International Journal of Engineering, Science and Mathematics
Vol. 7Issue 3, March2018, (Special Issue)
ISSN: 2320-0294 Impact Factor: 6.765
Journal Homepage: http://www.ijesm.co.in, Email: ijesmj@gmail.com Double-Blind
Peer Reviewed Refereed Open Access International Journal - Included in the International Serial Directories Indexed & Listed at: Ulrich's Periodicals Directory ©, U.S.A., Open J-Gage as well as in Cabell's Directories of Publishing Opportunities, U.S.A

Influence of Demographic and Socio-Economic Variations in Shaping Urban Structure - A Ward Level Study on Hyderabad, Telangana using Remote Sensing and GIS Techniques

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Abstract

The study aims at analyzing the 'cause-and-effect' relation between urban (spatial) form and demographic and socio-economic variations in Greater Hyderabad Municipal Corporation (GHMC), Telangana State. Proper understanding of the form is essential to comprehend variations at micro-level over time and vice-versa. In fact, establishing, 'intra and inter' relations on a spatio-temporal scale would help get the true perspective of urban planning. Multi-temporal datasets generated from Remote Sensing data of two periods i.e., 2001 and 2015 pertaining to 150 municipal wards of GHMC have been analyzed to discern change in form throughmulti correlation analysis in GIS environment. Various indicators like demography (population, density and literacy), economy (per-capita, work participation, gross ward domestic product [GWDP] etc.) and physical (sprawl, entropy, compactness etc.) dimensions were also analyzed and mapped. The results show majority (80) wards in the old city have very high density (>20,000 per./km^2) population led by Feteh Darwaza (1,34,217 per./km^2), Musheerabad (70,573 per./km^2) etc. with low GWDP of Rs. 2 - 2.75 billion. With high dense built-up area, these wards show high compact mono-centric form. Whereas, wards in fringe areas like, Gachibowli, Rajendra Nagar, Hayath Nagar, Serilingampally, Jubilee Hills, etc. (20 wards) show low density, (<5000 per./km^2) but with relatively high GWDP (Rs. 5.27, 5.55, 6.63, 9.07, 4.97 billion, respectively) with moderate to sparse poly-centric form. When compared with global averages Hyderabad has a form with increased complexity, low centrality, compactness, porosity and very high density form similar to developed countries. The results show that Hyderabad has a heterogeneous form due to unequal demographic and socio-economic structural conditions.

Keywords:

Urban structure;
Municipal wards;
Demography;
Socio-economic data;
Multi-criteria analysis.

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1. Introduction

The world's human population is growing rapidly with an unprecedented growth rate of a million every five days and fast transforming the agglomerations urban from hitherto rural. The percent world's urban population alarmingly increased from 5.5% in 1900 to reach 38% (2.3 billion) by end of this century. Rapid urbanization resulted in increase in number of mega cities with population more than 5 million from 25 in 1980 to 80 by 2015, of these three fourth of the cities emerged from the developing nations. The detrimental impact of population growth and urbanization on the environment and climate was already felt and is a major topic of discussion[11][12][13][14]. It is noticed that the role of human influence on environment is more significant in those countries where national economy largely implies environmental / agricultural change. Nevertheless, these factors are largely associated and influenced by a combination of several factors which in turn play a vital role in environmental change analysis and sustainability evaluation of the urban areas[15]. Indian urban scenario is no distinct than other evolving countries and its rate of urbanization has been very quick in contrast to developed nations. In fact, it is more acute in some respects, such as sanitation, availability of drinking water, pollution (air pollution is more critical), unauthorized developments and spontaneous settlements (slums/squatters). If this tendency persists, it is estimated that by the turn of this century, around 500 million population (about 38%) would be dwelling in urban localities.

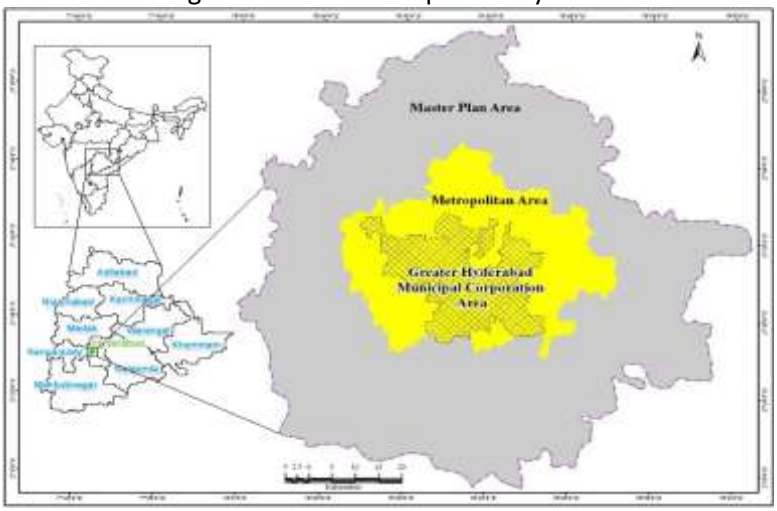
Hyderabad is the capital of the state of Telangana in India witnessed an exponential growth in its population and its structure which was pushed by various elements characterized with urbanization such as industries, institutions, transportation and technology. Like many other Indian cities, the city bears its urban structure largely from natural growth driven by its population and related elements rather from the need of a plan and management which should be the foundation of all designing allocation and implementation. This paper tries to demonstrate the understanding of urban structure through mapping of population growth and socio-economic character and also through the possible lines of deriving additional inferences using Remote sensing and GIS techniques.The prime objective of the study is to identify and map the micro-level changes in urban growth patterns of Hyderabad in relation to changing demographic, socio-economic, urbanization and industrialization using GIS and Remote sensing techniques. The study deeply focuses on the aspects of high significance to urban growth, such as, demographic trends at ward level, i.e., physical, social, economic characteristics of the population and spatial patterns.

2. Research Method

2.1. Study Area

GHMC has administratively restructured into 150 municipal wards grouped into 5 Zones (North, South, and Central, East and West) and 18 Circles. Study area map is shown in Fig. 1.

Figure 1: Location Map of Study Area



The GHMC has 7.7 million population with 625 km^2 of area. The City is well connected with other metropolitan cities in India i.e. Mumbai, Delhi, Chennai, Kolkata and Bangalore by road, rail and air.The city has situated at 580m (m.s.l.) with average altitude of 542 m m.s.l., while the highest point in the city is Banjara Hills at 672 m. Irregular topography with several small hillocks are scattered on the grey to pink granites. Musi is the prominent river traversing through the city. The entire study area is covered by the Survey of India (1:50,000 scale) toposheets, numbered, 56K/2, 56K/3, 56K/6, 56K/7, 56K/10, 56K/11, and 56K/15.

2.2. Data and Sources

Various map and attribute data sources have been used for the study as mentioned below. Topographical maps published by Survey of India (SoI) on 1:50,000 scale, numbered, 56K/2, 56K/3, 56K/6, 56K/7, 56K/10, 56K/11, and 56K/15 have been used for the preparation of base maps for the study. Multi-temporal remote sensing data acquired by IRS-P5 CartoSAT-1 PAN and ResourceSAT-2 LISS-III (merged data) with 2.5 m spatial resolution for the year 2011 and IRS-1D, PAN and LISS-III (merged data) with 5.8 m spatial resolution for the year 2001 is used for the study. Ward boundary and other administrative boundary map data was generated from the maps published by GHMC according to the notification (2109/Elec/TPS/HO/GHMC/2008) dated 24-02-2009. Census of India, publications pertaining to the years 1991, 2001, and 2011 has been used for the demographic analysis. Data pertaining to various socio-economic parameters were collected from village and town directory of Hyderabad, Census of India, and GHMC.

2.3. Process FLow

Topographic sheets pertaining to the study area have been georeferenced and used them as the basemap reference keeping the projection system as UTM of Zone 44 N and datum WGS84. Image acquired by IRS-P5 CartoSAT-1 PAN and ResourceSAT-2 LISS-III were referenced and merged for generating hybrid image which has inherits the multi-spectral qualities as well as high resolution capabilities from both the images. Similarly, IRS-1 D PAN and LISS-III image were also merged for use them as source of base temporal data. Spatial data has been extracted by means of employing visual interpretation and onscreen digitization techniques in GIS environment.Thematic mapping of land use/land phenomena helpdetect the urban sprawl in the wards of GHMC during 2001-15 using Shannon's entropy and change thereof using relative entropy.

2.4. Variations in Demography

Population growth of a region, whether positive or negative, generally reflects human response to its environmental suitability and possibilities [16]. Growing population needs more food and essentials of life thus exerts considerable influence on agricultural processes [2]. Population of GHMC has increased by 5 folds during 1881-2011, from 3,67,417 to 68,09,970 with a net addition of 64,42,553 persons or 1418%. The decennial growth shows higher growth than state average.GHMC has developed faster than Ahmedabad, Chennai and Kolkata during 2001-11. In terms of population growth Hyderabad has reported a maximum growth (87.22%) followed by Surat (83.3%), Ahmedabad (58.25) and Bengaluru (54.94%) during 2001-2011 in India.It is inferred that the population in GHMC will continue to accelerate further similar to 1991, 2001 and 2011. The projections indicate by 2021 the metro area have a population of 10.86 million.

2.5. Economic Characteristics of Population

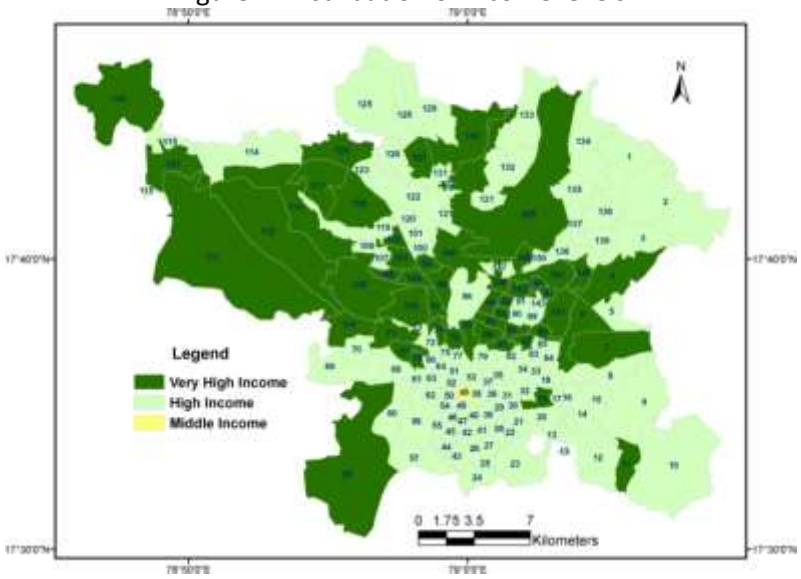
Socio-economic structure of the society draws its vital input from proportion of working population called 'participation rate'. Both, participation rate and occupational structure reflects the economic and social development of a society and typifies its cultural identity, especially for countries like India where cultural mooring have strong bearing on citizen's livelihood. Heavy dependence on primary occupations like extraction, farming etc. considered as a sign of under development, while predominance of secondary and tertiary activities is considered as a

reflection of improving economy [17]. Economic power of a place largely depends on the proportion of productive workers judiciously employed across different sectors. Work participation and occupational structure are two important economic characteristics, hence workforce of these two are discussed in detail.

2.5.1. Work Participation

Wards of GHMC are categorised into 5 income groups based on average annual per capita income (PPP) namely, Very High Income (Rs. >=4150001), High Income (3150001-4150000), Middle Income (200001-3150000), Low Income (66001-200000) and Very Low Income (<66000).

Figure 2. Distribution of income levels

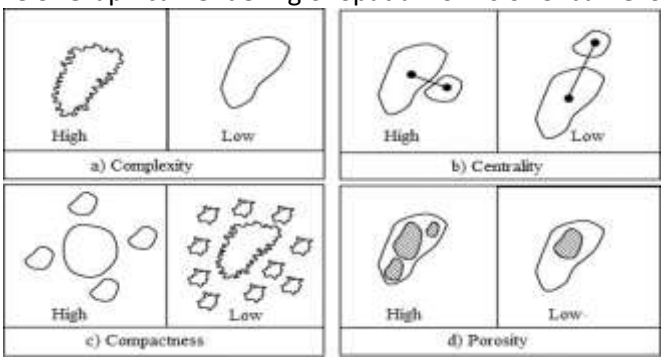


The gross ward level GDP (GWGDP) is derived using population in each group. Fig. 2 shows majority wards (100) with High Income levels, where as 51 wards with Very High levels. Only w.no. 49 is found with Middle Income.

2.6. Urban Form Characterisics

Urban spatial form is defined as the evolution of distinctive spatial patterns due to human activities at a specific point in time [1]. It may reveal the characteristics of evolution of an urban class [4].The study focuses on the form of GHMC at metropolitan level as described by [9] (Fig. 3).

Figure 3. Graphical rendering of Spatial Forms of Urban Growth



Source: Huang et al. (2007)

Based on the disposition of spatial pattern, urban form can be classified as, density, diversity and structure. The spatial structure characterized as an urban area helps in distinguishing the land use phenomena, whether it is mono or poly-centric form, centralized or decentralized pattern,

relentless or dis-relentless expansion etc. In the context of varied scales, urban form can be classified as metropolitan, city and neighborhood. The scale dependency is due to different variables, which contribute to urban form and operates at certain scale and have different meaning. Form endeavors to analyze the characteristics of urban area (i.e., size, density, sprawl etc.) to determine the type of urban form evolve to grow.

2.6.1. Spatial Metrics to Measure Other Forms of Urban Growth

With increasing acceptance for sustainable development as a guiding concept, researchers have renewed attention on urban form trace back to start of modern planning and urban studies [6][7][8][3].Majority of these studies focuses on the aspects of 'good city form' or 'sustainable urban form' to enhance economic vitality, social equity and check deterioration of environment [5]. In order to quantitatively define the urban form and change thereof in GHMC, various spatial metrics have been employed. These metrics are quantitative indices measures physical characteristics of landscape mosaic. The important indices which measure the five dimensions of urban form are compactness, centrality, complexity, porosity and density (Table 1).

Table 1. Spatial Metrics and Urban Form Indicators

Indicator	Formula	Description
Area Weighted Mean Shape Index (AWMSI)	$\frac{\sum_{i=1}^{i=N} p_i/4\sqrt{s_i}}{N} \times \frac{s_i}{\sum_{i=1}^{i=N} s_i}$	Where, s_i and P_i are the area and perimeter of patch I; and N is total patches.
Area Weighted Mean Patch Fractal Dimension	$\frac{\sum_{i=1}^{i=N} 2\ln 0.25 p_i/\ln s_i}{N} \times \frac{s_i}{\sum_{i=1}^{i=N} s_i}$	s_i and P_i are the area and perimeter of patch i and N is total patches.
Centrality	$\frac{\sum_{i=1}^{N-1} D_i/N-1}{R} = \frac{\sum_{i=1}^{n-1} D_i/N-1}{\sqrt{S/\pi}}$	D_i is the distance of centroid of patch i to centroid of the largest patch; N is total no. of patches; R is the radius of a circle with area S; S is summarized area of all patches
Compactness Index (CI)	$\frac{\sum_i P_i/p_i}{N^2} = \frac{\sum_i 2\pi\sqrt{s_i/\pi}/p_i}{N^2}$	s_i and P_i are the area and perimeter of patch I; P_i is the perimeter of a circle with the area of s_i; and N is total patches
Compactness Index of Largest Patch (CILP)	$\frac{2\pi\sqrt{s/\pi}}{p}$	s and P are the area and perimeter of largest patch.
Ratio of Open Space (ROS)	$\frac{S'}{S} \times 100\%$	S' is the summarized area of all 'holes' inside the extracted urban area, S is the summarized area of all patches.
Density	$\frac{T}{S}$	T is the total population of city, S is summarized area of all patches.

Source: McGarigal and Marks (1995), World Bank (2000) and UNDP (2001)

2.6.2. Area Weighted Mean Shape Index (AWMSI)

AWMSI values range from 1 to infinity, where large value indicate increase in irregularity. Value near 1 indicate patch in circle form. Analysis shows increase in value during 2001-15 indicating highly irregular urban form (Table 2).

2.6.3. Area Weighted Mean Patch Fractal Dimension (AWMPFD)

AWMPFD measures the complexity of urban growth by means of describing the ruggedness of the urban boundary (Longley and Mesev, 2000). It is basically the average patch fractal dimension of corresponding patch type weighed by its area. Larger patches are assigned more weight (Table 2). The index values range between 1 and 2, where value close to 1 indicates simple shape and values >1 indicates shape complexity. The AWMPFD results for Hyderabad shows values 1.4 for 2001 and 2015. This indicates medium complexity in urban form (Table 2).

2.6.4. Complexity

Complexity is the degree of irregularity of the shape of urban area. Area Weighted Mean Shape Index (AWMSI) and Area Weighted Mean Patch Fractal Dimension (AWMPFD) are the metrics used to measure and map the complexity in the development of GHMC.

2.6.5. Centrality

Urban development is in general concentrates around a core region called central business district (CBD) due to various favorable conditions. Centrality measures distance of centroid of an urban area to the CBD. The urban area is gradually extended out from the CBD adding layers of growth as cycles of development. Urban growth with high degree of development close to CBD ideally should have low sprawl. In order to minimize the bias of urban scale, average distance of surrounding urban areas would be divided by radius of an imaginary circle which is equal to the total urban area. Analysis on GHMC indicates decrease in the values of centrality from 1.19 to 1.12 during 2001-15, suggesting elongated development in a specific direction (Table 2).

2.6.6. Compactness

Compactness measures the degree of fragmentation or closeness of overall urban landscape [10]. Compactness is measured by 2 indicators namely, Compactness Index (CI) and Compactness Index of Largest Patch (CILP) (Table 2). CI indicates compactness of the overall urban area, while CILP focus on the CBD. CI analysis of GHMC indicates decrease in its value suggesting an increase in its sprawl during 2001-2015 (Table 2).

2.6.7. Porosity

Urban areas generally consist built-up and natural patches include green spaces, waterbodies and open areas. These porous areas are crucial for the livability. Though, interspersed with lakes and green areas marginal decrease in porosity is noticed in GHMC during 2001-15 (Table 2).

2.6.8. Density

Density is a measure of compactness of sprawl and is calculated by comparing the population to unit area (Table 2). Density during 2001-15 shows a considerable increase (Table 2).

Table 2. Values obtained for Standard Spatial Metrics (2001 and 15)

Year	Complexity		Centrality	Compactness		Porosity	Density
	AWMSI (↑)	AMPFD (↑)	(%) (↓)	CI (↓)	CLIP (↓)	ROS (%) (↓)	(Persons/k m^2) (↑)
2001	24.12	1.45	119	0.0010	0.035	20.9	17143
2015	26.91	1.46	112	0.0008	0.031	20.7	19380

It may be noticed that the values of AWMSI, AMPFD for Complexity, Density reported an increase during 2001-15, while Centrality, Compactness, Porosity have reported a decline.When compared to the averaged values derived by Huong and Sellers for cities in developed and developing countries (Table 2), HUA's urban form is found very similar to the cities of developed countries. Increase in complexity, decrease in centrality, compactness, porosity and a very high population density indicates GHMC urban form similar to developed countries.

3. Results and Analysis

Demography, socio-economic and knowledge base in GHMC play a vital role in understanding the urban growth and function. The temporal distribution and trends of these phenomena help in identifying the spatial character of urban structure which is important to determine the class and quality of overall urban environment.Population growth trends (Table 3) of 2001 indicate that 65% of the growth occurred due to natural development, while migration

contributed for 25% growth. Natural growth contribution has significantly increased to 72% by 2011. This suggests that though the mitigation measures are in place to control the migration, the urban growth will continue to take place in Hyderabad. Hence, long term planning and strategy is crucial to encourage equal economic growth and service delivery.

Table 3: Factors contributing for population growth

Composition	**Population Growth**					
Year	**1981-1991**		**1991-2001**		**2001-2011**	
(figures in)	**Million**	**%**	**Million**	**%**	**Million**	**%**
Natural Increase	0.87	59	0.90	70	-	72
Migration	0.37	25	0.31	24	-	18
Jurisdictional Change	0.24	16	0.08	06	-	10
Total Increase	1.48	100	1.29	100	3.17	100

Source: Census of India

During 2001-11 decade, population of Hyderabad reported a record growth rate of 87.22%, which is the highest decadal growth since 1881. The reason for growth could be growth in IT and other industrial sectors.

3.1. Classification of Wards based on Sprawl

In order to identify the wards with very high dispersion (sprawl) or highly compact form based on relative entropy results, they have been classified into five categories. The 5 classes along with their relative entropy ranges are Highly Compact (0.016), Compact (0.017-0.047), Medium Compact (0.048-0.067), High (0.068-0.087) and Very High dispersion (>=0.088). The relative entropy results shows only 3 classes (Fig. 4) mostly compact form rather dispersion.

Figure 4.Change in entropy between 2001 and 2015 at ward level

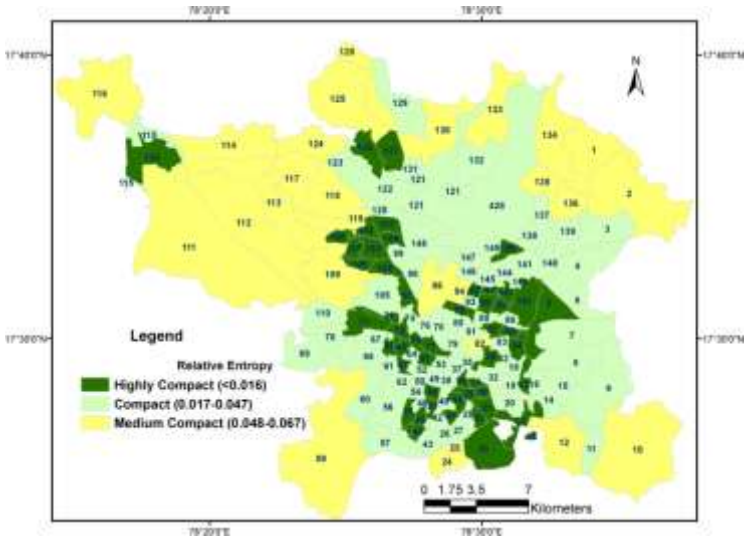


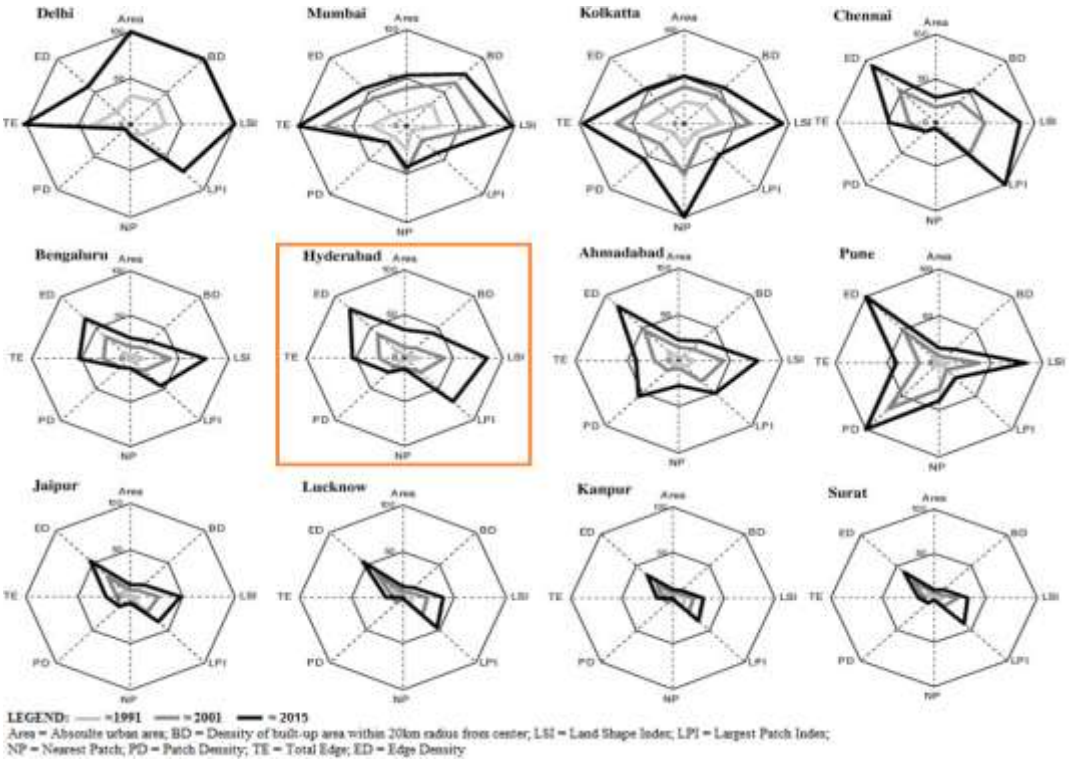
Fig. 4 shows majority wards (76) encircling the core city in Compact class. These wards namely Mallapur (w.no. 3), Rama Krishna Puram (w.no. 15), Moghalpura (w.no. 40), Begumpet (w.no. 148) etc. with 283.54km^2 of area have 39,03,341 population. Around 51 wards namely Habsiguda (w.no. 6), Shali Banda (w.no. 47), Musheerabad (w.no. 91), Addagutta (w.no. 150) etc. mostly confined to core city with 89.20km^2 area and 21,89,004 population are found under Highly Compact class. The remaining 27 wards include Kapra (w.no. 1), Khairatabad (w.no. 96), Mothinagar (w.no. 119), Moula Ali (w.no. 136) etc. mostly on the city edges, especially in the north-western parts are found under Moderately Compact category. These wards have an area of 359.09km^2.The results indicate wards in the center of the city have not shown much change and lack signs of any horizontal growth and classified as either Highly Compact or Compact. Satellite

image of 2001 also reveals no further scope of horizontal growth in these wards. It is important to notice that, in order to accommodate the growing population, the wards situated in the center might have shown a vertical change, which can only be established by analyzing the 3D planimetric data. Verzosa and Gonzalez (2010) states that, it would be interesting to see the vertical entropy of areas located in the center. However, due to data constraints and other limitations, the study has not focused on the change taken place due to vertical growth.

3.3.1. Urbanization in GHMC Compared to Other Metros

In order to quantify the extent of urbanization in GHMC during 2001-15, spatial indices are employed which uses the land cover data for analysis. Growth of GHMC is compared with other major cities of India like Delhi, Mumbai, Kolkata, Chennai, Bengaluru, Ahmedabad, Pune, Jaipur, Lucknow, Kanpur and Surat using Spider charts which uniquely distinguish the growth based on the indices employed (Fig. 5). Near circular form indicates the balanced growth. The spatial indices used for comparing urban form and growth are area, built-up density within 20km radius from CBD, Land Shape Index (LSI), Largest Patch Index (LPI), Nearest Patch (NP), Patch Density (PD), Total Edge (TE) and Edge Density (ED). Indices like LPI, NP and PD represent different forms of open spaces within the urban area. These indices are used to compare the temporal trends (1991, 2001 and 2015) of these cities. The comparison indicates the temporal trends (1991, 2001 and 2015) of these cities and shows a balanced growth in Hyderabad.

Figure 5: Spatial forms of development of metros as spider charts



4. Conclusion

The growth of Hyderabad is measured using spatial analysis and linked to the demographic trends. It is found that the land use characteristics are the causative effects of growing population and increasing needs.Built-up category has seen an increase from 37.88% (279.11km2) to 61.89% (455.97km2) with overall 176.86km2 increase (24.01%). Extent of green area was reduced from 29.68% to 4.77% (-24.91%). Built-up classes developed rapidly to accommodate the burgeoning population which resulted in increase in extent of residential, industrial, transportation and recreational classes. The steep growth in these classes occurred at the expense of agricultural, forest and open areas.Built-up class has experienced a lot of change due to sprawl, horizontally. A

clear trend of sprawl is detected along the north, north-east and south-east directions. The urban metrics shows an increase in complexity of the urban form. GHMC shows a constant decrease in centrality and compactness due to outward growth. This observation is constant with the increase in density which shows an increase in >2000 persons/km^2. The porosity of the city shows a slight decrease indicative of loss of open and green areas.

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