Site selection for ring road in the Coimbatore smart city using GIS and AHP

Elangovan K[1], Gowtham G[2], Pranav Srinidhi B[3], Siva Venkatesh Anand S[4]
{ ela.civil@psgtech.ac.in[1], gowthamg@iitk.ac.in[2], srinidhipranav@gmail.com[3], sivavenkatshanand@gmail.com[4]}

Professor, Department of Civil Engineering, PSG College of Technology, Coimbatore, Tamil Nadu, India[1], PhD student, Department of Civil Engineering, Indian Institute of Technology Kanpur, Kanpur, Uttar Pradesh, India[2], M.Tech student, Department of Water Resources & Ocean Engineering, National Institute of Technology Karnataka, Surathkal, Karnataka, India[3], Former undergraduate student, Department of Civil Engineering, PSG College of Technology, Coimbatore, Tamil Nadu, India.[4]

Abstract. Urban population of India is increasing day by day. The amount of traffic all cities are exponentially raising and along with poor traffic planning this leads to a chaos. In order to develop various cities in India, Smart City Mission was introduced by the Government of India. One such city is Coimbatore in Tamil Nadu, South India. The traffic congestion in the city has reached its peak and the number of vehicles coming into the city has risen. This study aims in proposing a route for a ring road connecting all the major roads of Coimbatore, which would reduce the traffic coming in to the city. For this study concept of remote sensing, GIS and AHP have been used. The maps corresponding to population, land-use land-cover, slope, guideline value, location of roads, schools and colleges, depth of ground water table for Coimbatore city were prepared. Using the weightages for different criteria from AHP, Site suitability map was created. From the site suitability map, inner and outer ring roads were proposed. This article is based on the undergraduate project done by the authors [1].

Keywords: AHP, GIS, Digitization, Weighted overlay, Ring-road.

1 Introduction

A 'smart city' is an urban region that is highly advanced in terms of overall infrastructure, sustainable real estate, communications and market viability. In India, under the Smart City Mission, in the Phase I of the project, 100 smart cities have been proposed. Under this, Coimbatore city in Tamil Nadu, South India also finds a place. For this increasing population it is necessary to provide an integrated mobility system. There is a catastrophic increase in the use of personalised vehicles now-a-days. The increase in the use of personalised mobility and with increase in trade in the city, the number of vehicles that enter the city is increasing. And due to lack of interconnectivity between various national and state highways of the city, all the vehicles that need to travel along that highway should necessarily pass through the heart of the city. Restrictions are laid by the government bodies restrict the entry of trade vehicles during the peak hours. This leads to delay in the trade operations. So, if a ring road linking all the major highways that feed the traffic into the city, is planned then it will reduce the amount of traffic entering into the city.

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2 Objective

The objective of this study is to select suitable sites for ring road for Coimbatore city using GIS and AHP.

3 Study area

The study area is Coimbatore Municipal Corporation, Coimbatore district in Tamilnadu. Located on the banks of the Noyyal River surrounded by the Western Ghats, it is the second largest city in the state after Chennai and 16th largest urban agglomeration in India. Coimbatore City was constituted as a Municipality in November 1866 and Upgraded into a Municipal Corporation in May 1981. It is one of the fastest growing level-II cities in India. It is often called as the "Manchester of South India" due to its high cotton production and textile industries. The Coimbatore city corporation is divided into five zones and has 100 wards in total. The area of the city is 257.04sq.km and the current population (as per Census 2011) is around sixteen lakhs. Fig: 1 shows the Coimbatore city delimitation map as per Coimbatore city Municipal Corporation (www.ccmc.gov.in).

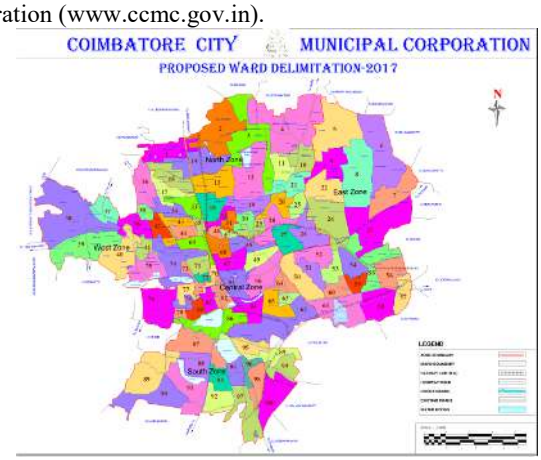
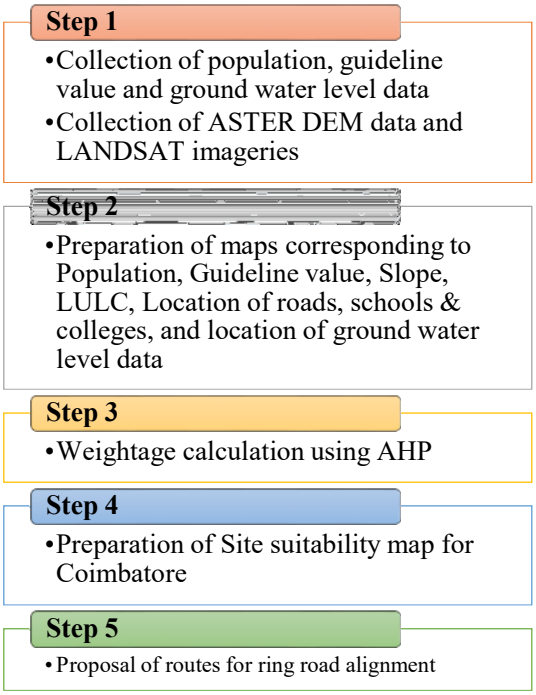


Fig: 1 – Coimbatore city delimitation map

4 Methodology

The following flow chart shows the methodology adopted.



4.1. Data collected:

- The data that are to be collected was referred from a journal on *Ring road alignment for Thuraiyur using GIS* by Subramani. T, et.al.[1]
- The data collected for Coimbatore region includes, the population data, guideline values for various areas and the depth of ground water table in various bore wells/ dug wells.
- The population data for Coimbatore was obtained from the web portal of Census of India, www.censusindia.gov.in.
- The guideline value for Coimbatore was obtained from https://tnreginet.gov.in/portal/
- The depth of ground water level was obtained from State Ground and Surface Water Resources Data Centre, Tharamani, Chennai – 600 113.
- From www.earthexplorer.usgs.gov, the official website of the United States Geological Survey, the ASTER DEM data and the LANDSAT imageries were downloaded as GeoTiff. format.
- From Google Maps (https://maps.google.co.in/), the locations of schools, colleges and national and state highways were obtained.

4.2. Software used:

Throughout the study ArcMap software of version 10.4 from ESRI was used.

5 Digitization of map

Digitization is a procedure in which the raster image formats like .jpeg, .jpg, .png, .tif, etc. are converted to vector formats in the form of shape files (.shp). Only after the digitization process, the map can be used for further analysis in ArcMap software. Fig: 2 shows the digitized Coimbatore Ward map.

5.1. Population map:

Using the Microsoft Excel (.xlx) file that is added to the ArcMap window, the population map for Coimbatore city was created. In the attribute table, the ward number, area in sq. km and the population were added. Using the Symbology tool, map corresponding to population was created. Fig: 3 shows the population map of Coimbatore. The legend gives the number of people in that area.

5.2. LULC map:

From Band 1 to Band 7 of the LANDSAT Images obtained from the USGS website was added to the window. By using the *Image analysis* tool, all the bands were merged to form a single image.

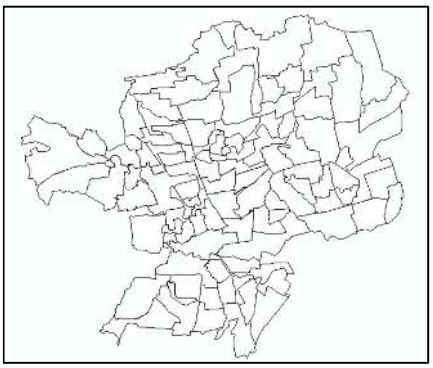


Fig: 2 – Digitized Coimbatore ward map

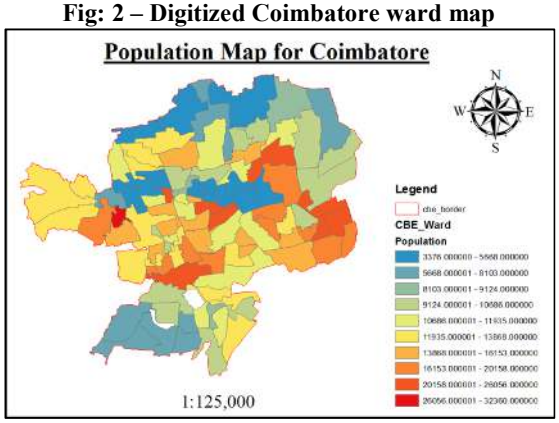


Fig: 3 – Population map for Coimbatore

In order to prepare the Land Use Land Cover map, the True Colour Composite was created by changing the band numbers. In this Red was assigned to Band 4, Green to Band 3 and Blue to Band 2. By this process, any change in the original band numbers can be rectified

and a true colour composite of Coimbatore region was prepared. From this, using Maximum likelihood classification, the LULC map for Coimbatore was prepared as shown in Fig: 4. The colour coding in the legend is as per the Bhuvan, National Remote Sensing Centre recommendations.

5.3. Digital elevation model and slope map:

The Digital Elevation Model (DEM) is a map or a raster image showing the elevation of the ground surface. This map is very much useful for the studies related to the elevation. It helps in preparation of slope maps, contour maps, aspect maps, etc. The ASTER DEM data was merged to a single raster and then using the spatial analyst extension in ArcMap, slope map for Coimbatore was prepared. Fig: 5 shows the slope map for Coimbatore.

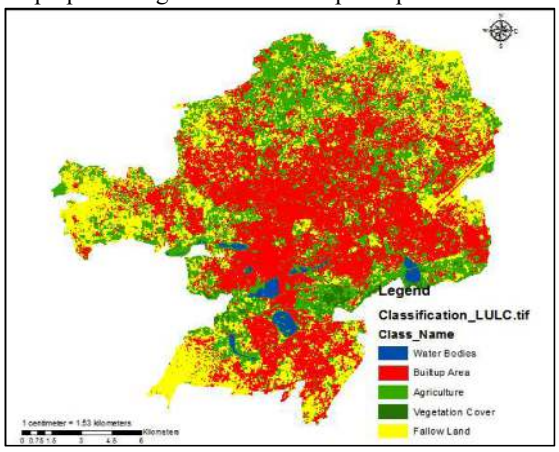


Fig: 4 – LULC Map for Coimbatore

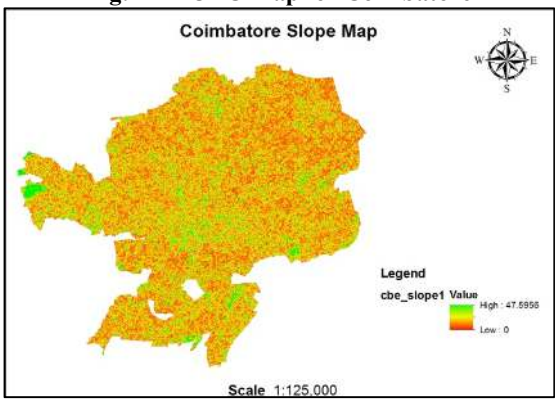


Fig: 5 – Slope Map for Coimbatore

5.4. Road map:

There are five national highways and three state highways that pass through the Coimbatore city. They are - *NH 181* (Mettupalayam Road), *NH 948* (Sathy Road), *NH 544* (Avinashi Road), Trichy Road, *SH 162* (Palldam Kochin Frontier Road), *NH 948* (Pollachi Main Road), *SH 167* (Marudamalai Road), *SH 164* (Anaikatti Road).

Using the Euclidean distance tool, the Euclidean distance raster have been created, and is shown in Fig: 6

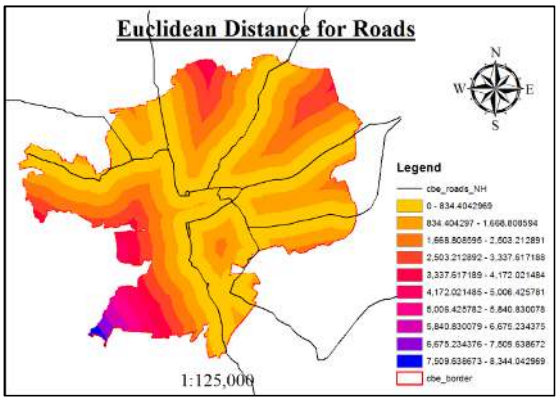


Fig: 6 – Euclidean distance for Roads

5.5. Locations of schools and colleges:

From the added XY data containing the locations of schools and colleges, separate raster images showing the Euclidean distance were created. The Euclidean distance for school is shown in Fig: 7 and Fig: 8 shows the Euclidean distance for colleges.

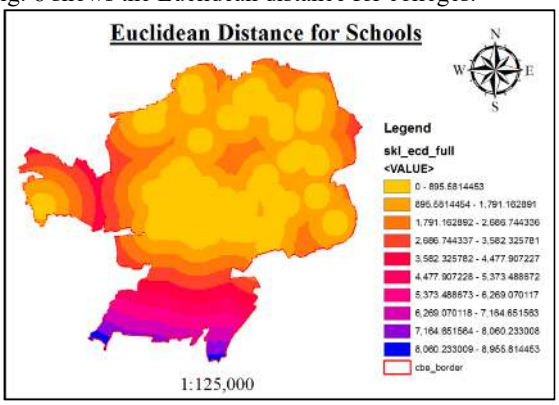


Fig: 7 – Euclidean Distance for schools

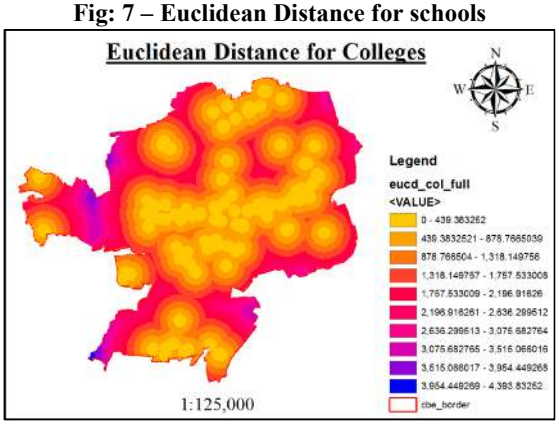


Fig: 8 – Euclidean distance for colleges

5.6. Ground water level map:

The added XY data of locations of wells and the depth of ground water level corresponding to it. Using the Kriging interpolation technique, the surface raster showing the details of ground water level as a contour map was created. The ground water level map for Coimbatore is as shown in Fig: 9.

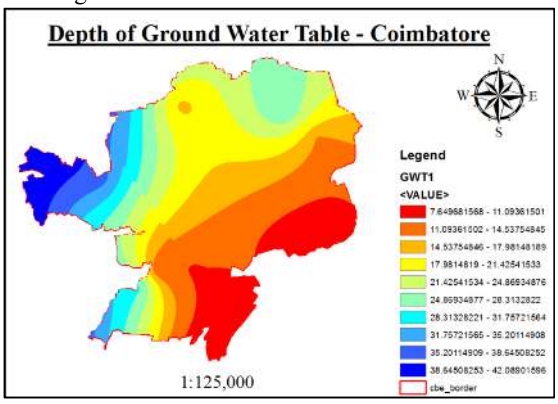


Fig: 9 – Depth of ground water table in Coimbatore

5.7. Guideline value map:

The preparation of Guideline value map for Coimbatore is similar to the groundwater level map using Kriging technique. The guideline value map for Coimbatore is as shown in Fig: 10.

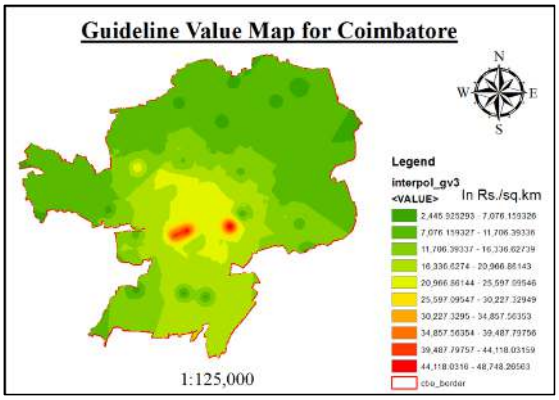


Fig: 10 – Guideline value map for Coimbatore

6. Reclassification of maps

Reclassification of maps has been done in order to change the class values into unique values like 1, 2, 3, 4 and 5. All the maps created have been reclassified as shown in Fig: 11, 12, 13, 14, 15 16, 17 and 18.

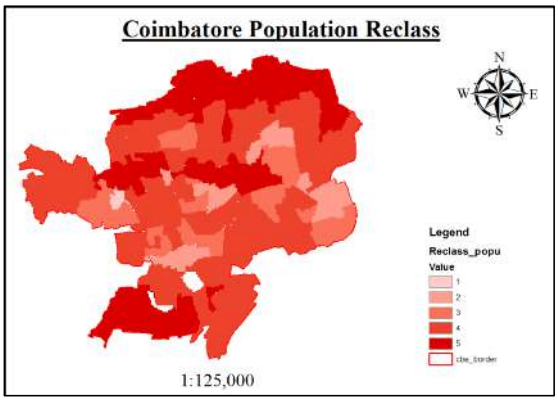


Fig: 11 – Reclassified population map

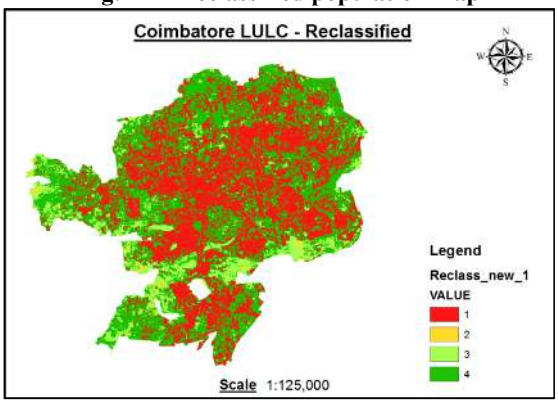


Fig: 12 – Reclassified LULC map

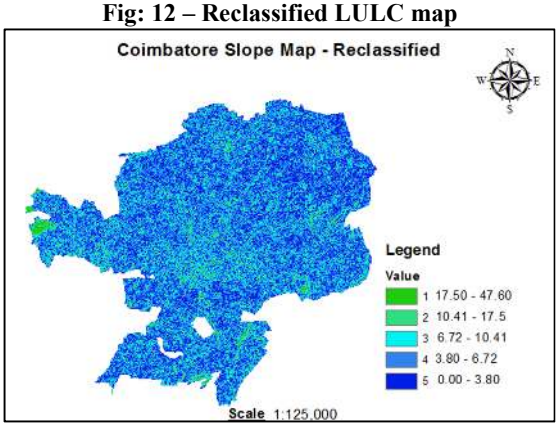


Fig: 13 – Reclassification of slope

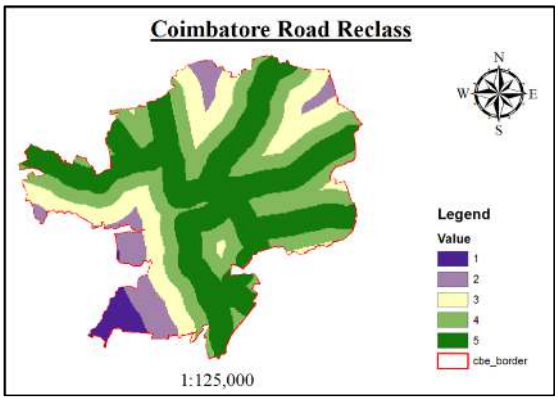


Fig: 14 – Reclassification of road map

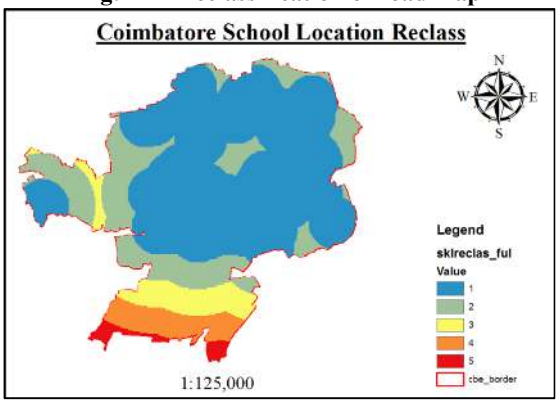


Fig: 15 – Reclassification of School map

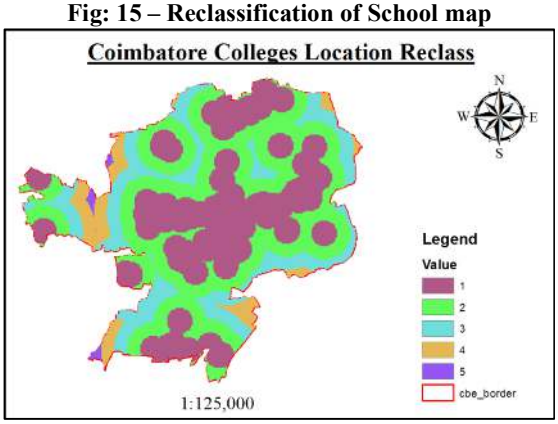


Fig: 16 – Reclassification of College map

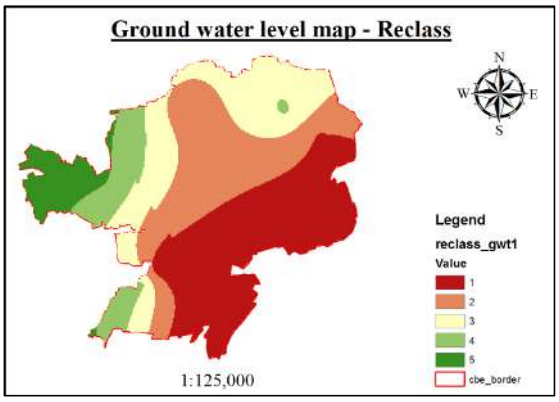


Fig: 17 – Reclassified Ground water level map

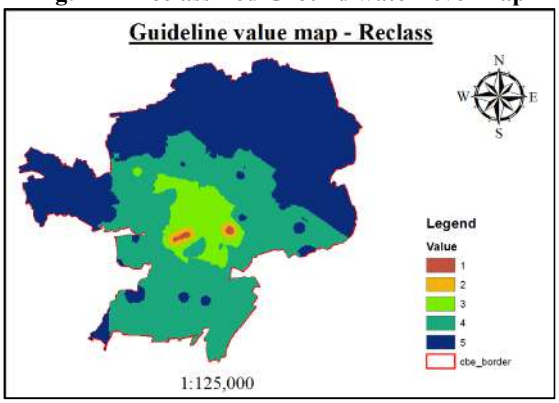


Fig: 18 – Reclassified Guideline value map

7. Weightage calculation using AHP

The Analytical Hierarchy Process (AHP) is used to calculate the weightage that need to be given to various criteria. This also gives the percentages of influence for the criteria used for the site suitability map for Coimbatore.

The steps involved in the AHP includes the creation of priority matrix, normalisation procedure of the priority matrix, formulation of priority vector and checking using consistency index and consistency ratio.

Table I shows the weightages for various criteria considered after the AHP procedure.

Consistency index, CI = $\frac{(\lambda_{max} - n)}{(n-1)}$ *Eqn. 7.1*

where, λ_{max} is the maximum Eigen value, which was calculated as 7.680 and n is the number of criteria considered, here seven criteria were considered. So, n = 7. After calculation, CI = 0.113.

Consistency Ratio (CR) = CI/RI *Eqn. 7.2*

where RI is the Randomness Index, which is specified by Prof. T.L. Saaty[1] in his research paper. For n = 7, RI = 1.35

So, CR = 0.113/1.35 = 0.08.

As per Prof. T.L. Saaty[2], allowable CR for a n value of 7 is 0.10. Since CR of 0.08 < 0.10 (allowable CR), the judgement made is correct.

Table I: Weightage after AHP

Criteria	Weightage
Population	34%
Guideline Value	23%
LULC	20.4%
Slope	9.1%
Location of roads	6.1%
Location of Institutions	4.9%
Location of GWT	2.4%

8 Site suitability map and ring road routes

By making use of the weightages from AHP and with the help of weighted overlay tool from spatial analyst extension, all the reclassified raster maps can be overlaid for creation of a site suitability map for Coimbatore. The site suitability map for Coimbatore is shown in Fig: 19.

The cost path technique in ArcMap Tool box provides a great way to find the best route between the start and end points, in terms of least cost. Using this, two ring roads – Inner ring road (of 29 km) and Outer Ring Road (of 41 km) were proposed. The view of the inner and outer ring roads is shown in Fig: 20.

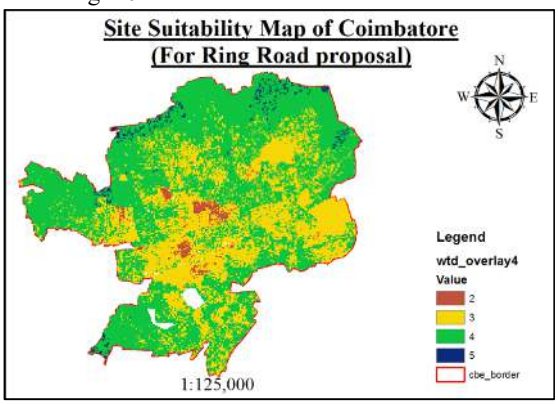


Fig: 19 – Site suitability map of Coimbatore

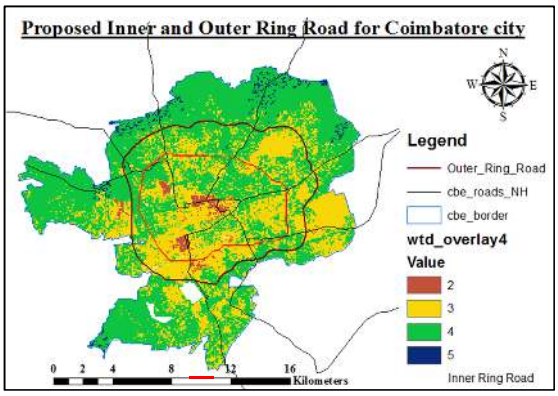


Fig: 20 – Proposed Inner and Outer Ring Road

9 Conclusion

In this study, in order to reduce the traffic that drives in to the city and divert them to other major and minor roads, two ring roads – *Inner ring road (29km length)* and *Outer Ring Road (41km length)* were proposed. For these maps corresponding to population, LULC, Slope, Guideline value, ground water level, location of schools, colleges and roads were prepared. Using AHP technique, weights for various criteria were calculated. By the Weighted overlay technique and using the weights, after redistribution, from AHP, the site suitability map for Coimbatore was prepared. The cost path technique is very effective in finding the least cost path between start and end points. Using this technique, both Inner and Outer ring road routes were proposed, effectively.

10 Abbreviation:

AHP – Analytical Hierarchy Process
ASTER – Advanced Spaceborne Thermal Emission and Reflection Radiometer
CI – Consistency Index
CR – Consistency Ratio
DEM – Digital Elevation Model
ESRI – Environmental Systems Research Institute
Eqn. – Equation
GIS – Geographical Information System
km - kilometre
LULC – Land Use Land Cover
NH – National Highway
RI – Randomness Index
SH – State Highway
sq.km – square kilometre
USGS – United States Geological Survey

λ_{max} – Maximum Eigen value

11 Acknowledgments

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Last but not the least; we thank our parents and God for the moral support given to us.

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