Spatiotemporal Land Use Patterns in Urbanization

P.Kalyani *purini_kalyani@yahoo.co.in*
Dept. of Computer Applications
Priyadarshini College of Engineering
Nellore.

P.Govindarajulu *pgovindarajulu@yahoo.com*
Dept. of Computer Science,
S.V. University
Tirupati, Andhra Pradesh, India.

Abstract

Urban planning was very much a design and engineering exercise with the state as a single stake holder. Megacities with millions of population, which has undergone a series of physical as well as socio-economic changes over the last 60 years. These for in different areas of India, new planning approaches require the need to understand the complicated urban land development process. GIS- Geographic Information System and remote sensing provide the advance techniques and methods for studying urban land development and assist urban planning. This research survey firstly describes the urban expansion process till now and land use changes in the inner city.

Keywords: GIS, Remote sensing, Spatio-temporal, patterns of urbanization, land use change, spatial pattern analysis, urban planning.

1. INTRODUCTION

Over the last 50 years the world has faced dramatic growth of its urban population. Mega cities the largest category of urban agglomeration, attract considerable attention because of their population size, economic, socio-cultural, environmental and political influence and geographical complexity. Until 1975 there were just three mega cities in the world. The number of so-called mega cities increased in the period from 1975 until today from 4 t0 22, mostly in less developed regions [13].The number of cities increased to 27 mega cities until 2015 [11].

The population development of the world is expected to increase continuously from 6.7 billion to 9.3 billion in 2050. But a heavy increase of mega cities creates a serious problem in India. The population of India (today 1.2 billion) has grown two and half times, but the urban population has grown nearly five times. The number of Indian mega cities will double from the current three (Mumbai, Delhi and Kolkata) to six by the year 2021, (new additions will be Bangalore, Chennai and Hyderabad), when India will have the largest concentration of mega cities in the world [4].

Then the number of six mega cities (Mumbai, Delhi, Kolkata, Bangalore, Chennai and Hyderabad) is increased by twelve by the year 2015 (new Ahmadabad, Pune, Surat, Kanpur, Jaipur and Lucknow) [21]. With the rapid increase of urban growth, makes us to face lot of socio-economic, environmental and political problems. This phenomenon will necessitate advanced methodologies such as space technologies, which help city planners, economists, environmentalists, ecologists and resource managers solve the problems which accompany such growth [12]. Urban planners need information about the rate of growth, pattern and extent of sprawl to provide the basic amenities such as water, sanitation and electricity etc. Since planners currently lack such information, most of the sprawl areas lack basic infrastructure facilities.

On the last decade, earth observation sensors developed to a stage where global maps have been made possible on low resolution (LR) from 250m to 2 Km [15]. Examples are global urban extent maps based on e.g., DMSP-OLS night-time lights imagery [7] ,MODIS data [3][16].

A list, analysis and comparison of the various available global data sets is presented and discussed by Potere and Schneider [14]. However, most of them are provided for a single time step, and the cause geometric resolution is a clear restriction tracing the small-scale urban outlines, extents and patterns.

Even though higher resolution sensors systems are available e.g., Land sat, spot, Rapid Eye, IRS, IKONOS, Quick Bird, World View-I and II. The provision of a global coverage or at least of a large amount of cities – is not an easy task. Limitations such as cloud coverage, on bound storage capacity, sensor utilization and sharing of the same source with other EO projects cause a several years lasting acquisition period. Furthermore, data costs and processing effort are significant. Thu, a global coverage at the scale covered by the medium (MR: here defined as on 10m to 100m) and high resolution (HR: 1M-10m) to very high resolution (VHR: <1m). EO sensors are inexistence.

Research studies on long term monitoring of the spatial effects of the urbanization are mostly based on MR (Medium Resolution) data from sensors such as Land sat or spot, having lower geometric resolution and thus allow for fewer thematic details.

Different studies have also shows that radar imagery is an excellent basis for classifying, monitoring and analyzing urban conglomerations and their development overtime especially in cases of large area mapping [5].

Using of MSS[Multi Spectral Scanner) data ,ETM (Enhanced Thematic Mapper data) and & Terra SAR-X Strip map data is used for monitoring urbanization in mega cities from space for analysis of 22 to 27 mega cities and their number is constantly increasing [11].

Temporal and spatial urban sprawl, re-densification and urban development in the tremendously growing six mega cities to 12 mega cities in India, and became the largest urban agglomerations [21].

In India, by using Quick bird data of VHR (Very High Resolution <=1M i.e., 0.61M) with a sub-meter geo-metric resolution is applied for the multi-scale urban analysis of the Hyderabad metropolitan area of deriving parameters such as houses, streets, shadows, vegetation, bare soil etc.,[20].For the analysis of the urban patterns, first we have to classify the obtained data. The classification of the various land-sat scenes is based on an object-oriented classification procedure [19]. The first step is a multi-resolution segmentation. The second step is a hierarchical thematic classification procedure allowing mapping four different thematic classes, namely 'water', 'vegetation', 'undeveloped land' and 'urban' [1].For the classification of TerrraSAR-X (ie., Radar data) data, a pixel- based classification algorithm is applied [8].

The main objective of the survey is to investigate the dynamics of the urban landscapes in response to rapid urbanization among the most populated and the fastest growing cities.

More specifically, our objects are two:

- Characterize intra-level urban landscape transformations between time periods.
- Quantify relations between landscape transformations, urbanization patterns.

2. STUDY AREA

The term 'Megacity 'refers to the largest category of urban agglomerations. The UN 2007[24] defines mega cities quantitatively as conurbation having more than 10 million inhabitants. Today, based on official number UN, 2009[22], there are 27 mega cities throughout the world and their number is expected to increase [11].

Cities such as Bangkok, Hyderabad, Chicago, Caracas, just to name a few, are already close to becoming a mega city. India is a prominent example for dynamic mega city development already having three mega cities (Mumbai, Delhi, and Kolkata)[13] the country will increase to six by the year 2020(including Bangalore, Chennai and Hyderabad), then having the largest concentration of mega cities in the world [4].

Less attention is paid to “Smaller” explosively fast growing cities, whose high growth rates may precipitate transmission into mega city status.

And the six mega cities increased by twelve mega cities by the year 2020(including Ahmadabad, Poona, Surat, Kanpur, Jaipur and Lucknow)[21].

It is clearly reveals that since 1975 the population development and thus, the rate of urbanization in mega cities outside the high developed countries, were enormous. The explosion of mega cities is low developed countries results from both the population growth (due to the demographic transition) and the process of migration (due to economic factors the gap between the urban and rural productivities and incomes and to sociological reasons: the attraction of the urban way of life).

In this study we understand the terms ‘urban foot print or urbanized areas’ as the land directly occupied by a particular physical man made structure. Thus, this definition is representing a ‘settlement mask’, defined by buildings, streets and impervious surfaces.

3. DATA AND METHODS

Data:

The Land sat program represents a series of earth observation satellites that have been continuously available since 1972.Therefore this system allows for an analysis of extended time series. It started with the Multispectral-scanner(MSS) featuring a geometric resolution of 59 meters and a spectral resolution of four bands(green, red, two near infrared bands).Since 1982 the thematic Mapper(TM) has operated with 30 m geometric resolution and seven spectral bands. Since 1999 the Enhanced Thematic Mapper (ETM) has operated with an additional panchromatic band and 15m geometric resolution. Since 2002 Ikonos data of with 1m geometric resolution and since 2005 Quick bird data with 0.61m geometric resolution for finding the illegal constructions in the inner city [20].With its field of view of 185 KM the satellite is able to survey the large metropolitan areas of the study sites-thus covering in dependence of their spatial position entire areas and no cloud coverage.

The secondary data is Demographic data i.e we get from Census of India.

The level of description with Landsat features is not flooded with microscopic detail, but re-gives nevertheless the specific features of the urban system. For this purpose, the requirements for the differentiation of classes are limited to the classification of built-up and non-built-up areas.

Methodologies for Land cover classification:

One of the primary obstacles to Urban land cover classification from optical data sets is the diversity and spectral heterogeneity of urban reflectance[9][10][17][18][25].Small(2005) shows that urban land cover is extremely variable at a variety of spatial scales; he also shows intra-urban spectral variability due to a diversity of materials used for man-made structures as well as interurban variability as a result of socio-economic, cultural, historical and Environmental differences among 28 different cities across the world.

Having this obstacle in mind, we developed a user interface with a fixed processing chain with a pre-defined feature set **fig(1),**but the possibility to interactively adapt classification thresholds to the specific spectral characteristics of the particular imagery [2].

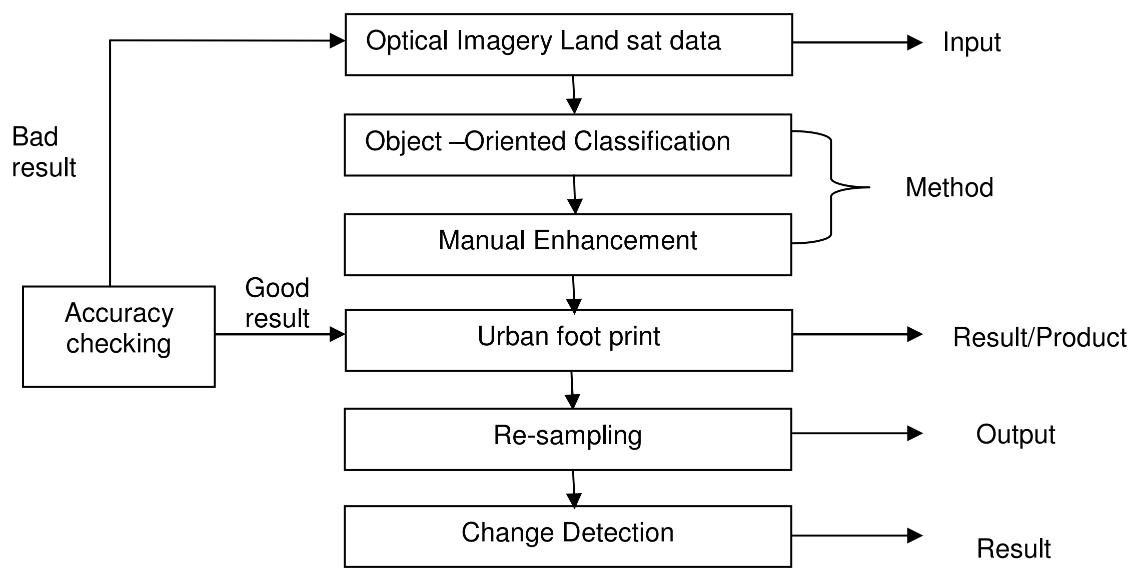

FIGURE 1: Flow chart of methodology for land use/land cover and change detection

The developed service chain is a semi-automatic classification procedure implemented as Defines Architect Solution. With this concept, we aimed at a straight forward classification approach being consistent, traceable and transparent for a large variety of optical Land Sat scenes at different times and parts of the world

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The classification of the various Land Sat scenes is based on an object-oriented classification procedure. The first step is a multi-resolution segmentation fig(2) bottom up regions merging technique starting with one pixel objects. Throughout a pair wise clustering process, underlying optimization procedure minimizes the weighted heterogeneity of n h resulting image objects, where n is the size of a segment and an h, a parameter of heterogeneity. In each step, that pair of adjacent image objects is merged which results in the smallest growth of the defined heterogeneity. If the smallest growth exceeds the threshold defined by the scale parameter, the process stops doing. So, multi-resolution segmentation allows adjustments of the scale parameter between 5 and 20 in dependence of the structure of the city.

The second step is a hierarchical thematic classification procedure allowing mapping four different thematic classes namely, 'water' , 'vegetation', 'undeveloped land' and 'urban' [1].However, in this study only the urban areas are considered. The methodology contains a hierarchical decision tree structure shown in figure Decision Tree.

Decision trees are compared of hierarchically structured decisions, which have to be traced, when classifying each segment @ pixel of an image [11].

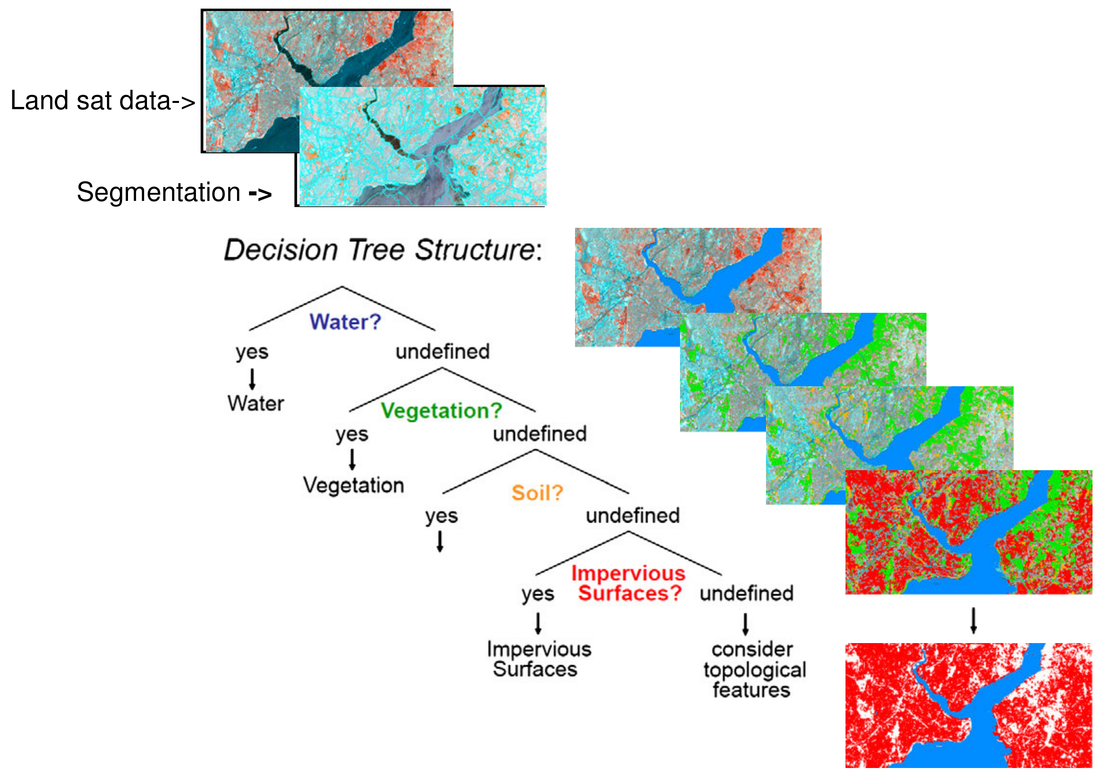

FIGURE 2: Schematic overview of the step-wise hierarchical structure of the classification algorithm for

But monitoring of large data sets across the world, it is better to use the strip map data i.e., Radar data [11]. These data have the advantage of being weather independent and consistently available for all mega cities today.

4. RESULTS, CHANGE DETECTION AND DISCUSSIONS:

For the mega cities of the world featuring four individual urban foot print classification at four time steps in the mid-1970's, around1990, 2000 and 2010. The change detection allows identifying, localizing and quantifying the pattern and dimension of urban sprawl overtime.

Fig (3) clearly reveals that since 1975 the population development and thus, the rate of urbanization in the mega cities outside the high developed countries were enormous [11]. At a first glance, a number of trends are immediately clear in terms of spatial dynamics of urbanization over the time period observed is the highest in developing countries. Beyond this, the spatial extents in developed countries are noticeably larger with respect to the absolute population.

The first and the most natural analysis is the measurement of spatial urban expansion over time. The quantification of urban growth for the metropolitan areas of the mega cities are calculates as relative growth. The absolute growth would be misleading due to a heterogeneous spatial base for comparison in dependence of the data availability at the four time steps i.e., 1975, 1990, 2000 and 2010. As one example illustrating the difference in spatial expansion between mega cities in absolute terms, the urbanized metropolitan area Osaka for the available extent was measured 1136 sqkm in 1975 and expanded to 2844 sqkm in 2010 (2.5 times its formal spatial dimension), while the urbanized areas in Kinshasa, Brazzaville grew, in the absolute terms, only from 106sqkm to 428 sqkm, however extending its urban dimensions four times.

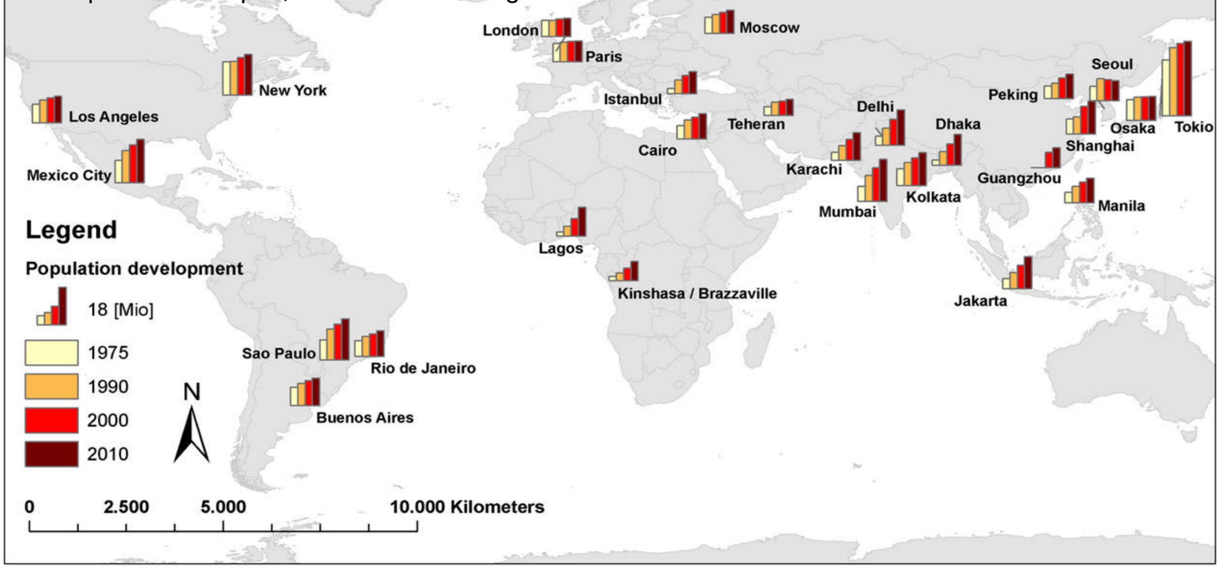

FIGURE 3: Spatial distribution of the current megacities of the world and their population development since 1975, Data source: UN (2007).

The relative urban growth result opposes the immense spatial sprawl of cities in Asia such as Mumbai (77.6 times its spatial dimensions in 2010 compared to 1975), Manila (77.1 since 1975) a Seoul (75.3 since 1975) with the comparatively reduced urban sprawl in cities such as London (1.7 since 1975), New York City (1.2 since 1975).However the metropolitan areas are captured and thus, relative spatial growth allows comparability across the world's mega cities fig (4)

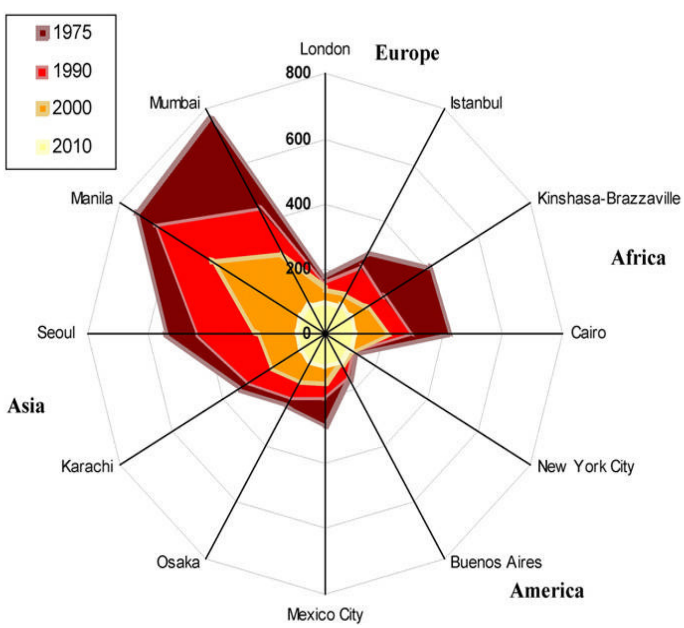

FIGURE 4: Relative spatial growth of mega cities in percent with 1975 as baseline

So, there is a heavy growth of urban sprawl in Asia and mainly focus in India. In 2005, 22 mega cities (urban agglomerations of 10 million inhabitants or more) around the world were identified. Three of the cities, Mumbai, Delhi and Kolkata, were on the Indian subcontinent [13[23]. Besides the three current mega cities, nine more urban agglomerations in India (Ahmadabad, Bangalore, Chennai, Hyderabad, Jaipur, Poona, Kanpur, Lucknow and Surat) currently have more than 2.5 million inhabitants and the population growth in the largest Indian cities in the Table (1) and fig(5) shows the geographic locations of the twelve cities on the Indian sub-continent.

City/Year	1975	1990	2000	2005	2015
Mumbai	7,01	12,31	16,08	18,20	21,87
Delhi	4,43	8,21	12,44	15,05	18,60
Kolkatta	7,89	10,89	13,06	14,23	16,98
Chennai	3,61	5,34	6,35	6,92	8,28
Bengaluru	2,11	4,04	5,57	6,46	7,94
Hyderabad	2,09	4,19	5,45	6,12	7,42
Ahmadabad	2,05	3,26	4,43	5,12	6,30
Poona	1,35	2,43	3,66	4,41	5,52
Surat	0,64	1,47	2,70	3,56	4,62
Kanpur	1,42	2,00	2,64	3,02	3,72
Jaipur	0,78	1,48	2,26	2,75	3,57
Lucknow	0,89	1,61	2,22	2,57	3,18

TABLE 1: Population growth in the 12 largest Indian cities in million inhabitants

FIGURE 5 : Location of India’s large urban agglomerations

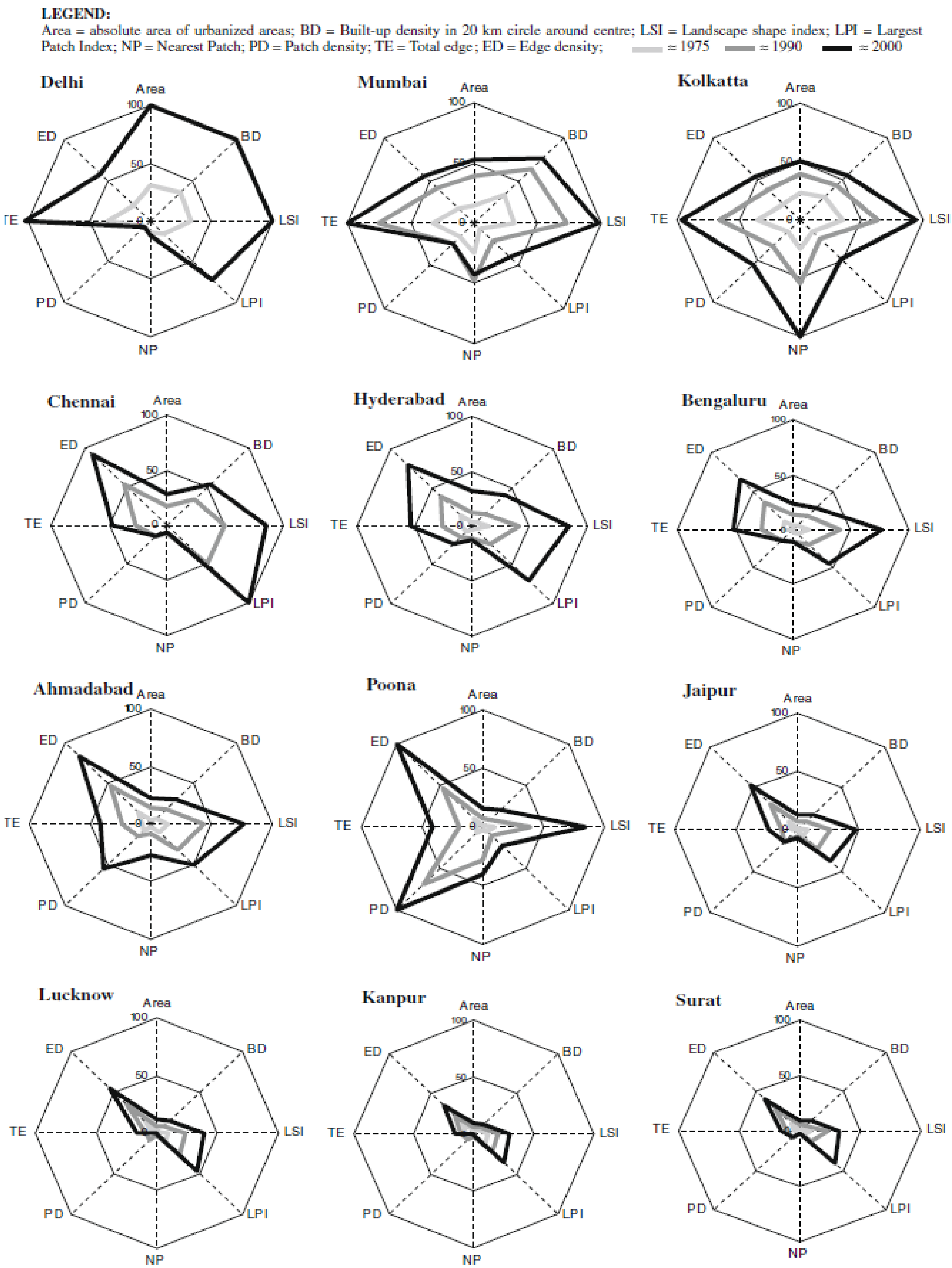

FIGURE 6: Spider charts characterizing Spatio-temporal urban development

The spider chart **fig (6)** allows us to spatially visualize the urban type by quantifying landscape metrics that spatially describe the urban environment [21]. In the following, the 12 largest urban agglomerations of India are displayed at three different time stager, beginning in 1970's. Thus we can analyze the development of spatial urban growth for individual cities: like Hyderabad, Poona, and Surat etc.

In future, a highly detailed structural analysis of the larger scale and heterogeneous inner structures of the urban morphology using satellite data with higher geometric resolution (eg IKONOS, Quick bird data) are expected to augment information for planning purposes [20]. Measuring the development stages of the large Indian urban agglomerations, conclusions about incipient mega cities in the same cultural area like Hyderabad, Bangalore and Chennai may support planning, future modeling and thus decision-making for sustainable and energy efficient urban futures.

5. CONCLUSION

The critical issues and challenges of development and management for growing urban centers have been the subject of extensive discussions and debates in recent years. The major problems associated with the urban centers in India are that of unplanned expansion, changing land use / land cover areas. Management of huge volumes of data, it is very difficult. For this, Remote Sensing imagery, with its repetitive and synoptic viewing capabilities, together with GIS, are important tools to map areas and monitor the changes in the urban growth. High-resolution satellite imagery (IKONOS, Quick bird) can also be used to monitor urban expansion and illegal construction over a period of time [20].Monitoring of urban sprawl over a period of time in large areas, better to use the radar data [11]i.e., TERRASAR-X data , it is easy to classify.

To fight with the problems faced by the rapid urban growth, and to meet the challenges of sustainable development, it is suggested that the use of remote-sensing and GIS in conjunction with geo-spatial data is of vital importance. There is need for the use of an urban information data base that can be generated using remote sensing data and GIS techniques. Top priority should be given to the issues related to the planned development of the city. The administrative, technical and managerial staff of the urban local bodies needs to be strengthened. The officials of various government departments should be given thorough exposure and training of remote sensing and GIS for its application implementation in the urban management plans. The problems and challenges faced by mankind are of national importance, but it has to be dealt at the local level.

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