# Predicting Future Urban Growth in Bhopal, India using Artificial Intelligence based Modelling

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Urbanization is happening at a very fast rate, especially in developing countries like India. Urbanization is a challenge if not managed properly but an opportunity if it is planned and foreseen beforehand. Hence, predicting the urbanization trend becomes inadvertently important in order to properly plan for it. Various techniques have evolved over time, for predicting future urban growth, and with development in Artificial Intelligence and Image Processing domains, this field has opened up opportunities for better research and knowledge creation. In light of same, the present study focusses on predictive modelling the future urban growth in central city of India, Bhopal. The study uses land cover data provided by USGS Earth Explorer 2011 and thereafter uses ArcMap 10.7 and QGIS applications to develop a urban growth forecasting model, which is a hybrid model based on Cellular Automata and Fuzzy Urban Growth Modelling. The study concludes that predictions are totally based on the type of input data as machine learning works when data is accurate similarly here also these machine learning model will give more accurate predictions based on input data. In this case the accuracy of prediction comes out to be 77 percent based on the data we feed into the model. Hence using more accurate data will give more accurate results, this study was an attempt to forecast future growth of a city using new technological advancements like artificial intelligence and machine learning.

**Keywords**: prediction, urban growth, cellular automata, modelling.

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# 1. Introduction

Rising global urbanization is one of the century's defining phenomena. According to the World Health Organization (WHO), global urbanisation is a process that is transforming the social and environmental settings on all continents, implying population migration from rural to urban areas, resulting in natural urban demographic expansion. Urbanisation in India has progressed in the same way that it has elsewhere in the globe as a result of and as a result of economic change. One aspect of the transformation is the movement of employment from agriculture to urban-based industry and services.

The control of urbanization is the fundamental issue for overall equilibrium. Urban growth modelling technologies that are reliable for urban planners and professionals in several sectors have evolved.[1] These techniques are primarily concerned with assisting in the decision-making process for the long-term development of urban areas.

# 2. Need of the study

In order to achieve planning and management in the urban environment, it is required to implement spatial planning policies. This step necessitates the use of spatial planning as the primary strategy, which is supported by land use planning policies.[3] Planning support tools based on geographic information systems and urban development modelling techniques have become increasingly popular in recent years for dealing with the decision-making process and planning assistance to promote sustainable urban growth. Hence, there is a need of techniques such as forecasting urban growth, for sustainable development of cities.

# 3. Literature review

## 3.1 Urban Growth

According to the census of India 2011, the urban population grew to 377million. The level of urbanization in the country as a whole increased from 27.8% in 2011 to 31.2% in 2011. Urban growth in India attracts the rural population with expectations of higher earnings. This gives rise to a stream of migration from rural to urban areas.[8] The persistence of earning differences eventually gives rise to declining opportunities in the formal segment of the economy, resulting in the growth of the informal sector often characterized by low paying, low skilled jobs. The same process leads to congestion in cities with the economy distributed asymmetrically in favor of urban segments. The 'Revision of World Urbanization Prospects', 2011,[2] published by the United Nations, analyses the rural urban distribution of population for 231 countries for the period 1950 to 2050. It states that about 52.1 per cent of the world population

lived in urban areas in 2011. The Report adds that about 78 per cent of the inhabitants of developed countries lived in urban areas whereas the figure was only 47 per cent for less developed countries. It is estimated that 67 per cent of the world population would live in urban areas in 2050, and for developed and developing countries the share would be 86 per cent and 64 per cent respectively.[2]

### 3.2 Urban Growth Patterns and Models

- Many diverse fields, such as urban planning, landscape ecology, and urban modelling, have investigated urban form and growth trends. Complexity, density, and compactness are urban form metrics that describe urban spatial patterns at a certain point in time.[8] On the other hand, urban growth patterns depict the spatial patterns of urban expansion across time.

- Several methods of urban modelling have been developed and applied in planning or research over the past several decades, and many geographic and urban spatial modelling techniques have been used to predict urban growth according to several variables and criteria. As one of the artificial intelligence techniques, Cellular Automata (CA) is a popular modelling technique that is a considered as an important support tool for city planners, economists and ecologists.[4] It could assist in deriving future planning strategies and decision making in the fields of urban development and resource management.

- CA model works in a way that automatically computes cells according to transitional rules (algorithm equations), simulates complex systems, such as urban growth dynamics, and helps understand cities.[3] The application of cellular automata in modelling urban development is "virtually impossible without the data management capabilities of GIS". The integration of Geographic Information Systems (GIS) and urban models is the most advanced and technical approach to study the dynamics of urban expansion which is currently being applied. Many researchers have successfully attempted to combining CA and fuzzy sets for the purpose of modelling future urban growth.[8]

### 3.3 Case Study of Ibb Governorate, Yemen

A similar study is done for the city of Ibb in Yemen (Figure 1). The city of Ibb is one of the important historical cities of the Republic of Yemen. The old city is characterized by a unique architectural style surrounded by green terraces and landscapes from all sides. The total area of the city is estimated at 57.87 sq.km, and the built-up area is about 16.44 km in year 2013. n 2013, the total population of Ibb was 488,725 person and the main activity of Ibb residents is agriculture.[8]

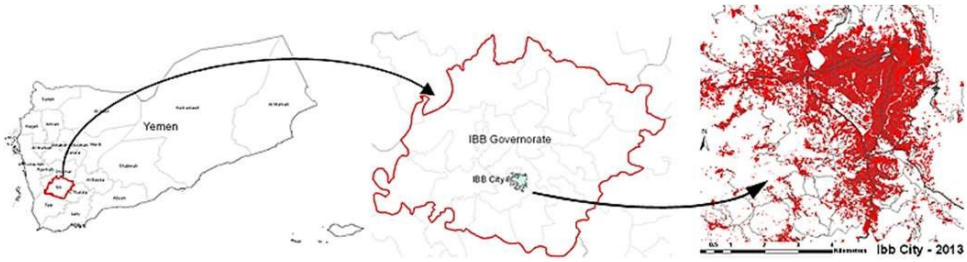


**Fig 1** Location Map Ibb Governorate, Yemen

This research begins with data preparation and the prepared data is simulated in GIS and further visualized. Figure 2 is the general model framework adopted to perform the analysis in this study

This research method is organized in stages: first, the urban growth models are evaluated, and then a hybrid model, Cellular Automata and Fuzzy Urban Growth Modelling, is chosen. Second, using GIS software, the relevant data is prepared and examined (e.g., land use data for years 2003 and 2013, socioeconomic data, inventory of urban growth determinants, etc.).[4] Third, utilizing the hybrid simulation model, the modelling process is carried out to anticipate the shape, scale, and pattern of expected future urban expansion through 2013. For both the simulation map and the actual map for the year 2013, the model is validated using the pixel matching approach.[9] Finally, for the year 2033, land use growth is forecasted, and conclusions are drawn.

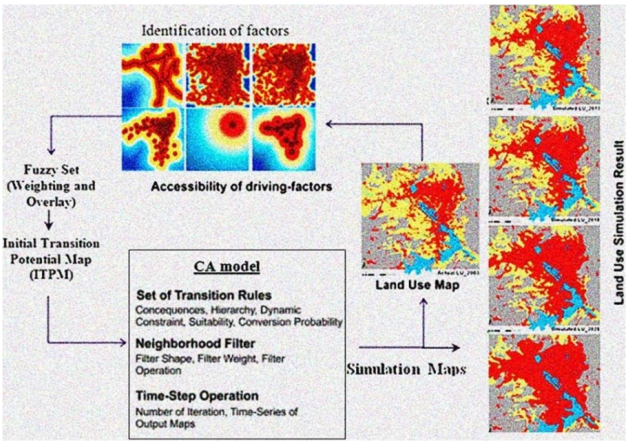


**Fig 2** General Model Framework

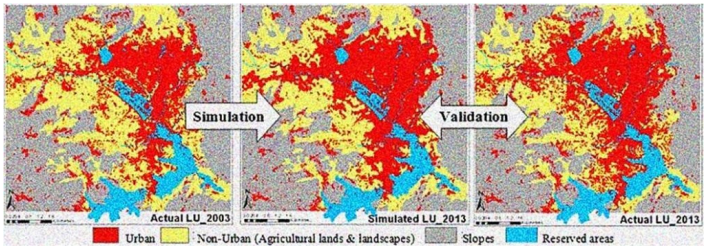


**Fig 3** Simulation and validation

In Figure 3 the results of the initial simulation of the year 2013 based on 2003 data. This step is considered important for the verification of the simulation process.

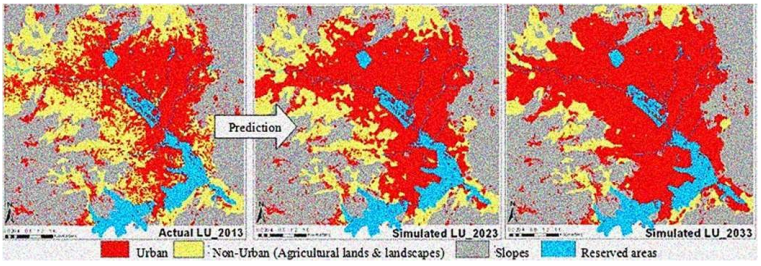


**Fig 4** Prediction for 2023 and 2033

In Figure 4 the results of the future forecasting process for urban growth in 2023 and 2033. The results show that the simulated urban growth reveals a growth pattern (in terms of directions and intensity rate) that is similar to the current growth.[8]

## 4. Study area

Bhopal is the state capital of Madhya Pradesh in India (Figure 5), as well as the administrative centre of Bhopal district and Bhopal division. Bhopal is well connected to all parts of the country due to its central location. Bhopal is one of India's 15 largest cities, with a planning area of 463 square kilometres. The Municipal Corporation of Bhopal has been on a path of continuous improvement from its foundation, setting benchmarks in service delivery. It was chosen for this study in order to better understand Bhopal's growth trajectory, where it is heading, and how to plan for future development.

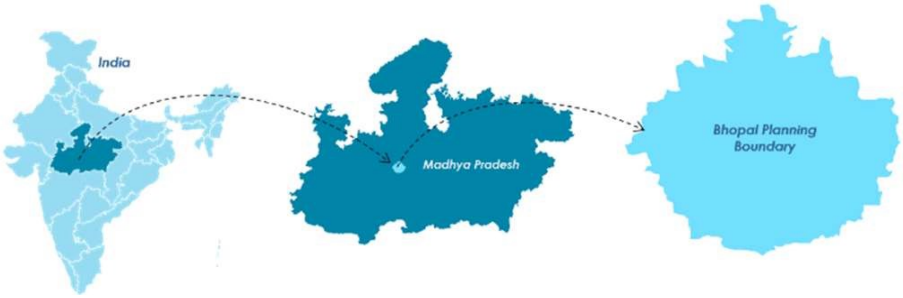


**Fig 5** Location Map of Bhopal

## 5. Data Acquisition and Processing

### 5.1 Data Acquisition

This analysis is performed on the land-use/land-cover data set provided USGS earth explorer in 2001, 2011 and 2021 based on Landsat4-5, Landsat 7 and Landsat 8 imageries Table 1. The land cover types were reclassified to built-up area and agricultural land, water body and forest. Also, we needed to exclude permanent or temporary shrinkage of the built-up area. In brief, urbanisation is treated as irreversible which means that once the urban pixels were urbanized, they remain urbanized forever.

**Table 1.** Data Collection.

| S No. | Type | Source | Use |
|---|---|---|---|
| 1. | LANDSAT 4-5 Imagery (2001) ;(30m Res) | USGS (Earth Explorer) | Performing the landcover analysis |
| 2. | LANDSAT 7 Imagery (2011) ;(30m Res) | USGS (Earth Explorer) | Performing the landcover analysis |
| 3. | LANDSAT 8 Imagery (2021) ;(30m Res) | USGS (Earth Explorer | Performing the landcover analysis |
| 4. | Shapefiles (roads, waterbodies, etc.) | Digitization on GIS | Calculation of Proximity analysis |

### 5.2 Data Processing

All the data is collected and organized through secondary sources and data analysis and processing was conducted in ArcMap 10.7 and QGIS. The following flowchart represents the data processing and the adopted methodology in this study.

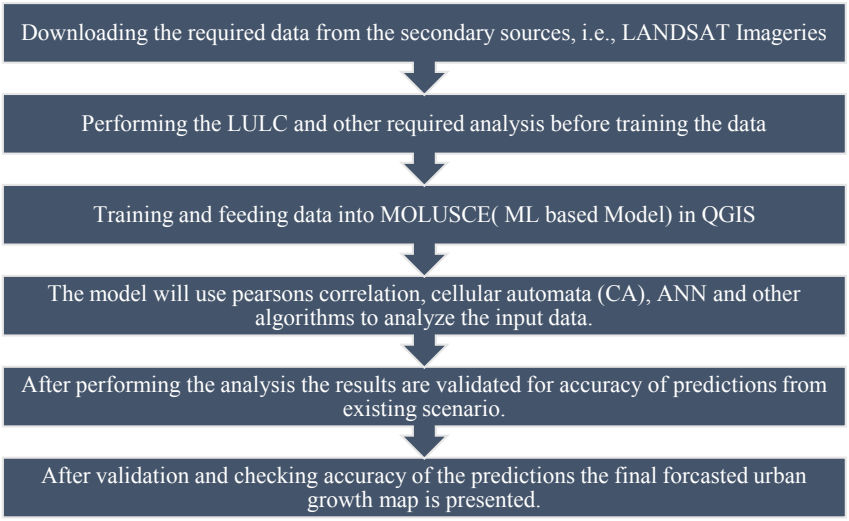


**Fig 6** Data Processing Flowchart

## 6. Results and Discussions

### 6.1 Urban Growth in Bhopal

Figure 7 represents land cover map represents the urban growth of Bhopal from 2001 to 2021. The land cover classification was performed via supervised classification taking 60-70 samples of each category into ArcGIS. It can be clearly seen that in 2001 the growth is scattered and after a decade it is headed towards the core and further expansion can be seen in 2021. Land Cover Maps are the base maps for this study as they are primary parameter to perform the predictive analysis along with some other accessible driving factors. Now the growth for the year
2031 is predicted using these layers in QGIS.

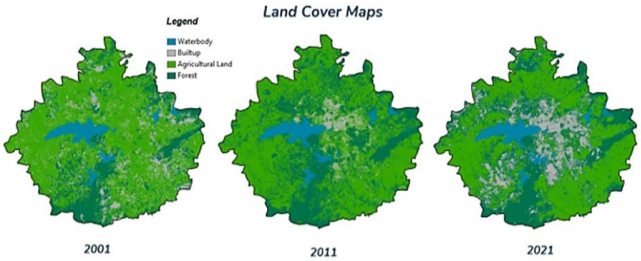


**Fig 7** Land Cover Maps

### 6.2 Other used parameters

Following are the identified factors which acts as accessible driving factor in the simulation for predictive outcomes. In this process Euclidean distances are calculated and used as secondary parameters after land cover. (Figure 8)

- Distance to Primary Roads
- Distance to Water Bodies
- Digital Elevation Model (DEM)

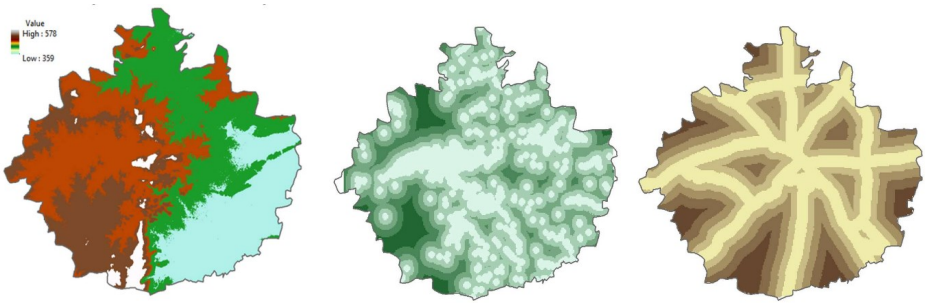


**Fig 8** DEM, Distance from waterbodies, and primary roads proximity

### 6.3 Model Output

Initial steps after feeding the data were to calculate area change and Pearson's correlation of the adopted parameters. As shown in Figure 9

| | wbcorrection | roadcorrection | demcorrection |
|---|---|---|---|
| wbcorrection | -- | 0.979935487559 | 0.979935487559 |
| roadcorrection | | -- | 1.0 |
| demcorrection | | | -- |

**Fig 9** Pearson's Correlation results

Area changes from year 2011 to 2021

| 2011 | 2021 | Δ | 2011 % | 2021 % |
|---|---|---|---|---|
| 4246.47 ha | 4121.10 ha | -125.37 ha | 4.22962214611 | 4.10474955111 |
| 11107.44 ha | 24167.16 ha | 13059.72 ha | 11.0633712732 | 24.0712768828 |
| 37798.83 ha | 22938.66 ha | -14860.17 ha | 37.6488632829 | 22.847650952 |
| 16835.22 ha | 13194.72 ha | -3640.50 ha | 16.7684263274 | 13.1423699976 |
| 19209.24 ha | 23420.79 ha | 4211.55 ha | 19.1330274119 | 23.327868103 |

**Fig 10** Area Changes

After the area calculation Artificial Neural Network (ANN) multi-layer training is used to train the input data for prediction. As shown in Figure 11

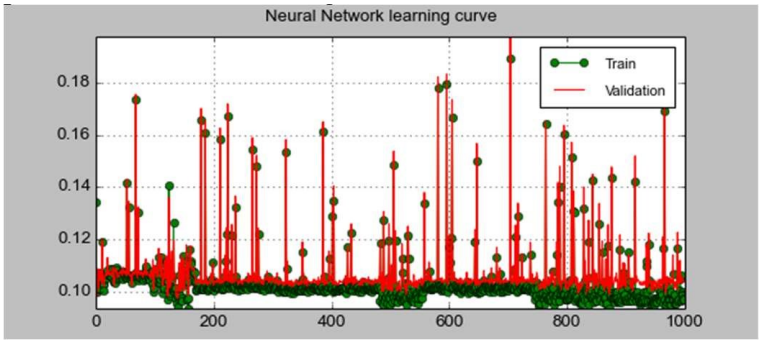


**Fig 11** Neural Network Learning Curve

After training of dataset, the final predicted map is obtained using Cellular Automata (CA) technique as shown in Figure 12


**Fig 12** Predicted Map for year 2031

The predictions are totally based on the type of input data as machine learning works when data is accurate similarly here also these machine learning model will give more accurate predictions based on input data. In this case the accuracy of prediction comes out to be 77% based on the data we feed into the model. Hence using more accurate data will give more accurate results, this study was an attempt to forecast future growth of a city using new technological advancements like artificial intelligence and machine learning.

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