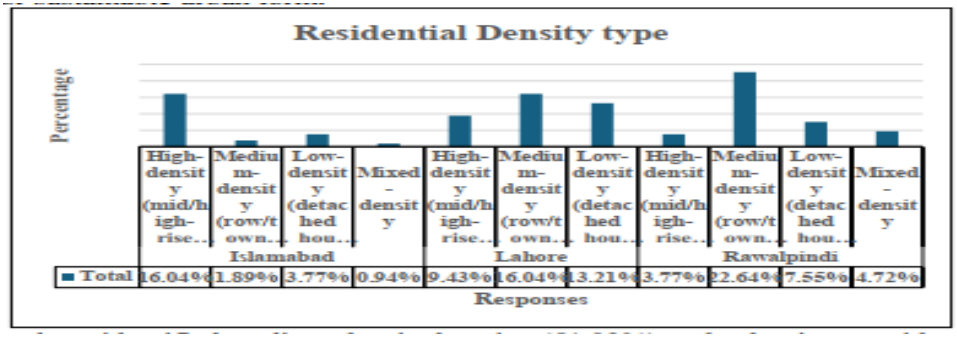
Input from Key People

We surveyed specialists to take their views on urban density, diversity, and the environmental condition. We identified 120 city experts like planners, designers, civil engineers, and environmentalists, and interviewed them. Their answers helped us to see the recognizable patterns related to urban density, form, and sustainability in Lahore, Rawalpindi, and Islamabad, which were highlighted in their responses.

Figure 10

Urban Morphology and Density



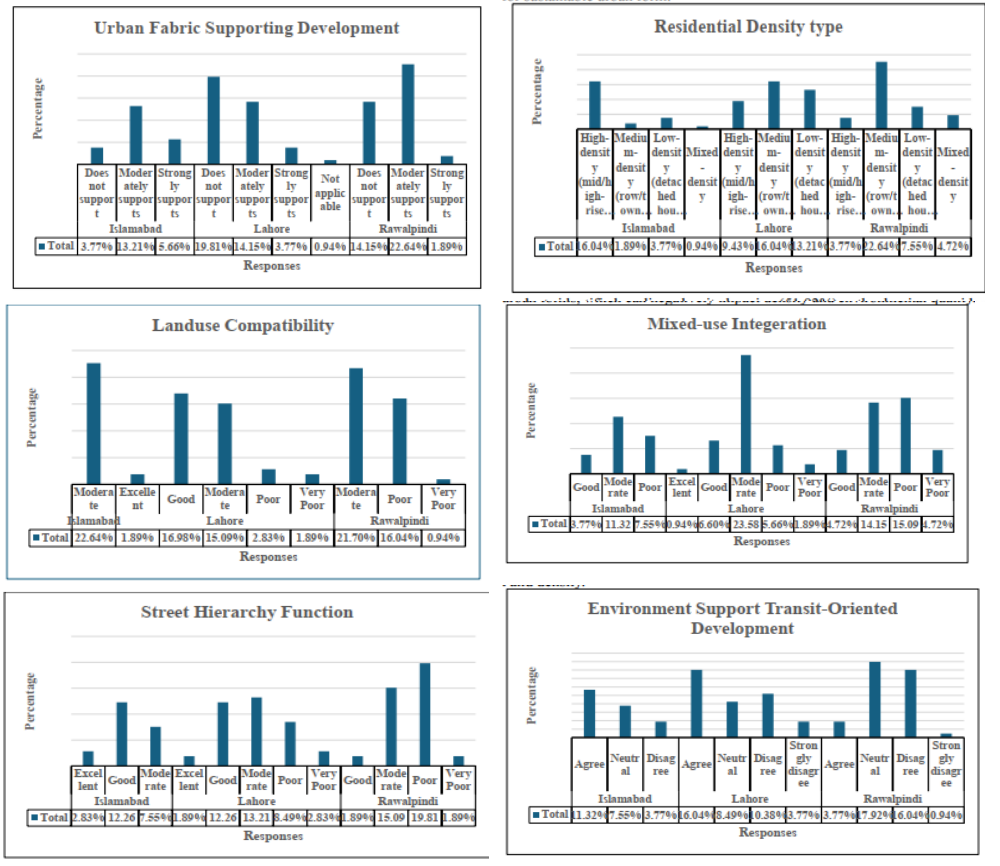


Urban Morphology and Density

The majority of the respondents characterizes the cities in which they live as having mostly organically grown or unplanned growth (around 30%), and in the second place gridiron (17.31%), hybrid (13.46%), linear (7.69%), and radial (6.30%) form layouts were identified. This suggests that the unplanned development has not been overtaken and thus it still plays a major role in determining spatial efficiency and environmental compactness. According to the reports most common residential type is medium, density housing (52%), as this indicates urban density at moderate levels, whereas high, density developments are only at (21%) level and (3.85%) of the respondents have mentioned mixed density thus implying that densification can be done sustainably.

Figure 11

Land Use and Zoning



Land Use and Zoning

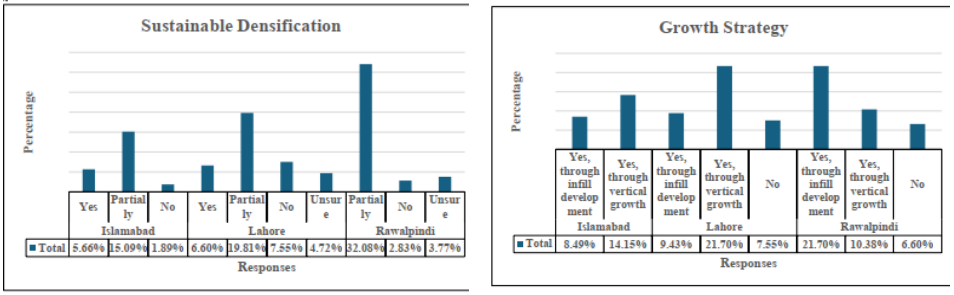
Judging by the survey results, the present urban fabric hardly supports compact development as 45.19% of the respondents indicated only moderate compactness while 43.27% of them said there was no support at all. A mere 9.62% of the respondents think that the urban fabric strongly fosters compact growth, which implies that there is weak structural and planning integration. The overall condition of land use zoning was most often described as being of moderate level (51.92%) with poorly mixed, use integration (30.77%) and only 1.92% of the respondents considered zoning as excellent. The street hierarchies were deemed to be of moderate functionality (37.50%), and the built environments were just slightly sufficient for the promotion of Transit, Oriented Development (TOD) (35.58%). These results, therefore, indicate that contemporary zoning measures are somewhat favorable to the development of compact urban growth, however, they are not strong enough to allow fully sustainable city forms.

Environmental and Infrastructure Considerations

Most respondents (67.31%) believe that building regulations and FAR guidelines only partially facilitate sustainable densification, which indicates that these regulations impose limits on the vertical growth and the efficient use of land. Nevertheless, the majority of them still approved of densification through vertical development as 43.27% of the respondents pointed to a professional consensus on the necessity of compact urban strategies.

Figure 12

Environmental and Infrastructure Considerations

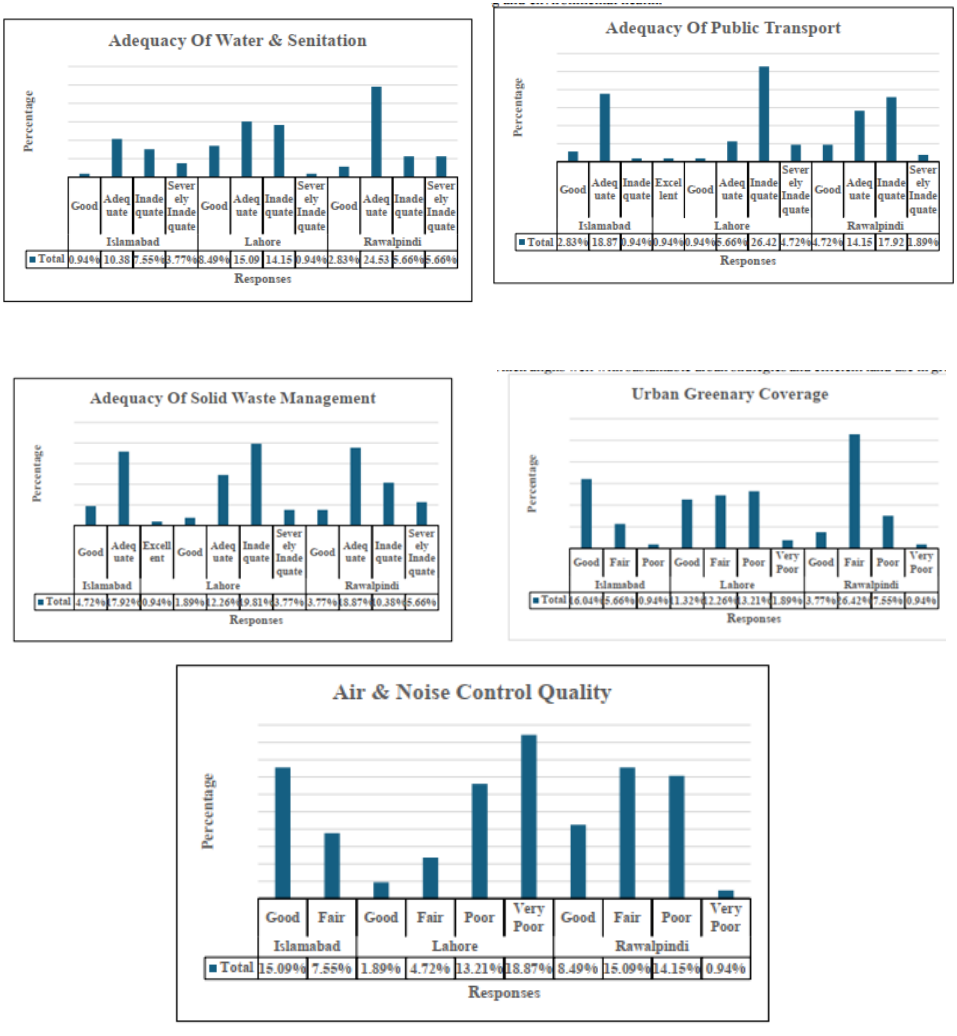


Opinions about urban infrastructure were divided. Water and sanitation services were considered sufficient by 43.27% of the respondents whereas

public transport and waste management were mainly referred to as partially adequate by 34.62% and 37.5% of the respondents respectively. The coverage of urban greenery was rated as average (39.92%) and good (31.73%) by 71% of the respondents, however, the environmental quality indicators, air and noise pollution, were mostly rated as poor (55.77%), which shows that there are still challenges in implementing environmentally friendly compact development.

Figure 13

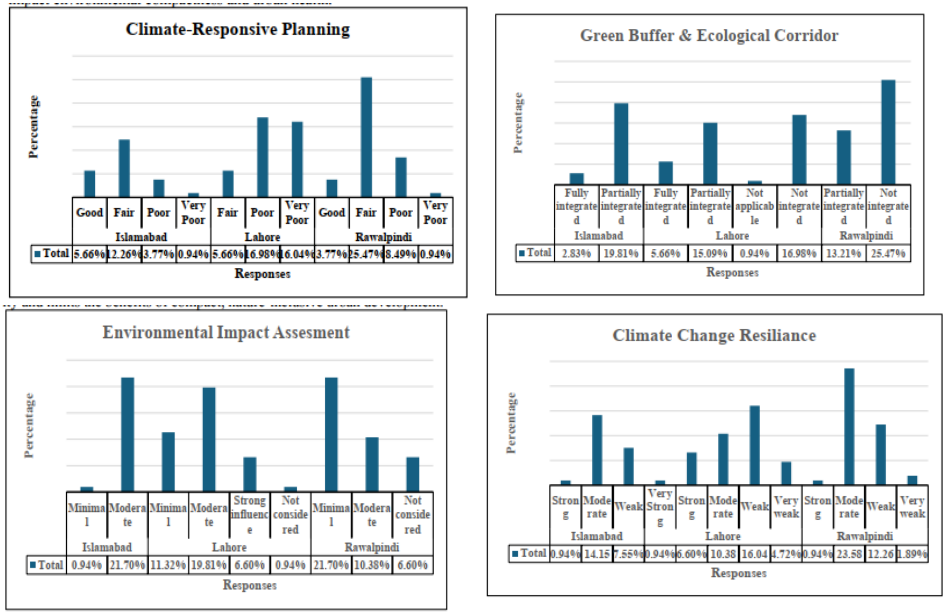
Urban Service Adequacy and Environmental Challenges



Climate, responsive planning was regarded as the most significant missing element. Just 5.77% of the people surveyed gave it a good rating, while more than 58% rated it poor or very poor, and the majority of urban plans (89.52%) did not have the features of green buffers and ecological corridors. The use of Environmental Impact Assessments (46.15%) and the implementation of measures for climate change resilience (47.12%) were only moderately significant in the shaping of urban projects.

Figure 14

Challenges in Mainstreaming Climate Resilience and Ecological Considerations

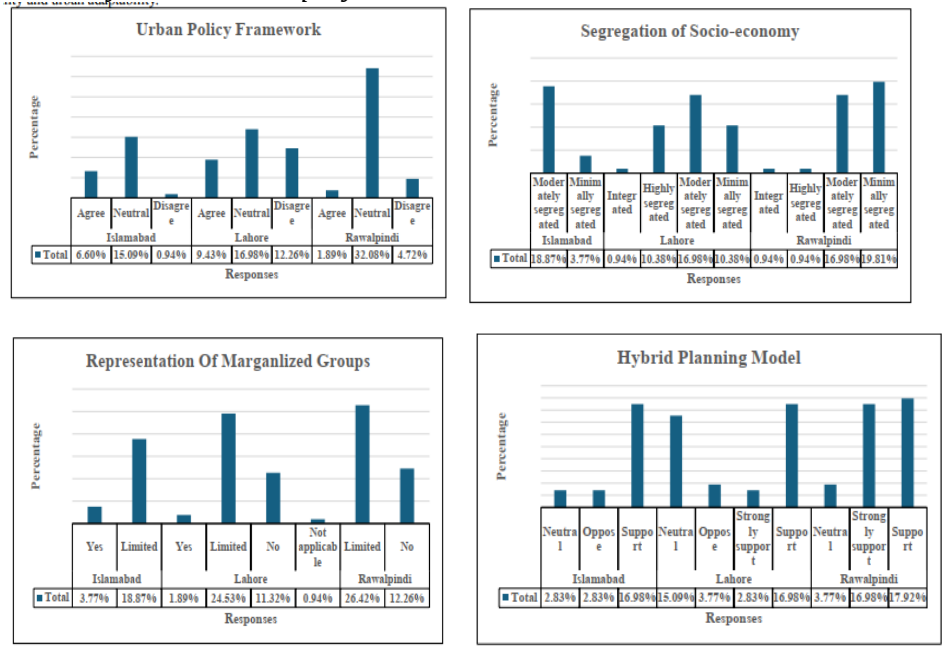


Inclusivity and Social Equity

Local experts noted that urban policy frameworks were not very inclusive, as most of the respondents (60.58%) were neutral and 22% of them disagreed that the policies promoted social equity. Socioeconomic segregation is still at a moderate level (48.08%), and the social exclusion of persons with disabilities is the most notable, especially in participatory planning (65%). In spite of these differences, the idea of using hybrid planning models, which combine the traditional urban principles with the modern sustainable strategies, is supported (45.19%).

Figure 15

Inclusivity and Social Equity

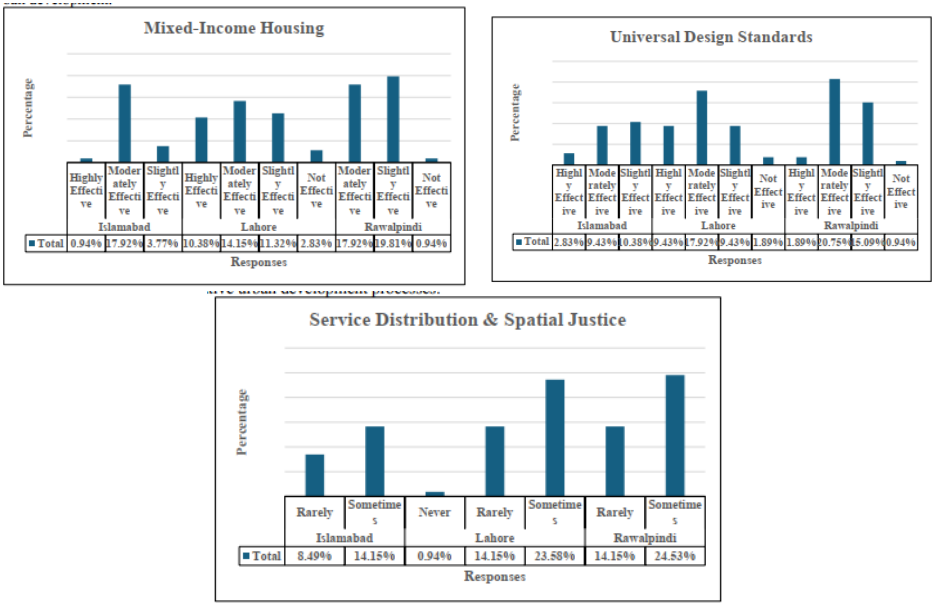


The survey results reveal that urban inclusion has been limited to a certain extent. Mixed, income housing was considered effective to a moderate degree by 50% of the participants, slightly effective by 31.73%, and highly effective by 11.54% of the participants. Universal design standards were a moderately effective factor for 51.92% of the respondents and slightly effective for 31.73%. Culturally and religiously oriented spaces were considered as a medium, effective factor by 53.58% and a highly, effective one by 22.12% of the respondents thus, referring to their role in social integration. Moreover, 58.65% of the respondents acknowledged that spatial justice is sometimes dealt with, which therefore, signifies that there are some efforts toward the equitable provision of services, but they are still very inconsistent, thus, limiting the development of inclusive urban areas.

These results imply that the infrastructure is in place to support inclusivity, yet there is a need for a stronger policy integration and community, centered planning to be able to create socially resilient and equitable urban environments.

Figure 16

Limited Urban Inclusivity and Inconsistent Spatial Justice in City Planning

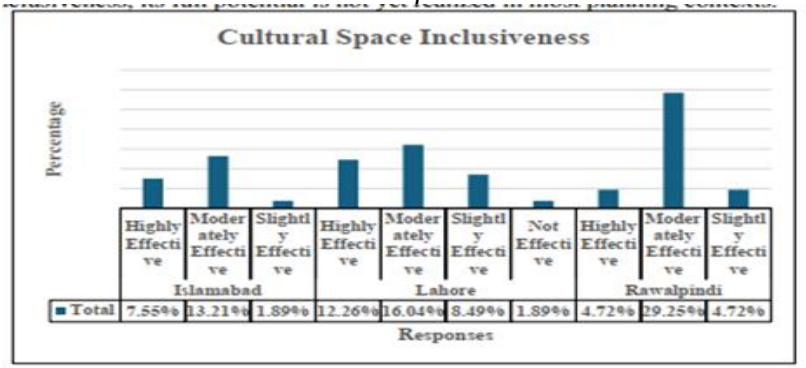


Barriers to Sustainable Urban Development

The major barriers impeding progress that came out from the survey are: absence of political will (44%), lack of money (23%), policy mismatch (16%), and institutional bottlenecks (12%), which imply that managing and leading constitute the major difficulties of unfolding urban growth that is compact, inclusive, and environmentally resilient.

Figure 17

Barriers to Sustainable Urban Development



Insights from Public Survey

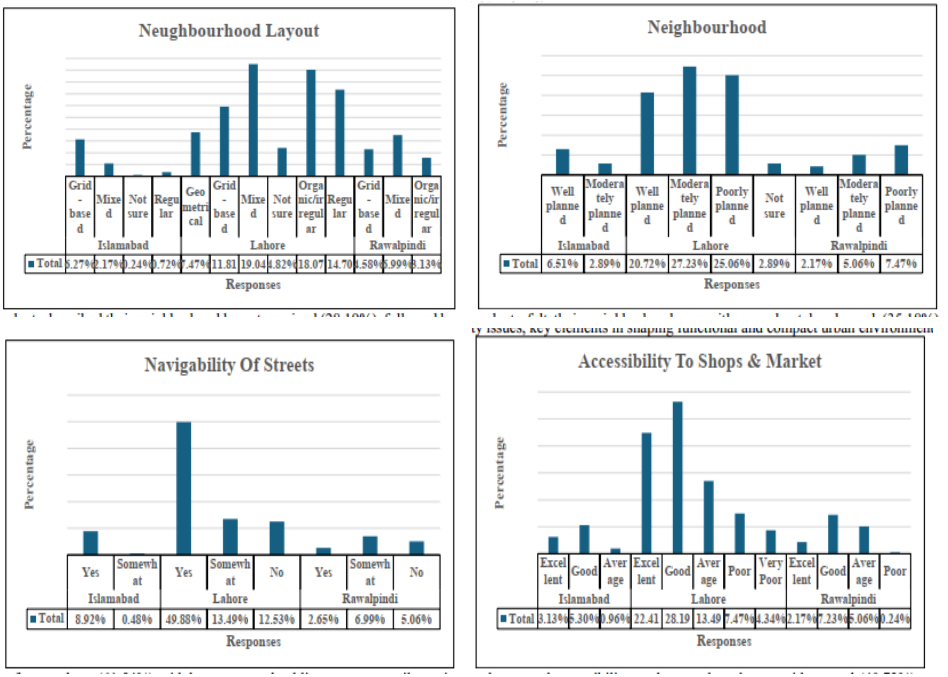
A survey of 400 residents provided complementary insights into lived urban experiences, emphasizing accessibility, environmental quality, and social inclusivity.

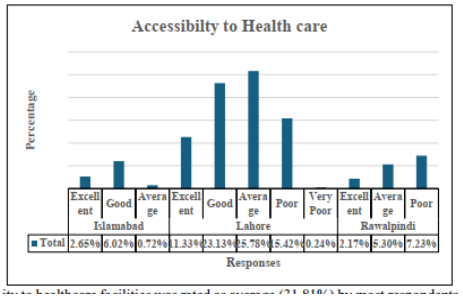
Neighborhood Planning and Accessibility:

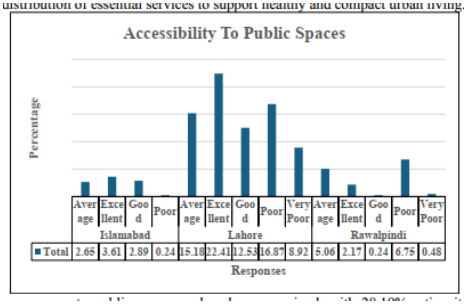
The majority of respondents referred their neighborhoods to be of a mixed type (28.19%), grid, based (23%), or organic/irregular (21%). Although streets and public spaces were considered to be of moderate navigability (61.54%) by the respondents, only a few neighborhoods were regarded as well, planned (29%). The accessibility to shops and markets was in most cases of a good to an excellent level (68%), while that of healthcare (46%) and public spaces (51%) was at a moderate level, thus pointing to an uneven distribution of services.

Figure 18

Neighborhood Planning and Accessibility





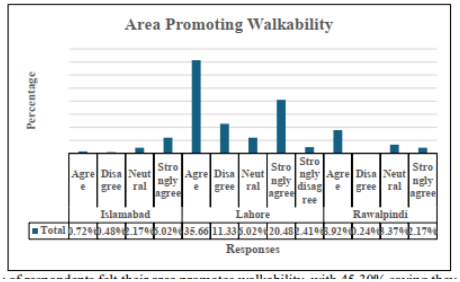


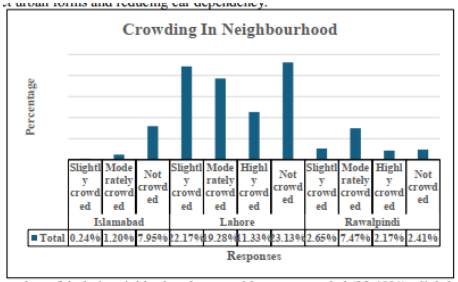
Walkability and Compactness

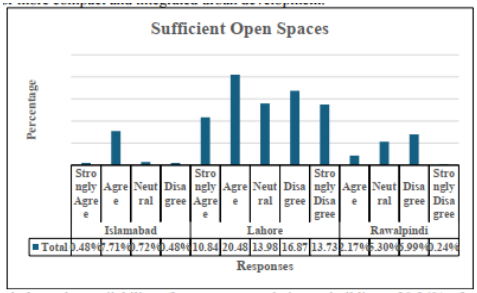
Most of the people agreed that neighborhoods should be walkable (74%) and that amenities should be located close to homes (79%), which indicates that the public strongly prefers compact, pedestrian, oriented urban forms. On the contrary, a considerable number of people have pointed out that there is building congestion (48%) and that there are few open spaces (41%), thus urban density is frequently a challenge for environmental comfort and livability.

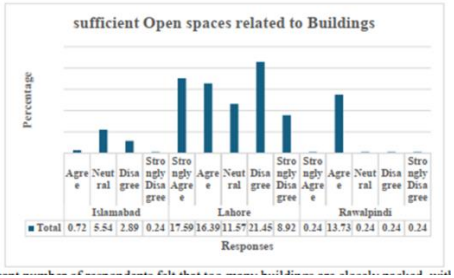
Figure 19

Walkability and Compactness







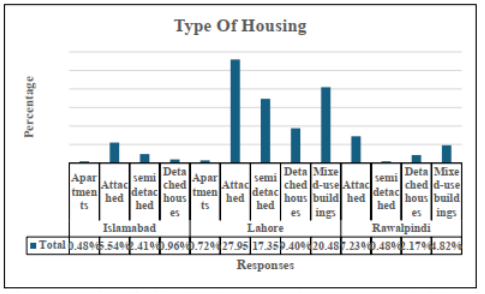


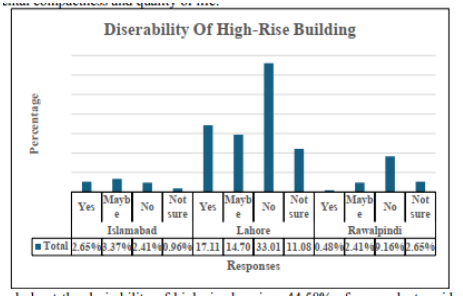
Housing and Vertical Development

Attached and semi, detached dwellings are the main type of housing in local neighborhoods (61%), whereas apartment living is almost non, existent (1%), which reflects that culturally people prefer low, to medium, density housing. On average, high, rise housing is not favored (45% of the people are against it), thus implying that there could be a considerable resistance to vertical densification even though it is more environmentally friendly.

Figure 20

Housing and Vertical Development



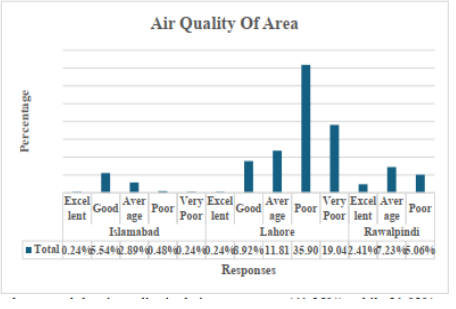


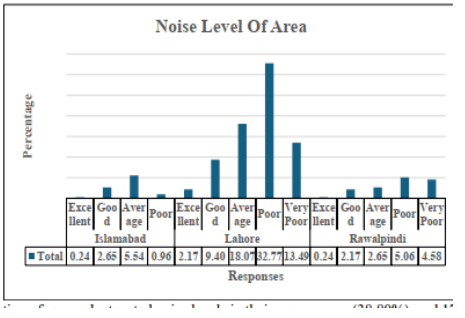
Environmental Conditions

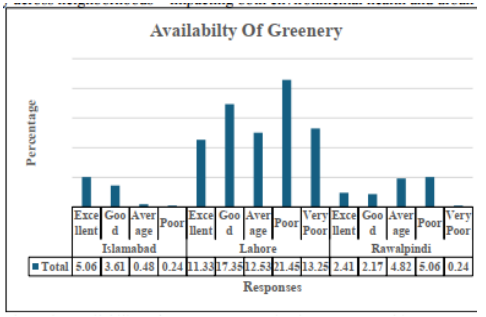
Air and noise pollution were considered to be major contributors to the overall poor environmental situation (41% and 39% respectively) and the distribution of greenery was not even as only 42% of people gave it a good or excellent rating. The frequency of visits to parks and green areas was low, however, the residents recognized the beneficial effect of green areas on both their mental and physical health (83% agreed or strongly agreed).

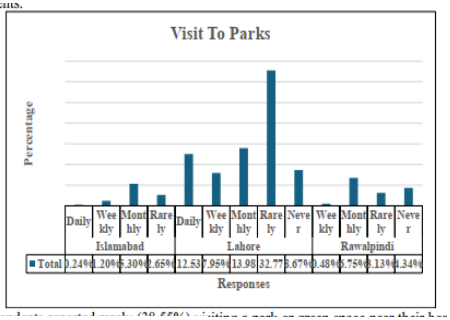
Figure 21

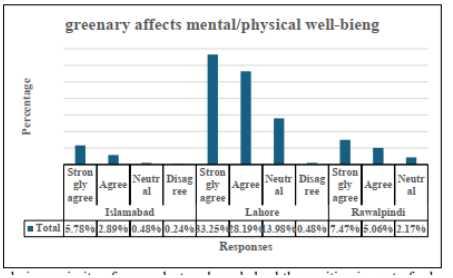
Environmental Conditions









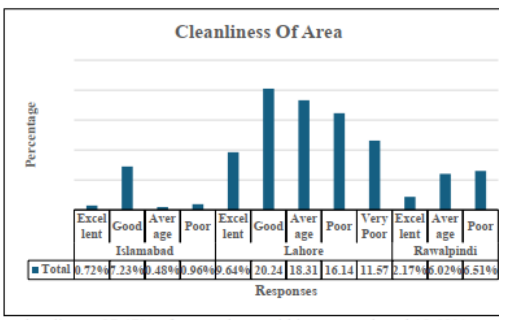


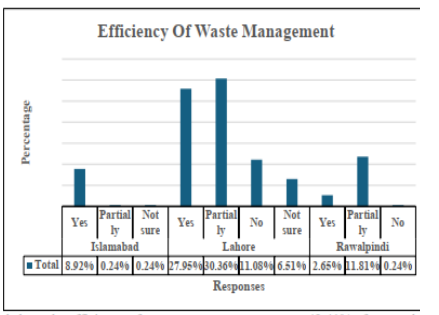
Cleanliness and Waste Management

People's views on cleanliness were a bit of a mix of all: 27.47% considered it good, 12.53% excellent, 24.82% average, 23.61% poor, and 11.57% very poor. The waste management system was rated as partially efficient by 42.41% of the people and efficient by 39.52%, thus pointing to the presence of some gaps in the provision of environmental services.

Figure 22

Cleanliness and Waste Management





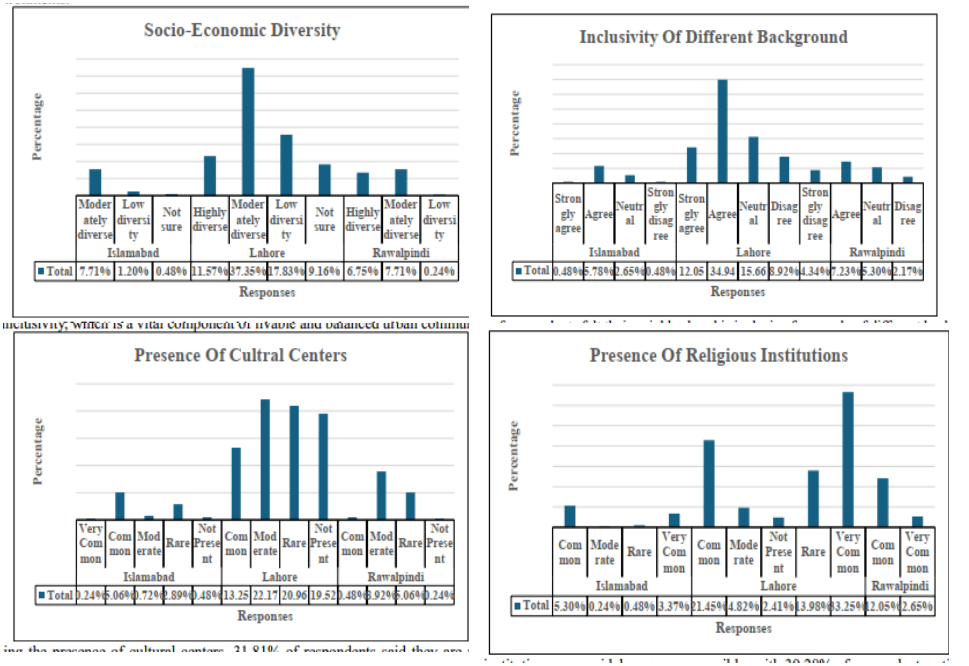
Inclusivity and Social Cohesion

In general, locals saw the neighborhood as having a moderate level of socioeconomic diversity (53%) and described the levels of social interaction between different groups as being mixed, with 55% of them stating that

interactions occurred occasionally. The distribution of cultural spaces and community centers (31.81%) was quite different, while religious institutions (78.08%) were very accessible. Neighborhoods with urban features that are inclusive, for example, affordable housing, spaces suitable for children, and streets that are friendly to women, were regarded as being necessary for making a neighborhood a welcoming one.

Figure 23

Inclusivity and Social Cohesion

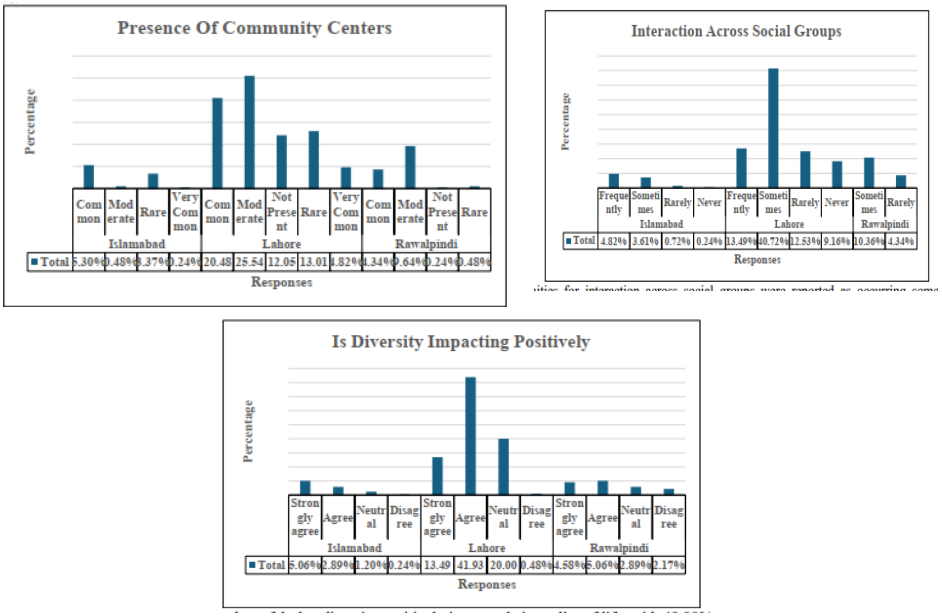


Community Spaces and Social Interaction

Community centers were average for 35.06% of the people and quite good for 30.12%. Social interactions were reported as happening sometimes by 54.70% of the people, frequently by 18.31%, rarely by 17.59%, and never by 9.40%, which reflects the limited access and participation. Diversity was seen in a positive way: 49.88% of the people agreed and 23.31% strongly agreed that it enhances the quality of life, which indicates the significance of social and cultural inclusion.

Figure 24

Community Spaces and Social Interaction

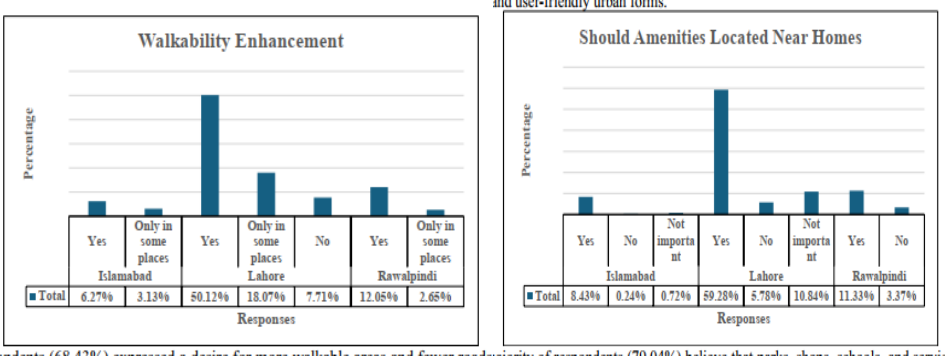


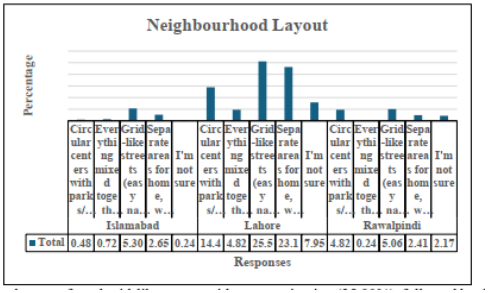
Urban Layout and Accessibility

Majority of the respondents wanted grid, like streets (35.90%) and services being close to homes (79.04%). Furthermore, 68.43% of the people were in favor of more walkable areas and less number of roads for cars, which is indicative of their preference for a human, centered urban design.

Figure 25

Urban Layout and Accessibility



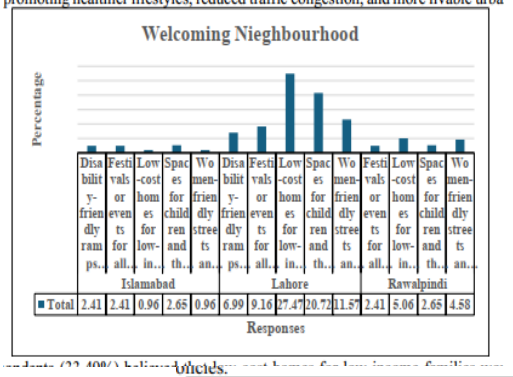


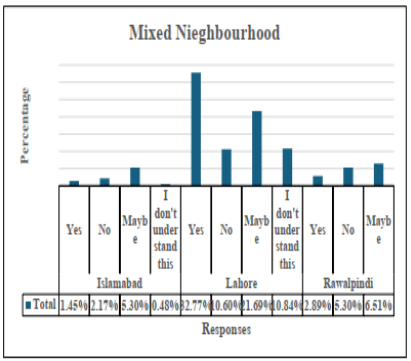
Inclusivity and Equity

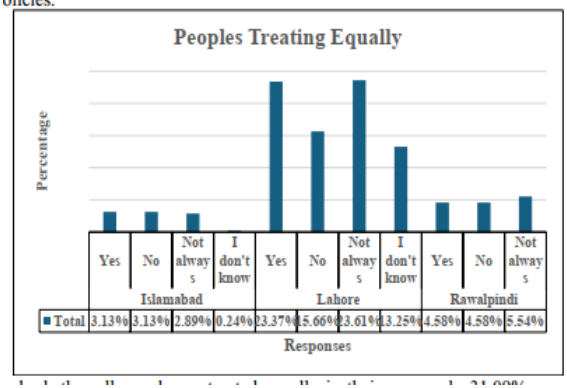
Low, cost housing (33.49%) and child/elderly spaces (26.02%) were the most prioritized inclusive features, while not more than 31.09% of people thought that neighborhoods are equally treated. The attitude towards mixed neighborhoods was at an average level: 37.11% yes, 33.94% maybe, thus indicating the necessity of fair policies.

Figure 26

Inclusivity and Equity







Integrated Results

The joint insights of experts and community members point to several key trends behind the urban development of cities. Urban Density and Morphology mainly consist of unplanned and medium, density growth, while the integration of mixed, use and transit, oriented development is very limited. This demonstrates that there is a necessity for not only planned densification strategies but also vertical growth strategies which do not lower the quality of life.

Environmental and Infrastructure Gaps that include insufficient services, bad air and noise quality, and lack of greenery, are factors that hinder the implementation of sustainable compactness measures. However, the residents' positive view of green spaces indicates that integrating the environment should be a top priority. Inclusivity and Social Equity have not improved much over the years. The situation of marginalized groups is getting worse as they are underrepresented, and social diversity is moderate, which implies that mixed, income housing, participatory planning, and the provision of inclusive amenities could serve as a vehicle for equity.

Policy and Governance issues that consist of politically constrained areas, institutional bottlenecks, and framework disconnects, are factors that impede the efficient solving of problems. Public Preferences are primarily oriented towards walkability, closeness to the amenities, and well, planned neighborhood layouts, which by focusing on the human aspect, can help in solving environmental issues and strengthening social bonds. The GIS/spatial mapping results (Table 1) along with the survey have helped to comprehend the density, land use, and Air Quality Index patterns at the city level which has helped to identify the gap between residents' perceptions and actual environmental conditions.

It is true that the majority of people support the principles of sustainable and inclusive development; nevertheless, the lack of properly planned environment, environmental management, and social equity is still quite strong. It is necessary to have a concerted, multi, scalar approach to fix these shortcomings that mix the priorities of policy, design, and community to produce urban areas that are compact, resilient, and livable.

Table 1

The integrated GIS/spatial Mapping Results Illustrating City by City Patterns of Density, Land Use, and AQI—Provide A Direct Linkage Between Residents' Perceptions and Objective Environmental Conditions

Indicator	Key Informants (Professionals)	Public Survey (Residents)	Interpretation / Discussion
Urban Morphology	Organic/unplanned: 30% (⚠ Moderate concern) Grid: 17% (◍ Positive)	Organic/irregular: 21% Grid: 23% Mixed: 28% (◯ Mixed)	Unplanned growth dominates both perceptions. Hybrid/mixed patterns offer opportunities for compact, organized urban development.
Housing Density	Medium-density: 52% (◯ Moderate) High-density: 21% (⚠ Low)	Attached/semi-detached: 61% Apartment: 1% (⚠ Low high-rise acceptance)	Medium density prevails; low acceptance of vertical housing limits sustainable densification strategies.
Land Use & Zoning	Moderate effectiveness: 52% Poor mixed-use: 31% (⚠ Concern)	Neighborhood planning: well-planned 29% Poorly planned/mixed 71% (⚠ Concern)	Current zoning partially supports compact growth; mixed-use integration is weak, limiting functional urban density.
Street Hierarchy / Walkability	Moderate: 38% TOD support moderate (◯ Mixed)	Walkable neighborhoods: 74% Amenities near home: 79% (◍ Positive)	Residents favor pedestrian-friendly environments. Professional planning partially supports street hierarchy; more focus on walkable networks needed.
Infrastructure Quality	Water & sanitation: adequate 43% Public transport: moderate (◯ Mixed)	Shops access: 68% good-excellent Healthcare: 46% moderate (◯ Mixed)	Basic infrastructure is functional, but healthcare access and public transport lag behind growing urban density needs.

Indicator	Key Informants (Professionals)	Public Survey (Residents)	Interpretation / Discussion
Environmental Quality	Greenery: mixed Air/noise: poor (⚠ Concern)	Air: poor 41% Noise: poor 39% Greenery good-excellent: 42% (⚠ Concern)	Environmental sustainability is a major gap; public values greenery, but pollution and limited green space reduce livability.
Social Equity & Inclusivity	Limited inclusion of marginalized groups; moderate policy effectiveness (⚠ Concern)	Socioeconomic diversity: moderate 53% Interaction across groups: occasional 55% (⚠ Limited)	Both professionals and residents indicate inclusivity is partial; participatory planning and policy support are insufficient.
Barriers to Sustainable Development	Political will: 44% Funding: 23% Policy disconnect: 16% (⚠ Critical)	Residents note limited open spaces & congestion (⚠ Concern)	Governance and leadership gaps are major obstacles for achieving compact, environmentally sustainable urban growth.
Public Preferences	Support hybrid planning: 45% (◍ Positive)	Favor walkability, proximity of amenities: 74–79% (◍ Positive)	Strong public support for human-centered, compact, and accessible urban planning; aligns with sustainable and inclusive design goals.

Conclusion

According to this study, the three cities, Lahore, Islamabad, and Rawalpindi, have changed dramatically their urban landscapes. Still, they share a few common negative aspects of the urban form, environment, and planning. The spatial analysis discloses that each city has changed substantially its structure: Lahore is undergoing unregulated densification and is losing its green spaces; Islamabad is growing with low, density areas and is thus transport, dependent; Rawalpindi has become a densely populated urban area with a mixture of different city types. These urban patterns in the cities have a profound effect on the major environmental

factors such as AQI levels, vegetation loss, and built, up expansion, which, in turn, affect the cities' long, term capacity to recover. It is also worth noting that the survey results show more weaknesses of the cities in terms of zoning, mixed, use planning, building regulations, universal design, and climate, neutral strategies. The public complains about air pollution, noise, and crowding, and a lack of green spaces, thus, pointing to the gap between the present urban policies and the real urban experience. All these results taken together indicate that the core parameters, density, diversity, environmental quality, and inclusivity, still are the cities of the three not properly aligned. Three targeted interventions would be instrumental in setting the cities on the path to sustainable, human, centered development: regulated vertical densification and transit investment for Lahore, inward compaction and enhanced walkability for Islamabad, and upgrading of infrastructure and strengthening of regulations for Rawalpindi. To move this forward, it is necessary to institutionalize evidence, based planning, improve governance mechanisms, and, at the same time, integrate climate resilience, green infrastructure, and mixed, use as the core elements of urban policy.

The study, in general, holds that sustainable urban development is an ongoing recalibration of the core parameters, density, diversity, environment, mobility, and governance, thus, spatial form is always kept responsive to ecological conditions and human needs.

Recommendations

This research proposes cohesive urban environment, density, and diversity strategies that target Lahore, Islamabad, and Rawalpindi with the main objectives of the intervention being air quality improvement, land use optimization, and urban resilience enhancement.

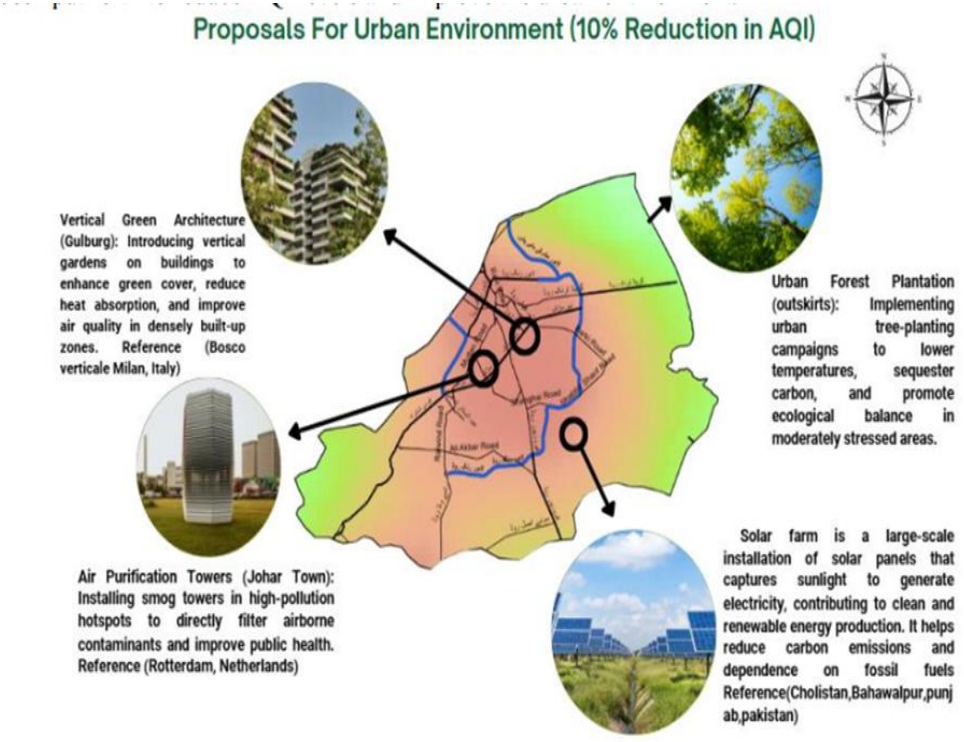
Urban Environment Interventions

Air pollution is the main air quality problem in the three cities alike that has resulted mainly from vehicular emissions, industrial activity, and dense building areas. The proposed measures are meant to address the air pollution problem from numerous directions, including vertical green architecture, air purification towers, urban forest plantations, and solar farms. Vertical greening in Lahore (Gulberg), Islamabad (Blue Area), and Rawalpindi (Chaklala) is expected to absorb particulate matter, alleviate urban heat islands, and enhance microclimates, which is in line with the results found

in Milan's Bosco Verticale. It is expected that air purification towers in areas of high, density (Johar Town, Jinnah Garden, Saddar) will be able to capture PM2.5 and NOx gases, thus, resulting in better health outcomes for the population living in these areas. The central city forests and solar farms are instrumental in carbon capture and the process of moving towards renewable energy. Together these interventions are projected to lower the AQI between 5 and 22%, a range that signals the strong potential of integrating clean energy solutions with green infrastructure.

Figure 27

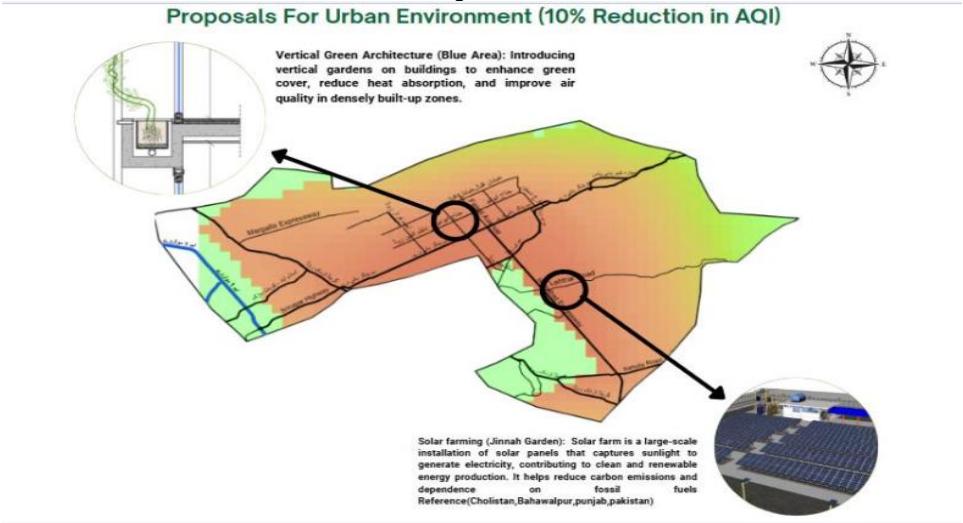
Lahore Urban Environment Proposal



Lahore is an example of a city that is struggling with bad air quality, which is mainly caused by traffic, industrial emissions, and the use of vehicles in the urban area. In order to lower the AQI levels and make the city environment better, the complex plan mentioned above has been presented

Figure 28

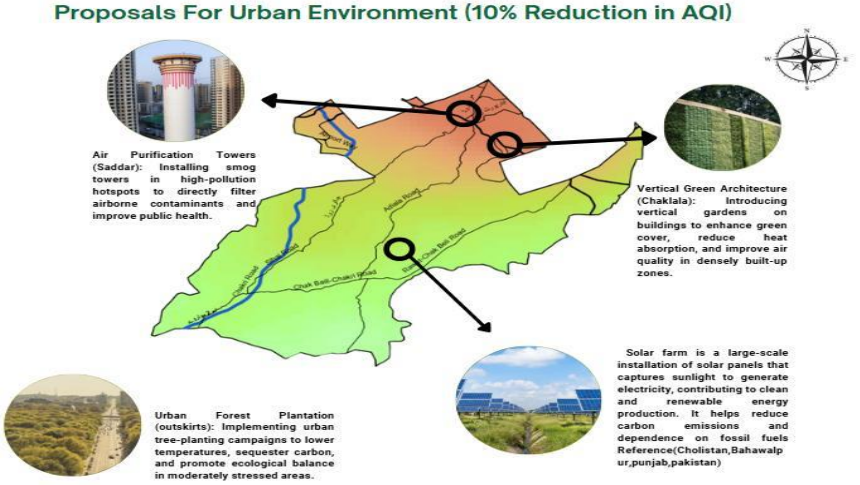
Islamabad Urban Environment Proposal



Islamabad, which is otherwise greener than the rest of Pakistani cities, continues to face air quality issues in spite of growing urbanization. The above-mentioned measures are specific to its particular topography and urban planning.

Figure 29

Rawalpindi Urban Environment Proposal



Rawalpindi's dense construction and poor urban ventilation contribute heavily to deteriorating AQI. This proposal integrates energy, vegetation, and air purification efforts.

Urban Density Strategies

Rapid urban growth, in most cases, has led to monocentric structures that limit the concentration of population and services in the centers of the cities, which in turn brings about congestion and over straining of the infrastructure. The multi, nuclei models proposed for Lahore, Rawalpindi, and Islamabad, therefore, intend to reverse this trend by decentralizing the growth through the creation of new urban nodes that are integrated with the road network and are guided by buffer zones. This strategy will, among other things, alleviate traffic congestion, make land use more efficient, and increase the ease of access to services. Mixed, use vertical development is facilitated in Lahore through peripheral nodes, thus lessening the pressure on the CBD. The new centers of Rawalpindi inject life into the areas of the city that have been underutilized, thus ensuring urban expansion that is fair and balanced, whereas the distributed nodes in Islamabad not only protect the green and agricultural areas but also guarantee compact growth. In general, multi, nuclei planning is in harmony with transit, oriented development and sustainable urbanism principles, thus it is a move in the right direction for future resilient and adaptive city forms.

Figure 30

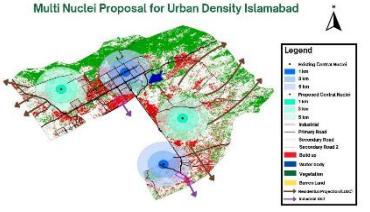
Urban Density proposal of Lahore

Figure 31

Urban Density Proposal of Rawalpindi

Figure 32

Urban Density proposal of Islamabad



Urban Diversity and Land Use

Entropic Index evaluation (Table 2) portrays different land use heterogeneity in the cities of Islamabad, Rawalpindi, and Lahore. The former had the highest diversity ($E \approx 0.922$), the latter one next ($E \approx 0.873$) and the third ($E \approx 0.808$) last. Increased heterogeneity improves urban functionality, environmental services, and livability, as green spaces, built, up areas, and water bodies are more evenly distributed. The moderate entropy of Lahore is indicative of the necessity for more integrated urban land use and ecological corridors to harmonize urban growth and environmental conservation.

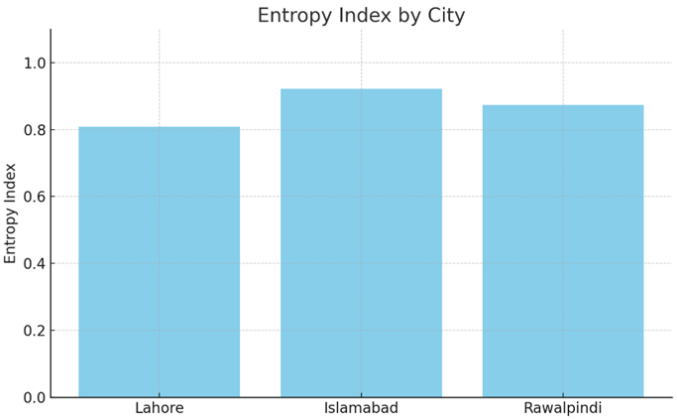
Table 2

Entropy Index Analysis- Land Cover Data Summary (2020–2021)

City	Built-up (%)	Vegetation (%)	Barren land (%)	Water (%)	Entropy Index (E)
Lahore	41.3	33.4	24.5	1.0	0.808
Islamabad	25.7	47.5 (est.)	18.1	1.5 (est.)	0.922
Rawalpindi	14.1	51.5 (adj.)	32.0	2.4	0.873

Figure 31

Entropy Index by Cities



Integrated Implications

One of the major ways to make cities grow in a nature, friendly manner is the integrated use of environmental measures, dense models, and varied land use scenarios (Table 3) that essentially constructs a comprehensive system. Some of the main positive outcomes (Figure 33) are improved air

quality, decreased city heat, fair access to the infrastructure, and increased ecological capacity. Local city measures also point to the need for changing the plans based on local city structures, population figures, and ecological sensitivities.

These results serve as a support to the council decisions that advise the bringing, in of green infrastructure, clean energy, and community planning into the urban government system as the method of ensuring a sustainable and inclusive future.

Table 3

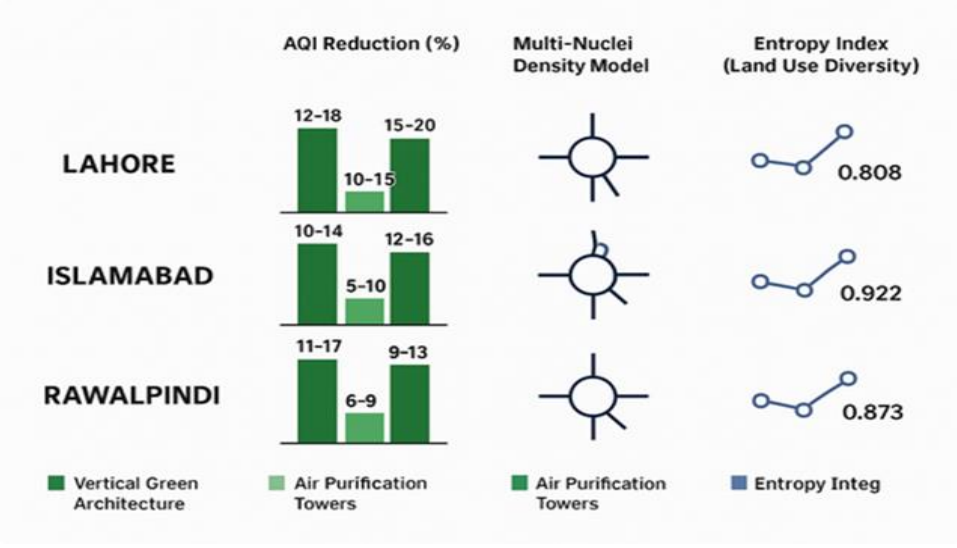
Summary of Urban Proposals and Expected Impacts

City	Proposal Type	Expected AQI Reduction (%)	Key Density/ Accessibility Outcome	Entropy Index (Land Use Diversity)	Long-Term Impact
Lahore	Vertical Green Architecture	12–18	Reduced urban heat islands, enhanced microclimates	0.808	Improved air quality, ecological and visual enhancements
	Air Purification Towers	15–20	Cleaner hotspot zones		Public health improvement
	Urban Forest Plantation	10–15	Peripheral cooling, carbon sequestration		Ecological restoration
	Solar Farm	5–10	Reduced fossil fuel dependency		Clean energy transition
	Multi-Nuclei Density Model	–	Decentralized growth, decreased congestion, improved service access		Equitable urban development, optimized infrastructure
Islamabad	Vertical Green Architecture	10–14	Cooler urban microclimates	0.922	Improved air quality and localized oxygen-rich areas
	Air Purification Towers	12–16	Targeted pollution filtration		Cleaner urban environment
	Multi-Nuclei Density Model	–	Reduced dependence on central sectors, integrated buffer zones		Balanced land use, protection of green/agricultural areas
Rawalpindi	Vertical Green Architecture	11–17	Particulate reduction, cooler built environment	0.873	Enhanced urban comfort and health benefits
	Air Purification Towers	15–22	Improved public spaces		Reduced respiratory risks
	Urban Forest Plantation	9–13	Peripheral ecological zones		Carbon sequestration, biodiversity support

City	Proposal Type	Expected AQI Reduction (%)	Key Density/ Accessibility Outcome	Entropy Index (Land Use Diversity)	Long-Term Impact
	Solar Farm	6–9	Renewable energy transition		Reduced fossil fuel use
	Multi-Nuclei Density Framework	–	Planned expansion, reduced central area pressure		Inclusive urban growth, improved livability

Figure 33

Key outcomes of Include Improved Air Quality, Reduced Urban Heat Islands, Equitable Distribution of Infrastructure, and Enhanced Ecological Resilience



To sum up, this study highlight that environmentally sustainable city change need combined solutions that take care of the nature, society, and space aspects all at the same time. Using such approaches means that Lahore, Islamabad, and Rawalpindi become the cities that are able to make the shift to the urban futures which are resilient, healthy, and inclusive.

Conflict of Interest

The authors of the manuscript have no financial or non-financial conflict of interest in the subject matter or materials discussed in this manuscript.

Data Availability Statement

Data associated with this study will be provided by the corresponding author upon reasonable request.

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