GIS AND REMOTE SENSING BASED URBAN SPRAWL DETECTION AND ITS IMPLICATIONS ON SUSTAINABLE DEVELOPMENT

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ABSTRACT

This paper analyzes the urban sprawl dynamics using geospatial techniques. Sprawl is studied for three temporal periods of 1975, 1990 and 2009 using GIS and Remote Sensing techniques in conjunction with Shannon's entropy. Urban sprawl characteristics, causes and effects are reviewed and analyzed with respect to Greater Visakhapatnam. Sprawl pattern is mapped and measured from various viewpoints to identify the specific local factors which control the growth pattern in the study area. Visakhapatnam is a fast developing port city and recording rapid rate of urbanization. With increasing population and ever increasing demand of land the new extensions of the city have taken place. It is expanding in all possible directions resulting in large scale changes in urban land use which affects the physical and social environment of the city. The city has gained real importance from 1970 onwards due to location of many industries which had resulted in considerable spread with the establishment of new residential colonies. The spatial growth of the city has been restricted by physical barriers on the north, south and east. Visakhapatnam city is growing along the southwest, northwest and northeast directions. The rate of land development is as high as 789% during the 35 year of study period while the population growth rate is 266%. Thus the per capita land consumption has increased markedly and it is true

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especially in the peripheral zones a strong indicator of sprawl. The distribution of population density in various wards also justifies the above characteristic of sprawl – "dense core and dispersed suburbs". The higher entropy values at different points during the study period indicate high rate of sprawl even in early seventies and sustained throughout. Therefore the entropy approach is proved to be efficient to identify measure and monitor the spatio-temporal patterns of urban phenomena.

Key words: *Urban Sprawl, Land use, Land Cover, Shannon entropy, Remote Sensing, GIS and Geo-spatial approach; Visakhapatnam, India.*

INTRODUCTION

The biggest challenge for science, engineering and technology in the 21st century is how to ensure adequate housing, sanitation, health, and transportation services in a habitable urban environment in developing countries and sprawl is considered as one of the potential threats for such development. To sustain rapid urban growth, development should be planned in a sustainable manner to fulfill all the facilities like infrastructure, drainage, water supply, sanitation etc. for the purpose of sustainability urban areas have to be properly monitored to maintain interval equilibrium (Borredo and Bemicheli, 2003). Taking it into account for future planning or urban development, the administrators and planners should have the knowledge of the present trend of urban growth. In order to provide basic amenities and infrastructure for complex urban environment, the up to date information pertaining to the dynamic processes within and around the city regions shall be of immense value and use to the planners and Administrators (Jothimani, 1997). The rapid growth in urban population, which affects patterns of production and consumption, is a principal source of pressure on the environment. There have been lots of debates on how to confine Urban Sprawl and conserve agricultural land resources. Since Urban Sprawl is resulting in increase in the built up area and associated changes in the spatial urban land use patterns causing loss of productive agricultural lands, forest cover, other forms of greenery loss in surface water bodies, depletion in ground water aquifers and increasing levels of air and water pollution, harmful to biological conservation it is imperative for the administrators and planets to monitor the sprawl dynamics for taking effective and corrective measures towards a planned and healthy development of urban areas.

Urban Sprawl in the case of Visakhapatnam is not an exception to other Indian cities but exhibits a peculiar pattern and complexity owing to its geographical setting. To a large extent the city represents most of the characteristics, causes and effects mentioned above. Therefore the need for monitoring urban development is imperative to help curb the problems of Urban Sprawl. Identification of the patterns of sprawl and analyses of spatial and temporal changes would help immensely in the planning of infrastructure facilities. The present rate of population growth and the projected figures also signify the prime responsibility of the planning department to plan for a future housing development which is attractive, affordable and sustainable – socially, economically, culturally and environmentally. Therefore in the present chapter an attempt is made to analyze the sprawl dynamics using geo-spatial techniques. Since the impact of sprawl is an extensive study major affects viz. land use/ land cover changes and Environmental Impact Assessment studies are dealt separately in the succeeding chapters.

Urbanization & Urban Sprawl:

Urbanization refers to a process in which an increasing proportion of an entire population lives in cities and the suburbs of cities. It is the movement of population from rural to urban areas and the resulting increasing proportion of a population that resides in urban rather than rural places. Urbanization is a form of metropolitan growth that is a response to often bewildering sets of economic, social, and political forces and to the physical geography of an area. Population increase as well as immigration from rural area towards larger cities, particularly in developing countries results in considerable increase in urban areas. Sprawl is a pattern and pace of land development in which the rate of land consumed for urban purposes exceeds the rate of population growth which results in an inefficient and consumptive use of land and its associated resources.

Nelson et al. (1995) have summarized various definitions of Urban Sprawl in the planning literature to create a working definition of the concept as "unplanned, uncontrolled and uncoordinated single use development that does not provide for a functional mix of uses and/or is not functionally related to surrounding land uses and which variously appears as low-density, ribbon or strip, scattered, leapfrog or isolated development". Lata et al. (2001) defined Urban

Sprawl as the scattering of new development on isolated tracts, separated from other areas by vacant land. The study on Urban Sprawl was attempted in India by (Jothimani, 1997; Lata et al, 2001; Sulochana, 2001, Pathan eta al 1991 etc.). Most of these studies on sprawl used impervious surfaces as a potential parameter to measure the Urban Sprawl.

Characteristics of Sprawl:

Urban Sprawl is widely spread-out development outside city centers, usually on previously undeveloped land. Urban Sprawl which is characterized by haphazard patchwork of development leads to an improper development in any city usually happens due to land use/land cover conversion in which the growth rates of urbanized land significantly exceeds the rate of population growth over a specified time period, with a dominance of low density impervious surfaces (Barnes et al, 2001**)**. According to Gillham (2002) there are four main characteristics of sprawl, which mirror the earlier definition given by Nelson et al. (1995). These characteristics are leapfrog or scattered development, commercial strip development, low density and large expanses of single-use development. Low population density, homes that are separate from commercial and industrial areas and branching street patterns, developments such as shopping malls, fast food chains, strip malls, and housing subdivisions are especially typical of Urban Sprawl. Another key characteristic its is low efficient use of space i.e. low-density land use, where the amount of land consumed per capita is much higher than in more densely populated city areas. Buildings in sprawl developments are generally single-story and widely spaced. The final aspect of Urban Sprawl, the proliferation of single-use development and an almost exclusive reliance on automobiles for transportation is just as important as density in the identification of Urban Sprawl. Single use zoning, is also a common part of modern city planning approach which separates residential, commercial and industrial areas from one another.

Causes and Effects of Urban Sprawl:

Some of the causes of the sprawl include population growth, both natural and migration, economy, infrastructure initiatives like the construction of roads and service facilities (such as hotels, etc.). The relation between population growth and Urban Sprawl is that the population growth is a key driver of Urban Sprawl. As Gillham (2002) elaborates “we owe our contemporary version of suburbs and sprawl to the Industrial Revolution of the nineteenth century. Burchell and Mukherji (2003) explained that Urban Sprawl has allowed people to gain access to less expensive, single family homes on large lots situated away from urban centers. The lifestyle choices of the general public, especially those who can afford to live in the attractive urban fringe, have proven to be very enduring (Carruthers and Ulfarsson, 2002). Suburban Sprawl is the direct result of a number of policies that encouraged urban dispersal and most significant of them is loan programs, road improvement and neglect of mass transit and the concept of planned development.

The direct effect of sprawl is the change in land use and land cover of the region. Urban Sprawl is referred as irresponsible and often poorly planned development that destroys green space, increases traffic contributes to air pollution and leads to congestion with crowding. Several environmental problems are associated with Urban Sprawl, which results in a loss of open space and agricultural land, increased dependence on automobiles and other vehicles and higher energy and water use. The spread out nature of Urban Sprawl can cause increased traffic, worsening air and water pollution, threats to ground water supplies, higher rates of polluted water, runoff, destruction of productive agricultural land and wild life habitat, and increased flooding. Environmentally, there are two main concerns related to Urban Sprawl: the rate at which it is consuming the landscape, and the air pollution that such a high level of automobile reliance is causing Guiliano and Narayan, 2003. Societal effects of Urban Sprawl are very difficult to measure accurately; they are also perhaps the most derogatory evidence of its un-sustainability.

STUDY AREA

The present study is an attempt to assess the urban sprawl in Visakhapatnam city. Visakhapatnam, a port city on the east coast of India is strategically located midway between Kolkata and Chennai and situated between $17^0$37'30" & $17^0$45'00"N latitudes and $83^0$07'30" & $83^0$22'30"E longitudes. The Government of Andhra Pradesh has reconstituted the municipal corporation of Visakhapatnam in the year 2005 by extending its jurisdiction by merging the adjoining municipality and 32 villages. The reconstituted Greater Visakhapatnam Municipal Corporation has (Fig.1) an area of 540 sq.km with a population of more than 4 million. It is ranked as the second largest urban agglomeration in Andhra Pradesh.

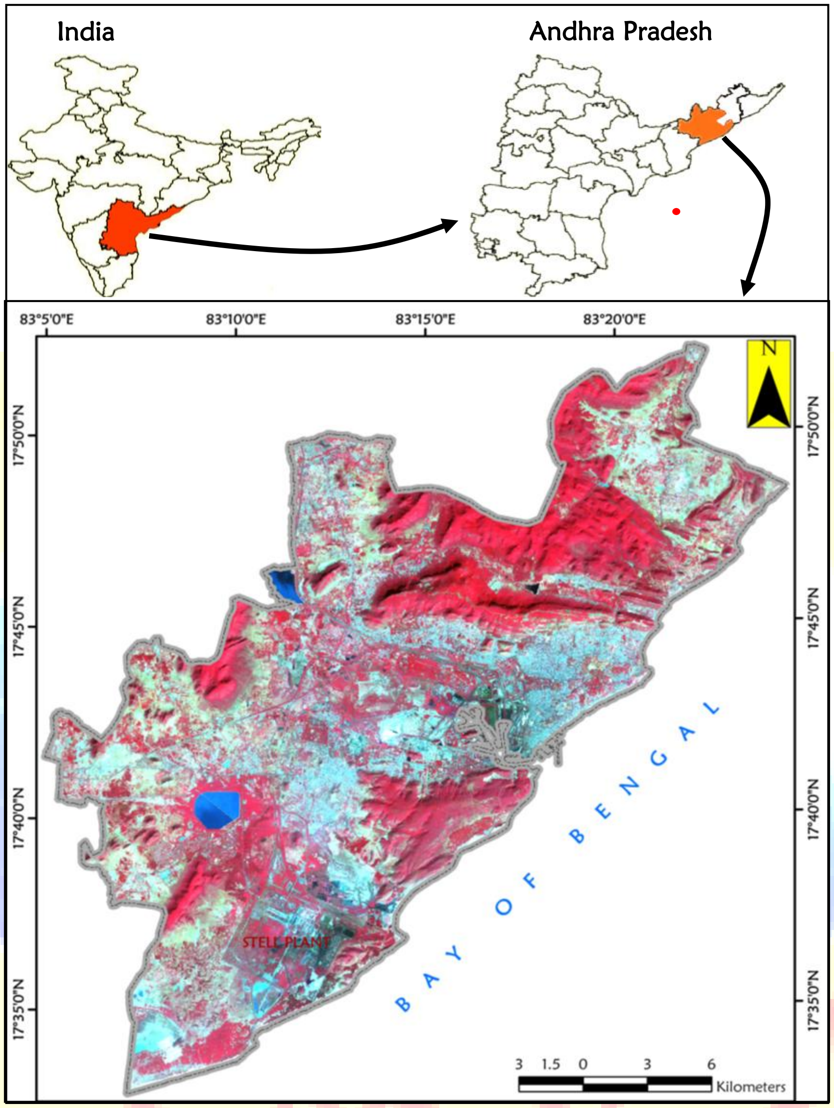


Fig.1: Greater Visakhapatnam – Study Area

METHODOLOGY & MATERIALS

The patterns of sprawl are described using a variety of metrics, through visual interpretation techniques, all with the aid of software and other application programmes. The built-up is generally considered as the parameter of quantifying Urban Sprawl (Torrens and Alberti, 2000; Barnes et al, 2001, Epstein et al.2002). It is quantified by considering the impervious or the built-up as the key feature of sprawl, which is delineated using topographic maps or through the aerial photos or satellite imagery. The physical expressions and patterns of sprawls on landscapes can be detected, mapped and analyzed using remote sensing and GIS technologies (Barnes et al 2001). Image processing techniques are very useful for monitoring rapid changes in the landscape resulting from urban development (Alberti et al., 2004) and capable of detecting and measuring a variety of elements relating to the morphology of cities (Yeh and Liu, 2001). The spatial patterns of Urban Sprawl over different time periods can be systematically mapped, monitored and accurately assessed from satellite data along with conventional ground data (Lata, et al, 2001). The current popularity of GIS is in the multitude of domains in which they can be applied and in their ability to automate simple but repetitive map based tasks as complex ones (De Mers, 2002). Shannon's entropy is a popular statistical technique to measure and determine the compactness or dispersion of built-up land growth in the urban areas. This measure is based on the notion that landscape entropy or disorganization, increases with sprawl. The convergence of GIS, remote sensing and database management systems will help in quantifying, monitoring, modeling and subsequently prediction of the process. Vinoth Kumar et al. 2007 monitored the urban growth in Indore city employing Remote Sensing and GIS techniques in conjunction with Shannon's entropy. Similar approach was employed by Lata et al., 2001; Sulochana, 2001; for characterizing Urban Sprawl of Hyderabad and Pune cities respectively. In an attempt to map the sprawling trends and changes in the urban core Jothimani (1997) used Land Sat MSS and IRS LISS-II data through visual interpretation techniques for Analysis and identified the trends of emergence of sprawl along transportation network in Surat and Ahmadabad Cities. Theil, (1967); Thomas, (1981); Yeh and Li (2001) used Shannon's entropy which reflects concentration or dispersion of spatial variable (built-up) in a specified area, to measure and differentiate types of sprawl.

Based upon these studies, a set of methodologies – Image processing & GIS techniques were integrated with statistical algorithm (Shannon's entropy) to study the spatio-temporal dynamics of the Urban Sprawl in Greater Visakhapatnam.

Data Base:

Survey of India topographical maps: 1975 Publication 65O/5SW, 65O/5SE, 65O/6NW, 65O/2NE, 65O/1SE (1:25,000)

Satellite Images: Landsat-6 ETM-Multi Spectral September, 1990,

IRS-P5 (Cartosat-1) PAN, Path-Row - 0569-314, 19th Feb, 2009

Collateral data: Boundary maps, and wards information from GVMC's office

Demographic details from Statistical abstracts

The topographic maps referred above were scanned, geo-referenced and all the maps were joined (mosaic) using the composer in ERDAS Imagine environment. Using this mosaic as base the above mentioned satellite imagery were also geo-referenced. Adequate ground truth samples were collected from different training sites with the help of hand held GPS instrument. After applying enhancement techniques like stretch and filter, supervised classification is performed using the enhanced images as input data with the ground truth obtained from the field work. Visual image interpretation techniques are also applied at the sites of ambiguity and rechecked in the field. Then the built up area on the imagery are highlighted by merging all other classes into one category, so that the final classified output imagery have only two classes – built up and non-built up.

The classified output imagery and topographic map are brought to the ArcGIS environment and the built up area alone is digitised on all the above layers. Using overlay technique the Boundary layer map is superimposed on the topographic map as well as satellite imagery and the study area is clipped out. So the output layers show only the study area boundary and the built up within. Then the statistics of geographical area and built up are extracted from the attribute tables for further analysis. To intensively study the sprawl patterns and also for intensive analysis concentric buffers were generated from the urban core (1km interval) as well as the National Highway (NH5) (1/2 km interval) and area statistics in each buffer zones were extracted from the attribute tables and used this information to measure the entropy index.

Shannon's entropy is a measure to determine the compactness or dispersion of built-up land growth in the urban areas. To find out the compactness or dispersion of the urban development, an integrated analysis has been carried out. To measure the compactness or dispersion of urban built-up, Shannon's entropy method (Yeh and Liu, 2001; Li and Yeh, 2004; Lata et al., Sudhira eta al., 2004) was adopted. It (Hn) can be used to measure the degree of spatial concentration or dispersion of geographical variable among 'n' zones. The Shannon's entropy, Hn is given by,

$$\mathbf{H_n = - \sum P_i \log (P_i)}$$

Where;

P_i = Proportion of the variable in the ith zone

n = Total number of zones

The value of entropy ranges from 0 to log n. If the distribution is very compact then the entropy value would be closer to 0 and when the distribution is very dispersed the value will be closer to log n. Large value of entropy indicates the occurrence of urban sprawl. This methodology is adopted to study the distribution of built up in different wards, around the core, and along the National Highway-5.

RESULTS and DISCUSSION

To study the spatio-temporal changes in sprawl over the past 35 years, maps and satellite imagery pertaining to the years 1975, 1990 and 2009 as mentioned in the above section (database) were procured and processed according to the detailed methodologies mentioned in the earlier section. The GVMC consists of 72 wards or divisions **(Fig.2.1)** divided into 6 zones **(Fig.2.2)** viz. North (zone-1), East (zone-II), Old city (zone-III), Central (zone-IV), South (zone-V) and West (zone-VI). In order to analyze the sprawl pattern and to identify the local influential factors different approaches were adopted and built up statistics for the city as a whole, ward wise, zone wise and distance wise have been extracted and tabled. **Fig. 2.3** shows the increase in built up area during the study period 1975 to 2009 at the above three selected years. The spatial expansion of sprawl during the study period is obvious from the figure. In 1975 the built up area is concentrated near harbor in zones I and II and also along the National High way 5 (near the urban core), whereas in the rest of the study area the built up is sparse and scattered all over like small dots. During that period Visakhapatnam was only a small municipality with 76.33.sq.km of area and a population about 400,000. Since Visakhapatnam had grown substantially in population and area as a centre of industries and institutions especially during the period 1960-75 the State Government constituted a Municipal Corporation in the year 1979. Mammoth growth of built up between 1975 and 1990 is observed in the figure. The urban core located near harbor has become denser with few vacant lots. Huge residential colonies have developed especially along the foot hills of

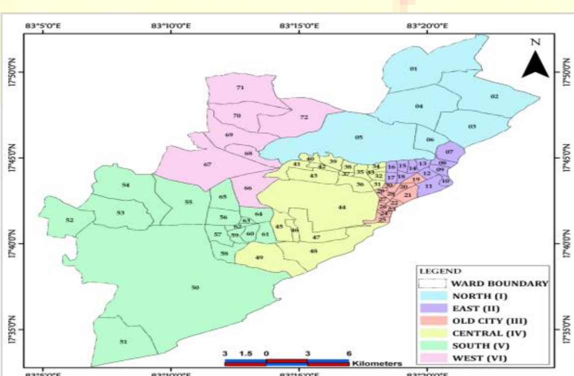


Fig. 2.1: Study Area – Ward Boundaries

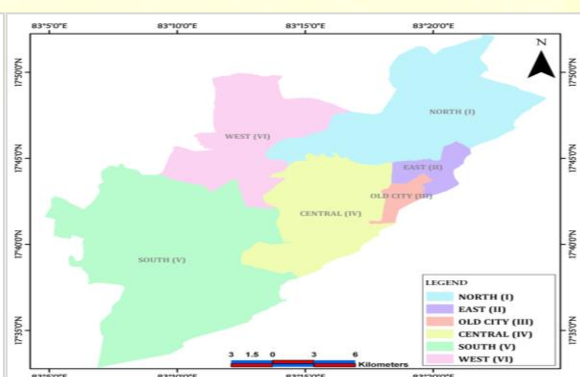


Fig. 2.2: Study Area – Zone Boundaries.

1975 1990 2009

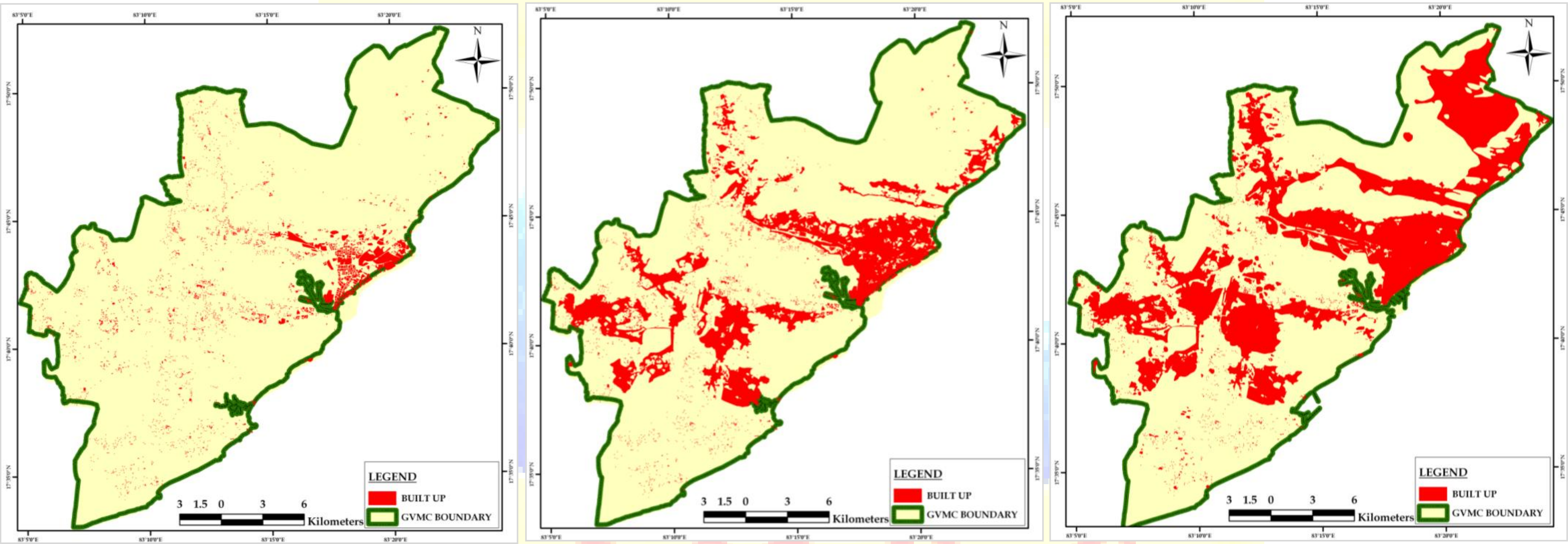


Fig. 2.3: Greater Visakhapatnam – Built Up.

Table.2.1: Built Up Density and the Growth Rate

Year	Geographical Area (Sq.Km)	Built-Up Area (Sq.Km)	Built-Up Density (%)	Built-Up Growth Rate (%)
1975	540	20.1	3.722222	-
1990	540	80.65	14.93519	301.25
2009	540	178.79	33.10926	121.69

Kailasa range, and also NH5. Similarly residential colonies have sprung around the industrial nuclei in southern parts of the city. As demand for residential layouts is on rise due to growing population (both natural and migration), Visakhapatnam Urban Development Authority (VUDA) has planned layouts beyond the Kailasa hills in the north and towards Pendurthi in the west zone. Owing to this planned development built up area started to increase along the beach towards Bheemilipatnam and also along the foot hills on the other side of Kailasa hill ranges. By the year 2009 Built up attained saturation in the core area and rapid growth is observed in the northeastern part (zone- III) of the city.

To assess and quantify this visible growth of built up areas under built up and total geographical area are extracted from the above maps and the built up density and the growth rate for each period have been calculated and presented in **Table 2.1**. This table also supports the observation inferred from the above map. The total built up area in 1975 was only 20.10sq.km and increased to 80.65sq.km in 1990 and to 178.79sq.km in 2009. Thus the growth rate between 1975 and 1990 was 301%; between 90 and 2009 was 121%. Overall percentage growth rate during the study period of 35 years is 789. This growth rate is comparable to that of Mumbai Delhi, Kolkata, and is higher than that of Chennai.

Table 2.2 Shows population density A and population density B calculated with respect to geographical area built up density respectively in the year 2009. Population densities B are much higher than the normal density A **(Fig.2.4)**. Abnormal values of both types A and B (25,312/sq.km and 33,517/sq.km) are observed in the old city closely followed by the East zone. This table exposes the magnitude of population pressure on land and need for the development. The rate of development of land in Visakhapatnam is far outstripping the rate of population growth. This implies that the land is consumed at excessive rates and probably in unnecessary amounts as well. Between 1975 and 2009 population in the area grew by about 266% while the area of built up increased by 789% or nearly 3 times greater than the rate of population growth **(Fig. 2.5).** This means that the per capita consumption of land has increased markedly over the past three decades. The per capita land consumption refers to utilization of all the land development initiatives like the commercial, industrial, educational and recreational establishments along with the residential establishments per person. Since creation of employment opportunities in one way or the other, is considered as a direct consequence of development of built up land, it can be concluded that the per capita land consumption is inclusive of all the associated land development. From this analysis it is also evident that high per capita built up is an indicator of urban sprawl.

Table.2. 2: Population Density (A & B) - 2009

S.No	Ward No	Zone No. & Name	Total Geographical Area (Sq.Km)	Built-Up Area	Population	Population Density (A)	Population Density (B)
1	1-6	I-North	124.08	37.76	116084	936	3075
2	7-18	II-East	15.58	10.11	255641	16408	25278
3	19-30	III-Old City	9.15	6.91	231607	25312	33516
4	31-49	IV-Central	86.58	46.16	379489	4383	8221
5	50-65	V-South	219.43	62.54	310437	1415	4964
6	66-72	VI-West	85.18	15.31	141841	1665	9264

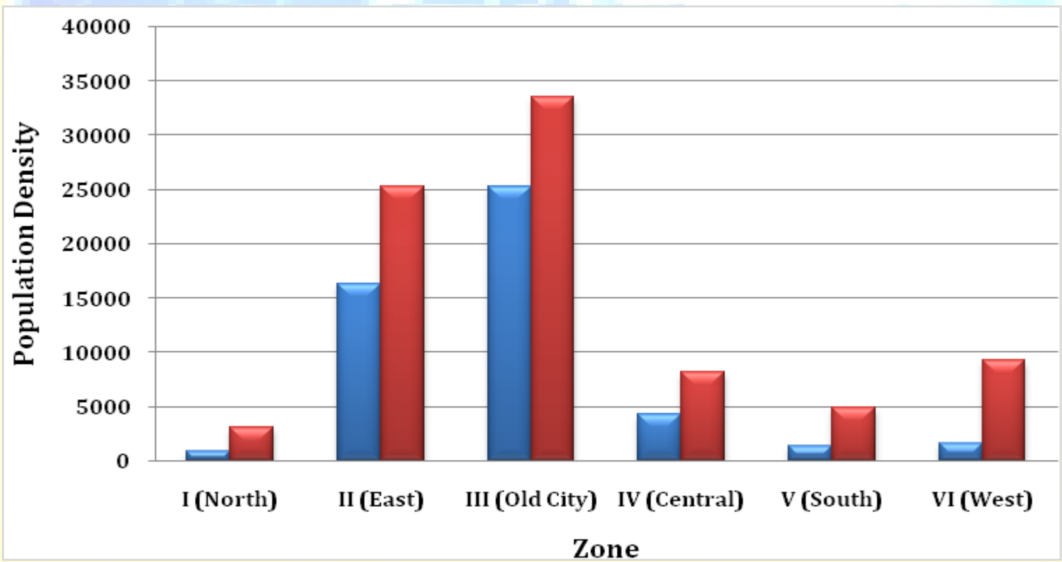


Fig.2.4: Population Densities A and B

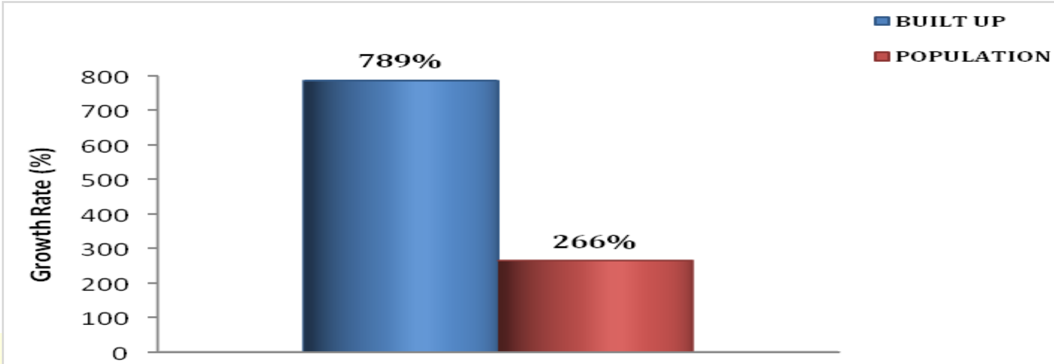


Fig.2.5: Growth Rate of Population & Built up between 1975 & 2009

To identify the specific and various influential forces in the study area, a zone wise analysis is attempted. Using the zone wise values of built-up and total area extracted from the attribute tables, built- up densities were calculated by dividing the built up area of each zone and converted to percentages. **Table 2.3** presents the zone wise statistics of the built up for the three selected years and depicts the variations in the built up and their densities in different zones.

Table.2.3: Zone wise Statistics of Built Up

Ward No	Zone No. & Name	Total Area (Sq.Km)	Built Up Area (Sq.Km)			Built Up Density			Built Up (%)		
			1975	1990	2009	1975	1990	2009	1975	1990	2009
1-6	I (North)	124.08	0.95	5.48	37.76	0.01	0.04	0.30	0.77	4.42	30.43
7-18	II (East)	15.58	3.44	7.57	10.11	0.22	0.49	0.65	22.08	48.61	64.91
19-30	III (Old City)	9.15	3.52	4.53	6.91	0.38	0.50	0.76	38.47	49.51	75.52
31-49	IV (Central)	86.58	6.57	18.73	46.16	0.08	0.22	0.53	7.59	21.64	53.32
50-65	V (South)	219.43	3.86	34.07	62.54	0.02	0.16	0.29	1.76	15.53	28.50
66-72	VI (West)	85.18	1.76	10.26	15.31	0.02	0.12	0.18	2.06	12.04	17.98

The total built up of the city in the year 1975 was only 20.10sq.km and most of it was concentrated in Old city, East zone, around the harbor in central zone and in South zone. Central zone alone consist of 33.8% of the total built up followed by South zone (19.9%), Old city (18%) and East zone (17. 0& %). About 90% of the total built up was concentrated in these four zones. Most of the built up around the harbor is of residential and commercial use. Educational institutions, Banks and other financial institutions, wholesale and a retail outlet, concentrated in these zones is one of the reasons for high density of built up. Besides, the concept of proximity to work place that is people's residential preferences in the early years of urbanization also played an important role in the distributional pattern of built up.High percent distribution of built up in central and south zones can be attributed to the pull factor of major industries. Due to the establishment of several major industries like HZL (1966), BHPV (1966), and Steel Plant (1970) in the south zone and HPCL (1957), Coromandel Fertilizers Ltd (1964) in central zone, vast areas have been converted to industrial as well as residential uses. All most all major industries were established in this region except LG. Polymers, erstwhile Hindustan Polymers (1967) which falls in the West zone is also located close to the industrial belt of the South zone. The North zone beyond Kailasa hill range and West zone are comparatively less developed in this particular year of study and consists of 4.89% and 8.75% of the total built up respectively. By the year 1990 i.e. after fifteen years the total built up increased by four times and has become 80.65sq.km. In general built up area has increased in all the zones but an abnormal growth observed in the South zone which can be attributed to the expansion of steel plant (both industrial & residential sectors) and establishment of Export Processing Zone in 1989. Considerable increase in built up is observed in Central, West and North zones also. Similarly in 2009 also maximum built up is observed in the South zone (62.54 sq.km) followed by Central (46.16sq.Km) and North zones (37.76sq.km). The North zone typically developed as an exclusive single use (residential) zone owing to the planning approach. From the above figures it can be inferred that the built up is more and increasing at a rapid rate in the Central and South zones when compared to the East zone and old cities. This gives an impression that the growth rate in the East zone and old cities are stagnant but the fact is that these zones have high densities at the beginning of the study period and have attained a maximum concentration 0.65 and 0.76 respectively at the end of the study period. Compact city cores usually record a low growth rate. Maximum increase in built up i.e. from 3.86sq.km in 1975 to 62.54sq.km in 2009 is observed in the south zone, the industrial region. In spite of this high growth rate the built up density remains lower than all other zones except the west, indicating possibility for development in future. Logistic hub, Special Economic Zone, Export processing zone, Pharma city at Parawada, Gangavaram Port, Gems and Jewellery Park and Apparel Export Park, Simhadri Power Plant, large number of educational institutions etc are the recent projects developed in the south western end during latter half of the study period. On the other hand large areas of built up is developed by the IT industry and Educational and

Technical Institutions on the northern end of the city. These developments are apparent reasons for the high growth rate of population and eventual growth of built up.

The general observation is that there is a tremendous growth rate in built-up and the sprawl did not follow any specific pattern and the strong impact of topography is obvious. This factor coupled with many multiple and complex growth factors have evolved the existing somewhat linear pattern along the high way and leap frog pattern towards the ends. Though the sprawl pattern seems to be of leap frog type towards north and south, it appears so because of the physical barriers such as hill ranges. Since they are not suitable either for residential purpose or for setting up of industries they appear vacant in the above maps. Owing to these barriers radial pattern of growth as observed in the cases of other Indian cities (mentioned in the review) did not occur and the pattern of built up appears scattered around the budding industries especially in the southern and central zones. However the typical characteristic of Urban Sprawl that is a high density urban core and rapidly decreasing built up densities toward suburbs with high growth rates is clearly observed in the study area. Planning aspects such as decentralization of metropolitan areas, the emergence of zoning over the past few years has contributed to the creation of single-use developments and the spatial separation of the home from all other activities. The low density, single-use automobile dependent type of development has come to dominate the urban environment.

An attempt is also made in the present study to measure the degree of sprawl for which entropy approach is adopted and applied the methodology described in the corresponding section. Ward wise & zone wise built up statistics of the three selected years are used to derive the required parameters (Pi, logPi and log(n)) and interpreted in the Shannon's entropy formula and the values are presented in **Table. 2.4.** The values of entropy range from 0 to log n. If the distribution is very compact then the entropy value would be closer to 0 and when the distribution is much dispersed the value will be closer to log n. High value of entropy indicates the occurrence of Urban Sprawl. log (n) in case of Visakhapatnam that is the total number of wards is 72 and log value of it is 1.86. The values are on higher side, close to the maximum value of log (n). The entropy index values calculated for the study area are consistently high during the study period and indicate a clear dispersion of the built up. Entropy index values are 1.55, 1.73 and 1.79 for the years 1975, 1990 and 2009 respectively. These values indicate the degree of dispersion is gradually on rise during the study period. However, the difference in the index value is very less (0.22) for the entire study period of 35 years. The value of 1.79 almost equaling the log (n) of 1.85 at the verge of 2009 accomplish saturation point that is the maximum possible degree of dispersion for the given study area. Similarly zone wise entropy index values are also calculated and they also in turn confirmed the above condition. The index values range between 0.52 and 0.74 where log n value is 0.78. Therefore it can be concluded that Visakhapatnam even during 1970s exhibited a clear inclination for the possible development which is proved to be true by attaining maximum values in the following decades.

Further the entropy approach is adopted to study the dispersion trends in various directions (zones) of the city as the degree of sprawl is not uniform radially due to the complex and multiple factors discussed above. Individual entropy index values are calculated for each zone for all the three years and are presented in **Table 2.5**. Interestingly **t**he index values of all six zones are closely approaching their respective log (n) values indicating high degree of dispersion. In other words the sprawl took place in all zones at more or less the same rate and at no point even a slight indication of concentration is observed. The index values ranged between 0.59 and 1.12 against varying log n values. The North zone (1) which is essentially a residential area has moderate index value (0.59) in 1975 recoded a gradual increase throughout and attained an index value of 0.74 against 0.79 (log n) in the year 2009,

Table.2.4: Shannon's Entropy in 1975, 90 & 2009

	Year	**Geographical area**	**Built-up**	**Entropy**	**Log (n)**
Ward Wise	1975	540.00	20.10	1.5555	1.85733
	1990	540.00	80.65	1.7319	1.85733
	2009	540.00	178.79	1.7872	1.85733

	Year	**Geographical area**	**Built-up**	**Entropy**	**Log (n)**
Zone Wise	1975	540.00	20.11	0.51709	0.77815
	1990	540.00	80.64	0.68136	0.77815
	2009	540.00	178.79	0.73836	0.77815

	Year	**Geographical area**	**Built-up**	**Entropy**	**Log (n)**
1Km Buffer from CBD (30 Circles)	1975	540.00	19.62	1.14	1.47712
	1990	540.00	90.64	1.28	1.47712
	2009	540.00	190.44	1.34	1.47712

500 Mts	**Year**	**Geographical area**	**Built-up**	**Entropy**	**Log (n)**

Buffer from NH-5 (10 Zones)	1975	500.00	19.59	0.07	1.04
	1990	500.00	99.90	1.00	1.04
	2009	500.00	191.12	1.03	1.04

indicating the increase in sprawl. Not much variation is observed or expected in the old city and East zones as there is a minimum possibility for growth. A peculiar situation is observed in the South zone which recorded a slightly lower index value (though it is as low as 0.05) from 1975 to 1990 and again an increase by 0.02 in 2009. It means the distribution of built up in 1975 was more dispersed that in 1990 and 2009. It should be noted that the entropy value indicates the degree of dispersion or compaction of the built up in the area. The above values are closer to the maximum limit of log n, thus indicating the degree of dispersion of built up in the region. However the degree of dispersion has come down marginally and the distribution are predominantly dispersed or there is the presence of sprawl. Except for the indication of slight fluctuations in the sprawl pattern, high dispersal throughout the study period is observed in all zones of the study area.

Table.2.5: Zone wise Individual Entropy (Hn) values

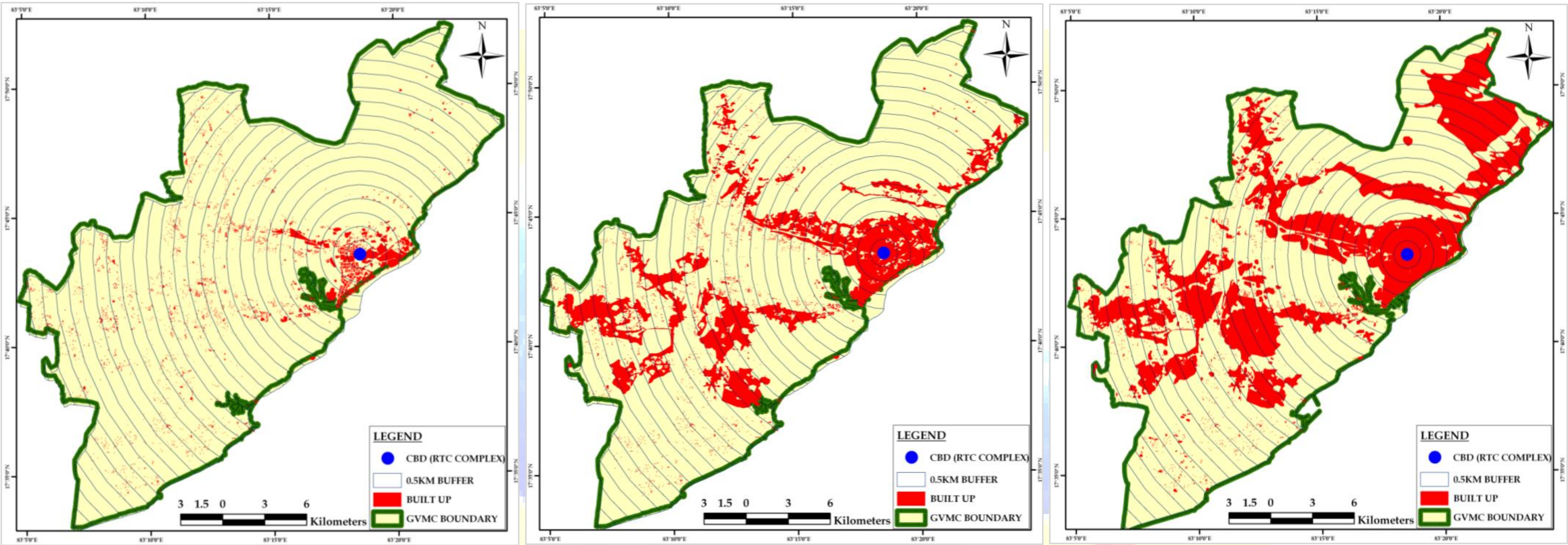
Zone No	**1975**	**1990**	**2009**	**Log (n)**
	Hn	**Hn**	**Hn**	
Zone – I	0.59	0.65	0.74	0.79
Zone – II	0.93	1.03	1.05	1.08
Zone – III	0.97	0.98	1.08	1.08
Zone – IV	1.06	1.21	1.25	1.28
Zone – V	1.12	1.07	1.09	1.2
Zone – VI	0.75	0.70	0.75	0.84

Distance Decay of Urban Sprawl:

Distance decay refers to the decrease of magnitude/intensity between two observations as the distance between them increases. Distance decay theory predicts that functions will peak at some distance relatively close to an urban centre and then decline exponentially as the distance increases. (Parthasarathy et.al, 2009). Since all functions are manifested by the land development it is assumed that built up is strongly influenced by the distance factor. Therefore an attempt is made in this section to analyze the impact of distance on built up, with respect to CBD and the National High Way-5.

Impact of CBD:

To measure the impact of Central Business District (CBD) on the development of built up area, concentric rings of 1km interval were generated on the built up themes from the urban core until the boundary is enclosed **(Fig.2.6).** Built up area was extracted and densities were calculated for the 30 concentric zones and eventually entropy for the three selected years was calculated and presented in **Table 2.6.** The range of index values varied from 1.14 to 1.34 where log n being 1.4. These results are also congruent with those of the above results. To estimate the impact of CBD on land development percentage built up densities at one kilometer interval, radiating from CBD are presented in **Table 2.6**. In 1975 percentage built up density was maximum (50.74%) around the CBD and sharply decreased to 18.1% at the 5km circle. From there onwards the values are observed to be fluctuated between 5% - 0.2%. In 1990 the percentage density of built up around CBD have increased to a maximum of 80% and showed the same trend of the earlier period with small exceptions. One is that along with time the overall densities of built up have increased and the second is that development of a second peak around 14^{th} km circle, indicating the presence of a second core which is identified as the erstwhile Gajuwaka Municipality. Again the densities decreased towards the peripheries. At the end of the study period built up density has attained the maximum value of 100% around the CBD and a general increase of density over the earlier period is evident. The trend observed in 1990 has become more prominent in the later period where the densities around the Gajuwaka core have increased to around 50%. Gajuwaka during the study period has developed into a prominent industrial and commercial hub and its impact can be seen from the peak built up density at the center and declining densities away from it. An odd observation in 2009 is that the percentage built up in the last buffer zone at 30km is 50% which is highly contrasting when compared to the densities (varies from 0.2- 11%) between 20-29 kilometers. The observation of original values will clarify this odd occurrence.



1975 **1990** **2009**

Fig. 2.6: Built Up Distribution in Concentric Circles (1 km interval) around CBD

The actual geographical area covered in the 30th km buffer zone is only .08sq.km, extremely small and the lowest of all the zones. The corresponding built up area is also very low i.e. 0.04sq but these values when converted to percentage and represented by a histogram shows an odd impression. Thus the irregular topography and morphology of the study area seems to have a reasonable effect on distribution of geographical area as well built up which is indicated by this odd fluctuation in the histogram. However the impact of CBD on land development is clearly evident. The analysis also recognized the evolution of Gajuwaka municipality and the density variations from its core further confirms the impact of distance on land development.

Table.2.6: Built up Density (%) Variations from CBD

Circle No.	Buffer in KMS	Total Area (Sq.)	Built Up Area (Sq.)			Built Up (Density)		
			1975	1990	2009	1975	1990	2009
1	CBD-1	2.97	1.51	2.13	2.97	0.51	0.72	1.00
2	1-2	8.90	3.52	7.09	8.71	0.40	0.80	0.98
3	2-3	13.15	2.94	7.87	9.75	0.22	0.60	0.74
4	3-4	16.31	2.08	4.21	8.00	0.13	0.26	0.49
5	4-5	18.56	0.87	3.26	9.83	0.05	0.18	0.53
6	5-6	20.72	0.80	2.54	9.19	0.04	0.12	0.44
7	6-7	23.28	0.49	2.21	8.47	0.02	0.09	0.36
8	7-8	26.19	0.46	3.27	8.28	0.02	0.12	0.32
9	8-9	27.18	0.64	3.72	8.63	0.02	0.14	0.32
10	9-10	28.30	0.36	2.33	7.98	0.01	0.08	0.28
11	10-11	29.98	0.49	2.67	10.05	0.02	0.09	0.34
12	11-12	31.19	0.56	4.83	11.94	0.02	0.15	0.38
13	12-13	32.06	0.54	6.49	15.95	0.02	0.20	0.50
14	13-14	32.29	0.56	7.62	13.98	0.02	0.24	0.43
15	14-15	30.40	0.68	8.76	13.09	0.02	0.29	0.43
16	15-16	25.47	0.36	5.76	11.18	0.01	0.23	0.44
17	16-17	22.34	0.36	3.34	8.43	0.02	0.15	0.38
18	17-18	17.58	0.23	1.45	6.86	0.01	0.08	0.39
19	18-19	17.52	0.42	3.03	5.60	0.02	0.17	0.32
20	19-20	18.45	0.56	3.43	6.20	0.03	0.19	0.34
21	20-21	19.04	0.16	2.63	2.19	0.01	0.14	0.11
22	21-22	17.63	0.15	0.79	1.57	0.01	0.04	0.09
23	22-23	15.51	0.29	0.54	0.84	0.02	0.03	0.05
24	23-24	14.42	0.29	0.30	0.38	0.02	0.02	0.03
25	24-25	12.14	0.21	0.24	0.28	0.02	0.02	0.02
26	25-26	6.63	0.03	0.07	0.07	0.01	0.01	0.01
27	26-27	4.18	0.01	0.02	0.01	0.00	0.01	0.00
28	27-28	2.35	0.01	0.02	0.01	0.01	0.01	0.00
29	28-29	1.04	0.01	0.02	0.01	0.01	0.02	0.01
30	29-30	0.08	0.01	0.02	0.04	0.18	0.24	0.46
31	Beyond 30	4.10	0.00	0.00	0.00	0.00	0.00	0.00

To further affirm the impact of distance from CBD on land development in various zones built up densities of all the six zones and their distance from CBD are measured and presented in **Table 2.7**. The density curves plotted **(Fig.2.7)** against their corresponding distance for the three selected years show a clear inverse relation between distances and built up density. That means closer the zone to the Core (CBD) higher is its density and vice-versa. In the year 1975 the Old City where the Urban Core is located, records the peak density (0.38) whereas low densities (0.01-0.02) are observed in the outermost zones viz. North, South and West zones, indicating a remarkable impact of CBD on land development. The

Table 2.7: Zone Wise Built Up Densities & Distance from CBD

Zone No. & Name	Built Up Density			Distance from CBD to Zone Center (km)
	1975	1990	2009	
I (North)	0.01	0.04	0.30	11.87
II (East)	0.22	0.49	0.65	2.96
III (Old City)	0.38	0.50	0.76	1.36
IV (Central)	0.08	0.22	0.53	3.05
V (South)	0.02	0.16	0.29	13.29
VI (West)	0.02	0.12	0.18	13.59

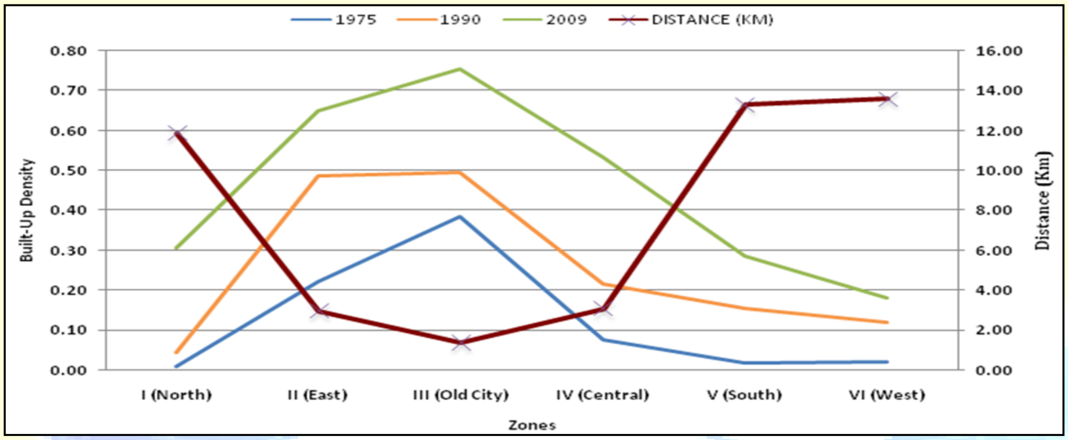


Fig.2.7: Impact of Distance on Built Up Density

same trend is continued throughout the study period except for the increasing densities with time. The density in the Old City has increased to about 0.8 in 2009 whereas in the farthest it has increased to 0.3. Another interesting observation from the graph is that the growth rate of built up near the core are moderate (about (about 2 fold increase) in contrast a maximum of 30 times increase of built up in the North zone. Therefore it can be concluded that in spite of the strong impact of distance on the land development there are other influential factors which resulted in the tremendous growth rates in the peripheries. The growth factors like development of commercial, industrial and institutional establishments, Planning policy, repulsion to higher rentals in the city centre and changing people's residential preferences, development of transport facilities and eventual increased access to city center etc. may have influenced the growth of built up in the peripheries. A noteworthy point regarding peoples residential preferences are rather a force in this area because most of the middle income group people could not afford a own house or an apartment due to higher costs which are beyond their reach in the city centre. Therefore, this section people prefer to purchase residential plots at cheaper prices in the suburbs. This situation is quite contrast to the people's choice of suburbanization in the western countries where wealthy people move away from the city centers to have luxurious housing environment free of pollution.

Impact of National Highway-5:

Buffer zones at 500 meters interval are developed along the NH-5 **(Fig.2.8)** up to 5.5 kilometers**.** Built up statistics are derived and presented in **Table 2.8**. The percentage densities of built up plotted against the distance **(Fig.2.9)** absolutely manifest the impact of NH-5 on land development. From the histograms it is evident that the percentage built up densities in all buffer zones increased considerably during the study period with a clear decreasing trend away from the High Way-5. In the year 1975 the percentages of built up density varied between 1.46 and 7.77 with an average value of 4.5. In 1990 percentage densities are observed to range between 7.98 and 44.71 whereas in 2009 they varied from 23.52 to 61.23. Normally maximum density is expected in the first buffer zone that lies on either side of the transport arteries and lower densities away from them. The density statistics are concurrent with this general notion and maximum density is observed in the first while the minimum density in the peripheral zone beyond the 5.5 kilometer. As evident from the figure the trend of density distribution is observed throughout the study period. Since the built up density histogram showed an obviously inverse relationship with distance, land development in the study area can be attributed to the impact of High Way.

Table.2.8: Built up Density (%) Variations from NH-5

Circle No.	BUFFER IN KMS	Total Area (Sq.Km)	Built Up Area (Sq.Km)			Built Up(Density)		
			1975	1990	2009	1975	1990	2009
1	0-0.5	47.16	3.52	20.24	27.72	0.07	0.43	0.59
2	0.5-1	44.91	2.54	15.98	22.09	0.06	0.36	0.49
3	1-1.5	43.84	2.67	11.12	17.80	0.06	0.25	0.41
4	1.5-2	40.93	2.42	8.45	16.45	0.06	0.21	0.40
5	2-2.5	37.81	1.62	5.99	14.38	0.04	0.16	0.38
6	2.5-3	34.74	1.12	5.83	13.86	0.03	0.17	0.40
7	3-3.5	31.76	0.90	5.26	12.50	0.03	0.17	0.39
8	3.5-4	30.84	1.14	5.38	11.82	0.04	0.17	0.38
9	4-4.5	30.16	0.80	4.82	9.00	0.03	0.16	0.30
10	4.5-5	28.49	0.48	3.76	7.00	0.02	0.13	0.25
12	Beyond 5KM	169.34	2.39	13.06	38.50	0.01	0.08	0.23

Impact of Transport Network:

Road densities of each ward, for 1975 and 2009 are calculated using the formula Road Length/Total Area x 100 and tabulated **(Table 2.9).** At the end of the study period road length in the South zone, the industrial hub of the city has maximum road length (635 km) but has a low density owing to its vast geographical area. In contrast the road length is minimum (66 Km) in the old city (CBD) but has high density due to limited geographical area. In 1965 road density varied between 65 in the North zone to 142 in the old city and central zones

1975 1990 2009

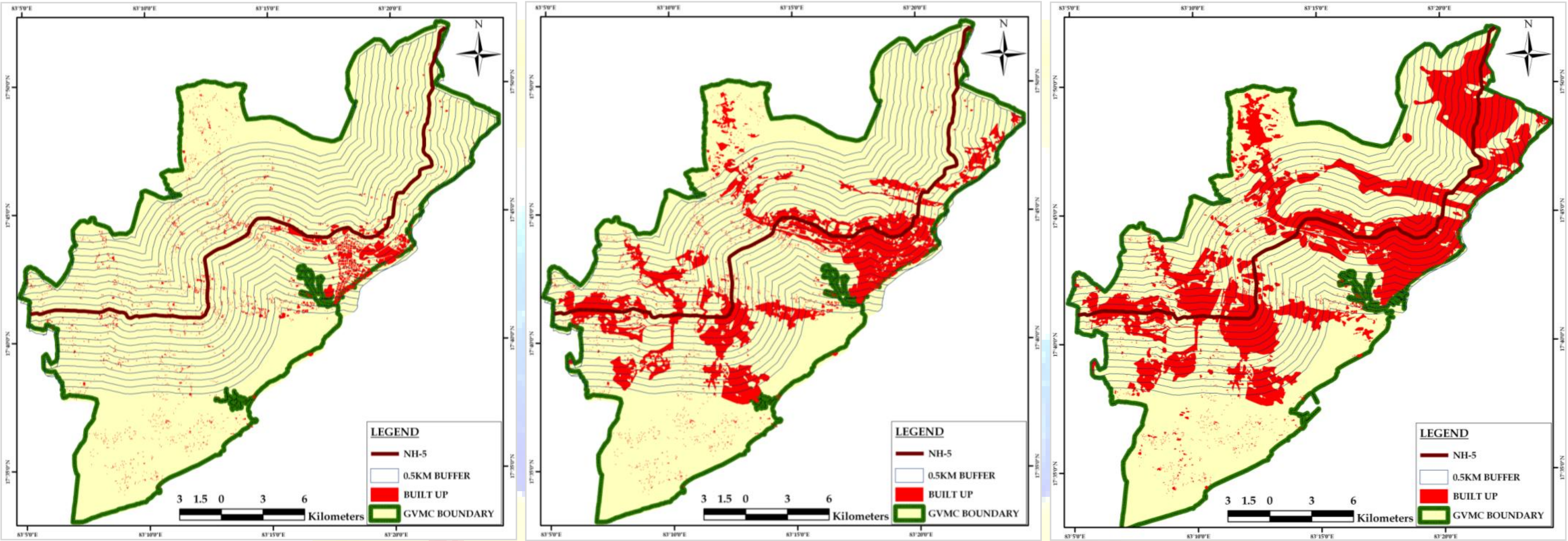


Fig. 2.8: Built- Up Distribution in Buffer Zones (500 meters interval) along NH-5

Table.2.9: Temporal Variations of Road Density

S.No	Zone Name	Zone Area(Sq.Km)	1975		2009	
			Road Length (Km)	Road Density (%)	Road Length (Km)	Road Density (%)
1	NORTH(I)	124.08	81.16	65.41	148.46	119.64
2	EAST(II)	15.58	17.57	112.75	154.78	993.48
3	OLDCITY(III)	9.15	13.04	142.51	66.00	721.36
4	CENTRAL(IV)	86.58	123.26	142.37	366.40	423.19
5	SOUTH(V)	219.43	187.91	85.64	635.71	289.71
6	WEST(VI)	85.18	80.45	94.44	286.40	336.23

(Fig.2.10). The zones surrounding the CBD have high densities when compared to the peripheral zones. Over a period of 35 years, the densities increased by many folds and varied between 119 to 993. As usual higher densities are observed around the Core and lower densities in the peripheries, the same trend at the beginning of the study period is carried forward. The built up densities are congruent with the road densities asserting the impact of transport network on land development.

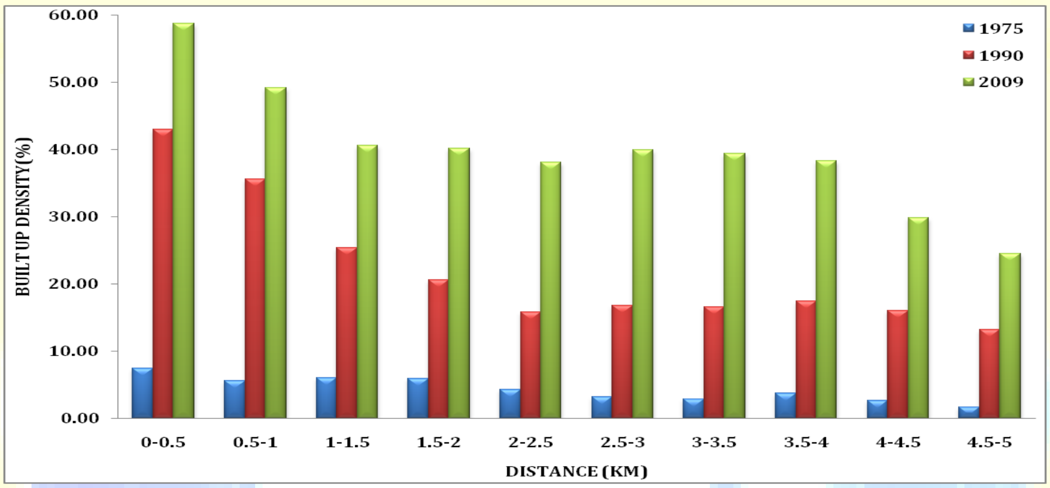


Fig.2.9: Built up Density (%) Variations from NH-5

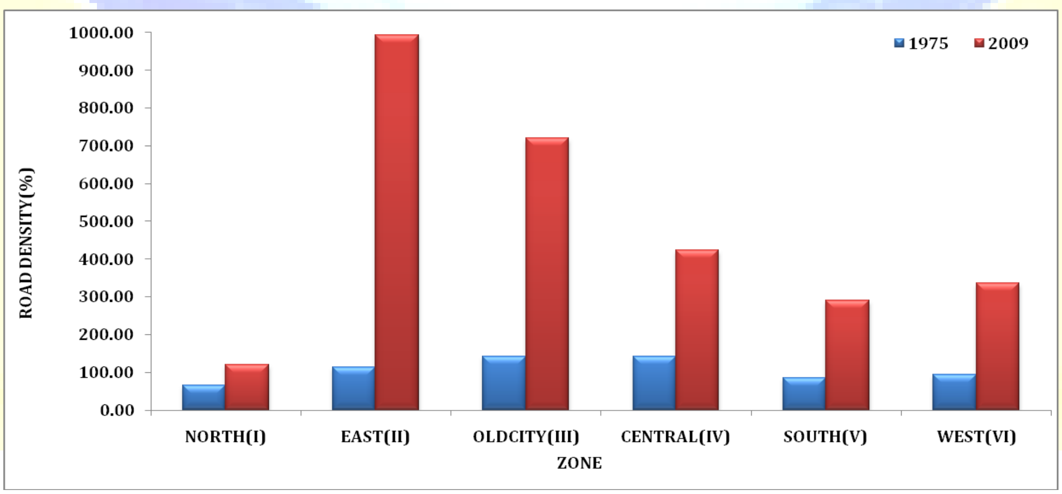


Fig.2.10: Temporal Variations of Road Density

CONCLUSION

Urban Sprawl in Greater Visakhapatnam did not follow a regular radial pattern like many other Indian cities owing to its peculiar topographic and morphologic conditions. Ribbon pattern of sprawl is observed along the Highway and Leapfrog type towards northern and southern ends of the city. Built up in urban areas reflect all its functions in total and the measurement of this parameter is essential for monitoring the urban dynamics. The rate of land development is as high as 789% during the 35 year of study period while the population growth rate is 266%. Thus the per capita land consumption has increased markedly and it is true especially in the peripheral zones a strong indicator of sprawl. The distribution of population density in various wards also justifies the above characteristic of sprawl – "dense core and dispersed suburbs". The higher entropy values at different points during the study period indicate high rate of sprawl even in early seventies and sustained throughout. Therefore the entropy approach is proved to be efficient to identify measure and monitor the spatio-temporal patterns of urban phenomena (Built up land). The impact of distance on land development is evident through the distance decay analysis. The growth rate of built up is high away from the city centre (CBD) and the NH-5, but the built up density (%) is low indicating possible growth in the future. The impact of primary developmental factors such as population growth, industrial growth, and infrastructural development combined with the regulatory and cultural aspects is clearly evident from the above study.

Greater Visakhapatnam like many other cities in the developing countries is in the middle of the transition process with very high growth rate. To ensure adequate housing, sanitation, health and transportation services to this sprawling city with exceptionally high growth rate is a big challenge to the administrators and planners. A proper understanding of the sprawl pattern, direction, and level of dispersion is required for planning the future developmental projects and as well as residential & facilities development and management. Thus the present study would provide this basic information and efficiently support the planners in decision making.

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