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Density and Neighbourhood Environmental Quality – A Comparative Study in the context of Indian Cities

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ABSTRACT: The study attempts to understand the relationship between density and neighbourhood environmental quality. A multiple case research design (Yin, 1994) is adopted by identifying different residential patterns in three case study cities. Amritsar, Chandigarh and Gurgaon are selected as the case study cities. The chosen cities are typical in nature and it is expected that through intensive analysis generalizations can be made that are applicable to other rapidly urbanizing Class I cities in the Indian context. There are important differences between the older habitations in the historic city of Amritsar with newer settlements of the city, post-independence planned interventions in Chandigarh and modern residential areas in the millennium city of Gurgaon. The assessment of Neighbourhood Environmental Quality and formulation of the Environmental Quality Index help in classifying different neighbourhoods according to the level of environmental quality. The study also helps in identifying significant relationships between different density variables and neighbourhood environmental quality. The future work envisages re-examining density measures of different residential patternsfor environmentally conducive development in our existing and future cities.

Keywords: Residential Patterns, Density, Neighbourhood Environmental Quality and its Assessment, Environmental Quality Index, Correlation Analysis

I. INTRODUCTION

Several studies indicate that majority of the Indian cities present a very similar pattern of urban development. All major towns and cities are found to be witnessing an explosive increase in urban population that strains the existing system and finally manifests into an environmental chaos. It is increasingly felt that the problems related to environmental quality in urban areas are very complex and require a systematic approach and careful analysis of all the relations between the variables that are part of the urban environment. Hence, in order to provide a cleaner and sustainable environment to the city residents, it becomes pertinent to look at the urban environment at a micro scale, specifically the habitat of a neighborhood in our Indian cities.

II. DENSITY & ENVIRONMENTAL QUALITY

The literature study outlines that Environmental Quality is an abstract concept resulting from both human and natural factors operating at different spatial scales. *In urban areas the local scale is dominated by individual buildings, streets and trees, but regional scale influences may include the whole city and beyond*(van Kamp *et al.,* 2003; Pacione, 2003; Nichol and Wong, 2005). Hence, environmental quality is both objective and subjective in nature and in other words, spatial and physical features in addition to socio-economic factors affect the environmental quality.

At the same time, a general study of the urban morphology of our cities reveals that different configuration and types of built form and related population distribution characterise the urban form across the geographical extent of the city. Alternatively, it can be stated that density given by distribution of buildings, their typology and geometry, layout patterns, distribution of open spaces, quality of infrastructure etc. varies from one locality to the other within the city. Density gives rise to particular urban forms, land use and transit patterns in the city.

Concurrently, it is also understood from various studies that urban form, land use and transport system of a city are critical factors affecting the environmental quality. Thus, it can be hypothesised that density has an impact on environmental quality.
The relationship between density and environmental quality is also found to be based on the concept of viable thresholds: at certain densities, the amount of development and number of people within a given area becomes sufficient to generate the interactions needed to make urban functions or activities viable without putting a stress on the environmental carrying capacity. In a wider sense, as Carl, 2000 puts it; *'Sustainable Cities are a matter of Density'*.

Thus, it is seen that one of the enduring themes behind the search for more sustainable urban forms is that of the density of development. Capello and Camagni, 2000 argue that *"with the increase of residential density and the concentration of human activities within smaller built areas, it helps to exploit economies of scale for public services (e.g. schools, public buses and public utilities) and environmental resources (e.g. land, petrol and water). However, an excessive concentration of activities and proximity result in aggravated negative environmental externalities like traffic congestion, less privacy, poor access to natural agents (air, daylight, view, etc.) and overcrowding, which tend to outweigh the claimed benefits of urban compaction"*(Burgess, 2000; Rudlin and Falk, 1999; Williams *et al.,* 2000).

Hence, a research on environmental quality with an objective analysis of the built environment of a residential neighbourhood can really prove useful. It can be used as a tool by residents to highlight and communicate concerns and positive aspects of their area to fellow residents or decision makers (e.g. local authorities, planners, policy makers and organisations). It can also be used as a framework for the planning and development of new residential areas of the city.

III. OBJECTIVES OF THE STUDY

The present study is concerned with understanding the impact of density on neighborhood environmental quality. The study is limited to the objective analysis of the physical aspects of the built environment of the different neighborhoods. The investigation of people's perception to check the subjective values of an objective situation is presently kept out of the scope of the study. This is based on the argument given by Alexander (1993)that though individual cognitive factors provide a wider thinking on density as a concept, what determines density that is perceived by people is the physical density of the built environment. Also, even though people evaluate their environments as perceived, it is the physical density that provides a basis to objectively assess spatial quality of a place. Therefore, the objectives of the study are:
(i) To operationalize density and ascertain objective indicators of environmental quality at the neighborhood level.
(ii) To identify different residential patterns and find representative neighborhoods in the case-study cities.
(iii) To assess aggregated neighbourhood environmental quality and formulate the environmental quality index.
(iv) To identify significant relationships between density variables and neighbourhood environmental quality.

IV. OPERATIONALIZING DENSITY AND IDENTIFYING INDICATORS OF ENVIRONMENTAL QUALITY

'Density' is broadly disaggregated into Population Density; Built Form Characteristics like Residential Density, Height, Ground Coverage and Built to Open Ratio; Amount of Roads and Sidewalks; etc. to cover all significant physical aspects of the neighbourhood. On the other hand, the indicators of neighbourhood environmental quality are identified as: Crowding and Congestion, Nature and Use of Open Spaces, Shade and Ventilation, Temperature Variations, Average Noise Levels, Level of Cleanliness, Neighbourhood Walkability and Air Quality. A conceptual matrix showing possible correlations between Density Variables and Indicators of Environmental Quality is generated (Table 1).

V. RESIDENTIAL PATTERNS IN INDIAN CITIES

Patterns of urbanization within a city differ from one location to another. While the indigenous or traditional city is irregular in composition; the annexes (cantonment, civil lines, etc.) are found to be much more organized. These varying patterns of urban development result in differences in levels of population density, concentration and mixing of residential or commercial uses, amount of open spaces, etc. (Galster *et al.* 2001). The inner core is found to be a compact city largely designed for pedestrians and cycle rickshaws. The entire built up mass is more or less a compact monolithic volume with small punctures for the purpose of light, ventilation and movement. Old parts of Shahjahanabad (Delhi), Jaisalmer and Jaipur (Rajasthan), Ahmedabad (Gujarat), etc. exhibit these characteristics (Kapadia, 2010). The city outside is sometimes dominated by the British annexes with buildings more clearly distinguished and grouped according to their functions (Smailes, 1986).
Looking beyond, newer parts of the city are found to have developed haphazardly as a result of accelerated industrialization and rapid urbanization.

High densities are found in commercial and industrial zones offering jobs to resident and migrant population and along transport corridors promoting easy accessibility to and from the place of work. The built forms are designed asheterogeneous projects that rarely respond to their surroundings in the city (Bharne, 2011). Lastly, the residential development seen in most city outskirts are the gated communities dominated by high rise apartment blocks, community open space and shared facilities. Though these communities are usually high density enclaves but at the scale of the city, lying on the fringes they are generally part of a low-density car-orientated suburb, which is highly unsustainable and does nothing to support the traditional energy and vitality of urban life. The urban form is thus characterized by different configuration of built forms and population distributions across the city.

Table 1: Conceptual Correlation Matrix.

Density Variables	Environmental Quality Indicators							
	Crowding & Congestion	Nature and use of Open Spaces	Shade & Ventilation	Temp. Variations	Noise Levels	Level of Cleanliness	Neighbourhood Walkability	Air Quality
Population Density	●	●			○	●	○	○
Built form Characteristics	●	●	●	●	○			
Amount of Roads and Sidewalks	●				●		●	●
Amount of Open Spaces	●	●	●	●	○		●	●

● Direct Correlation ○ Indirect Correlation

VI. AREA OF STUDY

Most of India's urban centers are smaller towns. The 8000 urban centers identified in the 2011 census comprise of only 53 cities with a population of over 1 million. Out of the total urban population, only 20% live in cities of 10 million or more. Eighty percent of the urban population lives in cities and towns of population ≤1 million. Hence, the most meaningful approach is to anticipate the rapid growth of these Class I cities and devise ways for their sustainable development (Sudhira and Gururaja, 2012).

Amritsar, Chandigarh and Gurgaon with 0.75 million≤population≤1.5 million are selected as case study cities since they are from different time periods and have imprints of all types of residential patterns. There are important differences between the older habitations in the historic city of Amritsar with newer settlements outside, post-independence planned interventions in Chandigarh and modern residential areas in Gurgaon. For detailed investigation, eight neighbourhoods based on population density, residential density and height of buildings (most prominent built-form characteristic) are identified from the three case study cities (Plate 1).

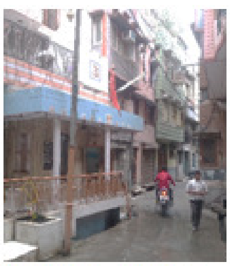
The population density is categorised as low density with <200pph, medium density with 200 to <400pph, high density with 400 to <600pph and very high as ≥600pph (refer Table 2). Similarly, the residential density is categorised as low density with <50DUs/hectare, medium density with 50-100DUs/hectare and high density with >100DUs/hectare (refer Table 4). In Table 3, G+3 storeyed structures that do not require elevators are considered low-rise. Structures with more than 8 storeys or 25m in height with mandatory provision of diesel generators in case of an electricity failure are considered high rise as per the National Building Code 2005 Fire Safety and Fire Protection Norms and buildings having 5-8 storeys are considered as medium rise structures. This is based on the population densities, residential densities and heights observed in different neighbourhoods in several Indian cities.

Table 2: Neighbourhoods grouped according to Population Density.

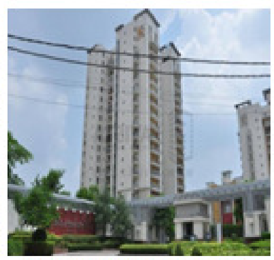
Neighbourhood	Population Density (pph)	Range	Level
Sector 8, Chandigarh	95	<200pph	**Low**
World Spa, Gurgaon	178		
Ranjit Avenue, Amritsar	256	200 to <400pph	**Medium**
Marble Arch, Chandigarh	345		
Sector 38W, Chandigarh	441	400 to <600pph	**High**
Sector 20, Pkl, Chandigarh	540		
KatraDullo, Amritsar	641	≥600pph	**Very High**
Uniworld City, Gurgaon	798		

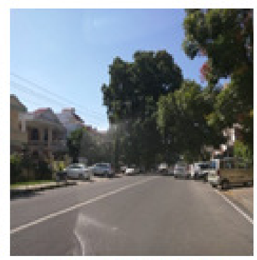
Table 3: Neighbourhoods grouped according to Height.

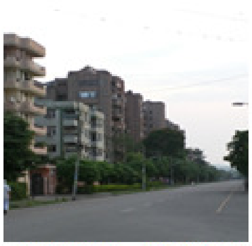
Neighbourhood	No. of Storeys	Range	Rise
Sector 8, Chandigarh	G, G+1, G+2	≤G+3 storeys	**Low**
Ranjit Avenue, Amritsar	G, G+1, G+2		
Sector 38W, Chandigarh	G+2		
KatraDullo, Amritsar	G, G+1, G+2, G+3		
Marble Arch, Chandigarh	G+4	5-8 storeys	**Medium**
Sector 20, Pkl, Chandigarh	G+5, G+6, G+7		
World Spa, Gurgaon	G+16	>8 storeys	**High**
Uniworld City, Gurgaon	G+18		


KatraDullo, Amritsar

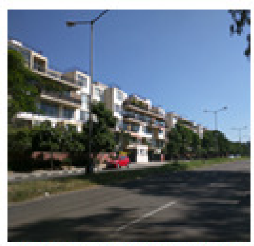

Ranjit Avenue, Amritsar


Uniworld City, Gurgaon


Sector-8, Chandigarh


Sec-20, Pkl., Chandigarh


World Spa, Gurgaon


Marble Arch, Chandigarh


Sector-38W, Chandigarh

Plate 1: Residential Neighbourhoods in Case Study Cities.

Table 4: Neighbourhoods grouped according to Residential Density.

Neighbourhood	Residential Density (DUs/hectare)	Range	Level
Sector 8, Chandigarh	17	<50DUs/hectare	**Low**
Ranjit Avenue, Amritsar	36		
World Spa, Gurgaon	44		
Marble Arch, Chandigarh	65	50-100 DUs/hectare	**Medium**
Sector 38W, Chandigarh	76		
Sector 20, Pkl, Chandigarh	98		
KatraDullo, Amritsar	149	>100DUs/hectare	**High**
Uniworld City, Gurgaon	200		

VI. METHODOLOGY

Data Collection and Organization

Data is collected from both primary and secondary sources (Fig. 1). Certain mechanical instruments like the Temperature and Humidity Data logger and Smartphone Android Applications like deciBel are used to record ambient temperatures and average noise levels in different places of the neighbourhoods.

The environmental quality indicators are measured using several variables as shown in Table 5. They are subsequently compared with threshold values given by CPCB, New Delhi; URDPFI 2014; Handbook of Service Level Benchmarking, MoUD, Govt. of India 2011; etc.

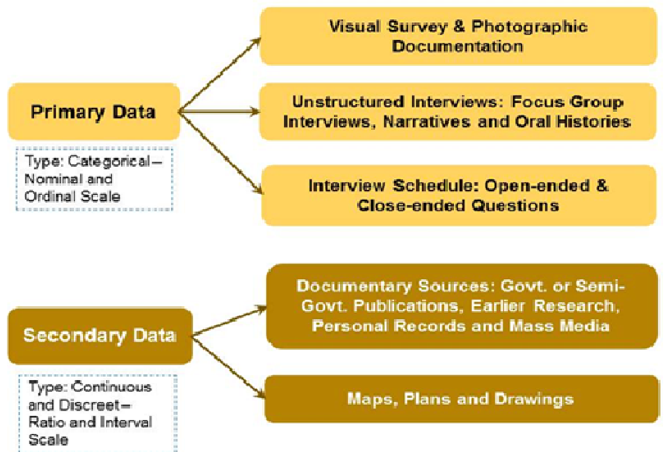


Fig. 1: Types of Data and Methods of Data Collection

Table 5: Variables to Assess Neighbourhood Environmental Quality.

Indicator	Measurement Variables			
Crowding and Congestion	BUA/Capita (Built-up Area per Capita)	PGA/Capita (Public Ground Area per Capita)	PRL/Capita (Paved Road Length per Capita)	Mobilization Factor
Nature and Use of Open Spaces	Type of Open Space	Area of Open Space	Percentage Tree Cover	Activity Intensity
Shade and Ventilation	Shade Rating - No. of hours of Shade in the Neighbourhood		Orientation of Streets w.r.t Prevailing Winds	
Temperature Variations	Temperature inside the Locality		Temperature outside the Locality	
Average Noise Levels	At Entry Points	Inside the Locality	On Main Roads	
Level of Cleanliness	Cleanliness Indicator	Sewage Indicator	Drainage Indicator	
Neighbourhood Walkability	Proximity to Daily Needs	Type of Sidewalks	Availability of Streetlights	Type of Open Space
Air Quality	NO_x	SO_2	RSPM	

Source: Synthesis of Milbrath and UNESCO, 1978; Rahman *et al.,* 2011 and Handbook of Service Level Benchmarking, MoUD, Govt. of India, 2011.)

Assessing Neighbourhood Environmental Quality

Each of the eight neighbourhoods are divided into smaller study units along the streets and all the parameters listed in Table 5 above are objectively ascertained using primary and secondary data for each of the neighbourhoods. Thereafter these values are merged together using Standardized Z-scores in IBM SPSS Statistics 22 (Statistical Package for Social Sciences) to get the Standardized Aggregated Environmental Quality (ZAEQ) ofall the neighbourhoods (Table 6).

The ZAEQ values are used to create an Environmental Quality Index (refer Figure 2) that can be further used to generate illustrative maps for each of the neighbourhoods showing sections with most favourable, favourable, average, less favourable and least favourable environmental quality.

Since, the aggregated environmental quality values are derived from standardized z-scores, they lie between -1 (least favourable) and +1 (most favourable).
Any number of neighbourhoods can be analysed to generate the standardized environmental quality scores and the process can be applied to entire cities thus enabling the identification of areas with good, average and poor environmental quality at the city level. It can further help in conducting cross-case comparisons and help rank cities based on the environmental quality in its residential neighbourhoods. This is partially represented by the row indicating the level of Environmental Quality in Table 6.

Table 6: Standardized Aggregated Environmental Quality of Case Study Neighbourhoods.

Study Units	AMRITSAR		CHANDIGARH				GURGAON	
	KatraDullo	Ranjit Avenue	Sec-8	Sec-38W	Marble Arch	Sec-20, Pkl	Uniworld City	World Spa
1.	0.18	0.34	-0.37	-0.35	0.37	-0.35	0.17	0.43
2.	-0.14	0.28	-0.46	-0.34	-0.16	-0.11	0.32	0.44
3.	-0.22	0.37	-0.31	-0.48	-0.06	0.01	-0.03	0.35
4.	-0.06	0.53	-0.21	-0.24		-0.45	0.23	0.36
5.	-0.21	0.41	-0.33	-0.26		-0.56	0.09	0.34
6.	-0.37	0.3	-0.27	-0.08		-0.12	0.4	0.31
7.	-0.61	0.38	0.13	-0.23		-0.36	-0.04	0.41
8.	-0.28	0.35	-0.22	-0.25		-0.27	0.23	0.49
9.	-0.24	0.64	0.05	-0.2		-0.49	0.17	0.33
10.	-0.4	0.39	0.23	-0.3		-0.51	0.4	0.3
11.	-0.19	0.46		-0.3		-0.59	-0.05	0.41
12.	-0.37	0.48		-0.2			0.21	0.34
Avg. ZAEQ	**-0.24**	**0.41**	**-0.18**	**-0.27**	**0.05**	**-0.35**	**0.18**	**0.38**
Level as per EQI	**Less Favourable**	**Favourable**	**Average**	**Less Favourable**	**Average**	**Less Favourable**	**Average**	**Favourable**

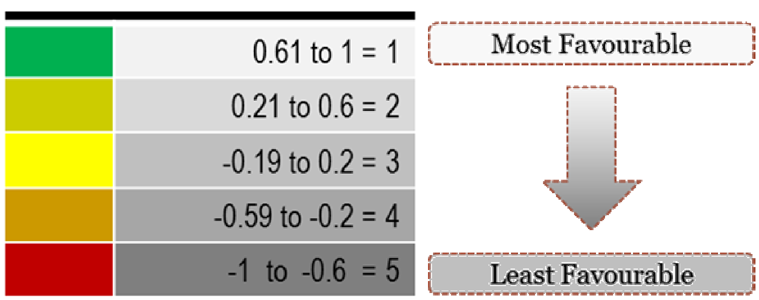


Fig. 2. Environmental Quality Index.

Preliminary Findings

It is observed from Table 6 that Ranjit Avenue, Amritsar and World Spa, Gurgaon with medium and low population density (<400pph), low residential density of 20-50DUs/hectare and low/high rise buildings have favourable environmental quality whereas neighbourhoods with high and very high population density (≥400pph), medium and high residential density (>70DUs/hectare) and low and medium rise buildings (G to G+7) have less favourable environmental quality due to crowding, congestion and lack of open spaces.

This is especially demonstrated by KatraDullo, Amritsar, Sector 38West and Sector 20, Panchkula, Chandigarh. It is also seen that rest of the three neighbourhoods have average environmental quality. The preliminary findings are summated in Table 7.
Thus, it can be said that from among the residential patterns assessed, the environmental quality is more favourable in both low and high-rise neighbourhoods with low residential density and medium and low population density respectively. This is seen in Figure 3 and Figure 4.

Figure 3 indicates that mostly areas with more favourable environmental quality have low residential density of <50DUs/hectare whereas areas with higher residential densities of ≥50DUs/hectare generally have less favourable environmental quality. Figure 4 shows that most of the areas with above average, more favourable and most favourable environmental quality have >100 and <400pph which constitute low and medium population density. Areas with ≥400pph i.e. high and very high population density fall in the category having below average, less favourable and least favourable environmental quality.

Table 7: Residential Patterns and Environmental Quality.

Built Form Characteristics	Population Density		
	Low Population Density	Medium Population Density	High / Very High Population Density
Low Rise Low Residential Density	Average	Favourable	×
Low Rise Med. Residential Density	×	×	Less Favourable
Low Rise High Residential Density	×	×	Less Favourable
Med. Rise Med. Residential Density	×	Average	Less Favourable
Med. Rise High Residential Density	×	×	×
HighRise Low Residential Density	Favourable	×	×
High Rise High Residential Density	×	×	Average

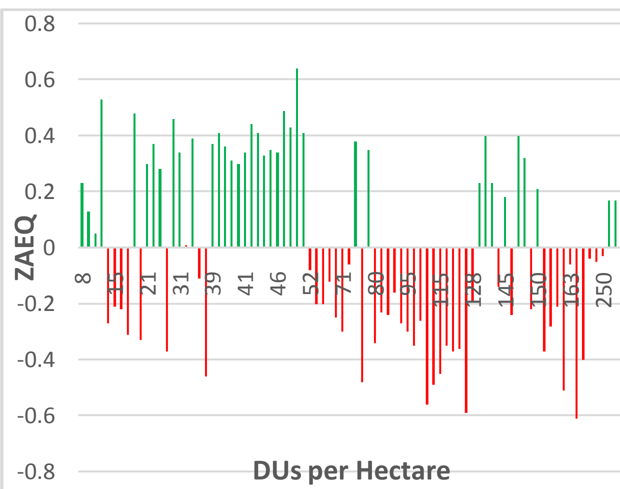


Fig. 3. Variation in Environmental Quality with Residential Density.

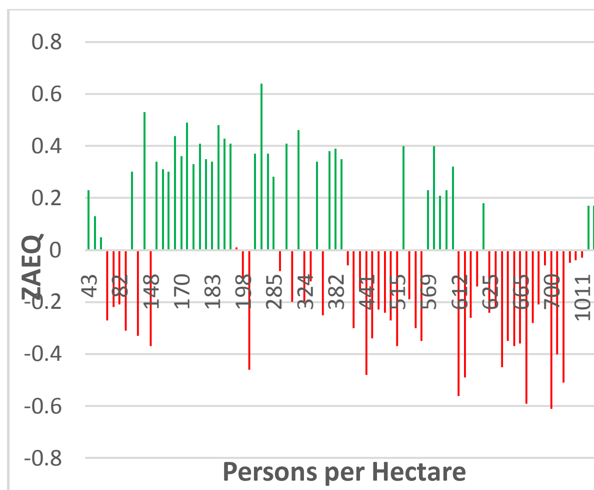


Fig. 4. Variation in Environmental Quality with Population Density.

Correlation Analysis

To statistically establish the relationship between density and neighbourhood environmental quality, a correlation analysis is carried out between density variables like persons per hectare, dwelling units per hectare, height of buildings, plot coverage, etc. and standardized aggregated environmental quality (ZAEQ) of all the residential neighbourhoods. Significant correlations at 99% confidence level are seen between many density variables and neighbourhood environmental quality. While environmental quality varies negatively with population density, residential density, plot coverage and encroachment; it shows positive correlation with height, amount of open spaces and condition of sidewalks (Table 8). In other words, this means that as population density, residential density, etc. goes on increasing the environmental quality deteriorates whereas with increase in height of buildings, amount of open spaces and good condition of sidewalks permitting walkable neighbourhoods, the environmental quality starts improving. This is also in compliance with Table 7 above.

Table 8: Correlation between Density Variables and Environmental Quality.

DENSITY VARIABLES		ZAEQ
Persons per Hectare	Pearson Correlation	-.355**
	Sig. (2-tailed)	.001
DUs per Hectare	Pearson Correlation	-.263*
	Sig. (2-tailed)	.016
Height	Pearson Correlation	.433**
	Sig. (2-tailed)	.000
Built to Open Ratio	Pearson Correlation	-.387**
	Sig. (2-tailed)	.000
Plot Coverage	Pearson Correlation	-.651**
	Sig. (2-tailed)	.000
Open Space	Pearson Correlation	.283**
	Sig. (2-tailed)	.009
Road Density	Pearson Correlation	-.097
	Sig. (2-tailed)	.382
Encroachment	Pearson Correlation	-.271*
	Sig. (2-tailed)	.013
Proximity to Daily Needs	Pearson Correlation	.107
	Sig. (2-tailed)	.331
Condition of Sidewalks	Pearson Correlation	.389**
	Sig. (2-tailed)	.000
StreetLights	Pearson Correlation	.039
	Sig. (2-tailed)	.726

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

The future course of work involves carrying out hierarchical multiple regression that will help assess the extent to which the observed variance in the dependent variable (in this case Neighbourhood Environmental Quality) is explained by the variance in the independent density variables. Also the standardized 'β -coefficient' will be used to indicate the relative importance of a density variable thus helping in re-examining the density measures for achieving optimum environmental quality.

CONCLUSION

The present study helps to take up a multiple case study approach to assess and compare the environmental quality of different neighbourhoods from three rapidly urbanizing cities in the Indian context. An analytical framework devised on the basis of detailed literature review showing possible correlations between density variables and indicators of environmental quality helps in understanding the relationship between density and environmental quality. It shows that density has an impact on environmental quality.

The study further emphasizes the need for detailed empirical analyses for better planning at both micro and macro levels of existing urban structure as suggested by Radberg (1996). It envisages identifying desirable density ranges for neighbourhoods having different residential patterns so as to derive guidelines and suggest methods to achieve environmentally conducive patterns of residential development in our present and future cities.

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