Rural Road Network Planning by using GIS Methodology

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Abstract **- Rural roads are important roads within a district connecting areas of production with markets and connecting these with each other or with the State and National Highways. The rural transport infrastructure consists of roads, paths, and their associated bridges and other forms of water crossings. The major constraints on access to rural areas are poor condition in rural infrastructures and road database. This study has undertaken an extended attempt to develop Geographic Information System (GIS) based rural road database so that planners, decision makers, researchers and other different level authorities in the rural road sector will be benefited from the final output. The study area is located in Sangareddy District, Telangana, India. The study also aimed to select the shortest and alternative paths from different villages towards growth centers. Network analysis has been conducted to select shortest path in terms of travel time between two locations in the study area. Growth centers have been selected from 39 habitations found in the study area, based on the facilities of rural infrastructures and the number of trough-routes they have. Mirzapur village was designated as a growth centre of the mandal. Furthermore, structural analyses of the road in the study have been done based on connectivity indexes and maintenance strategy was developed based on population benefited by the link and average PCI value of the link.**

Keywords: PMGSY, Shortest Path, GIS, PCI

1. INTRODUTION

Rural areas play a major role in country development. Villages are the backbone of any developing country. In India, rural roads comprise over 85% of the road network of the country. Hence keeping them in serviceable condition is crucial for the rural people get access to social facilities like medical, education and market. Lack of maintenance affects the residents of rural areas significantly as the time for access to markets and other social infrastructure is increased. The rural roads in India form a substantial portion of the Indian road network. However, their connectivity is not to the desired level. Over 30% of Indian farmer's harvest had been spoiled postharvest because of the poor infrastructure (MORTH, 2012).

In recent past, 2000, the Government of India launched the nationwide program known as PMGSY, to provide connectivity to all the villages in a phased manner, so as to connect through all-weather roads to unconnected habitations with population 1000 and above by 2003 and those with population 500 and above by 2007 in rural areas. In respect of Hill/ desert/ tribal areas, the objective is to link habitations with population 250 and above. The package is being implemented through the state level agencies by preparing the detailed district level rural road plans (DRRP) and the core network plans (CNP), which provide prioritized links for connectivity of habitations carved out of DRRP with quantifying population. This entire process generates a large amount of information related to rural roads such as number of habitations in a block, number of blocks in a district, the population of the habitations, block boundary, district boundary, DRRP Roads, CN Roads, CN Road Segments, road surface type, bridges, level crossings (manned & unmanned), stone and sand quarries, market centers, water bodies, tourists places, drainage, railway lines and much more. This volume of information is difficult to process, manage, update, sort and retrieve by traditional, manual methods due to the fact that handling, managing and updating of the data by the traditional methods is not only tedious and time consuming but also it is difficult to sort and retrieve. To obviate these difficulties it is, therefore, considered necessary to develop all the spatial and attribute data in digital format. Therefore, Geographic Information System (GIS) is an essential tool to be placed on comprehending the information of spatial and non-spatial data over a space and time. GIS is a computer-based tool which can handle the entire database and help in the management of the entire rural development program (Durai et al. 2004).

Mishra and Naresh (2009) explained the use of geo-informatics for development of rural roads under Pradhan Mantri Gram Sadak Yojana (PMGSY). They developed a spatial and non-spatial rural road database which can be viewed by common man to get the interactive and exciting way on the map with related attributes. Praveen et al. (2013) demonstrated the use of network analysis, in determining the optimal route between two or more destinations based on a specific travel expense Based on the above research studies it is observed that, GIS can be used as an effective tool to prepare a Geo-spatial rural road information system which will be useful for planning and development of rural road networks. Hence, in this paper, an attempt is made to prepare a rural road information system using GIS.

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1.1 OBJECTIVES OF THE STUDY

The main intention of this study is to develop road information system so that it will be useful for solving complex planning, Decision making and management problems of rural roads in the study area. It covers the application of GIS to find optimal route by using network analysis. The objectives are

- To develop spatial and attribute database for the road network of this study area
- To identify the growth centers and rural hubs
- To select the optimal route between two locations
- To prepare up-gradation and maintenance priority list

2. METHODOLOGY

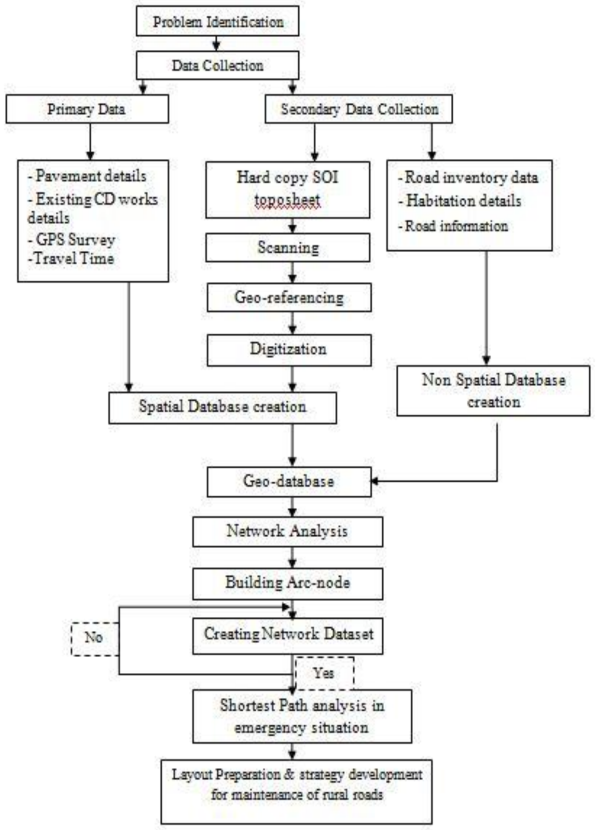

Fig. 1: Flow chart showing methodology for Development of Rural Road Information System

This study aimed at developing RRIS and making shortest path analysis for the road networks of the study area. The framework for the methodology is as in Figure 3.1. Further, the detail descriptions of the step by step procedures used are given below. The steps are as follows:

- Collection of data in the form of map for the study area from different sources.
- Development of database of the road network by putting attributes variables.
- Development of network dataset of the road network.
- Performing Network Analysis to find the optimal route.

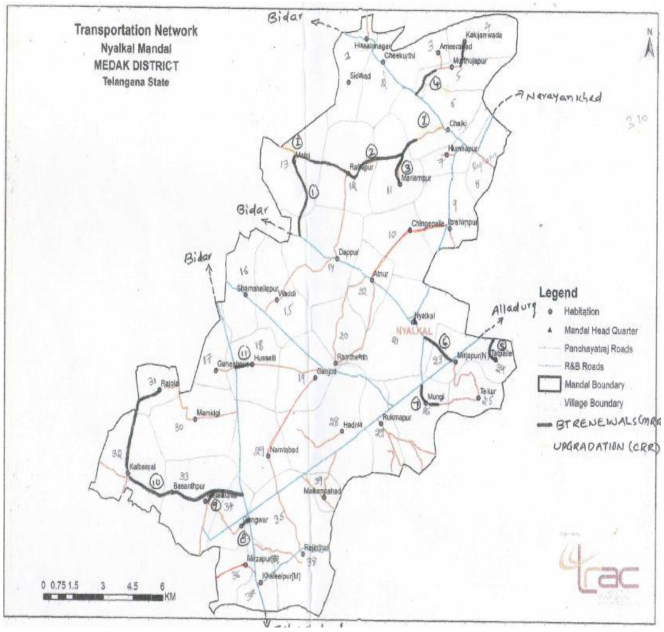

Fig. 2: Study area map and its connectivity

3. STUDY AREA AND DATA COLLECTION

3.1 Study Area

Nyalkal mandal was selected as the study area to develop rural road information system (RRIS). This mandal is among 26 mandals in Sangareddy District. It is more suitable to select the rural hubs and growth centers from the existing habitations, and perform network analysis. Nyalkal is a village in medak district of Telangana, India. Nyalka is located at 17.85˚N and 77.67˚E. It has an average elevation of 585 meters (1922 ft). In this mandal two temples are famous. One is Sri Siddivinayaka Temple and another one Saraswathi temple.

3.2 Data Collection

3.2.1 Primary Data Primary data like chainage length, water way span, type of CD work and condition of each CD work were also collected. Similarly pavement details were gathered. The attribute data collected through field survey entered in Arc GIS and database files were prepared for all attribute data. The PCI of each road link were surveyed based on comfortable driving speed possible. The location of different rural infrastructures like banks, educational facilities, health centre's/hospital, post office etc. were also collected.

3.2.2 Secondary Data Secondary data like Map, habitation details as well as road information data and other ancillary data were collected from Panchayath Raj and Roads & Building department of Sangareddy district. The map consists of road network of Nyalkal Mandal in accordance with their types. In addition to this details of habitation, location of major health, educational and market centers in the mandal /subdivision headquarter. The detail distribution of villages by population range are given in below table 1

Table 1: Distribution of villages by population range

Population range	No. of Villages
Less than 500	02
500 to 999	10
1000 to 1499	14
1500 or more	13

3.3 Existing Road Network

The study area has total 117.50 Km of roads. The roads of study area can be classified in three categories i.e., Major District Roads (MDR), Other District Roads (ODR) and Village Roads (VR). The existing road network of a mandal is as shown in the Table 2 and Figure 3 shows the percentage surface types of roads in the area. The roads of a mandal have been maintained by different departments of the Government like R&B Deportment and Panchayath Raj Department.

Table 2: Existing Road Network of Nyalkal Mandal

S. No	Surface Type	Total length	Percentage
1	Bitumen Treated (BT)	56.38	48%
2	Water Bound Macadam (WBM)	27.44	23.35%
3	Cement Concrete	8.33	7.08%
4	Gravel	20.25	17.23%
5	Track	5.10	4.34%

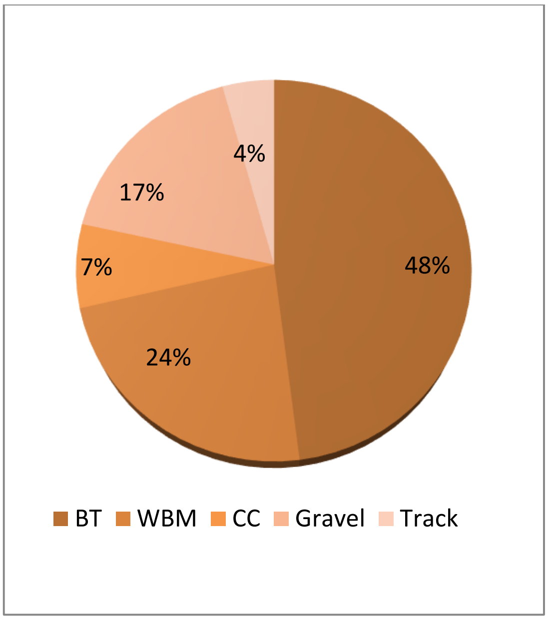

Fig. 3: Percentage of surface type of the roads in Nyalkal

4. MODEL DEVLOPMENT FOR RURAL ROADS

In India the existing methods for develop a planning model is based on the prioritization of the road link and settlements connected. These methods need further strengthening and quantification of the roads linking a settlement in a systematic way so as to provide benefit to the maximum habitation (Singh2010). In the present study the Up-gradation of the network is done by strengthening/Maintenance of the road links. The strengthening of road link is based on the population benefited by the link and the Pavement Condition Index (PCI) of the road. In this study PCI value of each road link is determined based on the comfortable driving speed of the vehicle as per PMGSY guidelines and PCI values are indexed on scale from 1 to 5 where '1' shows worst possible condition and '5' shows the best possible condition of the pavement given in table 3.

Table 3: Pavement Condition Index (PCI) values

Normal Driving Speed (Kmph)	PCI	Description of Pavement Condition
Over 40 km/hr	5	Very Good
30 to 40 km/hr	4	Good
20 to 30 km/hr	3	Fair
10 to 20 km/hr	2	Poor
Less than 10 km/hr	1	Very Poor

4.1 Strengthening of Roads

The population benefited and PCI value of the links are taken as a measure for strengthening of the pavement based on the criteria is given below.

- First strengthening of the through rout based on which is covered more population and who's PCI value is < or = 2.
- After this strengthening of those link routes based on which is covered more population and who's PCI value is < or =2.

5. STRUCTURAL AND SHORTEST PATH ANALYSIS OF NETWORK

5.1 Structural Analysis of Network

Structure in transport geography refers to a system of arrangement consisting of a number of edges (e) and vertices (v)in a plain surface in terrestrial surface by making a nexus of spatial activities of people in order to get the connectivity (sarkar 2013). There are different techniques of analyzing the structure of a road network. Connectivity, circuitry and accessibility are some the methods. In the present study analysis is done by connectivity method. Connectivity is the combined effect of Aggregate Transportation Score (ATS) which is the summation of alpha index (α), beta index (β), gamma index (γ) and Cyclomatic number (μ). The formulas for determine these indices and correlation with the connectivity is given in Table 3 (sarkar 2013). Higher the ATS value means good connectivity in the network.

Table 4: Formula for Structural Analysis of Existing Road Networks

S. No	Indices	Formula	Correlation with Connectivity
1	Road Density	$\frac{Road\ length}{Area\ Sq.Km}$	Higher the Density Higher the Development
2	Beta Index	$\beta = \frac{e}{v}$	Higher value indicate more connectivity
3	Alpha Index	$\alpha = \frac{e-v+1}{2v-5}$	Higher value indicate more connectivity
4	Gamma Indices	$\Upsilon = \frac{e}{3(v-2)}$	Higher value indicate more connectivity
5	Cyclomatic Number	$\mu = e - v + 1$	Higher value indicate more connectivity
6	Aggregate Transportation Score	ATS= $\beta + \alpha + \Upsilon + \mu$	Higher value indicate more connectivity and efficiency

5.2 Shortest Path Analysis

There are many types of shortest path problems. For example, the most economic path or fastest path or minimum fuel consumption path from one specified node to another in a network. To conduct network analysis, this study focused on determining the optimal route between two or more destinations based on a specific travel expense. For the purposes of this study, those expenses of travel would be based on the length of time required traveling from origin to any destination point by visiting certain locations. The analysis was done by using the extension Network Analyst extension of Arc GIS software on the whole study area to locate some best routes. This network dataset is used for identify the number of nodes, edges present in the network to calculate the ATS.

6. RESULTS AND CONCLUSIONS

Results are obtained after structural analysis is given in Table 5. Rural road network planning is important to connecting areas of production with markets and connecting these with each other or with the State and National Highways.

Table 5: Summary of Structural Analysis of Network

Vertex	49
Edge	85
Length (km)	117.5
Area(Km^2)	253.8
Road Density	0.462
Alpha Index	0.397
Beta Index	1.734
Gamma Index	0.602
Cyclomatic Number	37
ATS	39.73

The major constraints on access to rural areas are the unavailability of database. This study has undertaken an extended attempt to develop Geographic Information System (GIS) based rural road database. From the present study the salient conclusions are listed below.

- Mirzapur (Bangla) is concluded as a Rural Hub.
- Tekur to Mirzapur (Nyalkal) village roads need to be Renewal (BT).
- Ganeshpur to Huselli, and Chalki to Humnapur roads need to be Up-graded.
- GIS based rural road model has been developed for strengthening of roads based on population benefited and PCI value of the link.
- The concept of shortest path analysis can be applied for emergence cases, service area allocation and facility allocation.

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