

Statistical Analysis of the Urban Population and its Amenities in Multiple Ring Buffers of Largest Cities in Different Regions of India.

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Abstract

In this paper Walter Christaller's Central Place Theory is used to examine the spatial relationship between urbanization and infrastructure across five regions of India: NCR, Southern, Eastern, Western, and Central (Mitra, Mukherji, and Bose, 1980). Using the largest city in each region as the core, multiple ring buffers (0–50 km, 50–100 km, and beyond 100 km) were generated using ArcGIS 10.8.1. The study analyses city size classes and infrastructure indicators such as number of latrines, electricity connections, and hospitals within these buffers using Census 2011 data from District Census Handbooks and HL-14 tables. Statistical methods including descriptive, correlation, and regression analyses were employed.

Findings reveal regional disparities in infrastructure quality. The National Capital Region (NCR), Southern, and Eastern regions exhibit better infrastructure within the 50 km ring, while the Western region shows higher quality beyond 100 km. The Central region displays mixed outcomes across all rings. A strong positive correlation is observed between urbanization and infrastructure within the 0–50 km and 50–100 km rings, but the correlation weakens positively beyond 100 km. Regression analysis identifies latrines, electricity connections, and hospitals as significant predictors of urban growth, with exceptions: electricity is not a significant factor in the 50 km and beyond 100 km rings of NCR and in the Southern region's 50–100 km ring. This study underscores the spatial variation in urban infrastructure development and its alignment with urban population distribution in India.

Keyword: Multiple ring buffer, Dominance ratio, Amenities, Quality of Life Index (QLI), Correlation and Regression.

Mathematics Subject Classification: 62J20, 62H20, 62S25.

1. Introduction

India's urban population has grown rapidly in the 21st century, reaching over 377 million by 2011 (31.16% of the total population). The country had 53 cities with populations exceeding one million, including three mega cities Mumbai, Delhi, and Kolkata each with over 10 million people. By 2011, Delhi

had surpassed Kolkata as the second-largest urban agglomeration after Mumbai. These cities also rank among the world's ten most populous cities.

Walter Christaller (1933) introduced Central Place Theory (CPT) as a way to explain the location, number, and size of settlements, where these locations acted as central places that provided services to surrounding areas. The phenomenon of central place theory is the relationship between settlements of different sizes, related to their economic activities with the population and it is based upon the central place system and city size distribution, and Walter Christaller was the first person to develop the central place theory, he tested this theory in Southern Germany and concluded that people assemble in cities to share goods and ideas in that central place which exist for purely economic reason. In urban geography and urban economics, Central Place Theory is the spatial theory, and it explains the spatial arrangements, patterns and distributions of urban areas and human settlements. India is commonly divided into five broad regions viz., NCR, Southern, Eastern, Western and Central regions (Mitra, Mukherji, & Bose, 1980).

The rapid, unplanned growth of metropolitan cities in India are largely driven by population explosion and rural-to-urban migration which is one of the most pressing issues that the country might face. This uncontrolled urbanization is leading to severe environmental degradation, resulting in Water, Air and Noise pollution and also housing shortages leads to increasing the slums. Cities like Mumbai, Kolkata, Delhi, and Bangalore are witnessing the worsening effects of this haphazard growth, and the situation is progressively deteriorating (Jitendra Kumar, 2015).

Access to basic amenities is a key factor in determining the quality of urbanization. Essential services such as electricity, water, sanitation, and clean fuel play a crucial role in shaping the living conditions and overall health of urban populations. These amenities are fundamental in ensuring a decent standard of living and promoting well-being in rapidly growing urban areas (R. B. Bhagat, 2011).

Improving access to essential services such as clean water, housing, sanitation, electricity, and drainage plays a vital role in enhancing people's living conditions. International organizations like UNDP, UN-HABITAT, UNESCAP, ADB, and the World Bank emphasize the importance of these basic amenities, recognizing their contribution to well-being, comfort, and overall quality of life. (Arjun Kumar, 2015). The quality of infrastructure is an essential prior condition for economic growth and social development. India's economic development poses a serious threat if there is a lack of infrastructure facility (Annmary Jose, 2019).

Spatial inequalities persist across India's urban landscape, and decentralization efforts have achieved only partial success. As a result, certain dominant states continue to shape regional dynamics, while economically stronger states influence national urban patterns. This concentration of urban growth is reflected in the phenomenon of urban primacy, where a single major city holds a disproportionately large share of the urban population (Das and Dutt, 1933).

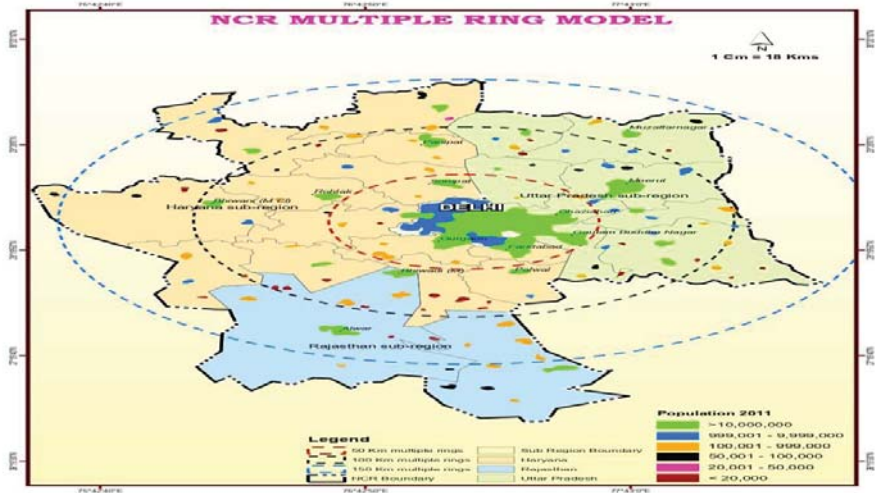
Regional disparity in India is attracting a lot of attention in urban development. The high urbanized region in India is Southern and Western region and these regions have many slums. Whereas the Eastern region has low levels of urbanization, and this region has a huge proliferation of slum population which exerts pressure on the basic urban amenities and infrastructure, and this determines the standard of living (Mala Mukherjee, 2017). Seema Rani (2021) has given an attempt to study the spatial and temporal pattern in drinking water source availability and accessibility for the period 1981-2001 for Indian states and shows that India gained a significant advancement in drinking water from 1981 to 2011.

This paper consists of multiple ring buffers for different regions of India. It is considered the largest city of the region as a core center for the multiple ring buffers and covers up to whole state of that region and considers only that state for the study of distance affecting the amenities. For different regions like the National Capital Region (NCR), Southern region, Eastern region, Western region, and Central region, the largest cities in these regions respectively are Delhi, Chennai, Kolkata, Mumbai and Kanpur. The objective is to promote the decentralization of economic activities and housing development from largest city centre to different rings, and to examine how distance from these centres influences settlement transformation across different regions of India. The urban settlement boundaries were digitized using Geographic Information System ArcMap, this paper also examines the impact of distance on various tiers of settlements surrounding the largest cities in three different rings of the National Capital Region (NCR) as well as the Tamil Nadu, West Bengal, Maharashtra, and Uttar Pradesh states of India. It also explores the distribution of urban amenities across these settlements. The paper is organized into four sections: the first introduces the study, the second outlines the data sources and methodology, the third presents the analysis and interpretation of findings, and the final section concludes the study.

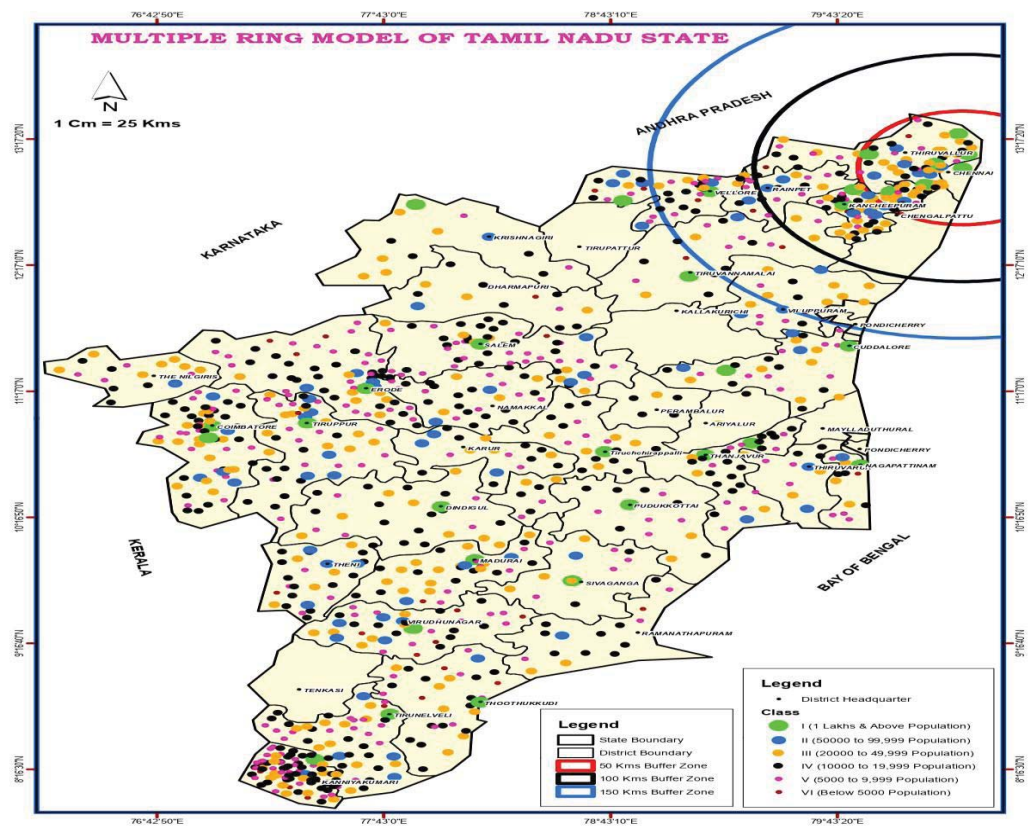
2. Methods and Materials

The data for the study is collected from the Census of India for the year 2001 and 2011 from District census Handbook which were used to extract urban population, number of latrines, number of electricity connections, number of colleges, number of hospitals, number of stadiums and tap drinking water. All urban settlements in all the regions were classified into million plus cities (>1000000), cities (100000-1000000), large (50000-100000), middle (20000-50000) and small (<20000) settlements. Further population classification, million-plus cities and other large urban centres are categorized as upper-tier cities, while medium and small cities are classified as lower-tier cities. To assess the impact of distance on urban transformation, these categories were further analysed using multiple ring buffers generated in ArcGIS 10.8.2. (see maps 1 to 5).

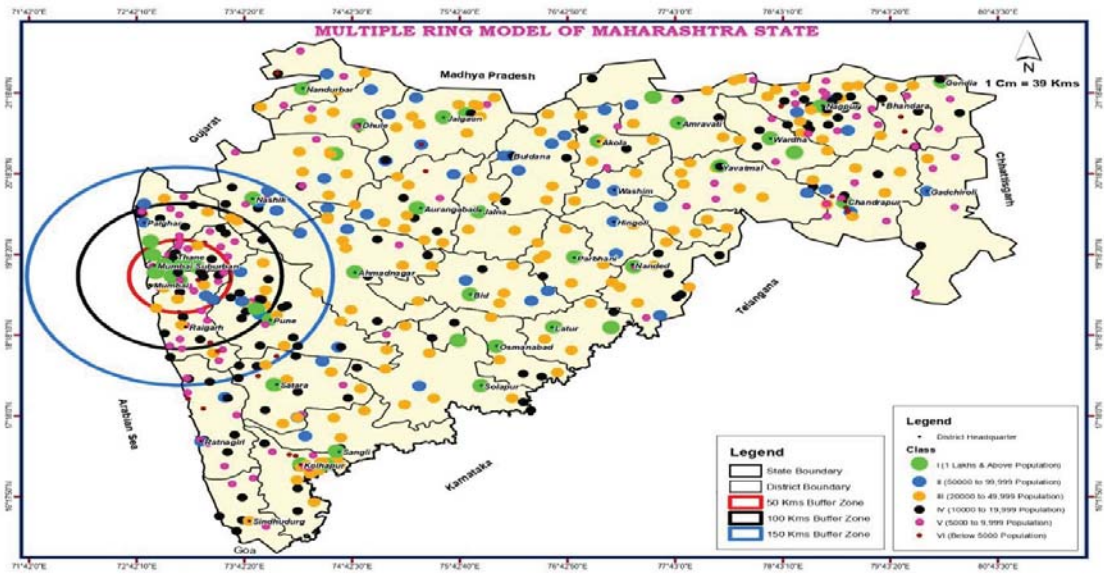
Map 1. Multiple ring buffers map of NCR.



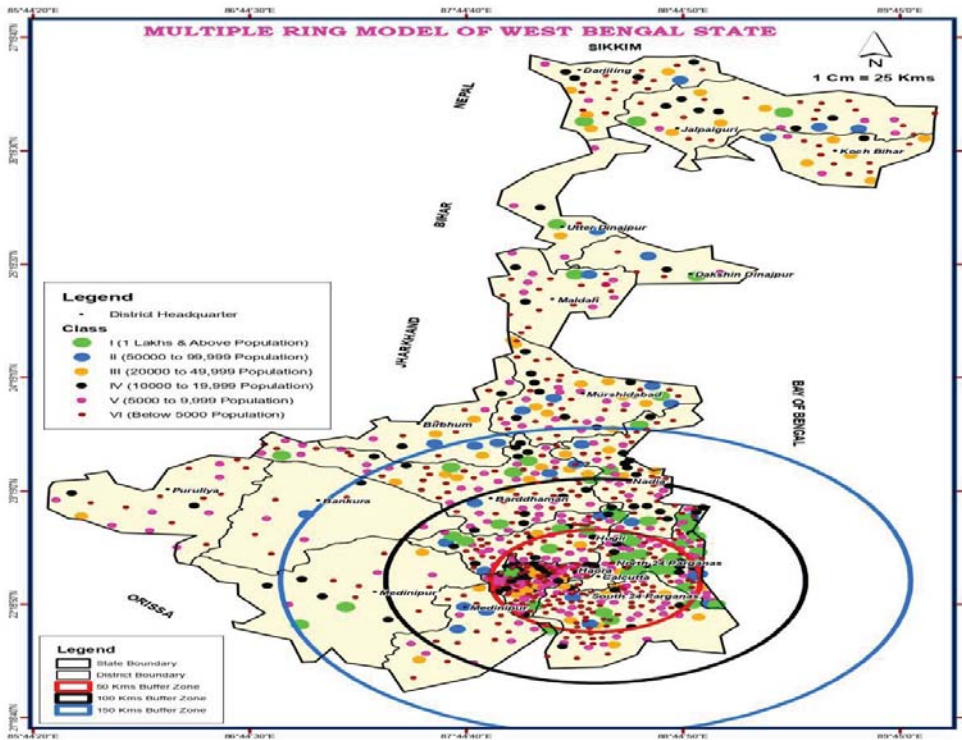
Map 2. Multiple ring buffers map of Southern region.



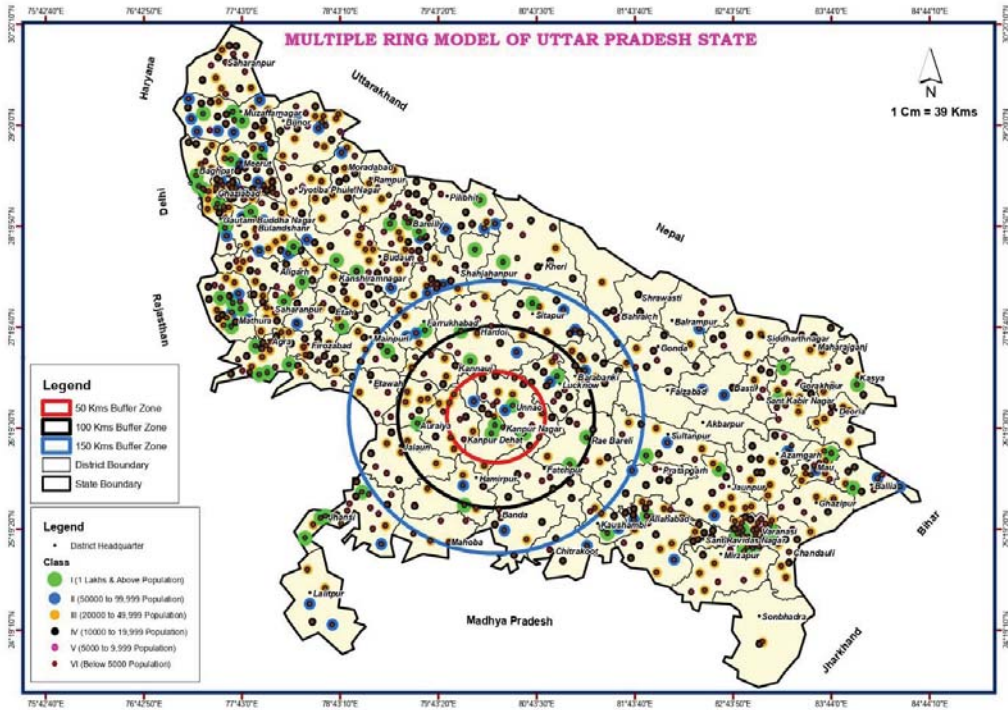
Map 3. Multiple ring buffers map of Western region.



Map 4. Multiple ring buffers map of Eastern region.



Map 5. Multiple ring buffers map of Central region.



2.1 Construction of Quality-of-Life Index

The Quality-of-Life Index was constructed using Principal Component Analysis (PCA) based on six indicators to assess holistic urban development across different regions of India. Additionally, a region-wise analysis was carried out to facilitate inter-regional comparisons.

Principal Component Analysis (PCA) is applied for construction of Quality-of-Life Index. The variables used in this index are namely Number of Latrines, Electricity connections, Number of Hospitals, Number of Schools/Colleges, Number of Stadiums and Drinking water facilities. The first step in PCA has been normalized for each variables using standardization technique which is given as,

$$Z_{ti} = \frac{X_{ti} - \mu_t}{\sigma_t}$$

Where X_{ti} , is a value for t^{th} variable of i^{th} city, $i=1,2,\dots, c$

μ_t is mean of t^{th} variable,

σ_t is standard deviation of t^{th} variable and

Z_{ti} is standardized values of t^{th} variable of i^{th} city.

In this study, after standardizing the variables, weights for each variable were assigned based on the coefficients derived from the first principal component (PC1), which captures the highest variance among all components. Principal Component Analysis (PCA) is an unsupervised data-mining technique commonly used for dimensionality reduction. It aims to reduce data complexity while retaining as much variability as possible, assigning composite weights across observations. Mathematically, PCA transforms an initial set of n correlated variables into a new set of uncorrelated principal components,

each representing a linear combination of the original variables weighted by their contribution to total variance.

The value of the index for component K of QoL is given below. Index K of city 'i' can be obtained as,

$$Index\ K = \sum_j \alpha_j^k x_{i,j}^{rk}$$

Where $x_{i,j}^{rk}$ is j^{th} transformed variable of component k for city 'i' and α_j^k is the weight corresponding to indicator j of component k derived from the first PC.

After finding out the Quality-of-life Index values for all the three rings with respective different regions. The percentiles are calculated for each index, finally ranges based on percentiles are obtained which are very low, low, average, high and very high quality of life of cities.

2.2 Correlation and Regression Analysis

To examine the relationship between urbanization and various amenities, Karl Pearson's correlation coefficient was computed. Additionally, to assess the impact of specific amenities on the level of urbanization, a regression model was developed. In this model, the percentage of urban population serves as the dependent variable, while selected explanatory variables include the number of latrines, hospitals, schools/colleges, stadiums, electricity connections, and access to drinking water facilities. The regression model is given below

$$U(t) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6$$

Where, β_0 = Intercept, $\beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6$ = Regression Coefficients.

X_1 = Number of latrines, X_2 = Electricity connections, X_3 = Number of Hospitals,

X_4 = Number of Colleges, X_5 = Number of Stadiums, and X_6 = Drinking water facility

3. Analysis and Interpretation

The research followed a three-step approach. The first step focused on analysing the effect of distance on urban transformation and the dominance of million-plus cities across the NCR and four regions of India. The second step examined how distance influences the transformation of different classes of settlements within these regions. The final step assessed the quality of life in urban settlements region-wise. To study the spatial effect, each region was divided into three concentric 50 km rings, centred on major urban hubs: Delhi (covering parts of Haryana, Uttar Pradesh, and Rajasthan within the NCR), Chennai in the Southern region, Kolkata in the Eastern region, Mumbai in the Western region, and Kanpur in the Central region. While most of these are mega cities, Kanpur represents a major metropolitan centre (see, Maps 1-5).

3.1 Distribution of dominance ratio in different rings

As part of the first step, the dominance of million-plus cities within each region was examined and is presented in Table 1, while Table 2 outlines the indicators used to analyse the spatial

transformation of settlements. Following Mutlu's (1989) framework, the dominance ratio was employed to assess the extent of million-plus city dominance over other cities. According to Mutlu, a city is considered primate if the population of the largest city is atleast twice that of the second-largest city. In this study, the dominance ratio was calculated by dividing the total population of million-plus cities by the total population of all other cities category within the same ring.

Table 1. Dominance Ratio in five different states of largest cities in India for 2001 and 2011.

	Delhi		50 km		50-100 km		Beyond 100 km	
	2001	2011	2001	2011	2001	2011	2001	2011
NCR	6.8	4.5	0.5	1	0.8	0.6	NM	NM
Tamil Nadu	NA	NA	4.19	3.32	NM	NM	NM	0.39
West Bengal	NA	NA	1.14	0.99	NM	NM	0.24	0.24
Maharashtra	NA	NA	5.54	5.89	1.97	NM	0.73	0.99
Uttar Pradesh	NA	NA	10.41	9.67	7.76	7.25	0.41	0.5

Source: Census of India 2001 and 2011.

Note: NA- not applicable, NM- No Million Plus cities.

In Table 1 the study shows in NCR, highest dominance ratio is seen in Delhi state is 6.8 in 2001 and 4.5 in 2011 census this shows that Delhi's population which was 6.8 times of the totals of the cities categories, because of highest employment and population concentration. The dominance ratio in 50 km ring in 2011 shows double the size in 2001, this may be due to the inclusion of Ghaziabad million plus city.

In Tamil Nadu state of Southern region, dominance ratio is 4.19 in 2001 and is declined to 3.32 in 2011 in 50 km ring and also 50 km ring of West Bengal of Eastern region shows dominance ratio only in 2001 (1.14), whereas in Maharashtra state of Western region both census 2001 (5.54) and 5.89 in 2011 for 50 km ring shows dominance ratio and for 100 km ring a dominance ratio is seen only in 2001 (1.97), lastly in Uttar Pradesh state of Central region dominance ratio in 50 km ring is 10.41 for 2001 census and 9.67 for 2011 and in 100 km ring 7.76 in 2001 and 7.25 in 2011 census, this ratio is highest among all the regions of India. This is due to the reason that in 50 km ring no other city shows larger population as compared to Kanpur in 50 km ring and Lucknow in 100 km ring 2001 and 9.67 in 2011.

3.2 Distribution of Spatial Transformation in different rings

The second step of the study focuses on urban transformation, with findings presented in Table 2. In the National Capital Region (NCR), the 50 km ring exhibits the largest urban settlement area. According to the 2001 and 2011 Census data, Delhi state recorded the highest growth in urban settlement, with a 37.83% increase. The urban population growth rate in the 50 km ring of the NCR rose significantly to 88.48%, surpassing that of the other rings. In terms of population density, the 50–100 km ring had the highest density in 2001; however, by 2011, the inner 0–50 km ring became the most densely populated.

Hence this shows that as distance from the core centre of the Delhi increases, the urban settlement, urban population, density and the urbanization level goes on decreasing. In Tamil Nadu state of Southern region, the highest urban settlement is observed in beyond 100 km (9160.13 sq. km)

in 2001 and 121660 (sq. km) in 2011 as this area is bigger than other two rings and the lowest is observed in 50 km ring by 720.74 sq. kms. in 2001 and 892.31 sq. kms in 2011 even this is same in urban population, where the density in Tamil Nadu state is high in 50 km ring for both the census period and as distance increases this density goes on decreases, also the urbanization level is high in the 50 km ring by 77.70%, and it goes on decreasing as distance increases. The similar case is observed in Eastern region of West Bengal state but in this state, Kolkata shows negative growth rate in urban settlement (-0.66%) as well as in urban population by -1.83% and in 50 km ring because of decline in terms of offering jobs, particularly manufacturing sectors which is a prime cause of declining population, decline of fertility rate is also another cause. The large-scale shutdown of manufacturing units, stagnation in industrial activity, and the closure of several processing facilities have contributed to negative population growth in certain areas. Additionally, the declassification of some statutory towns and their subsequent merger with adjacent urban centres may also account for the observed population decline. (Anwaruzzaman et.al., 2018). The density in West Bengal state during 2001 census shows highest in beyond 100 km ring later in 2011 census period, the highest density is taken place by 50 km ring and as distance increases the density and urbanization goes on decreasing from 50 km to beyond 100 km ring.

Table 2. Indicators of Spatial Transformation in Multiple Ring Buffers for 2001 and 2011.

	Urban Area (km ²)		Urban Population		Density		Growth Rate (%)		Urbanization Level
	2001	2011	2001	2011	2001	2011	Area	Population	2011
Delhi	783.61	1080.02	12905780	16368899	1646965	1515611	37.83	26.83	28.15%
50km	921.78	1140.23	3606496	6797473	391253	596149	23.7	88.48	11.70%
50-100km	803.25	972.55	4428140	5629146	551278	578803	21.08	27.12	10.00%
beyond 100km	565.09	644.16	2369920	2918755	419388	453110	14	23.16	4.75%
Chennai	175	175	4343645	4646732	2482083	2655275	0	6.98	53.69%
50km	720.74	892.31	6418117	7987771	890490	895179	23.8	24.45	77.70%
50-100km	515.41	577.25	1233503	1833265	239325	317586	12	48.62	50.71%
beyond 100km	9160.13	12166	19779239	25096404	215927	20628	32.81	26.88	42.33%
Kolkata	186.23	185	4580546	4496694	2459618	2430645	-0.66	-1.83	31.86%
50km	1136.48	1127.51	5230643	7404387	460249	656703	-0.79	41.56	53.03%
50-100km	1106.14	1172.68	4389386	5695966	396820	485722	6.02	29.77	31.42%
beyond 100km	2731.17	2770.21	13233111	15590856	484522	562804	1.43	17.82	20.63%
Mumbai	603	603	11978450	12442373	1986476	2063412	0	3.87	67.56%
50km	781.38	781.38	17602008	20172221	2252682	2581615	0	14.6	77.82%
50-100km	1211.12	1218.95	2195751	3924259	181299	321938	0.65	78.72	55.50%
beyond 100km	7338.62	7566.8	21509076	27127686	293094	358509	3.11	26.12	38.40%
Kanpur	17.19	17	2555811	2768057	14868010	16282688	-1.1	8.3	66.00%
50km	447.55	450.312	3205119	3542565	716148	786691	0.61	10.52	39.22%
50-100km	848.86	1111.78	3546622	4633221	417810	416739	30.97	30.63	24.05%
beyond 100km	6391.99	6418.25	27656178	35807850	432669	557907	0.41	29.47	21.02%

Source: As in Table 1.

In Maharashtra state of Western region of India, the urban settlements go on increasing from 50 km ring to beyond 100 km ring by almost 3% and the growth rate of urban population increased from 50 km to 100 km ring from 14.0% to 78.71% and it got decreased in beyond 100 km ring by 26.12%, whereas the Maharashtra state 50 km ring shows highest density as compared to other rings in this state and the level of urbanization is decreasing as distance increases. In case of Kanpur similar case is identified in Central region of Uttar Pradesh state where the density in 50 km ring shows highest as compared to other rings for both the census period.

3.3 Distribution of Total Settlements in different rings

The third step of the study focused on analysing the effect of distance on the transformation of different tier settlements across the five different states of India. Urban settlements were classified into five categories. million-plus cities, cities, large, middle, and small settlements.

Table 3. Total Number of Settlements in Different Categories of Cities in Five Different states of India for 2001 and 2011.

Categories of cities	50 Km		50-100 Km		beyond 100 Km	
	2001	2011	2001	2011	2001	2011
NCR						
Million Plus Cities	1	2	1	1		
Cities	15	21	9	13	6	6
Large	12	24	9	13	3	3
Medium	32	36	20	22	20	26
Small	71	82	43	46	27	34
Tamil Nadu						
Million Plus Cities	1	1			1	2
Cities	6	7	2	2	18	23
Large	1	7	2	7	53	66
Medium	21	31	16	21	146	196
Small	24	30	27	35	510	672
West Bengal						
Million Plus Cities	1	1			1	1
Cities	20	21	18	17	21	23
Large	3	3	6	10	20	24
Medium	13	21	9	12	33	49
Small	69	245	56	169	105	291
Maharashtra						
Million Plus Cities	3	4	1	2	3	4
Cities	9	8	2	2	27	32
Large	4	3	3	4	38	31
Medium	3	7	7	11	128	156
Small	18	29	20	27	109	212
Uttar Pradesh						
Million Plus Cities	1	1	1	1	4	5
Cities	3	4	3	4	48	58
Large	1	2	4	6	51	56
Medium	3	11	13	17	162	211
Small	23	20	42	50	349	471

Source: As in Table 1.

These settlement categories were further differentiated in multiple ring buffers to assess the effect of distance on urban transformation. Between 2001 and 2011, noticeable changes occurred across different classes of urban settlements in all five different states of India. In the National Capital Region (NCR), a sharp increase in urban settlements was observed across all rings during both census years. However, a decline in the number of settlements was noted as the distance from Delhi increased. In contrast, other states of respective regions exhibited growth across all urban categories, with a greater increase in settlements beyond the 100 km ring attributable to the larger geographical coverage of this outer zone compared to the inner 50 km ring (see Table 3).

3.4 Percentage of Amenities in Different rings

The fourth step focused on assessing the quality of life in urban settlements across the NCR and largest cities state of respective four regions of India. Deficiencies in urban amenities can significantly undermine living standards. To gain a deeper understanding, the per capita availability of amenities in 2011 was analysed based on distance from the largest city in each region. The percentage of urban amenities in each city category was calculated by dividing the total number of amenities within a ring by its population and multiplying the result by 100. Hospitals and stadiums were measured per 100,000 inhabitants, while colleges were assessed per 10,000 inhabitants. A lower per capita provision of latrines and electricity connections reflects a lower standard of living. Similarly, limited access to hospitals, degree colleges, and stadiums suggests overpopulation or insufficient infrastructure.

Table 4 presents the percentage distribution of urban amenities across different rings and city categories for the year 2011. In Delhi state, lower-tier settlements exhibit better access to urban services compared to higher-tier settlements. Within the 50 km ring, small cities report the highest percentage of urban amenities across most categories, except for electricity connections, which are more concentrated in cities. The number of hospitals and the availability of treated drinking water are notably higher in million-plus cities within this ring—specifically Delhi, Ghaziabad, and Faridabad due to their more developed infrastructure and service provision.

Table 4. Percentage of Amenities in NCR 2011 with respective different categories of cities.

Categorie s of Cities	Number of Latrines/ 100	Electricity Connection/100	Number of Hospitals /1 lakh pop	College s / 10000	Stadium / 1 lakh	Tap drinking water
NCR						
Million plus	19.63	22.62	5.61	4.19	8.39	55.48
Cities	18.58	20.67	4.73	1.17	2.34	54.98
Large	19.97	22.43	3.43	2.88	5.77	54.87
Middle	20.17	25.7	8.82	5.89	11.76	55.33
Small	22.12	26.79	10.5	16.87	33.91	55.21
50 km ring						
Million plus	11.56	21.5	18.45	6.79	9.13	55.3

cities	15.11	36.48	8.92	3.87	5.76	51.97
large	18.83	21.62	4.37	2.57	4.96	51.74
middle	19.09	24.67	10.15	4.77	8.57	52.18
small	20.38	25.26	12.22	33.85	27.69	52.43
100 km						
Million plus	9.28	19.28	17.21	5.6	9.12	39
Cities	11.31	23.73	4.96	3.68	4.17	43.26
Large	10.56	16.6	3.62	2.15	4.2	44.37
Middle	13.76	16.26	9.43	4.63	5.82	45.84
Small	14.28	16.73	11.46	32.68	24.73	45.06
Beyond 100 km						
Cities	10.64	17.64	4.72	1.95	1.12	41.53
Large	10.18	16.06	3.25	1.73	4.09	42.23
Middle	13.6	16.05	9.08	3.6	1.2	31.24
Small	14.27	15.08	11.05	31.2	25.3	42.32

Source: As in Table 1 and author computation.

In 100 km ring the percentage of latrines, colleges, stadiums and treated sources of drinking water are high in lower tier settlements and electricity connection is high in higher tier settlements, only the number of hospitals is high in million plus cities. And in beyond 100 km ring the number of electricity connections is better in higher categories of cities than the lower category of cities and whereas other amenities are opposite direction, but the source of drinking water from treated source is good in all the categories of cities except in the middle category of city.

By observing these results, study says that as the distance from the center of largest city Delhi increases the provision of urban amenities decreases in all types of settlements and the results also says that there are good facilities of amenities in Delhi and as the distance increases these facilities become low. It might be because of the concentration of better amenities around Delhi which is the result of its role as a political, economic, and administrative centre. As distance increases, these advantages reduce due to lower investment, lesser budget based on population, and weaker governance frameworks. Distance away from the centre have fewer industries, IT parks, or service centres, leading to less development pressure (see Table 4). The policy recommendation for this region is investment in middle and large cities beyond 50 km to address the infrastructure lag, strengthen water supply systems in metros and their peripheries, especially NCR and cities within 100 km, promote balanced regional development by integrating small towns into urban planning and improving connectivity, capitalize on small-town infrastructure strengths and support their growth as future regional hubs.

Table 5 shows amenities in different rings including Tamil Nadu a state of Southern region better infrastructure facilities for the amenities like number of latrines, electricity connections and drinking water facility in million plus cities compared to other categories of cities with respect to all the urban services, similar observation is seen in 50 km ring and 100 km ring, in beyond 100 km ring million plus cities shows better facilities for number of latrines, electricity connections and colleges, number of hospitals, stadiums and drinking water facilities is good in small categories of cities.

Million plus cities percentage of urban amenities like number of latrines, electricity connections and drinking water facilities decreases as distance gets increase from the center and the remaining three amenities increase as distance increases, similar observation is seen in all the categories of cities. Hence large populations justify larger investments in public amenities and more efficient use of infrastructure, million plus cities in this region might generate more tax revenue, higher revenue means more funds for civic services infrastructure and maintenance, whereas in the smaller cities despite being in a developed region still face challenges in budget, planning and investment that limit their amenities. Tamil Nadu shows strong concentration of social infrastructure in small towns (health, education and stadiums), but basic utilities deteriorate with city size and distance highlighting a need for balanced development beyond metropolitan cities.

Table 5. Percentage of Amenities in Tamil Nadu state of Southern region 2011 with respective different categories of cities.

Tamil Nadu	Number of Latrines / 100	Electricity Connection /100	Number of hospitals /1 lakh pop	Colleges / 10000	Stadium / 1 lakh	Tap Drinking water (%)
Million plus	24.14	35.98	5.73	0.16	0.18	87.17
Cities	23.3	32.37	5.06	0.83	1.05	68.59
Large	20.48	31.22	8.99	5.22	7.86	65.95
Middle	19.23	29.51	16.25	12.34	20.08	60.56
Small	16.01	29.84	33.54	32.62	45.34	55.87
50km						
Million plus	23.81	38.05	6.8	0.77	0.09	93.1
Cities	24.51	35.67	6.23	0.22	4.37	10.7
Large	22.31	23.71	5.42	0.78	1.08	40.17
Middle	23.58	31.75	11.03	0.38	11.83	47.04
Small	19.94	25.76	23.78	0.74	12.17	51.84
100km						
Cities	23.67	23.79	5.27	0.48	2.01	6.7
Large	22.36	22.94	8.4	0.44	8.62	18.56
Middle	17.87	24.19	14.65	0.53	16.99	10.71
Small	15.41	25.54	35.74	0.83	20.97	23.02
Beyond 100 km						
Million plus	22.9	31.34	3.34	3.48	0.39	2.75
Cities	22.3	20.14	4.1	0.49	2.08	1.5
Large	19.71	21.76	8.27	0.44	5.58	15.6
Middle	17.34	23.48	17.31	0.54	7.82	9.62
Small	15.05	20.23	33.9	0.85	12.42	21.66

Source: As in Table 1 and author computation.

Enhancing the basic utilities (drinking water and electricity) in small and distant towns, especially beyond 50 km. Maintaining and supporting the higher density of educational and health infrastructure in small towns. Addressing the disparity in tap water access, which is alarmingly low beyond 50 km.

Utilizing the strength in social infrastructure to promote regional centres of growth beyond metropolitan cities like Chennai and Coimbatore are the policy recommendations for this region.

In West Bengal, part of the Eastern region, million-plus cities exhibit a higher concentration of key urban amenities such as the number of latrines, electricity connections, and access to treated drinking water compared to lower-tier settlements. This indicates better infrastructure provisioning in these larger urban centres. In contrast, lower-tier settlements show limited access to hospitals, colleges, and stadiums, likely due to inadequate funding for such facilities. Within the 50 km ring, million-plus cities demonstrate the highest percentage of urban services; however, this percentage declines as distance from the city centre increases. A similar trend is observed across other settlement categories, with the exception of large cities, where the availability of latrines slightly increases from the 50–100 km ring to areas beyond 100 km.

Table 6. Percentage of Amenities in West Bengal state of Eastern region 2011 with respective different categories of cities.

West Bengal	Number of Latrines / 100	Electricity Connection /100	Number of hospitals /1 lakh pop	Colleges / 10000	Stadium / 1 lakh	Tap Drinking Water / 100
Million plus	16.81	37.22	0.5	0.38	2.46	77.4
cities	14.25	26.18	0.01	2.82	0.93	54.45
large	5.51	7.38	0.01	7.15	5.64	36.89
middle	4.84	6.48	0.01	19.59	17.13	25.75
small	8.44	9.52	0.02	141.12	109.63	21.58
50 km						
Million plus	17.57	40.4	0.11	0.13	4.14	84.9
cities	14.28	28.37	5.85	2.82	0.46	49.96
large	10.56	12.81	5.11	24.25	0.46	78.57
middle	17.58	18.47	13	32.13	47.26	23.84
small	15.37	16.85	26.56	96.38	176.44	19.52
100 km						
cities	14.12	18.29	12.56	2.06	2.45	44.71
large	15.86	11.79	6.18	26.55	20.65	48.81
middle	15.52	18.8	26.11	39.65	55.42	14.25
small	15.9	16.23	30.52	145.55	180.13	6.91
Beyond 100 km						
Million plus	13.64	23.95	2.14	2.25	12.72	70.2
cities	14.29	18.32	9.67	3.29	3.78	42.12
large	15.49	10.88	15.64	27.63	25.4	40.12
middle	12.62	17.24	27.73	70.77	56.26	10.12
small	13.37	16.48	32.55	430.4	226.63	0.12

Source: As in Table 1 and author computation.

In contrast, the provision of hospitals, colleges, and stadiums is better in lower-tier settlements which indicate a low accessibility of amenities. Kolkata is the largest million plus city in this region which has been a million plus city since 1901 and it was the only million plus city in the country at that time, therefore the million plus cities have better amenities than other categories of cities due to urban concentration and infrastructure planning. Policy recommendations for this region are prioritizing basic

infrastructure (tap water and electricity) in small and remote urban centres. Balance infrastructure allocation i.e., align the development of health and education services with basic utilities. Promote equitable urban planning to bridge disparities between Kolkata and smaller towns in the region (see Table 6).

In Table 7 Uttar Pradesh state of Central region shows million plus cities have good endowment of amenities due to high percentage in number of electricity connections and drinking water from treated source and lower tier settlements have high percentage of number of latrines, hospitals, colleges and stadiums. 50 km ring shows a high percentage of the number of latrines, electricity connections, number of hospitals and drinking water from treated sources in higher tier settlements compared to other lower settlements, whereas remaining amenities like number of colleges and hospitals shows highest percentage in lower tier cities.

Table 7. Percentage of Amenities in Uttar Pradesh state of Central region 2011 with respective different categories of cities.

Uttar Pradesh	Number of Latrines / 100	Electricity Connection/ 100	Number of hospitals /1 lakh pop	Colleges / 10000	Stadium / 1 lakh	Tap Drinking water
Million plus	9.06	22.18	48.51	1.91	0.11	63.83
cities	9.51	20.66	24.9	1.07	0.72	44.71
large	9.79	15.77	49.84	7.31	5.36	38
middle	10.83	14.31	57.18	17.43	13.3	32.95
small	9.57	13.3	36.43	46.94	35.89	27.82
50km						
Million plus	15.94	21.63	21.73	0.12	0.07	63.83
Cities	14.49	21.78	21.93	0.43	0.23	69.1
Large	13.68	24.25	24.26	6.19	4.76	65.65
Middle	10.14	17.86	18.3	20.61	15.7	19.42
Small	8.8	12.05	12.98	56.48	43	26.83
100km						
Million plus	12.12	21.59	12.09	0.1	0.07	53
Cities	12.93	24.24	11.6	0.37	0.28	41.93
Large	8.21	20.11	58.32	7.16	5.07	31.22
Middle	10.72	16.81	49.77	15.31	11.78	19.31
Small	7.8	12.47	80.34	45.16	34.77	25.67
Beyond 100 km						
Million plus	5.06	21.38	15.54	0.25	0.14	50.1
Cities	8.24	19.94	10.86	12.7	0.86	31.1
Large	9.86	15.18	11.2	7.35	5.4	31.16
Middle	10.87	13.95	14.63	17.49	13.33	10.22
Small	9.77	13.4	18.59	46.78	35.74	21.19

Source: As in Table 1 and author computation.

In 100 km ring, it shows better facilities of amenities in million plus cities and low facilities in lower tier settlements because of the high percentage in number of latrines and drinking water from treated sources in million plus cities and low level of hospitals, colleges and stadiums. The higher percentage of latrines, electricity connections and safe drinking water is observed in higher tier cities as compared to lower tier cities, on contrary number of hospitals, colleges and stadium shows higher percentage in lower tier cities and highest percentage is observed for small categories of cities. However, in beyond 100 km ring middle cities show a high percentage in high percentage of electricity connections and drinking water from treated sources in million plus cities and number of hospitals, colleges and stadiums shows high value in small cities. Number of electricity connections and drinking water are high in upper tier cities and rest of the amenities are high in lower tier cities.

Overall, in multiple ring buffers 50 km rings most of the high endowment of facilities is seen in first 50 km ring. In this state a million plus cities in 50 km ring shows a highest availability of amenities compared to other million plus cities in 100 and beyond 100 km ring. In this region Kanpur in 50 km ring have a good facility of amenities than other largest cities as being a capital city, Kanpur has benefitted from planned urban development and it might receive more funds under schemes like Smart Cities Mission, AMRUT etc. which improves amenities like water supply, drainage, transportation and housing and even Kanpur has major institutions like King George's Medical University, Indian Institute of Management and Dr. Ram Manohar Lohia Institute which attract students, professionals and health care seekers justifying better infrastructure and amenities.

Policy recommendations for Uttar Pradesh shows that expand electricity and water infrastructure in small and middle towns especially beyond 50 km radius. Leverage strong social infrastructure in small towns to promote them as regional service hubs. Improve integration between physical infrastructure (water and electricity) and social services (health and education) for balanced development. Focus on latrine and tap water coverage, particularly where existing indicators remain modest.

In the Western region, specifically in Maharashtra, Table 8 reveals that lower-tier settlements generally have a higher percentage of urban amenities, including latrines, electricity connections, hospitals, colleges, and stadiums except for drinking water from treated sources, where upper-tier cities show better endowment. Within the 50 km ring, lower-tier settlements report the highest percentage of electricity connections, hospitals, and stadiums compared to upper-tier cities. However, upper-tier cities lead in the provision of latrines, colleges, and treated tap water.

Table 8. Percentage of Amenities in Maharashtra state of Western region 2011 with respective different categories of cities.

Maharashtra	Number of Latrines / 100	Electricity Connection /100	Number of hospitals /1 lakh pop	Colleges / 10000	Stadium / 1 lakh	Tap Drinking water
Million plus	10.34	7.43	0.7	0.21	0.15	91.36
cities	11.15	17.33	2.6	0.93	0.04	82.75
large	12.59	23.06	8.73	7.97	1.05	76.17
middle	12.21	23.42	13.45	17.35	2.59	67.86

small	12.46	22.01	19.83	51.7	5.57	60.31
50 km						
Million plus	8.48	4.33	0.4	0.08	0.15	94.88
cities	9.02	10.53	0.84	0.32	0.29	94.73
large	8.83	20.32	5.25	7.73	1.09	87.7
middle	9.59	26.51	6.74	0.1	10.06	86.33
small	5.51	18.55	12.77	0.52	20.4	75.23
100 km						
Million plus	8.98	18.13	1.23	0.66	0.27	83.8
cities	8.98	18.13	2.31	0.66	0.27	88.43
large	13.52	25.15	17.4	7.9	5.8	87.43
middle	11.78	27.02	17.57	0.17	13.18	84.67
small	12.65	21.23	12.98	0.53	41.75	68.09
Beyond 100 km						
Million plus	20.56	17.79	1.38	1.59	1.07	89.85
cities	14.05	25.19	4.73	1.69	0.48	63.31
large	14.46	22.51	18.02	8.8	8.14	62.94
middle	11.77	22.45	17.8	1.16	25.95	63.37
small	12.8	21.66	19.41	1.49	53.63	63.09

Source: As in Table 1 and author computation.

In the 100 km ring, most amenities remain concentrated in lower-tier settlements, except for colleges and treated drinking water, which are more prominent in upper-tier cities. Beyond the 100 km ring, million-plus cities exhibit the highest share of latrines and access to treated water; electricity connections are most prevalent in the cities category; hospitals and stadiums are concentrated in small cities, while middle-tier cities have the highest number of colleges. Overall, upper-tier cities dominate in the provision of latrines, electricity, colleges, and treated water, whereas lower-tier settlements show higher concentrations of hospitals and stadiums.

In this state as the distance increases from the center the amenities of urban services increase which is reverse from all other considered states of India. This might be because of urban population pressure, infrastructure strain, and uneven urban development, which makes the cities struggle to keep infrastructure and public services up to speed with rapid growth of population also the slum proliferation in the 50 km ring of Western Indian cities of Maharashtra state reflects the failures of affordable housing, coordinated planning, and infrastructure provisioning. Until these informal settlements are integrated into formal urban plans with secure tenure and civic rights infrastructure gaps will persist. Areas farther from Mumbai like Pune, Nashik etc. have lower population density, more open spaces and greenery with better planned infrastructure, hence these areas can be developed with modern urban planning without legacy problems like Mumbai's colonial-era layout and outdated sewage systems.

3.5 Quality of Life in Different rings

The quality-of-life index (QoL) is very important for standard of living in the present study. An attempt is made to know the QoL in different rings and states of respective regions of India. The composite indices are constructed with the help of Principle Component Analysis (PCA) to assess the quality-of-life index (QoL). To construct the composite index, computed the weights for each variable

with the help of PCA, weights of different variables are multiplied by the respective cities standardized values of the variables and added up to make the final index. The quality-of-life index comprises – number of latrines, electricity connections, hospitals, colleges, stadiums and tap drinking water.

The below Table 9 represents the percentage of cities which belongs to the different ranges within different states of India and the results shows that in 50 km ring the Maharashtra state shows 50% of cities are in the very high quality of life followed by the NCR which have 20% of cities in this range, in high quality of life range Uttar Pradesh state shows highest percentage of cities i.e., 68.24 % followed by NCR in this range. In low quality of life range the lowest percentage of cities is observed in Maharashtra state and highest percentage of cities is seen in West Bengal state. Whereas in very low quality of life range, lowest percentage of cities is in Uttar Pradesh state and highest in NCR. Therefore in 50 km ring Maharashtra state has the very high quality of life, West Bengal state has the low quality of life and Tamil Nadu state, and NCR region shows highest percentage of cities in very low quality of life range.

Table 9. Percentage of cities for different ranges within NCR and different states of India of PCA index values.

Rings	States	Very High QoL	High QoL	Low QoL	Very Low QoL
50 km	NCR	20.00	12.94	27.84	33.33
	Tamil Nadu	10.00	9.41	10.18	30.43
	West Bengal	10.00	68.24	49.10	11.59
	Maharashtra	50.00	7.65	6.29	15.94
	Uttar Pradesh	10.00	1.76	6.59	8.70
100 km	NCR	9.09	12.50	26.91	14.18
	Tamil Nadu	18.18	23.08	9.42	11.35
	West Bengal	18.18	53.85	37.67	39.01
	Maharashtra	18.18	5.77	10.31	15.60
	Uttar Pradesh	36.36	4.81	15.70	19.86
>100 km	NCR	17.65	0.00	0.84	5.02
	Tamil Nadu	23.53	49.61	21.28	49.37
	West Bengal	23.53	13.77	19.43	6.83
	Maharashtra	17.65	10.80	17.91	19.94
	Uttar Pradesh	17.65	25.82	40.54	18.83

Source: Author computation

In 100 km ring the 36.36% of cities are in the Uttar Pradesh state in very high quality of life range followed by Tamil Nadu, West Bengal and Maharashtra states each with 18.18% of cities. In high quality of life range the 53.85% of cities are in the West Bengal state followed by 23.08% of cities in Tamil Nadu state. The lowest percentage of cities are in the Tamil Nadu state in low quality of life range and highest are in the West Bengal state. In very low quality of life the lowest percentage of cities are in the Tamil Nadu state and highest are in the West Bengal state. Hence in this ring Uttar Pradesh state has a large number of cities in very high quality of life and West Bengal state have a large number of cities in high, low and very low quality of life ranges.

The Tamil Nadu and West Bengal states have each 23.53% of cities in very high quality of life range which shows highest percentage of cities followed by all other states each with 17.65% of cities. In high quality of life range 49.61% of cities are in Tamil Nadu state which is the highest percentage

followed by Uttar Pradesh state 25.82%. In low quality of life range lowest number of cities are in NCR and highest number of cities are in Uttar Pradesh state. Lastly in very low quality of life lowest number of cities are in NCR and highest are in Tamil Nadu state. Therefore, in beyond 100 km ring the Tamil Nadu state has highest number of cities in high and very high quality of life range and Uttar Pradesh state the highest number of cities in low quality of life range.

According to actual quality of life index the result shows that very high quality of life index is highest for only the cities with population more than one lakhs category in NCR, Tamil Nadu state and West Bengal state in all the three rings, for the Uttar Pradesh state the highest value in very high quality of life index is observed in 50 km ring for cities category, 100 km ring shows for cities and middle categories of cities and for beyond 100 km ring, cities and large categories of cities shows highest value for very high quality of life index. Whereas the Maharashtra state shows the highest value of high quality of life index in cities, middle and small categories of cities in 50 km ring and only the cities category shows highest value for high quality of life index in both 100 and beyond 100 km ring.

3.6 Influence of Urbanization and Infrastructure facilities in Different rings

The growth of urban population is influenced by many factors such as quality of infrastructural facilities namely essential amenities like Number of Latrines, Electricity connections, Number of Hospitals, Colleges, Stadiums and Tap Drinking water are important. To study the relation between urbanization and different amenities correlation coefficient was studied. High positive correlation is observed between urbanization and number of latrines, number of electricity connections for all the rings and states is identified, except for latrines in 100 km ring of NCR and electricity connection in 50 km ring of Maharashtra state of Western region.

Table 10. Correlation between the urbanization and different infrastructure variables for different rings and NCR and different states of India.

Rings	Number of latrines	Electricity connection	Hospitals	Colleges	Stadiums	Drinking water
NCR						
50 km	0.83	0.78	0.71	0.82	-0.05	0.02
100 km	0.54	0.98	0.74	-0.34	-0.56	0.20
>100km	0.98	0.69	0.73	-0.20	-0.43	0.20
Tamil Nadu						
50 km	1.00	1.00	1.00	-0.02	-0.06	0.17
100 km	0.99	0.96	0.41	0.01	-0.10	0.03
>100km	0.99	0.99	0.79	0.58	0.61	-0.01
West Bengal						
50 km	0.99	0.99	0.07	-0.17	-0.09	0.19
100 km	0.83	0.89	0.40	0.02	0.15	0.27
>100km	0.98	0.82	0.87	0.91	0.08	0.16
Maharashtra						
50 km	0.99	0.36	0.53	-0.86	-0.14	0.17
100 km	0.99	0.97	0.80	0.89	-0.08	0.11
>100km	0.98	0.82	0.87	0.91	0.08	0.16
Uttar Pradesh						
50 km	1.00	1.00	0.13	-0.04	0.08	0.35
100 km	1.00	1.00	0.29	-0.83	0.00	0.02
>100km	0.77	0.97	0.62	-0.86	-0.65	0.03

Source: Author computation.

The degree of relationship between percentage of urbanization and number of hospitals is highly positive for the regions like NCR for all the rings, states like Tamil Nadu state of Southern for 50 km ring, West Bengal state of Eastern beyond 100 km ring, Maharashtra state of Western region for 100 and beyond 100 km ring and Uttar Pradesh state of Central region only for the beyond 100 km ring, this may be true because of the NCR and states consists of most populous cities namely Delhi, Chennai and Mumbai. These cities are having good health infrastructural facilities compared to smaller size cities and this relation is low positive for Uttar Pradesh and West Bengal states for 50 and 100 km ring. Lastly relation between urbanization and number of colleges is high positive for 50 km ring in NCR and 100 km ring in Maharashtra state and for the remaining rings and regions urbanization is poorly and negatively correlated. The relation between Urbanization and percentage of tap drinking water is low positive for all the rings and regions except beyond 100 km ring of Tamil Nadu state which shows small negative correlation (see Table 10).

In summary, there is a strong relation between urbanization and physical amenities for all the rings and regions, strong relation between urbanization and health infrastructure is observed for all the states except 50 km ring in West Bengal and Uttar Pradesh states and very poor relation is observed for colleges and stadium.

The Table 11 represents the regression analysis using the chosen variables to know the impact of different types of amenities on the urban population. The regression buffers is formulated in which the urban population has been regressed on carefully chosen explanatory variables such as number of latrines, electricity connections, number of hospitals, colleges, stadiums and source of drinking water.

The analysis shows, in NCR, according to regression coefficients of different amenities, the number of latrines shows 1 per cent level of significance in all the three rings which shows 1 unit increase in the number of latrines leads to 4.5 units and 4.6 units increase in the urban population of 50 and beyond 100 km rings respectively and 1 unit decrease in the same variable leads to 1.9 units decline in the urban population of 100 km ring. For the amenities number of electric connections, there is 1 per cent level of significance is observed for 100 km ring and it shows the 1 unit increase in this variable leads to 4.9 units increase in the urban population. For the number of hospitals, 1 per cent in 50 kms and 5 per cent level of significance in 100 and beyond 100 kms ring shows 1 unit increase in the variable leads to 2538.6 units increase in the urban population in 50 km ring and 5 unit increase in the number of hospitals leads to 837.2 and 1735.7 units increase in the urban population in 100 and beyond 100 km ring respectively.

The Tamil Nadu state of Southern regions show 1 per cent level of significance in all the three rings for the number of latrines which shows that the 1 unit increase in the number of latrines leads to 3.9, 3.6 and 2.5 units increase in the urban population respectively in 50, 100 and beyond 100 km ring. In the electricity connections only in beyond 100 km ring this amenity shows 1 per cent level of significance that is 1 unit increase in the number of electricity connections leads to 1.3 units increase in the urban population in beyond 100 km ring. For the number of hospitals 5 per cent level of significance is observed in 50 km ring and 1 per cent level of significance in 100 and beyond 100 km ring which represents the 5 unit increase in the independent variable leads to 491.9 unit increase in the dependent variable in 50 km ring and 1 unit increase in the independent variable leads to 559.1 units and 230.2 units increase in the dependent variable in 100 and beyond 100 km ring respectively. Only in beyond

100 km ring the number of stadiums shows 1 per cent level of significance which shows 1 unit increase in this variable leads to 725.5 units increase in the urban population.

In all the three rings in West Bengal state of Eastern region, for the number of latrines there shows 1 per cent level of significance which shows 1 unit increase in the variable leads to 2.3, 1.8 and 3.8 units increase in the urban population in 50, 100 and beyond 100 km ring respectively. The same is observed for the electricity connections where 1 unit increase in the independent variable leads to 1.5 units in 50 km ring, 2.8 units in 100 km ring and 0.41 units in beyond 100 km ring increase in the independent variable. For the number of hospitals there shows 1 per cent level of significance in 50 and beyond 100 km ring whereas in 100 km ring there shows 5 per cent level of significance which means in 50 km ring and beyond 100 km ring 1 unit increase in the number of hospitals leads to 575.9 and 148.7 units increase in the urban population and in 100 km ring 5 unit increase in the variable leads to 453.4 units increase in the urban population. In the tap drinking water facility 50 and 100 km ring shows 1 per cent level of significance whereas in beyond 100 km ring there shows 5 per cent level of significance which means the 1 unit increase in the independent variable leads to 283.2 and 190.1 units in 50 and 100 km ring respectively increase in the dependent variable and 5 unit increase in the independent variable leads to 100.1 units increase in the dependent variable.

Table 11. Regression analysis of different infrastructure variables on urbanization for different buffer rings in NCR and different states of India.

Rings	Number of Latrines	Electricity connections	Hospitals	Colleges	Stadiums	Drinking water
NCR						
50 km	4.5090**	-0.011	2538.6130* *	408.581	-315.588	-178.688
100 km	-1.9900**	4.8690**	837.2020*	56.408	-781.07	-125.289
>100km	4.5710**	0.055	1735.7900*	-444.011	2573.194	-39.598
Tamil Nadu						
50 km	3.8850**	0.109	491.8570*	425.877	82.198	-16.096
100 km	3.5760**	0.438	559.0680**	218.844	-375.058	2.114
>100km	2.4800**	1.2830**	230.1470**	-115.694	725.4430**	-23.541
West Benagl						
50 km	2.2880**	1.4880**	575.9390**	-75.735	2290.643	283.1660* *
100 km	1.7730**	2.7770**	453.4330*	-99.758	2074.74	190.0140* *
>100km	3.7380**	0.4100**	148.6920**	-183.966	1202.465	100.1240*
Maharashtra						
50 km	11.9730**	-0.6240**	-641.8310**	-34039.3390*	1278.92	-317.573
100 km	6.7820**	3.1500**	-955.7330*	-5158.2670*	4613.246	-140.229
>100km	5.3050**	0.2540**	4871.2610* *	-1661.6690**	823.397	32.045
Uttar Pradesh						
50 km	1.9550**	3.1640**	30.41	10.027	382.953	134.016
100 km	4.1850**	2.0000**	-50.9190*	3716.8940*	8706.288	-172.492
>100km	0.8970**	3.6800**	-312.5730**	11247.5580**	9406.6900*	43.272

Source: Author computation.

Note: ** - Significant at 1 % level of significance, * - Significance at 5 % level of significance

In Maharashtra state of Western region the 50 km, 100 km and beyond 100 km rings shows 1 per cent level of significance in the number of latrines and electricity connections where for the number of latrines show that 1 unit increase in the variable give rise to 11.9, 6.8 and 5.3 units respectively increase in the urban population for 50, 100 and beyond 100 km rings, 1 unit decrease in the electricity connections leads to 0.6 units decrease in the urban population and 1 unit increase in the same variable give rise to 3.1 in 100 km ring and 0.2 in beyond 100 km ring units increase in the urban population. For the number of hospitals there shows 1 per cent level of significance in 50 and beyond 100 km ring and 5 per cent level of significance in 100 km ring where the 1 unit and 5 unit decrease in the number of hospitals in respective 50 km (641.8) and 100 km (955.7) units decrease in the urban population and 1 unit increase in the beyond 100 km ring of number of hospitals give rise to 4871.3 units in the urban population. The number of colleges shows 5 per cent level of significance in 50 and 100 km ring and 1 per cent level of significance in beyond 100 km ring that shows 5 units decrease in the 50 km and 100 km ring of number of colleges leads to 34039.3 and 5158.2 respective units decrease in the urban population and 1 unit decrease in the beyond 100 km ring of the same variable leads to 1661.6 units decrease in the urban population in this region.

The 1 per cent level of significance is observed in all the three rings for the number of latrines and electricity connections which shows the 1 unit increase in the independent variable (number of latrines) give rise to 50 km (1.9), 100 km (4.2) and beyond 100 km (0.9) units increase in the dependent variable. Similarly, 1 unit increase in the electricity connections leads to 3.2 (50 km ring), 2.0 (100 km ring) and 3.7 (beyond 100 km ring) units increase in the urban population. The 5 per cent level of significance and 1 per cent level of significance is observed in 100 and beyond 100 km ring for the number of hospitals which indicates 5 units decrease in the number of hospitals leads to 50.9 units decrease in the urban population in 100 km ring and 1 unit decrease in the same variable leads to 312.6 units decrease in the urban population in beyond 100 km ring. Similar observation is seen in the number of colleges with 5 per cent level of significance and 1 per cent level of significance in 100 and beyond 100 km ring which shows 5 units increase in the number of colleges leads to that 3716.9 units increase in the urban population and 1 unit decrease in the same variable leads to 11247.6 units decrease in the urban population in 100 and beyond 100 km rings. Finally in the number of stadiums there shows 5 per cent level of significance only in the beyond 100 km ring which indicates that 5 units decrease in this variable leads to 9406.6 units decrease in the urban population in Uttar Pradesh state of Central region.

Hence the amenities like number of latrines, electricity connections and number of hospitals are the main infrastructure facilities which are responsible for the growth of urban population in all the states and NCR of India except for electricity connections in 50 and beyond 100 km ring for NCR and 50 and 100 km ring for Tamil Nadu state of Southern region. The other infrastructures like number of colleges, stadiums and drinking water are not much responsible for the growth of urban population except beyond 100 km ring for the number of stadiums in Tamil Nadu Southern region, in all the three rings for the tap drinking water in West Bengal state of Eastern region, for number of colleges in Maharashtra of Western region for all the three rings and in Uttar Pradesh state of Central region for

the number of colleges 100 and beyond 100 rings and for the number of stadiums only in beyond 100 km ring shows significance for these variables.

4. Conclusion

This study examined the spatial distribution of urban infrastructure across five largest cities of different regions of India viz., NCR, Chennai of Southern, West Bengal of Eastern, Mumbai of Western, and Kanpur of Central regions by analysing amenities such as number of latrines, electricity connections, hospitals, colleges, stadiums, and tap drinking water with respect to urban population across different categories of cities. The different concentric distance rings (0–50 km, 50–100 km, and beyond 100 km) from centre of the largest city is drawn in different regions of India.

The result of the dominance ratio in NCR shows that the Delhi state has the highest dominance ratio as compared to the different rings. In all the states of India the highest dominance is seen in 50 km ring as compared to other rings. Comparing the dominance ratio between the states in 50 km ring Uttar Pradesh state shows highest dominance ratio. This may be due to the reason that in 50 km ring no other city shows larger population as compared to the Kanpur in 50 km ring and Lucknow in 100 km ring in Uttar Pradesh state of Central region and lowest is seen in West Bengal state because next to Haora which is almost equal population is Kolkata. The level of urbanization in all the regions of India goes on decreasing as distance increases from the centre of the largest cities of all the regions. Almost all the urban settlements in all the three rings urban area have increased from 2001 to 2011.

The ring-wise analysis of infrastructure across India's five major states highlights stark regional and spatial disparities. Tamil Nadu state and Maharashtra state exhibits more balanced and widespread infrastructure, reflecting effective planning and peri-urban development. In contrast, NCR and Uttar Pradesh state of Central regions show core-centric growth, with outer rings lacking basic amenities. The West Bengal state reveals poor infrastructure in core cities but relatively better facilities in outer towns, possibly due to demographic pressures or rural-focused investment. Notably, Maharashtra's outermost rings show high infrastructure levels, likely due to industrial corridors and planned development. Strengthening basic amenities in lower-tier towns especially latrine facility, electricity, and drinking water can promote decentralization, improve quality of life, and support more equitable urban growth.

The decline in quality of life with increasing distance from city centres highlights the value of integrating spatial data on digitized urban settlements with census information on population, employment, and amenities. This combination offers a deeper insight into the ongoing processes of urban transformation and the nature of urbanization across Indian cities. As one moves farther from the major urban hubs, settlements experience reduced access to essential services and the diminishing benefits of agglomeration economies, leading to slower growth. The concentration of populations in core urban areas is driven by the desire to fully utilize available amenities, which helps explain the stagnation observed in settlements located beyond the 100 km radius.

In Maharashtra state of 50 km ring shows very high quality-of-life and West Bengal state shows low-quality of life. In 100 and beyond 100 km ring Tamil Nadu state of Southern region shows high quality-of-life and West Bengal state of Eastern region in 100 km ring and Uttar Pradesh state of Central region in beyond 100 km ring shows low quality-of-life.

Urbanization is positively related with all the amenities except for Schools and Colleges which shows most of the rings and regions are negatively correlated. The physical and health infrastructures are most important factors which are responsible for the growth of urban population in all the regions of India.

5. References

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