

# Geospatial scenario based modelling of urban revolution in five major cities in India

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**Abstract** - Urbanisation being irreversible and very rapid with fast growth of population and settlements during the last century, needs to be monitored and visualised for evolving strategies towards sustainable development approaches. This study visualises the growth of major Tier I cities of India such as Delhi, Mumbai, Pune, Chennai and Coimbatore, India through AHP Fuzzy based Cellular Automata Markov model. CA Markov model is considered to be one of most effective algorithm to visualise the growth of urban spatial structures. The analysis performed in previous studies such as spatial pattern of land use change in the area was considered and the future growth was modelled considering agents of growth applying fuzzy AHP CA-Markov model. The projection as predicted using the model was validated to obtain better validation and was then used to predict future projections. Modelling suggested a clear trend of various land use classes' transformation in the area of urban built up expansions.

## I. INTRODUCTION

Rapid urbanization is one of the most important factor affecting the local ecology and loss of biodiversity in India during the last two decades (Shivaramakrishnan et al., 2005; MOUD., India, 2011; Ramachandra et al., 2012; Bharath H. A., 2012; Ramachandra et al., 2014a). Urbanisation is a form of growth with implications of economic, social, and political forces and to the physical geography of an area (Sudhira et al., 2007; Ramachandra et al., 2014a). The sprawl takes place at the urban fringes resulted in radial development of the urban areas or development along the highways results in the elongated development of urban forms (Sudhira et al., 2003).

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It can also be defined as a finite cycle through which nations evolve to form industrially dominant regions, which further results in rural push and spreading of city towards outskirts (Ramachandra et al., 2013) also refers to urban sprawl.

This urban development in the fringes is called sprawl. The study on urban sprawl was attempted by various researchers across the globe (Batty et al., 1999; Torrens, 2000; Sudhira et al., 2004; Huang et.al 2007; Bhatta, 2009a, 2009b, 2010; Ramachandra et al., 2012). These sprawl areas do not have a fixed plan or process of development due to which the process of preparing visionary documents such as developmental plans, specific corridors of developments are being ineffective considering the fact that spatial patterns and dynamic behaviour of growth and also may be attributed to lack of skills and tools to help in informed, accurate decision making (Adhvaryu, 2011; Bharath H.A., et al., 2014). This can be improved and timely decisions may be enabled using technological improvements such as remote sensing and tools such as Geographic Information system (GIS).

Remote Sensing data acquired through space borne remote sensors enables a bird eye view of the landscape at low cost (Lillesand and Kiefer, 2005). The advantage of remote sensing data is to acquire repeated measurements of the same area on periodic basis which helps in detection and monitoring of LULCC and surveillance of problematic sites (Campbell, 2002). The analysis of changes at local, regional and global scales is possible through the collection of remote sensed data covering the larger spatial extent. Remote sensing aids in identification and assessment of land use patterns which is important for environmental management and decision making. Further it is essential to visualise and provide better planning strategies for future urban growth. This can be planned and visualised using various modelling techniques.

Traditional large-scale urban simulation approaches of early 90's were based on theories, and suffered from significant weaknesses such as poor handling of space-time dynamics and too much generalisation of data. The integration of space, time, and attributes in modelling was further enhanced with the implementation of Cellular automata (CA) models (Allen 1997; Batty 1999; EPA 2000; Alberti and Waddell 2000). CA modelling is capable of addressing the spatial complexity with discrete time change. A

number of CA-based models of urban growth have produced satisfactory simulations of spatial urban expansion over time (Clarke et al., 1997; Leao et al. 2004; Bharath and Ramachandra, 2013; Ramachandra et al., 2013; Arsanjani et al., 2013). The main advantages of CA are simplicity, easy integration with raster GIS, and adaptability to various urban growth situations. CA models can realistically generate and represent complex patterns through the use of simple rules and considering its neighbouring properties since these models operate on basis of cell states, size, neighbourhood and transition rules (White and Engelen 2000). This communication presents the Land use change modeller (Bharath H.A. et al., 2013) and Fuzzy AHP based CA (Bharath H.A et al., 2014) models implemented to visualise the urban growth in five Tier I cities in India.

## II. DATA AND METHOD

Temporal remote sensing data of Landsat TM and ETM+ downloaded from GLCF were preprocessed to correct geometrical and radiometrical accuracy USGS (<http://www.usgs.gov>). This was further used to analyse and model LULC changes. Remote sensing data were supplemented with the Survey of India topographic maps (of 1:50000 and 1:250000 scale), which were used to generate base layers of the administrative boundary, drainage network, Road network etc. Slope map was extracted using ASTER data (30 m) downloaded from USGS ([www.usgs.gov](http://www.usgs.gov)). Ground control points (GCPs) and training data were collected using pre calibrated Global Positioning System (GPS) and virtual online spatial maps such as Bhuvan and Google Earth. GCPs were useful in geometric correction of remote sensing data. Census data (1991, 2001 and 2011) was used to capture population dynamics.

Modelling of urbanization and sprawl involved: i) Remote Sensing data acquisition, geometric correction, field data collection, ii) Classification of remote sensing data and accuracy assessment using GRASS, iii) Land use analysis, iv) Identification of agents and development of attribute information, v) Prediction: Designing scenarios of urban growth and calibrating the model to find out the best weights based on the influence on the neighborhood pixels vi) Accuracy assessment and validation of the model, vii) Prediction of future growth based on validated data.

Land use analysis was carried out using supervised pattern classifier - Gaussian maximum likelihood algorithm based on probability and cost functions (Duda et al., 2000). Land use with gradient analysis results were further used in Modelling. These results can be accessed in previous working literatures

(Ramachandra et al., 2014a, 2014b, 2014c, 2014d, Chandan et al., 2014). These data was used in Modelling and visualizing the growth of these cities.

## III. MODELLING USING FUZZY AHP-CA

Using the combination of Fuzzy Logic, Analytical Hierarchical Process (AHP), Multi Criteria Evaluation (MCE), Markov chains and Cellular Automata (CA). Agents of urbanisation such as roads, industries, educational institutions, bus stands, railway stations, metro, population, etc. were normalized. Conservation regions as per city development plan (CDP) water bodies were considered as constraints. The fuzzy based analysis is used to normalize the contributing factors between 0 and 255, where 255 showing the maximum probability of change and 0 indicating no change, for different land uses. The normalized agents were taken as input to AHP to determine the weights of driving factors using pair wise comparisons  $i^{th}$  weights as Eigen vectors. The weights analysed and calibrated through AHP is verified using measured consistency ratio (CR). CR below 0.1, the model is consistent and used for subsequent processes.

These weights along with the factors of growth are combined along with the constraints to obtain site suitability maps for different land uses using equation below

$$LC = \frac{1}{n} * \sum_{i=1}^n D_i * W_i \quad \dots\dots (1)$$

Where LC is the linear combination of weights, n is the number of factors, D decision factor, W is the weight of the factor.

The Markov chains are used to determine the change probability between two historical datasets to derive the growth in the future scenarios based on different criteria's. The Markovian transition matrix indicates the probability of the particular land use being converted to other land uses on single time step.

Criteria	Factors and Constraints
Without CDP as a constraint	Slope, Distance from roads, Distance to industries, Distance to Bus stops and Railway stations, Distance from metro, Distance from educational institutions, Population Density
With CDP	Slope, Distance from roads, Distance to industries, Distance to Bus stops and Railway stations, Distance from metro, Distance from educational institutions, City Development Plan, Population Density

Table 1: Criteria's for simulating and predicting urban sprawl

The cellular automata based on the site suitability and the transition matrix is used to spatially predict the changes in land use based on current land use at every

single time step, based on the neighbouring pixels. Two scenarios were designed to predict the land use changes as shown in table 1.

Validation of the simulated datasets of were performed with classified datasets through kappa indices, as a measure of agreement. Once these data and agents are trained and validated, data is used to model and simulate for the year 2030 (ten years) with definite time steps.

#### IV. RESULTS

Geo-visualisation of urbanisation of five tier I cities are depicted in fig.1 to fig.5 and results are provided in tables 2 to 6 respectively. The cities on an average would grow by 1.5 to over 2 times the current state in next decade. By 2025, it is predicted that built up area in these cities and surroundings, grows over 57% (Delhi), 27% (Mumbai), 45.8% (Chennai), 50% (Pune) and 37% (Coimbatore) respectively. The various drivers of growth for different cities are as in annexure 1. In all these cases, spatially it could be understood that the CDP if implemented properly would play a major role in curtailing the unsustainable growth of the city in its limits, while some growth still takes place at the outskirts. Prime factors of growth include the transportation network, industrialisation, and educational sector.

##### Modelling growth of Delhi

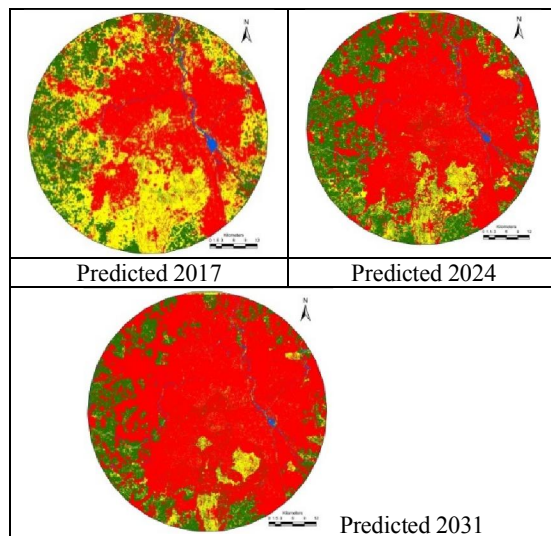


Fig.1: Predicted landscape dynamics of Delhi

Year	Built up	Vegetation	Water	Others
2017	45.80	17.98	1.25	34.97
2024	57.37	8.77	1.18	32.68
2031	70.86	3.76	1.19	24.18

All units as percentage area

Table 2: Predicted landscape dynamics of Delhi

##### Modelling growth of Mumbai

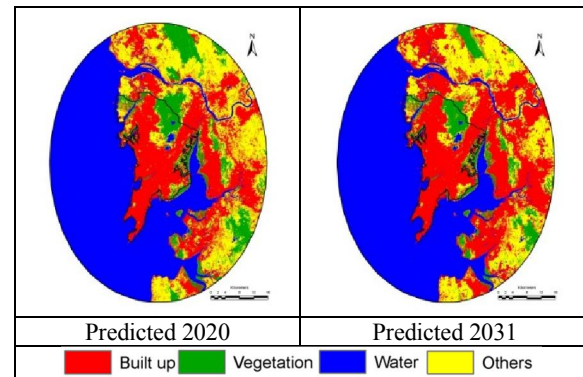


Fig.2: Predicted landscape dynamics of Mumbai

Year	Built up	Vegetation	Water	Others
2020	25.83	9.09	44.52	20.56
2031	31.27	6.33	44.52	17.88

All units as percentage area

Table 3: Predicted landscape dynamics of Mumbai

##### Modelling growth of Chennai

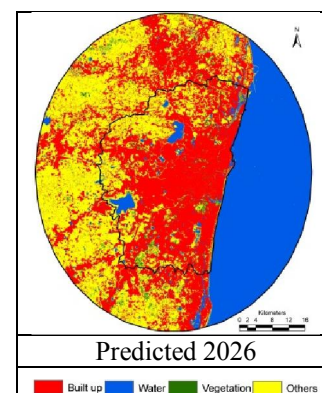


Fig.3: Predicted landscape dynamics of Chennai

Year	Built up	Vegetation	Water	Others
2026	45.80	17.98	1.25	34.97

All units as percentage area

Table 4: Predicted landscape dynamics of Chennai

## Modelling growth of Pune

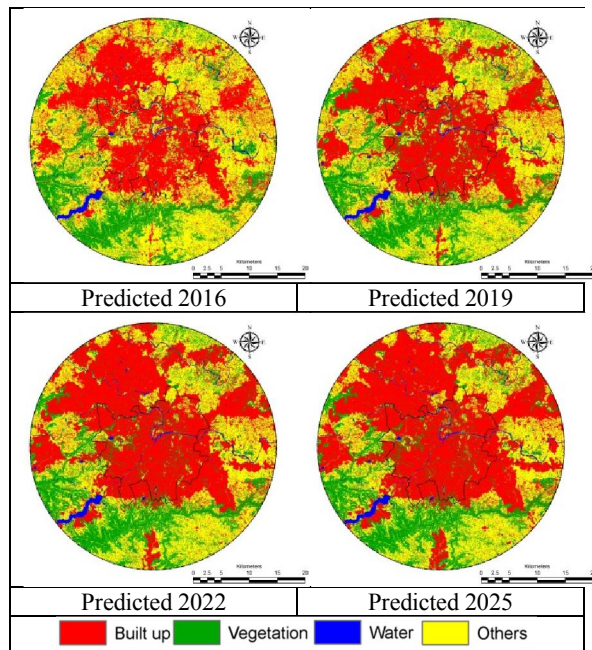


Fig.4: Predicted landscape dynamics of Pune

Year	Built up	Water	Vegetation	Others
2016	37.78	1.75	16.37	44.11
2019	41.64	1.75	20.16	36.45
2022	47.89	1.75	20.16	30.20
2025	50.02	1.75	20.16	28.06

All units as percentage area

Table 5: Predicted landscape dynamics of Pune

## Modelling growth of Coimbatore

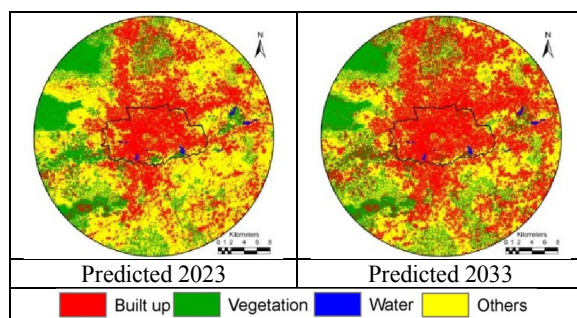


Fig.5: Predicted landscape dynamics of Coimbatore

Year	Built up	Water	Vegetation	Others
2023	32.64	0.29	17.14	49.94
2033	42.92	0.29	17.58	39.21

All units as percentage area

Table 6: Predicted landscape dynamics of Coimbatore

## V. CONCLUSION

This study demonstrates the application of temporal remote sensing data and Geoinformatics in mapping and understanding of urban dynamics. Advance geo-visualisation of urban growth would aid in decision making towards sustainable cities with basic infrastructure and amenities. Identification of regional factors that are most likely to influence a land-use changes has improved the accuracy of prediction. The predictions of land use/cover changes through CA-Markov model suggest a continual increase in urban settlements with a decline in local ecology and natural vegetation covers. The prediction using CA help to design sustainable urban transportation system.

## VI. ACKNOWLEDGEMENT

We are grateful to ISRO-IISc Space Technology Cell, Indian Institute of Science and NRDMs division, Ministry of Science and Technology, DST, Government of India for the financial support. We thank USGS Earth Resources Observation and Science (EROS) Center for providing the environmental layers and Global Land Cover Facility (GLCF) for providing Landsat data.

## VII. Publications

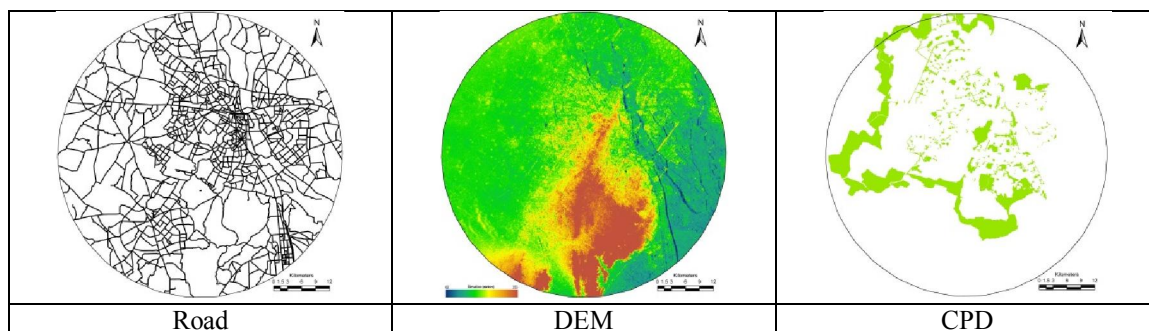
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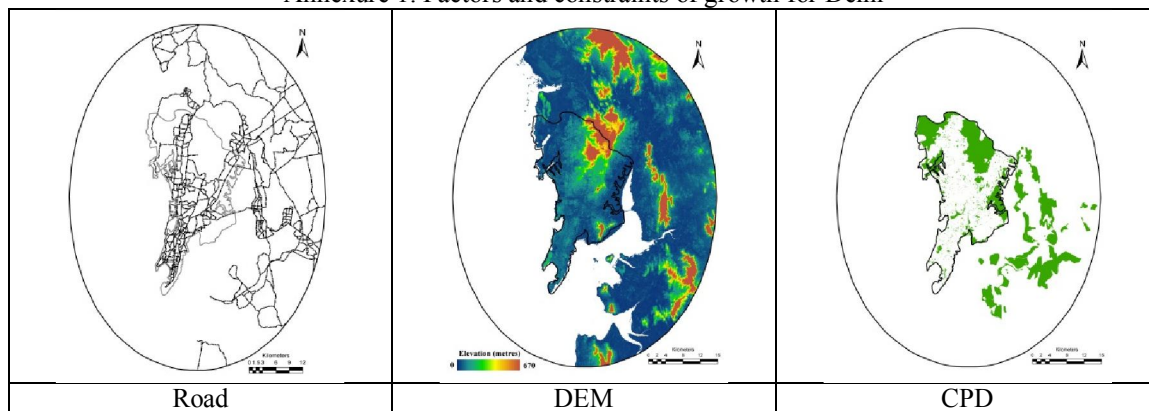


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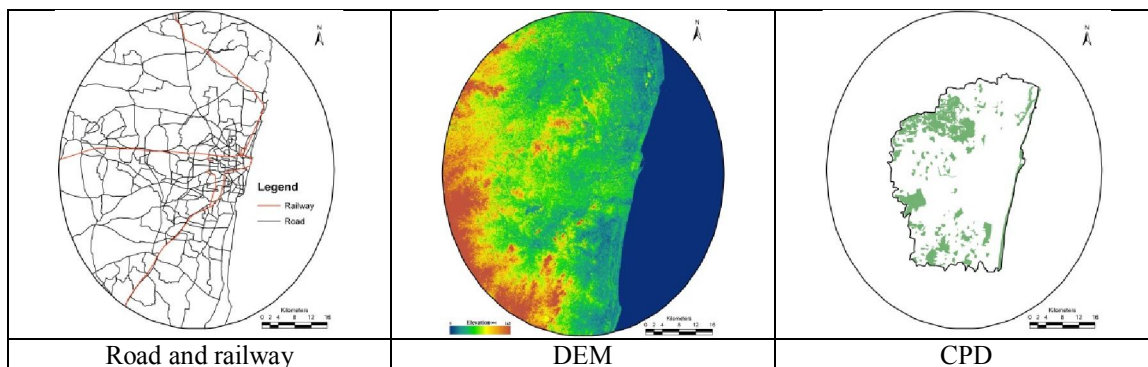
## Annexure



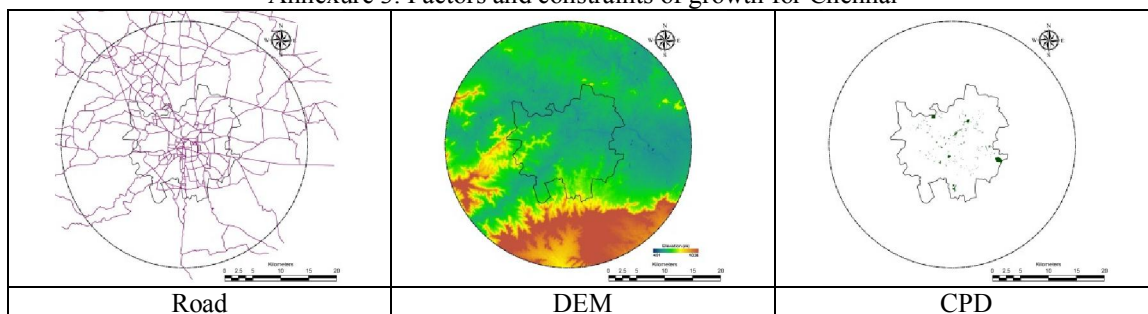
Annexure 1: Factors and constraints of growth for Delhi



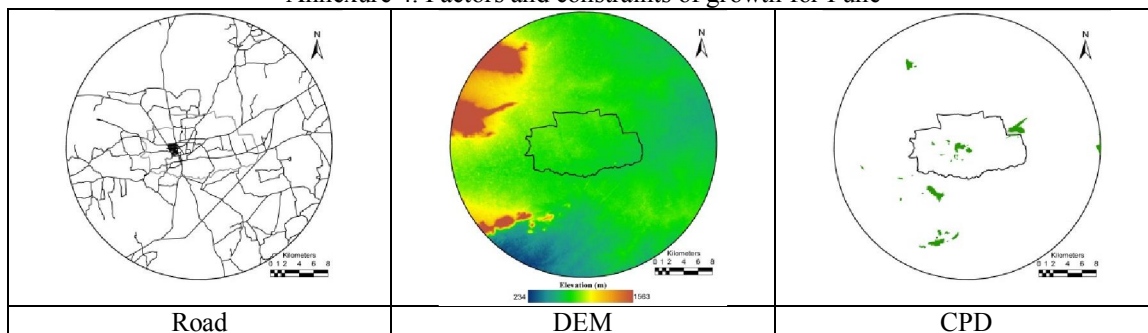
Annexure 2: Factors and constraints of growth for Mumbai



Annexure 3: Factors and constraints of growth for Chennai



Annexure 4: Factors and constraints of growth for Pune



Annexure 5: Factors and constraints of growth for Coimbatore