IOSR Journal of Engineering (IOSR-JEN) Volume 5 Issue 5 Version 3

IOSR Journal of Engineering

IOSR Journal of Engineering (IOSRJEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
Vol. 05, Issue 05 (May. 2015), ||V3|| PP 32-42

Highway Alignment Using Geographical Information System

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Abstract: - Planning a new road or highway can be expensive and time consuming process. There are numerous environmental issues that need to be addressed. The problem is exacerbated where the alignment is influenced by the location of services, existing roads and buildings, and the financial, social and political costs of land resumption. GIS, a powerful tool for the compilation, management and display data associated with geographic space, is used for the preparation of digital maps and analysis purposes. The conventional manual methods were difficult, time consuming and expensive. In this study the shortest and the economical path is identified using GIS software. The factors considered are mainly related to the land use, geology, land value and soil. The weights and ranks are assigned to each of the above themes, according to expert opinions, for GIS analysis. After assigning weights and ranks these themes are overlaid to get an overlaid map. The final overlaid map has the most suitable area to align the highway from Erode to Karur which is both are textile and enriched with water potential which is passing along the channels of Karur and Erode.

Keywords: *Highway, Alignment, Geographical Information System, Karur and Erode*

I. INTRODUCTION

Determining the best route through an area is one of the oldest spatial problems. This problem has recently been solved effectively using GIS and Remote Sensing technologies. During the last decade, a few attempts have been made to automate the route-planning process using GIS technology. Constructing a new road or railway, or aligning an old one can be very expensive, with costs depending on the alignment selected. Costs are increased by long structures, by large volumes of cut and fill, and by unbalanced cut and fill were discrepancy has to be dumped or borrowed. There are numerous environmental issues that need to be addressed to ensure that the alignment does not reduce bio-diversity or degrade the environment. The first step in producing high quality alignments depends on obtaining suitable data on geology, land use, slope, soil and drainage. In addition, there are issues such as land value and ownership, social and economic impact, and identifying environmentally sensitive areas.

1.1 General

Remote sensing can be defined as the collection of data about an object from a distance. Human and many other types of animals accomplish this task with aid of eyes or by the sense of smell or hearing. Geographers use the technique of remote sensing to monitor or measure of phenomena found in the Earths lithosphere, biosphere, hydrosphere, and atmosphere. Remote of the environment by the geographers is usually done with the help of mechanical devices known as remote sensors. These gadgets have a greatly improved ability to receive and record information about an object without any physical contact. Often, these sensors are positioned away from the object of interest by using helicopters, planes and satellites. Most sensing devices record information about an object by measuring an objects transmission of electromagnetic energy from reflecting and radiating surfaces - Remote sensing is the science of making inference about from measurements, made at a distance ,without coming into physical contact with the object under study. That remote sensing refers to any method, which can be used to gather information about an object without actually coming in contact with it.

1.2 Concept Of Signatures

Electromagnetic radiation when incident on a surface, gets reflected, absorbed, re-emitted or transmitted through the material depending upon the nature of the object and the wavelength.

1.3 Multi-Spectral Concepts

Spectral variation is the most often used signature, especially in the optical-IR region. The spectral variation of some of the natural objects in the 0.4 to 2 μm range. However, it is not easy to generate continuous spectral for identification objects. Therefore a practical solution is to make observance in a number of discrete spectral regions, usually referred as spectral bands.

1.4 Remote Sensing System

With the background treatise on remote sensing we have made so far, it would now be easier to make an analysis of the different stages in remote sensing.

- Origin of electromagnetic energy (sun, transmitted carries by the sensor)
- Transmission of energy
- Intervening of energy or self emission
- Detection of energy
- Transmission or coding of the sensor output
- Collection of ground truth
- Data analysis and interpretation
- Integration of interpretation images

We shall now briefly describe the various components of a remote sensing system.

II. AIM AND SCOPE OF THE INVESTIGATION

- To establish shortest path for road network from Karur to Erode
- To provide a better and comfortable base for updating the traffic and other related information in road administration.
- To identify the short route for the vehicles traveling from Karur to erode. And to reduce the time travel for the vehicles.
- Our main scope is to reduce the traffic and travelling time in the roads.
- To prepare various thematic maps for analyzing the environmental status.
- To find possible paths/routes/places for laying eco-friendly highway.

III. STUDY AREA

3.1 Erode

Erode is a city, a municipal corporation and the headquarters of Erode district in the South Indian state of Tamil Nadu. It is situated at the centre of the South Indian Peninsula, about 400 kilometres (249 mi) southwest from the state capital Chennai and on the banks of the rivers Cauvery and Bhavani, between 11° 19.5" and 11° 81.05" North latitude and 77° 42.5" and 77° 44.5" East longitude. As per Census 2011 alignments. It has population around 156,953.Erode Local planning Area extends up to 54sq.km. Within the city, and will be extended to 109 km^2 . The roadway connects all the parts of the state and nearby states such as Kerala, Karnataka and Andhra Pradesh with the city. The City has both local (City) and mofussil (city-tocity) bus services with connections to nearby towns and villages. Plenty of city buses are ply to connect all parts of the city.

3.2 Karur District

It is a district located along the Kaveri and Amaravathi rivers in the Indian state of Tamil Nadu. The main town in Karur District is the city of Karur, which is also the district headquarters. The district had a population of 1,064,493 with a sex-ratio of 1,015 females for every 1,000 males. Karur is one of the oldest towns in Tamil Nadu and has played a very significant role in the history and culture of the Tamils. Its history dates back over 2000 years, and has been a flourishing trading center even in the early Sangam days. In the ancient and medieval times, the area was ruled by the Cheras, Gangas and Cholas. Karur was the capital of Cheras.The Pasupatheesvarar Temple sung by Thirugnana Sambhandar, in Karur was built by the Chola kings in the 7th century.Later the Nayakars followed byTipu Sultan also ruled Karur. The British added Karur to their possessions after destroying the Karur Fort during their war against Tipu Sultan in 1783. There is a memorial at Rayanur near Karur for the warriors who lost their lives in the fight against the British in the Anglo- Mysore Wars. Thereafter Karur became part of British India and was first part of Coimbatore District and later Tiruchirappalli District. With headquarters at Karur, it is the centrally located district of Tamil Nadu. It is bounded by Namakkal district in the north, Dindigul district in the south, Tiruchirapalli district on the east and Erode & Tiruppur districts on the west. Karur is located at 10°57'° N 78°4'° E has an average elevation of 122 Metres (400 feet). It is about 371 km (231 mi) south west of Chennai (Madras), the state capital of TamilNadu. b

According to 2011 census, Karur district had a population of 1,076,588 with a sex-ratio of 1,015 females for every 1,000 males, much above the national average of 929. A total of 102,731 were under the age of six, constituting 52,969 males and 49,762 females. Scheduled Castes and Scheduled Tribes accounted for 20.8% and .05% of the population respectively. The average literacy of the district was 68.3%, compared to the national average of 72.99%. The district had a total of 287,095 households. There were a total of 543,298 workers, comprising 83,800 cultivators, 182,639 main agricultural laborers, 10,162 in house hold industries, 231,906 other workers, 34,791 marginal workers, 2,072 marginal cultivators, 18,198 marginal agricultural laborers, 1,178 marginal workers in household industries and 13,343 other marginal worker. Study area topo sheet shown in Figure 3.1 and Study Area Map shown in Figure 3.2.

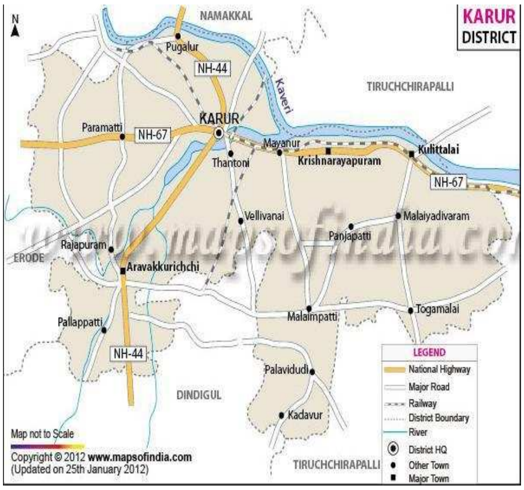

Figure 3.1 Study area topo sheet

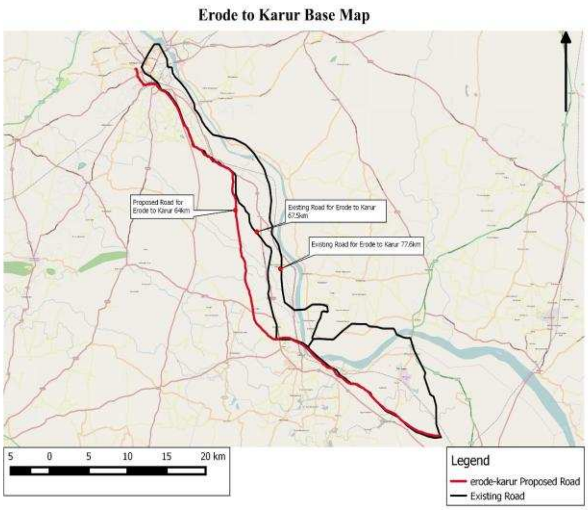

Figure 3.2.Study Area Map .

3.3 Data Collection

Survey of India Toposheet No. 58E/11, 58E/12, on 1:50,000

LAN SAT (MSS) DATA 2007

Maps, field work and remote sensing techniques are necessary for proposed road design and construction. Topographic maps, geomorphology, Land use/Land Cover, Drainage, DEM, road, Slope and Contour maps were used for this proposed route. The favourable path analysis, using various data and GIS analysis, was intended to confirm the best transport route within this site.

3.4 Data Process And Analysis

In this implementation, the best route is found for a new road. The steps to find possible path are outlined below. Path is identified by using ArcGIS 9. Spatial Analysis Module.

Create Source, Destination and Datasets

Generate different Thematic Maps (Classify and Weight age) Perform Weighted Distance

Create Direction Datasets

Identified Shortest Path with Distance and Direction

Datasets

IV. DESIGN GUIDELINES

4.1 Planning of road in plain areas

Planning of roads in plain area is somewhat different from hill areas. In hill areas alignment of roads has to be circuitous and is primarily governed by the topography. In the plain area we should find the elevation and depression by the surveying. The elevation areas should be levelled by removing the upper surface of the earth and this soil can be used for the filling up the low lying areas. The roads in our country in plain areas, they have been classified as National Highways, state Highways, Major District Roads, and Other District Roads and Village Roads according to specification, traffic needs, and socio economic, administrative or strategic consideration. Some National Highways are point to point which will connect the state boundaries. State Highways will connect all the National Highways. Major District Roads will connect all the state Highways. Other District Roads and Village Roads will connect the major district Roads however from topographical considerations; these can be broadly being divided into arterial Roads and link roads. Arterial roads will include national/state highways and major district roads. Link roads take off from arterial roads to link villages/production areas in small/sub- valleys. These will comprise other district roads and village roads.

4.2 Highway Alignment

–The position or the layout of the centre line of the highway on the ground is called alignment.In general alignment is of two types,

- Horizontal alignment
- Vertical alignment

Existing road network is shown in Figure 4.1

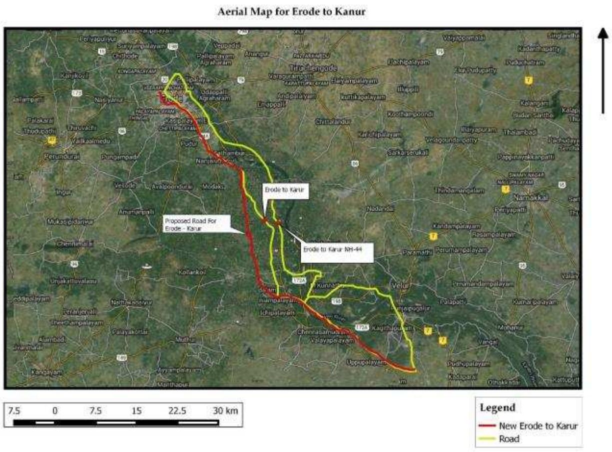

Figure 4.1 Existing Road Network

4.2.1 Requirements

The basic requirements of ideal alignment between two terminal stations are

- Short- A straight line alignment would be the shortest, though there may be several practical considerations which would cause the deviation from the shortest path.
- Easy - The alignment should be such that it is easy to construct and maintain with minimum problems.
- Safe – The alignment should be safe enough for construction and maintenance from the view
- point of stability of natural hill slopes, embankments, cut slopes.
- Economical – The alignment is considered economical only if the local cost including the initial cost, maintenance cost.

4.2.2 Factors Controlling Alignment

For an alignment to be shortlisted, it would be straight between two terminals which are not always possible due to practical difficulties such as intermediate obstructions and topography. A shortest route may have very steep gradients and hence not easy for operations. Similarly, there will be construction and maintenance problems along the route which may be otherwise short and easy. Canals are often deviated from the shortest route in order to cater for intermediate places of importance or obligatory points.

A highway which is economical in its initial construction cost need not be necessarily economically maintenance or operation cost. It may also happen that at the shortest and the easiest route may work to be the costliest of different alternatives from construction point of view. Thus it may be seen that an alignment can seldom fulfill all requirements simultaneously; hence a judicial choice is made considering all factors. The various factor which control the canal alignment in general may be listed as,

4.2.3 Obligatory Points

These are control points governing the alignment the canal. These control points may be broadly divided into two categories,

- Points through which alignment is to pass.
- Points through which alignment should not pass.

Obligatory points through which alignment has to pass may cause alignment to often deviate from the shortest or easiest path

4.2.4 Geometric Design

Geometric design factors gradient, radius of curvature governs the final alignment. As far as possible while aligning a canal the gradient should be gradually increasing. It may be necessary to make adjustments in horizontal alignment of canal keeping in view the minimum radius of curvature and the gradient.

4.2.5 Economic Considerations

The alignment finalized based on the above factors should also be economical. In working out economics, the initial cost, operation cost, maintenance cost is taken into account. The initial construction cost could be minimized by avoiding embankments and deep cuttings and alignment is chosen in a manner to balance cutting and filling.

4.2.6 Slope Stability

While aligning canal, special care should be taken to align along the side of the hill which is stable. A problem in doing this is that of the landslides. The cutting and filling to construct the canal on the hill side causes steepening of existing slopes and affect its stability.

4.2.7 Engineering Surveys For Highway Alignment

Before canal alignment, engineering surveys are to be carried out. The surveys may be completed in four stages; first three stages consider all possible alternate alignment keeping in view the various requirements.

Four stages of engineering surveys are,

- Map study
- Reconnaissance
- Preliminary survey
- Final location and detailed survey

4.3 Horizontal Alignment

The horizontal alignment should be fluent and blend well with the surrounding topography. The horizontal alignment should be coordinate carefully with the longitudinal profile. Breaks in horizontal alignments at cross drainage structure and sharp curves at the end of long tangents/straight section should be avoided.

Short curves give appearance of kinks, particularly for small deflections angles, and should be avoided. The curves should be sufficiently long and have suitable transitions to provide pleasing appearances. Curve length should be at least 150 m for a deflection angle of 5 degrees and this should be increased by 30 m for each degree deflection angle. For deflection angle less than one degree, no curve is required to be designed.

Reverse curves may be needed in difficult terrain by very sparingly used. It should be ensured that there is sufficient length between the two curves for introduction of requisite transition curves. Curves in the same direction separated by short tangents, known as broken back curves, should be avoided as far as possible in the interest of aesthetics and safety and replaced by a single curve.

Compound curves may be used in difficult topography but only when it is impossible to fit in a single circular curve. To ensure safe and smooth transition from on e curve to the other, the radius of the flatter curve should not be disproportional to the radius of the sharper curve. A ratio of 1:5:1 should be considered the limiting value. Horizontal curves should consist of circular portion of the curve followed by the spiral transitions on both sides. Design speed, super elevation and coefficient of friction affect the design of curves.Length of transition curve is determined on the basis of change of centrifugal acceleration or the rate of the change of super elevation.

4.4 Vertical Alignment

Broken back grade lines, i.e. two vertical curves in the same direction separated by a short tangent should be avoided due to poor appearance, and preferably replaced by a single curve. Decks of small cross drainage structures should follow the same profile as the flanking road section, with no break in the grade line.

4.5 Co-Ordination Of Horizontal And Vertical Alignment

The overall appearance of a highway can be enhanced by judicious combination of the horizontal and vertical alignment. Plan and profile of the road should not be designed interpedently but in unison so as to produce an appropriate three dimensional effect. Proper co-ordination in this respect will ensure safety, improve utility of the highway and contribute to overall aesthetics. Vertical curvature superimposed upon horizontal curvature gives a pleasing effect. As such the vertical and horizontal curves should coincide as possible and their length should be more or less equal. It is difficult for any reason; the horizontal curve should be somewhat longer than the vertical curve.

V. METHEDOLOGY

The base (study area) map, Drainage, Slope and Contour maps were repared with the help of SOI Toposheet (on 1:50,000 scale). High resolution LANSAT satellite data of 2009 was used and by using Digital Image Processing techniques the following thematic maps such as geomorphology, Land use/ Land Cover were generated. The Digital Elevation Model (DEM) was generated using various GIS based analysis, such as overlay, raster network analysis. The DEM is used in order to understand the terrain condition, environmental factors and social economic status in this study area. Finally, possible/feasible route was identified based on various physical and cultural parameters and their inherent properties. The cost reduction analysis was also done for substantiating the formation of national highway.

5.1 Topography

Topographic and geologic data of the proposed road network area were prepares in a GIS ready format and used as input to the GIS data base. The location of roads, railways, wetland, forest and drainage features are derived from the topographic map layer. The map that produced by SOI is the base for national topographic database and has a number of features for instance location of roads, railways, wetland, forest and drainage features. In this proposed project, digital elevation model was prepared from elevation data. It was used as input to the least cost and shortest pathway analysis. Topo sheet shown in Figure.5.1

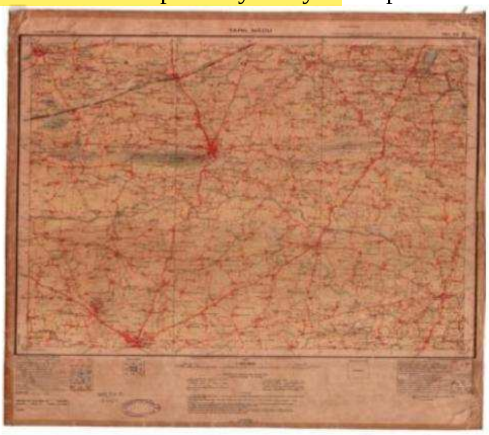

Figure.5.1 Toposheet 58 E/12

5.2 Geomorphology

Different landforms present in the area are depicted in this geomorphic unit were extracted data from the satellite image by digital interpretation and incorporated into the GIS database. These geomorphic units were classified into Plateau, Scarp face, Debris slope, bazada, residual hill and pediments (deep, shallow & moderate).

Geomorphology Map shown in Figure.5.2 Geology Map shown in Fig 5.3, Drainage Map shown in Figure 5.4, Land use and land cover shown in Figure 5.5, Water bodies map of study area shown in Figure 5.6 and Slope Map shown in Figure 5.7

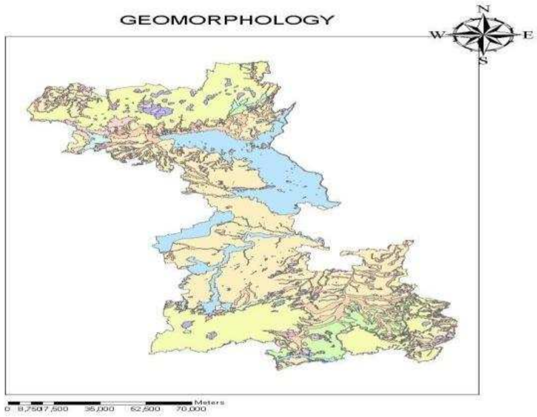

Figure.5.2 Geomorphology Map

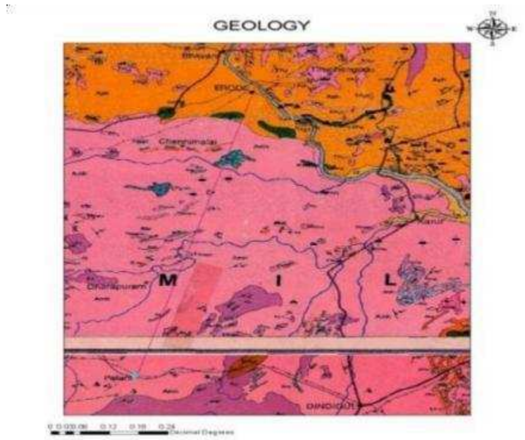

Figure.5.3 Geology Map

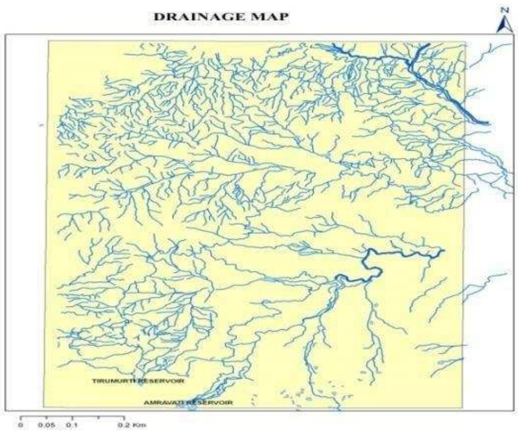

Figure.5.4 Drainage Map

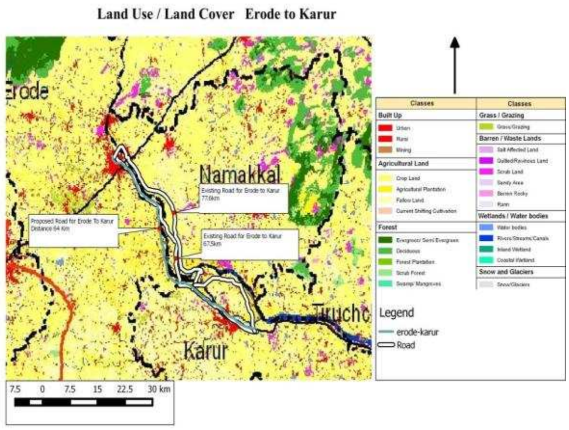

Figure.5.5 Land use and land cover

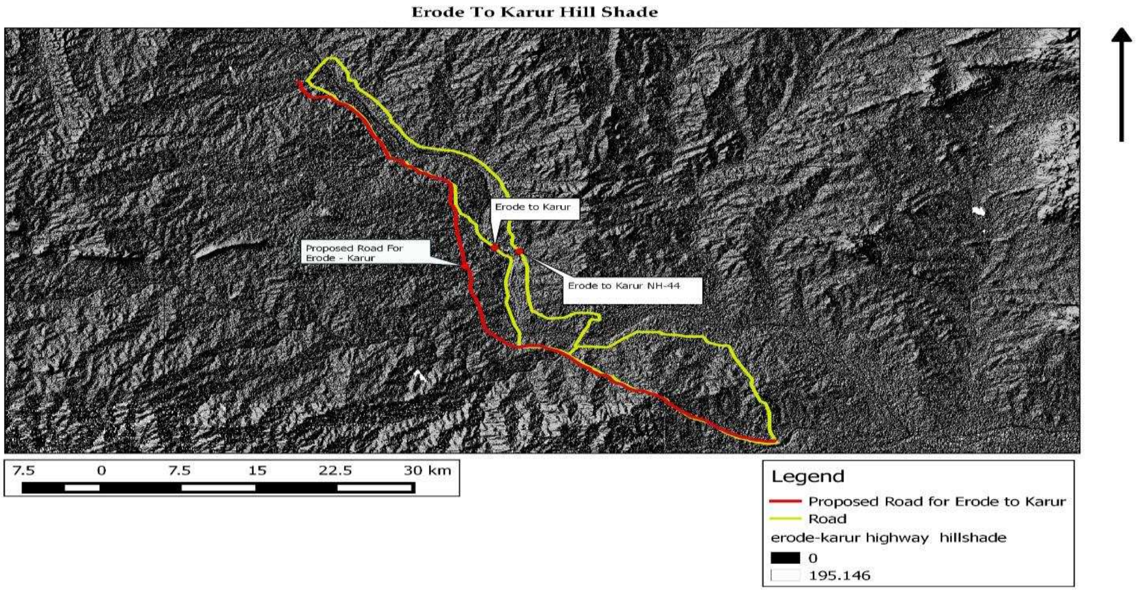

Figure.5.6 Water bodies map of study area

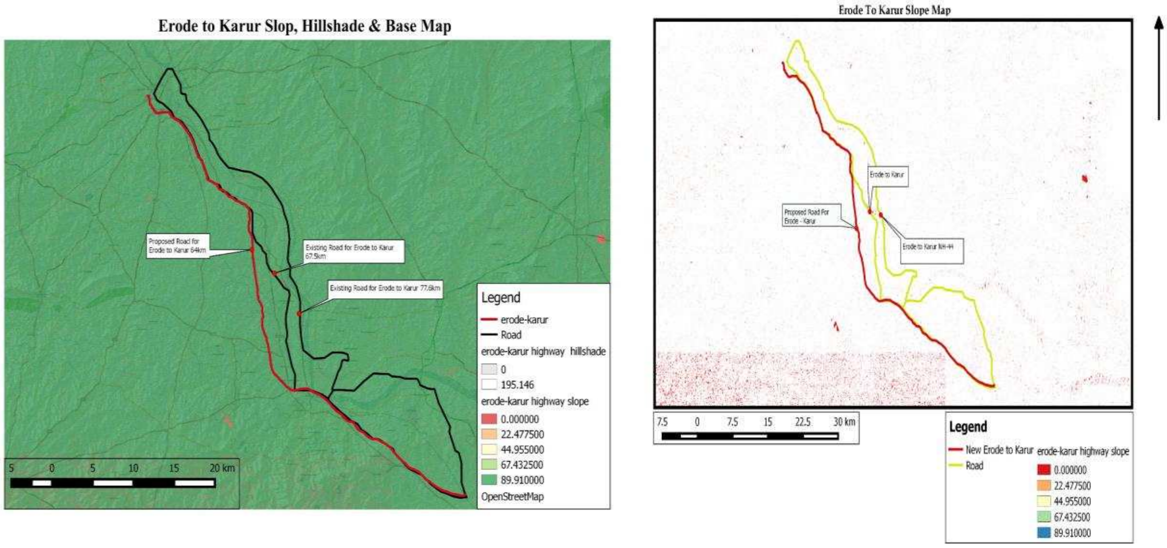

Figure.5.7 Slope Map

5.3 Geographical Information System

Visualization is a form of communication, which is universal and which has the ability to form an abstraction of the real world into graphical representation. Once a project proposal is developed, it is necessary to communicate the effect of proposed changes to other agencies and public review groups to facilitate decision making. Some of the changes in the environment can be modelled and visualized using GIS.

VI. OVERVIEW OF SOFTWARE

6.1 Introduction To ARCGIS

Arc GIS 9.2 is a product of ESRI. IT adds topology for the geo database. You can choose which feature classes in a feature dataset participate in a spatial relationship with other feature classes in that feature dataset or within themselves. Certain rules can be applied, such as polygons cannot overlap one another, lines cannot have dangling nodes, and points must be completely inside the bounds of a polygon. The number of spatial integrity rules offered for the geo database far exceeds those used in the Arc Info workstation coverage model, and are much more flexible. The editing abilities of Arc Map have been improved to leverage these spatial integrity rules and to help find and fix topological errors more easily and quickly. Arc Map is the premier application for desktop GIS and mapping. Arc Map gives you the power to:

6.1.1 Visualize

In no time you'llbe working with your data geographically; seeing patterns you couldn't see before, revealing hidden trends and distributions, and gaining new insights.

6.1.2 Create

It's easy to create maps to convey your message. Arc Map provides all the tools you need to put your data on a map and display it in a effective manner.

6.1.3 Solve

Working geographically lets you answer questions such as – Where is ...?, – How much...?, and – What if...?, Understanding these relationships will help you make better decisions.

6**.1.4 Present**

Showing the results of your work is easy. You can make great-looking publication-quality maps and create interactive displace that link reports, graphs, tables, drawings, photographs and other elements to your data. You'llfind that communicating geographically is a powerful way to inform and motivate others.

6.1.5 Develop

The Arc Map customization environment lets you tailor the interface to suit your needs or the needs of your organization, build new tools to automate your work, and develop standalone applications based on aroma mapping components. See about customizing Arc Map and Arc Catalog for more information.

6.1.6 Modelling

Statistical models allow life phenomena to be represented in a mathematical or statistical way. The advantage of modelling real life phenomena include:The determination of factors or variables which most influence the behavior's of the phenomena The ability to predict or forecast the long term behavior of the phenomena. Once a statistical model has been developed, simulations of the real life phenomena can be performed. The modeler can construct a wide range of scenarios by changing the influential factors. The key advantage of conducting simulations is that the phenomenon's predicted behavior can be observed without placing the phenomena.

6.2 The Vector Model

The vector model, the spatial locations of features is defined on the basis of coordinate pairs. These can be discrete, taking the form of points linked together to form discrete sections of line; linked together to form closed boundaries encompassing an area Attribute data pertaining the individual spatial features is maintained in an external database. In dealing with vector data any important concept is that Topology. Topology derived from geometrical mathematics, is concerned with order, contiguity and relative position rather than with actual linear dimensions. Topology is useful in GIS because many spatial modeling operations do not require coordinate locations, only topological information-for example to find an optimal path between two points requires a list of the arcs or lines that connect to each other and the cost to transverse them in each direction. It is also possible to perform the same spatial modelling and interrogation processes without using stored topology, by processing the geometrical data directly by generating topology on the fly or using vector object model as and when it is required.

6.3 The Raster Model

The following information should always be recorded when assembling, compiling and utilizing raster data.

- Grid size (Number of rows and columns)
- Grid resolution
- Geo referencing information e.g. comer coordinates, source projection
- Data collection

Topographic maps are collected to generate multilayered, geo-referenced digital maps on a GIS platform, with the basic inputs of available information. These comprehensive maps shall cover the following aspects:

- Slope map
- Land use and land cover pattern
- Population and settlement pattern
- Study area

This done using SOI toposheet (58E/11, 58E/12, 58F/9, 58F/11, 58F/10 NW) in the scale of 1:50,000. The boundary is traced over a tracing sheet. Traced boundary is converted to digital format using digitization in ArcGIS9.2

6.4 Raster Calculator

Build expressions in the Raster Calculator by using Map Algebra to weight raster and combine them as part of a suitability model, to make selections on your data in the form of queries, to apply mathematical operators and functions, or to type Spatial Analyst functions. Multiline expressions can be typed into the raster calculator. It is useful to build multiline expressions for complex functions, such as cost path, or to chain processes together. The output dataset shows how suitable the each location is for highway alignment, according to the criteria set in the suitable model. A higher value indicates the locations that are more suitable.

6.5 Performing Shortest Path

It is almost ready to find the shortest path from the source. We have already performed cost weighted distance, creating a distance dataset and a direction dataset using the source point. However it is necessary to decide on, and then create, the destination point for the road. Hence this requires the creation of destination point on the Erode to Karur which is used in the calculation of shortest path to the highway. The shortest path is calculated using the function „shortest path in the Spatial Analyst. Specifying the destination point as input along with the distance and direction theme, calculates the optimal path through which Highway has to run. It represents the least cost path-least cost meaning avoiding steep slopes and on land use types considered to be least costly for constructing the Highway from source to destination.

VII. DISCUSSION

In general the results of the project can be discussed under two aspects,

1. Geotechnical aspects
2. Ecological aspects

Geotechnical Aspects:

Case 1: The alignment of highway was done based on the following criteria (Table.7.1)

Table 7.1 Slope Weightage

Slope (degrees)	Rank
0-5	1
05-Oct	2
Oct-15	3
15-20	4
20-25	5
25-30	6
30-40	7
40-50	8
50-70	9
No data	No data

Table 7.2 LandUse Weightage

LANDUSE TYPE	RANK	LANDUSE TYPE	RANK
Barren land	2	Sheet rocky	3
settlement	4	Waste land	1
Non agri-use	7	Cultivable land	5

In this case, both the layers have an equal influence on the alignment of the highway(Table.7.2). This is done using the formula,(reclass_slope)*0.4+(reclass_landuse)*0.6

VIII. CONCLUSION

The purpose of this study was to develop a tool to locate a suitable less route between two points. The GIS approach using ground parameters and spatial analysis provided to achieve this goal. Raster based map analysis provide a wealth of capabilities for incorporating terrain information surrounding linear infrastructure. Costs resulting from terrain, geomorphology, land use, drainage and elevation resulting the shortest routes for the study area. The existing road path was 67.5 and 77.5km long from Erode to Karur (via Kodumudi). Results indicate that the route which was designed applying GIS method is more environmentally effective and cheaper which is 64.5km. This proposed shortest route (Figure.8.1) provides traffic free, pollution free, risk free, operating for movement of vehicle passing from Erode to Karur. Time and consumption of fuel will also be reduced considerably. A important tourist spot cum pilgrimage, Karur will approached without traffic problems. This has shown a potential savings which can be obtained by automating the route selection process. GIS method can also be used for route determination for irrigation, drainage channels, power lines and railways.

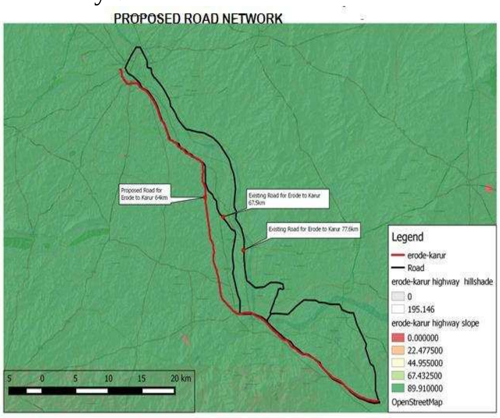

Figure.8.1 Proposed Shortest Route

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