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Site Suitability Analysis for Urban Development Using GIS

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Abstract: The future success of economic growth policies depends a lot on the infrastructure development. It is universally established that remote sensing and GIS tools play a major role in various infrastructure development. Several decisions taken by different planning agencies require spatial analysis of maps involving many parameters. The GIS based maps provide the most important sources for spatial analysis. Remote sensing data provide latest and accurate maps, when used in the GIS environment, they become integrated. Also, the non-spatial data attached to it provide great help to the urban planners and decision makers. The main aim of the study is to study the growth and trend of urbanization around city/town, as well as to find out the suitable sites for further urban development around the city/town. In this study, Roorkee town has been considered and site suitability map is prepared for 1967 and 1996 and the results are compared with land use maps of 1996 and 2003, respectively and found that urban development is following with the methodology proposed. Eventually site suitability map is prepared based on 2003 land use map for further urban development.

Key words: GIS, urban development, environment, remote sensing

INTRODUCTION

Urban development and migration of population from rural to urban areas are global phenomena. Any small and isolated population centers are rapidly changing into large metropolitan cities and hence the conversion of natural land to urban use is quite obvious (Hauser *et al*., 1982). According to United Nation's Population Division report published in 1975, about 38% of the earth's population is living in urban areas and by 2025; this proportion is expected to rise to 61%. This implies that about 5 billion people out of a total world population of 8 billion will be living in urban areas (UNPD, 1995; http:/www.wri.org/wri/wr-96-97). This rapid increase of urban population and the transforming urban economy lead to an ever-increasing load on the urban environment in terms of urban capture structure of the cities, creating many problems, such as unplanned sprawl, inadequate housing facilities, traffic congestion, insufficient drainage, sewerage facilities and lack of other amenities (Liu, 1998).

Shan (1999) applied remote sensing and GIS technologies for analyzing the dynamics of the urban spatial structure in Shanghai. Multi-temporal landuse information of the central city of Shanghai was obtained by the interpretation of aerial photos of 1958, 1984 and 1996. Based on Arc/View GIS concentric and sector methods, a conceptual model of the spatial structure of Shanghai was brought forth. Sao (2000) carried out a study to prepare location map of selected urban facilities and services using GPS technology and to identify the service areas of different facilities and services, which will be the inputs for preparation of comprehensive development plan of the city.

Ashraf (2001) carried out a study to find out the historical urban development of Kharga city, Egypt and used it for defining the main direction of city's development. Amarsaikhan and Ganzorig (2000) carried out study to investigate the urban changes that have occurred in central part of Ulaanbaatar area, Mongolia over the past few decades and describe the socio-economic reasons for the changes. In this study a topographic map of 1969 at 1:25.000 scale, SPOT XS image of 1986, SPOT PAN image of 1990 and SPOT XS image of 1997 were used. A survey showed that the GIS based multi-criteria approaches are most often used in site suitability analysis (Malczewski, 2006)

MATERIALS AND METHODS

Study area: Roorkee, a quiet town of moderate size in the district of Hardwar (Uttaranchal State), is located on the banks of the Upper Ganga Canal, which takes off at Hardwar. It is about 30 km south of the Shivalik range of the mighty Himalayas, about 170 km to the north of Delhi and is situated on Amritsar-Howrah main railway line. Roorkee is linked by rail to many important mega cities

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such as Delhi, Kolkata and Mumbai. Roorkee is also well connected by road, being located on the Delhi-Hardwar National Highway (NH 58). This is located at a latitude 29°52' N and Longitude 77°53'52"E and is 268 m above mean sea level. Roorkee town is an important centre of engineering activity.

Methodology: The Survey of India (SOI) Topographical map no. 53G/13, aerial photographs and satellite data were registered using polyconic projection system. Satellite images (IRS 1D PAN Data, dated: 02 Nov. 2003) was digitally enhanced in order to extract maximum information.

Different attribute layers such as urban area, agriculture area, forest area and rivers are generated by digitizing in GeoMedia Professional. These layers were exported to GeoMedia Grid to find out the changes and to prepare change detection maps. For suitability analysis, different parameters such as land use, roads, ground water availability and water bodies are considered and categorized with various attribute layers by using GeoMedia Grid tools. Methodology is shown as flow diagram, shown in Fig. 1.

Expansion trend during 1967-2003: In order to find out the overall expansion of Roorkee town, layers of various themes for years 1967 and 2003 has been intersected with each other and change of one land use into another land use has been determined. The map representing the trend of land use change is shown in Fig. 2 and their area extent is given in Table 1.

It is observed from Table 1 that most of the vacant land has been converted into the urban area, which is natural trend of the growth. But a large agriculture area has also been used for the development of urban area.

Table 1: Overall expansion of Roorkee town (1967-2003)

	Area in 2003 (km^2)				
Area in 1967 (km^2)	Urban	Agriculture	Thin	Vacant	Water
Urban	-	-	-	-	-
Agriculture	10.31	-	-	0.05	-
Thin vegetation	3.93	8.23	-	0.49	
Vacant	5.91	0.01	0.01	-	-
Water bodies	-	0.12	-	-	-

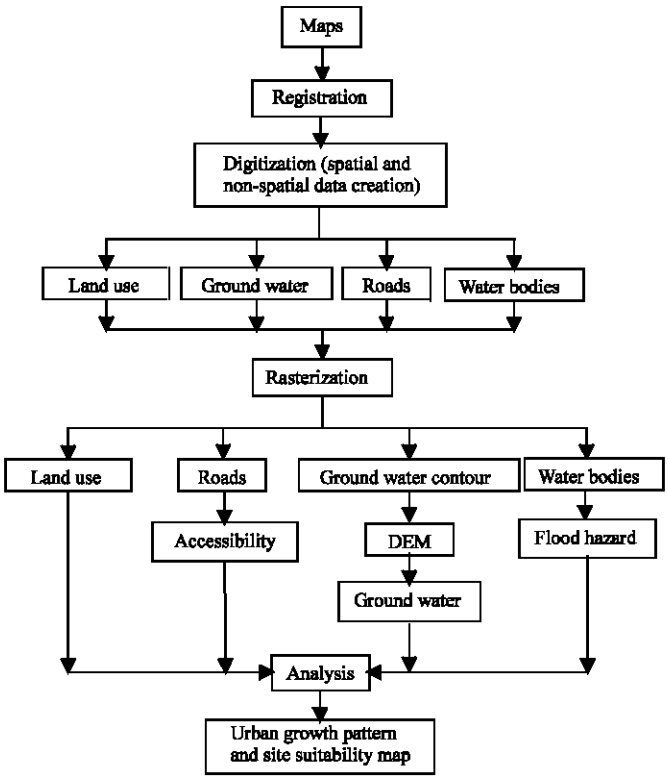

Fig. 1: Methodology to study the urban pattern and for site suitability analysis

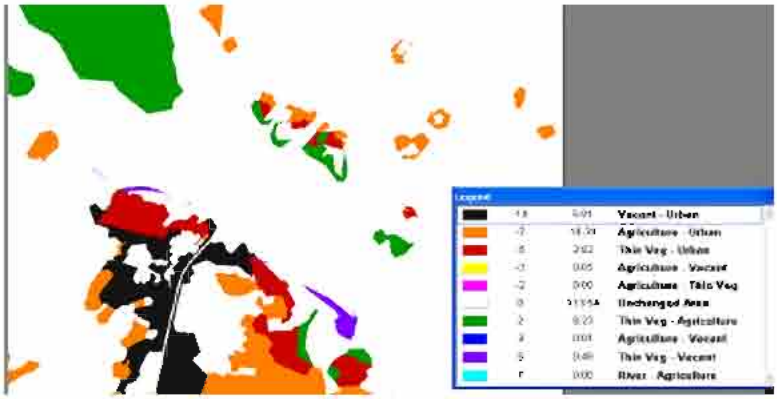

Fig. 2: Land use change trend during 1967-2003

GIS BASED SITE SUITABILITY ANALYSIS

The selection of suitable sites is based upon a specific set of local criteria. The characteristics of a site (e.g., present landuse, slopes, water availability, distance to employment, development costs, geology, geomorphology, etc.) influence its suitability for a specific land use type. To assess the overall suitability a scoring and weighting system is applied to the various aspects of suitability.

Site suitability is the process of understanding existing site qualities and factors, which will determine the location of a particular activity. The purpose of selecting potential areas for residential development depends upon the relationship of different factors, like location of available sites, extent of the area, accessibility, etc. and site association factors like slope, soil etc. The analysis may also determine how those factors will fit into the design process to evaluate site suitability (Hofstee and Brussel, 1995).

For any suitability analysis, appropriate base data is required (generally satellite data or air-photos, topographic maps and thematic maps and field data). The different land qualities, which can be considered for suitability modeling are, present land-use/land-cover, slope, proximity of transportation network, flood hazard, groundwater condition etc. (Sunil, 1998). The characteristics of a site (e.g., present land use, water availability, road accessibility, flood hazard, etc.) influence its suitability for further Urban Development. To assess the overall suitability a scoring and weighting system is applied to the various aspects of suitability. Suitable sites are found out by adding all layers which are affecting site suitability.

Selection of different parameters for suitability: Following parameters have been considered for the suitability analysis.

- Existing land use
- Flood hazard
- Ground water
- Road accessibility

Existing land use: Land use/Land cover map is a comprehensive expression of land use/land cover classification. This map has been prepared by using IRS PAN data and shown in Fig. 3. The main classes which affect the planning aspect, such as vacant, built-up land, agriculture land and thin vegetation and water bodies are considered here and the area covered is given in Table 2.

Flood hazard: Major rivers have been digitized from the topographical map. To delineate flood hazard prone areas, various buffer zones have been created by taking different distance values from both sides of the river banks as shown in Fig. 4 and areas covered by different categories are also given in Table 3.

Road accessibility: In this study, in order to find out the accessibility of the region, major roads, which are connecting to different areas have been digitized the SOI Topographical map of Roorkee town and buffer zones have been created by taking different distances from the road to generate road accessibility map. This way, buffer zones have been categorized accordingly, as given in Table 4. Fig 5 shows the buffer zones for the road accessibility.

Ground water table: Ground water is an important resource for urban existence and growth. In Roorkee town, growing population and desire for good quality of life is placing greater demands on good water resource of Roorkee town. The ground water map of the study area has been prepared by using ground water contour map (Singhal, 2003). Figure 6 shows ground water categories areas covered by different categories are also given in Table 5.

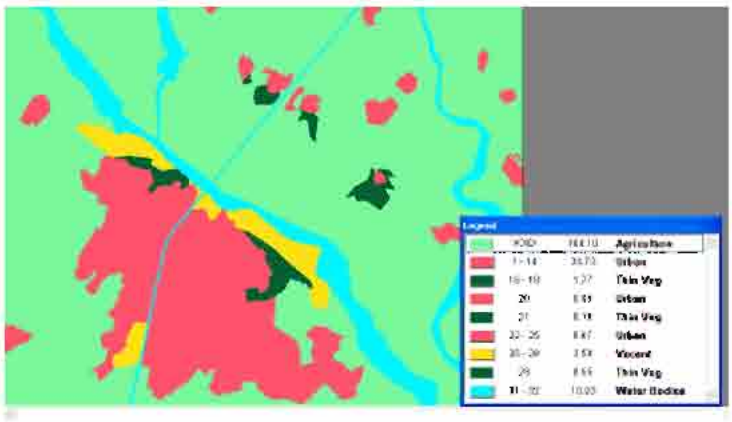

Fig. 3: Existing land use

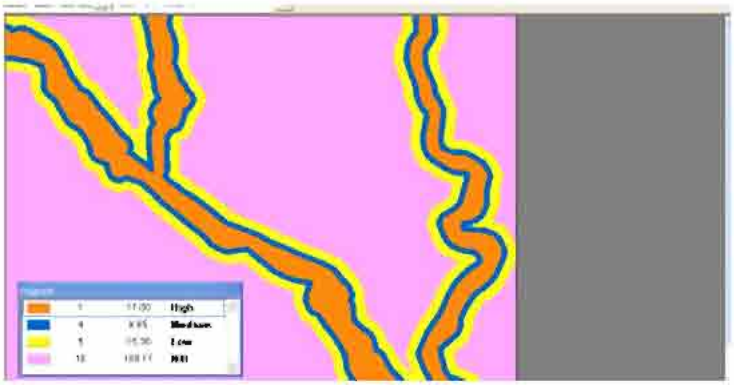

Fig. 4: Flood hazard zone categories

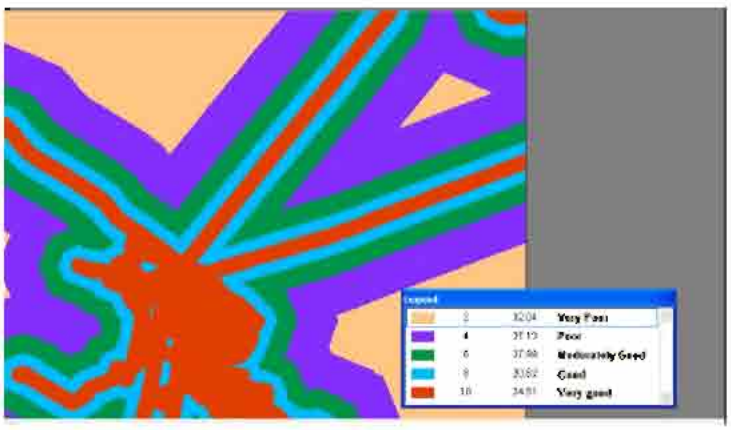

Fig. 5: Road accessibility

Suitability scoring and ranking: For suitability analysis, it is necessary to give some score to each of the category as per their suitability for urban development since each category will not have the same weightage or usefulness for urban development. The suitability scoring used in this study for each of the map and their category at 10 point scale are given in Table 6.

Suitability map with weighting system: All the four thematic maps have been converted in raster form, so that for each pixel, a score can be determined. These maps are then combined into a composite suitability map by simple addition of recorded maps with weight system.

In this study, higher weightage has been assigned to landuse as it has very important role in the urban

Table 2 Existing land use area, year 2001

Category	Area (km²)	Area (%)
Urban	25 45	17 86
Agriculture	100 10	70 26
Thin Vegetation	2 50	1 75
Vacant	3 50	2 46
Water Bodies	10 93	7 67

Table 3 Flood hazard zone categories

Buffer (m	Category	Area (km²)
0-100	High	17 00
100-250	Medium	9 95
250-500	Low	15 36
>500	Nil	100 17

Table 4 Road accessibility categories

Buffer (m)	Category	Area (km²)
0-200	Very good	24 81
200-500	Good	20 62
500-1000	Moderately good	27 88
1000-2000	Poor	37 13
>2000	Very poor	32 04

Table 5 Ground water categories

Category	Area (km²)
Very good	36 15
Moderately good	53 17
Poor	44 43
Very poor	8 74

Table 6 Suitability scoring

Parameters	Category	Scoring
Land use	Vacant	10
	Agriculture	7
	Forest	4
	Urban	0
	River	0
Road accessibility	0-200 m	10
	200-500 m	7
	500-1000m	4
	1000-2000 m	2
	>2000 m	0
Flood hazard	>500m	10
	250-500 m	5
	100-250 m	3
	0-100 m	0
Ground water	Very good	10
	Moderately good	7
	Poor	4
	Very poor	2

development. Next important parameter considered is the flood hazard as the as safety measure can be done to avoid damages and also urban development is higher at the vicinity of the river and canal. Following to the flood, next parameter is accessibility to the particular vacant sites. Distance to the main roads and other roads from the sites, on the other hand may not affect strongly, but large distance may involve some extra costs and increase in travel time and also for the development purpose accessibility is another important requirement. Moreover, new road might be required to change the situation. Considering this situation, weightage is assigned to the accessibility. Least priority has been given to ground water.

The weighting system in this case is designed to allow a maximum score of 550. The four scored maps have been added while applying the following weighting system.

Land use - 35
Flood hazard - 9
Accessibility - 7
Ground water - 5

A suitability map has been finally prepared by applying the above scoring using 'Recoding Tool' of GeoMedia Grid Software. The final output is a raster layer having particular suitability score which is based on following relationship:

Suitability score = (Land use score)*35+ (Flood Hazard)*9+ (Road Accessibility)*7+ (Ground water)*5

The range of suitability score has been divided into five parts and the areas have been divided into very suitable for higher range value to unsuitable for lower range value and final site suitability map is shown in Fig. 7. The areas which fall under different suitability zones have been calculated and are given in Table 7.

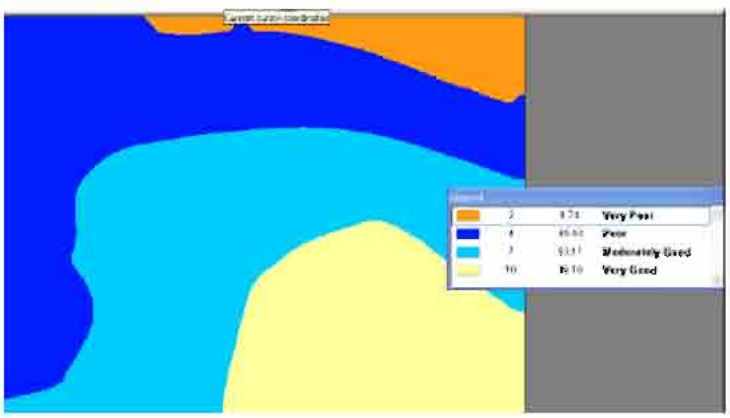

Fig. 6: Ground water categories

Table 7 Suitability classes for urban development

Class	Score	Area (km^2)
Highly suitable	466-545	1 55
Suitable	385-465	40 84
Moderate	305-384	56 19
Less suitable	224-304	7 49
Unsuitable	10-210	36 41
Total		142 48

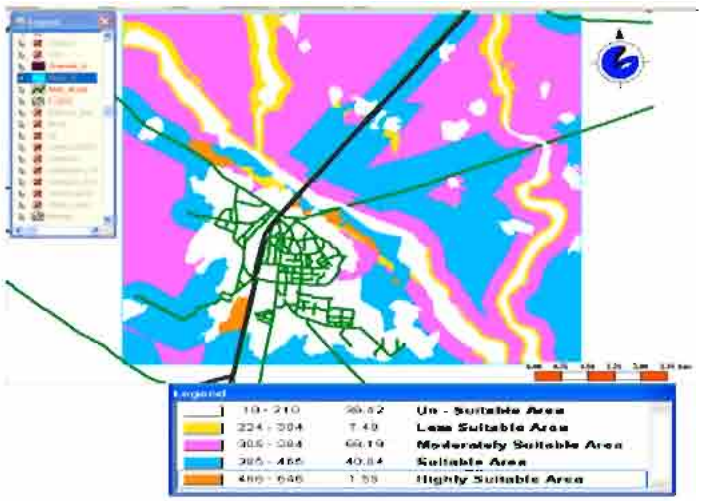

Fig. 7: Site suitability map for further urban development

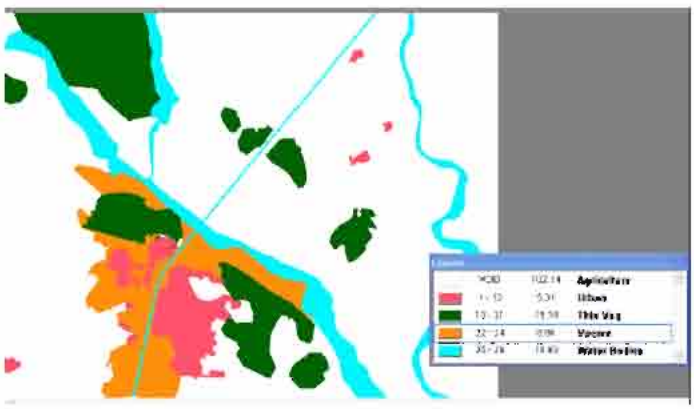

Fig. 8: Landuse map of 1967

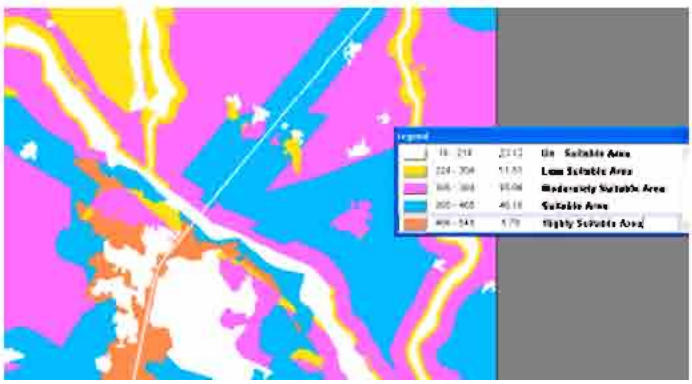

Fig. 9: Site Suitability map based on 1967

DISCUSSION

Using the 1967 land use map (Fig. 8), site suitability map (Fig. 9) is prepared for urban development and compared with the land use map prepared from 1996 (Fig. 10) and found that the urban development matches with the suitability map of 1967. Similarly, 2003 land use map (Fig. 12) matches with the 1996 site suitability map (Fig. 11) except with the areas such as Solanipuram, Avasvikas as they are proximity to the IIT Roorkee.

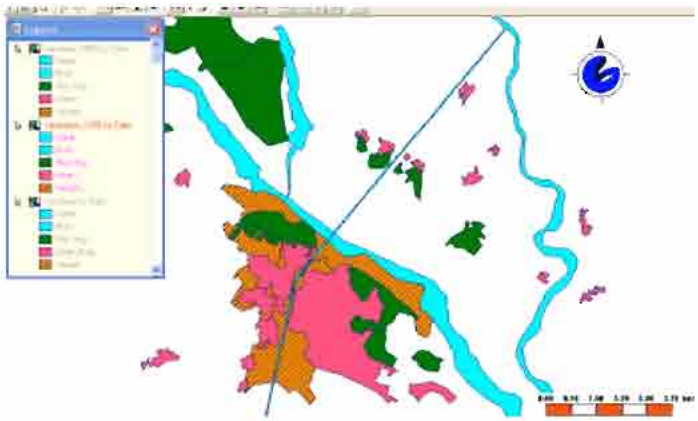

Fig 10: Landuse map of 1996

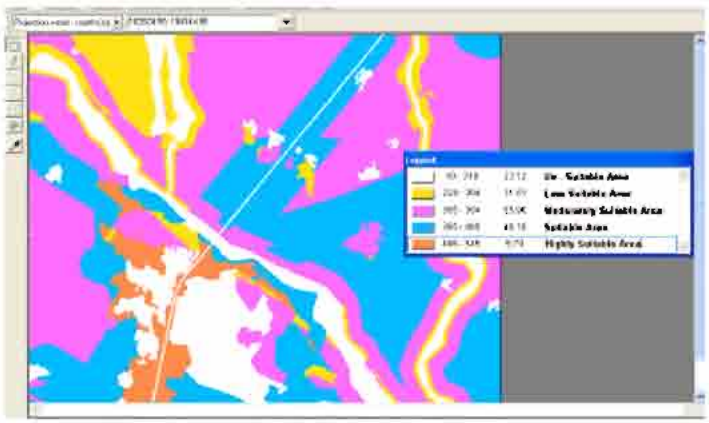

Fig. 11: Site Suitability map based on 1996

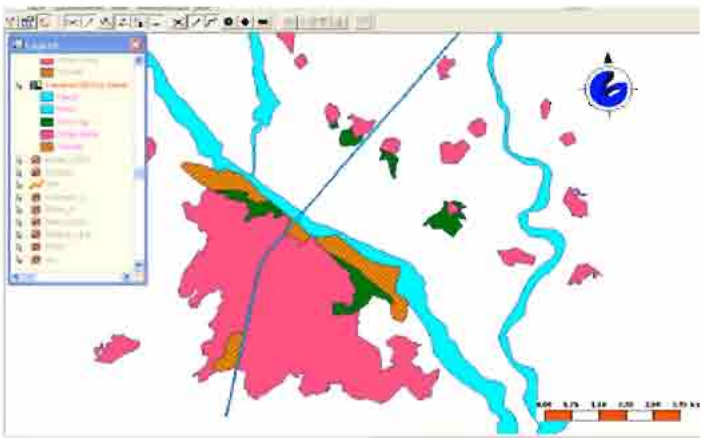

Fig. 12: Landuse map of 2003

CONCLUSIONS

Land use suitability analysis for urban development is necessary to overcome the problem with limited land availability against drastic growth of urbanization.

As per the suitability map, the south-west of the town matches with the development taken place over the years with the exception of area developed in Solampuram or near Ramnagar. This could be because of the proximity to IIT Roorkee campus or Avas Vikas. If the local parameters like the areas near to the IIT Roorkee, Avas Vikas etc. are considered, the results may be better. This study will be helpful for urban planners and urban development authorities to plan development of the city.

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