Chapter -3

GEO SPATIAL MODELING OF URBAN GROWTH PATTERN
IN HYDERABAD USING RS, GIS AND AHP

3.1 Introduction

The city of Hyderabad is growing physically year by year to accomplish radial and multi-dimensional activities. In the recent years, models of land-use/land-cover changes and urban growth have become important tools for city planners. Although urban modeling is not a new concept and has a long history, modeling of urban growth has not been widely practiced, especially in metropolis cities like Hyderabad. Patterns of growth and analyses of spatial and temporal changes could be done cost effectively and efficiently with the help of spatial and temporal technologies such as Geographic Information System (GIS) and Remote Sensing (RS) along with collateral data (such as Survey of India maps, etc.). Remote sensing techniques can provide reliable and spatially consistent data sets over large areas with both high spatial and temporal resolutions. Remote sensing data can represent urban characteristics and structure such as spatial extent and pattern of land cover, sometimes inferences about land-use and urban infrastructure. The physical expressions and patterns of growth are detected, mapped, and analyzed using remote sensing and geographical information system (GIS) with image processing and classification. Several problems have been identified in building, calibrating and applying models of urban growth and urban land-use/
land-cover change. The relationship between the urban growth and physical factors to determine suitable sites for future urban expansion is aimed in this modeling. AHP techniques in the past are used for conceptual modeling and evaluation of land use activity. A lead has been framed from the past researchers and developed a hierarchy algorithm to frame the spatial patronage of land-use, quantification and projection of each activity for future scenario. Various factors such as the transportation, existing built-up area, industrial sectors, public and semi-public areas, open space zone and water bodies were identified and analyzed using the Analytic Hierarchy Process (AHP).

3.2 Study area

The latitude and longitude for the study of area of Hyderabad city and environs extends from (17° 15´ 30´´, 78° 15´ 00´´) to (17° 40´ 15´´, 78° 40´ 15´´). The Hyderabad Urban Development Area (HUDA) is around 1865 sq.km. The HUDA area is divided into 29 planning zones (11 Zones inside municipal limits and 18 zones in the non-municipal limits or peripheral areas).

The topographical map for the study area of Hyderabad (56K) is obtained from Survey of India (SOI), referenced to a scale of 1:50,000, as shown in the Figure 3.1 and the cropped satellite image of the study area is shown in the Figure 3.2 for geo-referencing.
Fig: 3.1 Topographical map for the study area of Hyderabad
Fig: 3.2 Satellite Image for the study area of Hyderabad IRS-1C (LISS-III)
3.3 Methodology

Spatial thematic maps pertaining to the study area for the years (1980, 1990 and 2000) have been studied from previous data source as shown in the Figures 3.3.1, 3.3.2 and 3.3.3 for the years 1980, 1990 and 2000 which were georefered. Spatial thematic maps for the year 2007 have been prepared for the land-use/land-cover classification. These maps are used to analyze the relationship between urban expansion and various related factors. The conceptual framework of the methodology is displayed in the Figure 3.3.

![Conceptual Framework for Methodology](image_url)

Fig: 3.3 Conceptual Framework for Methodology
Fig: 3.3.1 Land Use-Land Cover map for the study area of Hyderabad, 1980.
Fig: 3.3.2 Land Use-Land Cover map for the study area of Hyderabad, 1990.
Fig: 3.3.3 Land Use-Land Cover map for the study area of Hyderabad, 2000.
3.4 Data Used

1. Revised and latest published reports of Hyderabad Urban Development Authority (HUDA) [143].

2. For Land Use: Survey of India topographical map (1980);
   IRS 1C (LISS-III) Satellite image with following details:
   
   Spectral Bands
   B2 (Green) - 0.52-0.59 microns
   B3 (Red) - 0.62-0.68 microns
   B4 (NIR) - 0.77-0.86 microns

   Ground swath 141Km @ 23.5m resolution.
   Date of Passing : 01-12-2007
   Path and Row : 100 and 60
   Scanner : LISS
   Season : Winter

3.5 Measuring Urban Sprawl

Spatial data in the form of satellite image for the preparation of land-use/land-cover (LU/LC) details for the study area of Hyderabad have been procured from National Remote Sensing Centre (NRSC), Hyderabad. The topographical map of the study area (56K) is acquired from the Survey of India (SOI), Hyderabad.

The study area map (Fig: 3.1), was first geo-registered with the satellite image of the study area (Fig: 3.2). The vector layers (Road network, Built-up area and Water bodies) were digitized from the topographical map. The standard procedure for the analysis of
satellite imagery such as extraction, restoration, classification, and enhancement is applied for the study area.

Examining the land use changes Remote Sensing Data, interpretation has been done using ERDAS Imagine (Version 8.7) Image Processing software. ERDAS IMAGINE uses the ISODATA algorithm to perform an unsupervised classification which is explained as stated below.

i. Procedure for Unsupervised Classification

1. Click on CLASSIFIER Icon of the ERDAS MAIN TOOL Bar.
2. Click on UNSUPERVISED CLASSIFICATION option. Then it will display the UNSUPERVISED CLASSIFICATION (ISO DATA) Window.

3. Browse for the Folder D:\ERDAS_EXERCISE_FILES and Select the File MOSAIC_IMAGES.IMG as the option for INPUT FILE
4. Browse for the Folder D:\ERDAS_EXERCISE_FILES and Type OUTPUT File as UNSUPER_CLASS.IMG

5. Uncheck the option for OUTPUT SIGNATURE SET.

6. Type 20 as the option for NUMBER CLASSES.

7. Type 10 as the Number of Iterations.

8. Click on OK to start the process of Classification. While processing the image classification observe the convergence value for each iteration.

ii. **Viewing the Image**

1. Click on VIEWER Icon of the Main Tool Bar.

2. Select Viewer type as CLASSIC VIEWER.

3. Click OK to get a blank Viewer Window.

4. Click on OPEN from the File Menu.

5. Select RASTER LAYER option.

6. Then browse for the File MOSAIC_IMAGES.IMG and select the same file.

7. Right Click the mouse button and select IMAGE FIT TO WINDOW Option.

8. Click on OPEN from the File Menu.

9. Select RASTER LAYER option.

10. Then browse for the File UNSUPER_CLASS.IMG and select the same file.

11. Right Click the mouse button and select IMAGE FIT TO WINDOW Option.

12. Click on UTILITY menu.
13. Click on SWIPE option.

iii. **Changing the COLORS**

1. Click on the RASTER Menu.

2. Click on the ATTRIBUTE option. Then it will display RATSER ATTRIBUTE EDITOR table.

3. Now Using SWIPE Window, Observe the features and Change the Colors Accordingly. After giving colors for all the 20 classes.

   Then the Raster Attribute Editor is looks like as given below.
Ground truth data collection and field verification has been done for the study area to strengthen the classification accuracy. The LU/LC details for the years 1980, 1990 and 2000 have been acquired from the authentic data source with the latest published reports by HUDA [143] in coordination with NRSC, Hyderabad as presented in Table 3.1. The referred data is also verified with the
research reports of the past researchers related to the study area for validation.

Spatial thematic maps pertaining to the LU/LC for the year 2007 have been prepared for the urban agglomerations of Hyderabad which is shown in Figures 3.4-3.6. The LU/LC map of the study area for the year 2007 has been prepared to study the growth patterns by merging all the thematic layers using ArcGIS (Version 9.0) as shown in Figure 3.7.
Fig: 3.4 Thematic map for important road network of Hyderabad 2007
Fig: 3.5 Thematic map for built-up area of Hyderabad 2007
Fig: 3.6 Thematic map for water bodies of Hyderabad 2007
Fig: 3.7 Land-Use / Land-Cover map for the study area of Hyderabad 2007.
The LU/LC details for the year 2007, determined by computing the area of all the settlements from the digitized topographical maps and comparing it with the area obtained from the classified satellite imagery have been incorporated in the Table 3.1.

Table 3.1 Land-use / Land-cover details showing the growth patterns of Hyderabad urban agglomerations for the years 1980, 1990, 2000 and 2007

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Built-up area</td>
<td>8.31</td>
<td>14.97</td>
<td>26.20</td>
<td>30.45</td>
</tr>
<tr>
<td>Transportation</td>
<td>0.79</td>
<td>0.98</td>
<td>2.62</td>
<td>3.88</td>
</tr>
<tr>
<td>Water bodies</td>
<td>4.39</td>
<td>4.77</td>
<td>4.98</td>
<td>5.10</td>
</tr>
<tr>
<td>Forests</td>
<td>2.43</td>
<td>3.98</td>
<td>4.74</td>
<td>5.02</td>
</tr>
<tr>
<td>Agriculture</td>
<td>83.47</td>
<td>75.30</td>
<td>61.01</td>
<td>54.74</td>
</tr>
<tr>
<td>Open space</td>
<td>0.0</td>
<td>0.0</td>
<td>0.45</td>
<td>0.81</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

From the Table 3.1 as given, the diagrams showing the percentage wise area break-up of land-use/land-cover to the study area for the years 1980, 1990, 2000 and 2007 have been represented in the Figures 3.8-3.11.
Fig: 3.8 Diagram showing the percentage wise area break-up of LU/LC for the year 1980 (Data Source).

1980

Fig: 3.9 Diagram showing the percentage wise area break-up of LU/LC for the year 1990 (Data Source).
Fig: 3.10 Diagram showing the percentage wise area break-up of LU/LC for the year 2000 (Data Source).

Fig: 3.11 Diagram showing the calculated percentage wise area break-up of LU/LC for the year 2007.
Fig 3.11.1 Diagram showing the comparative percentage wise area break-up of LU/LC
Further, the growth pattern analysis has been done for the urban agglomerations of the study area of Hyderabad, based upon the data available for the years 1980, 1990, 2000 and the data calculated for the year 2007 (using IRS-1C-LISS-III satellite image). The diagrammatic observation of the growth pattern has been represented in the Figure 3.12.
Fig: 3.12 Urban sprawl map for the study area of Hyderabad (1980-2007)
3.6 Analysis for the Urban Growth Pattern Using AHP

The potential map for urbanization was identified through GIS environment. The following factors have been used to analyze the urban growth pattern in the study area.

- Transportation
- Existing built-up area
- Industrial sectors
- Public and semi public
- Open space zone
- Water bodies

A systematic AHP method has been used for comparing a list of objectives or alternatives selected. AHP can be a powerful tool for comparing alternative design concepts in systems engineering process with multi criteria decision making system. The AHP method, commonly used in multi-criteria decision making, is found to be a useful method to determine the weights for both quantitative and qualitative criteria because, it can deal with inconsistent judgments and provide a measure for the inconsistency. Assuming a set of factors as mentioned above it is to establish a normalized set of weights to be used when comparing alternatives using these factors.

After selecting the factors, the first step of the Analytic Hierarchy Process (AHP) is to form a hierarchy of objectives, criteria and all other elements involved in the problem. Comparison matrices are to be developed after the formation of the hierarchical structure. For each level in the hierarchy, the evaluations made by the decision
makers on the intensity of difference in importance, a rank number on
a given numerical scale has been expressed.

An expert opinion is followed to make pair-wise comparisons
between the selected factors at a time to decide which factor is more
important. The degree of importance on a scale between 1 to 9 in
which 9 is the most important in the pair-wise comparisons to the
selected factors. Based upon the degree of importance specified to the
factors considered, the weights or priorities are determined using AHP
technique and finally, the calculated weights to the criteria considered
for the urban growth are checked for the consistency of the matrix
generated with the help of the consistency ratio.

On the basis of the weightage factors determined, the analysis
for the growth pattern with LU/LC data is carried. The following
approach is carried out in the schematic calculations using statistical
method.

3.6.1 Scales for pair-wise comparisons

Scales for pair-wise comparisons were adopted and the matrix is
shown in Table 3.2 for growth pattern in 2020. A pair-wise
comparison matrix A is formed, where the number in the \(i\)th row and
\(j\)th column gives the relative importance of \(Y_i\) as compared with \(Y_j\).
Using a 1-9 scale, with

- \(a_{ij} = 1\) if the two factors are equal in importance
- \(a_{ij} = 3\) if \(Y_i\) is weakly more important than \(Y_j\)
- \(a_{ij} = 5\) if \(Y_i\) is strongly more important than \(Y_j\)
- \(a_{ij} = 7\) if \(Y_i\) is very strongly more important than \(Y_j\)
- $a_{ij} = 9$ if $Y_i$ is absolutely more important than $Y_j$
- $a_{ij} = 1/3$ if $Y_j$ is weakly more important than $Y_i$
- $a_{ij} = 1/5$ if $Y_j$ is strongly more important than $Y_i$
- $a_{ij} = 1/7$ if $Y_j$ is very strongly more important than $Y_i$
- $a_{ij} = 1/9$ if $Y_j$ is absolutely more important than $Y_i$

Table 3.2 Matrix for the urban growth analysis of Hyderabad urban area
with scales of pair-wise comparisons using AHP

<table>
<thead>
<tr>
<th></th>
<th>Transportation</th>
<th>Existing Built-up area</th>
<th>Industrial</th>
<th>Public &amp; Semi Public</th>
<th>Open Space Zone</th>
<th>Water bodies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transportation</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td>7</td>
<td>9</td>
<td>3</td>
</tr>
<tr>
<td>Existing Built-up area</td>
<td>1/3</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>Industrial</td>
<td>1/5</td>
<td>1/3</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td>1/3</td>
</tr>
<tr>
<td>Public &amp; Semi Public</td>
<td>1/7</td>
<td>1/5</td>
<td>1/3</td>
<td>1</td>
<td>1/3</td>
<td>1/9</td>
</tr>
<tr>
<td>Open Space Zone</td>
<td>1/9</td>
<td>1/7</td>
<td>1/5</td>
<td>3</td>
<td>1</td>
<td>1/7</td>
</tr>
<tr>
<td>Water bodies</td>
<td>1/3</td>
<td>1/5</td>
<td>3</td>
<td>9</td>
<td>7</td>
<td>1</td>
</tr>
</tbody>
</table>
Table 3.3 Calculated weights of six factors for growth pattern in 2020

<table>
<thead>
<tr>
<th></th>
<th>Transportation</th>
<th>Existing Built-up area</th>
<th>Indus -trial</th>
<th>Public &amp; Semi Public</th>
<th>Open Space Zone</th>
<th>Water bodies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transportation</td>
<td>0.472</td>
<td>0.616</td>
<td>0.398</td>
<td>0.25</td>
<td>0.306</td>
<td>0.312</td>
</tr>
<tr>
<td>Existing Built-up area</td>
<td>0.155</td>
<td>0.205</td>
<td>0.239</td>
<td>0.178</td>
<td>0.238</td>
<td>0.521</td>
</tr>
<tr>
<td>Industrial</td>
<td>0.094</td>
<td>0.068</td>
<td>0.079</td>
<td>0.107</td>
<td>0.170</td>
<td>0.034</td>
</tr>
<tr>
<td>Public &amp; Semi Public</td>
<td>0.067</td>
<td>0.041</td>
<td>0.026</td>
<td>0.0357</td>
<td>0.011</td>
<td>0.011</td>
</tr>
<tr>
<td>Open Space Zone</td>
<td>0.052</td>
<td>0.029</td>
<td>0.015</td>
<td>0.107</td>
<td>0.034</td>
<td>0.014</td>
</tr>
<tr>
<td>Water bodies</td>
<td>0.155</td>
<td>0.041</td>
<td>0.239</td>
<td>0.32</td>
<td>0.238</td>
<td>0.104</td>
</tr>
</tbody>
</table>

Thus the matrix A is arrived in following form

\[
A = \begin{pmatrix}
1.00 & 3.00 & 5.00 & 7.00 & 9.00 & 3.00 \\
0.33 & 1.00 & 3.00 & 5.00 & 7.00 & 5.00 \\
0.20 & 0.33 & 1.00 & 3.00 & 5.00 & 3.33 \\
0.14 & 0.20 & 0.33 & 1.00 & 0.33 & 0.11 \\
0.11 & 0.14 & 0.20 & 3.00 & 1.00 & 0.14 \\
0.33 & 0.20 & 3.00 & 9.00 & 7.00 & 1.00
\end{pmatrix}
\]

As represented in Table 3.3, using an over bar to denote normalization of the matrix A, we get
The weights for the factor wise Hierarchy are computed as shown in Table 3.4.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Transport</th>
<th>Existing built-up area</th>
<th>Industries</th>
<th>Public and semi public</th>
<th>Open space zone</th>
<th>Water bodies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>0.392</td>
<td>0.256</td>
<td>0.092</td>
<td>0.031</td>
<td>0.041</td>
<td>0.182</td>
</tr>
</tbody>
</table>

Further, the weights would be expressed as

\[ W = [0.392 \ 0.256 \ 0.092 \ 0.031 \ 0.041 \ 0.182]^T \]

Where by construction, \( \sum_{i=1}^{6} W_i = 1 \)

The consistency measure using the Eigen values for the normalized comparison matrix is computed with the help of consistency ratio.
3.6.2 Determining the consistency ratio

To arrive at the consistency ratio, the weighted sum vector is determined. This is done by multiplying the factor evaluation number for the first system times the first column of the original pair-wise comparison matrix and so on with the help of the following java program.

```java
import java.util.*;

class MatrixMultiplication{
    public static void main(String[] args){
        Scanner input = new Scanner(System.in);

        int[][] A = new int[3][3];
        int[][] B = new int[3][3];
        int[][] C = new int[3][3];
        System.out.println("Enter elements for matrix A : ");
        for (int i=0; i < A.length; i++)
            for (int j=0; j < A[i].length ; j++){
                A[i][j]=input.nextInt();
            }
        System.out.println("Enter elements for matrix B : ");
        for (int i=0; i < B.length; i++)
            for (int j=0; j < B[i].length ; j++){
                B[i][j]=input.nextInt();
            }
        System.out.println("Matrix A: ");
        for(int i=0; i < A.length; i++){
            System.out.println();
            for (int j=0; j < A[i].length ; j++){
                System.out.print(A[i][j]+" ");
            }
        }
        System.out.println();
        System.out.println();
        System.out.println("Matrix B: ");
        for(int i=0; i < B.length; i++){
            System.out.println();
            for (int j=0; j < B[i].length ; j++){
                System.out.print(B[i][j]+" ");
            }
        }
        System.out.println();
        System.out.println();
        System.out.println("Result is: ");
        System.out.println();

        for(int i=0;i<6;i++){
            for (int j=0; j < 6; j++){
                for (int k=0; k < 6; k++){
                    C[i][j]+=A[i][k]*B[k][j];
                }
            }
        }
    }
}
```
for(int i=0;i<6;i++){
    for(int j=0;j<6;j++){
        System.out.print('+C[i][j]+" ");
    }
    System.out.println();
}

The resulting weighted sum vector is given by

\[
\begin{pmatrix}
1.00 & 3.00 & 5.00 & 7.00 & 9.00 & 3.00 \\
0.33 & 1.00 & 3.00 & 5.00 & 7.00 & 5.00 \\
0.20 & 0.33 & 1.00 & 3.00 & 5.00 & 0.33 \\
0.14 & 0.20 & 0.33 & 1.00 & 0.33 & 0.11 \\
0.11 & 0.14 & 0.20 & 3.00 & 1.00 & 0.14 \\
0.33 & 0.20 & 3.00 & 9.00 & 7.00 & 1.00
\end{pmatrix}
\times
\begin{pmatrix}
0.392 \\
0.256 \\
0.092 \\
0.031 \\
0.041 \\
0.182
\end{pmatrix}
=
\begin{pmatrix}
2.75 \\
2.01 \\
0.59 \\
0.19 \\
0.23 \\
1.20
\end{pmatrix}
\]

3.6.3 Calculation of consistency vector

By dividing the weighted sum vector by the factor evaluation values, the consistency vector is defined.

\[
\text{Consistency vector} = \begin{pmatrix}
2.75 \\
2.01 \\
0.59 \\
0.19 \\
0.23 \\
1.20
\end{pmatrix}
\div
\begin{pmatrix}
0.392 \\
0.256 \\
0.092 \\
0.031 \\
0.041 \\
0.182
\end{pmatrix}
=
\begin{pmatrix}
7.01 \\
7.85 \\
6.41 \\
6.12 \\
5.60 \\
6.59
\end{pmatrix}
\]
3.6.4 Computing the consistency index

The consistency index (CI) is computed as \[ CI = \frac{\lambda - n}{n-1} \]

Where \( \lambda \) is the average value of consistency vector = \[
\frac{7.01+7.85+6.41+6.12+5.60+6.59}{6} = 6.6
\]

\( n \) = the number of factors being compared = 6

Therefore, \[ CI = \frac{\lambda - n}{n-1} = \frac{6.6 - 6}{6 - 1} = 0.12 \]

3.6.5 Computing random index (RI)

The random index is a direct function of the number of alternatives or the factors being considered and, is determined from the following Table 3.5.

<table>
<thead>
<tr>
<th>n</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>RI</td>
<td>0.00</td>
<td>0.58</td>
<td>0.90</td>
<td>1.12</td>
<td>1.24</td>
<td>0.32</td>
<td>1.41</td>
</tr>
</tbody>
</table>

From the above table for n=6, RI=1.24

Therefore, the consistency ratio finely defined as

\[ \text{Consistency ratio} = \frac{\text{Consistency index}}{\text{Random index}} = \frac{0.12}{1.24} = 0.096 \]

According to [123], a CR of less than 0.10 indicated a reasonable level of consistency in pair-wise comparisons. Hence, the CR of 0.096 is acceptable.
3.7 The equation for approximating the potential map for urbanization

The calculated weights are used in summing the measures as required in the evaluation. Therefore, UF the urban area in future over a time period T is calculated using EQ (1) as given below.

\[ UF = aY_1 + bY_2 + cY_3 + dY_4 + eY_5 + fY_6 \ldots \ldots \ldots (1) \]

\[ = 0.392Y_1 + 0.256Y_2 + 0.092Y_3 + 0.031Y_4 + 0.041Y_5 + 0.182Y_6 \]

Where,

a, b, c, d, e and f are the calculated weightage factors based upon the scales for pair-wise comparisons.

UF» urban area in future over a time period (T)

Y_1» the proximity of urban growth area to transportation

Y_2» the proximity of urban growth area to existing built-up area

Y_3» the proximity of urban growth area to Industries

Y_4» the proximity of urban growth area to public & semi public

Y_5» the proximity of urban growth area to open space zone

Y_6» the proximity of urban growth area to water bodies

Based upon the weightage factors calculated for the urban area over a time period, the land-use/land-cover details of Hyderabad for the year 2010 have been calculated and represented in Table 3.6. The projected values for land-use/land-cover areas using knowledge based hierarchy process for the year 2020 is also shown in Table 3.6. The details of land-use/land-cover with percentage wise area break-up has been represented by the diagrams as shown in the Figures 3.13-3.14 for the years 2010 and 2020.
The percentage wise proximity values of various parameters using the resulting map shown in Figures 3.12.1 and 3.12.2 from the proposed method to assign weight to the attributes generated for urban mapping and changes are as given below in the Table 3.5.1.

Table 3.5.1 Percentage wise proximity values of the parameters

<table>
<thead>
<tr>
<th></th>
<th>Proximity for Built-up area</th>
<th>Proximity for Transportation Road Network</th>
<th>Proximity for Waterbodies</th>
<th>Proximity for Open space</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>13.906</td>
<td>0.66</td>
<td>1.86</td>
<td>1.707</td>
</tr>
<tr>
<td>2020</td>
<td>47.89</td>
<td>4.795</td>
<td>7.307</td>
<td>2.439</td>
</tr>
</tbody>
</table>
Fig. 3.12.1 Calculated attributes map to the proximity of urban growth for the year 2010

Fig. 3.12.2 Calculated attributes map to the proximity of urban growth for the year 2020
Table 3.6 Percentage wise Land-use / Land-cover areas showing the growth patterns of Hyderabad for the year 2010 and 2020

<table>
<thead>
<tr>
<th>% wise</th>
<th>Built-up area</th>
<th>Transportation Road Network</th>
<th>Water bodies</th>
<th>Open space</th>
<th>Agriculture and forest</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calculated for 2010</td>
<td>34.01</td>
<td>4.14</td>
<td>5.44</td>
<td>0.88</td>
<td>55.53</td>
<td>100</td>
</tr>
<tr>
<td>Projected for 2020</td>
<td>42.71</td>
<td>5.76</td>
<td>6.43</td>
<td>0.91</td>
<td>44.19</td>
<td>100</td>
</tr>
</tbody>
</table>

Fig: 3.13 Diagram showing the generated percentage wise area break-up of LU/LC for the year 2010.
Fig: 3.14 Diagram showing the projected percentage wise area break-up of LU/LC for the year 2020.

With this analysis and findings in this chapter, the further research study has been carried out to study the impact of urban growth on infrastructure on the selected municipal areas of Hyderabad. For the analysis of impact in the next chapter, the weightage factors worked out in this chapter with multi criteria decision making system (using AHP technique) have been applied to the selected parameters since, the calculated weights are found to be valid for the study area of Hyderabad.