# Facility based rural road planning using GIS

*Mukesh chandra[1], M.Anil[2] and Prof. CSRK Prasad[3]*

## ABSTRACT

Rural Roads plays an vital role in the development of any emergent country. In India rural roads shares more than 85% of the road network of the country. Keeping in view the fact that connectivity has a catalytic effect on the economic and social development and poverty alleviation in rural areas, the Ministry of Rural Development, Government of India launched a mega rural roads development programme in 2000, popularly known as Pradhan Mantri Gram SadakYojana (PMGSY) to improve connectivity in Indian villages. After implementation of this project rural road network increases rapidly and main challenges is selection of road link for upgradation. Present paper focuses on the development of a planning model for upgradation of rural roads keeping Pradhan Mantry Gram Sadak Yoyna (PMGSY) program as the base of this model. Database for the PMGSY roads of Nellikudur Mandal of Warangal district in Telangana state is prepared which includes data like village data, road network & travel time. In this study rural road planning methodology based on the facility index concept is presented.

Geographical information system (GIS) is used to prepare spatial database of the available facilities. Twelve parameters, which include the education facility, medical facility, transportation and communication facilities and market facilities have been considered and score of each facility is assigned by spatial analysis of each facility. The objective of the study is to find village facility index by two different approach, habitation-coverage approach and population-coverage approach based upon that, prioritization of road link has done. Buffer analysis tool is used for spatial analysis of each infrastructure facility and maximum coverage distance were determined. Score of each facility depends upon maximum coverage distance of each facility. Village facility indices comprise of education, medical, transportation and communication and market. Population, village facility index and travel time have been used for finding weightage of road link. The prioritization of the link was carried out on the basis of weightage and Pavement Condition Index (PCI) of the links. This will be helpful to government official in decision making for upgradation of rural road.

**Keywords:** GIS, Village facility index, PMGSY, Prioritization, PCI

1. M-Tech. (T.E) student, Department of Civil Engineering, National Institute of Technology Warangal (Telangana).

2. Research Scholar, Department of Civil Engineering, National Institute of Technology Warangal (Telangana)

3. Professor & Head, Transportation Division, Department of Civil Engineering, National Institute of Technology Warangal (Telangana)

## 1. INTRODUCTION

Rural Roads plays a vital role in the development of any developing country. In India rural roads shares more than 85% of the road network of the country As an estimate in India around 67.7 % of the population lives in 5, 86,000 villages scattered all over the country These are the tertiary road systems as defined in the third twenty year road development plan (1981–2000) of India which provides access to villages on to the main roads and various centers of activities or any other settlements (MORTH 1984)(*7).* In developing countries like India, rural roads are termed as the roads passing through rural and agricultural areas, connecting villages to main roads and/or a town/market centre. The traffic on these roads is relatively low, comprising of mixed modes of transport like bullock carts, bicycle and motorized vehicles(*13).* A well planned road network in rural areas is one of the most important infrastructure elements which improves rural accessibility and contributes to the rural development as a whole. To improve the connectivity among villages and also towards the facilities there is a urgent need to improve the condition of existing roads by upgradation planning. The proper planning and development of rural road network therefore, assumes its importance in terms of providing connectivity to the facilities.

PMGSY is the nationwide programme to provide connectivity to all the villages in a phased manner, so as to connect all the habitations having population of more than 500 persons and above in the plain areas and 250 persons and above in hill states, the tribal and the desert areas. The programme 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 withquantifying population. Under this process, a huge database spatial and non-spatial, related to rural roads, is being generated all over the country (*3).* Handling, managing and updating of the data by the traditional methods is not only tedious and time consuming, 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. Geographic Information System (GIS) is a computer-based tool which can handle the entire database and help in the management of the entire rural development programme.

## 2. LITERATURE REVIEW

In past different methodologies are developed for the rural road network planning. Some of rural road planning methodologies are reviewed. Kumar and Jain (1997) presented the facility based rural road network planning model. J. K. Shrestha et al (2003) many indicators consider social and economic aspects, from which only few of them may be significant in the context of rural areas. Durai et al. (2004) presented applications of GIS for Planning and Management for rural roads. They have generated GIS based database for preparation of district rural road plan and core network plan, including detailed project report. Garg (2008) carried out case study of Roorkee and surrounding area. He emphasized the power of GIS technology which will help the government of Uttrakhund state to better understand and evaluate spatial data and identify gaps in existing facilities using scientific criteria. Mishra and Naresh (2009) developed geo-informatics for planning, decision making, and monitoring of PMGSY scheme. A.K Singh (2010) accessibility index was designed for rural road network planning in developing countries in GIS environment. Amarnath et al. (2011) used the cluster analysis approach for optimal rural road planning. The villages having similar characteristics are grouped using cluster analysis considering the demographic and socio-economic factor. Chakraborty et al. (2012) identified the relationship between infrastructure, employment, opportunities and the level of living standard in rural India. They assumed influence area of some facility. Navatha et al. (2015) determined facility index, which was used to rank group of area based infrastructure availability, a number of parameter have to be taken into consideration.

## 3. STUDY AREA PROFILE

The Nellikudur mandal is in Warangal District of Telangana State, India. It'sHead Quarters is Nellikudur town. Geographically, it is situated in between 79º42′22″E to 79º55′42″E and 17º42′25″N to 17º31′8″N with an elevation of 223m. Ramanjapuram is the smallest Village and Nellikudur is the biggest Village. Warangal, Suryapet,Khammam ,Yellandu are the nearby Cities to Nellikudur. Total population of Nellikudur Mandal is 57,384 living in 12,581 Houses, Spread across total 110 villages and 22 panchayats. Males are 29,308 and Females are 28,076.

## 4. DATA COLLECTION

The collection of data is from both primary and secondary sources. The methodology employed in data collection and the procedure for analysis of collected data is presented below

### 4.1 Primary Data

Primary data was collected from field survey. The method employed for determining PCI is similar to method adopted by PMGSY. The PCI of each road link were surveyed based on comfortable driving speed possible. In this method, the driver is instructed to drive at the most comfortable and safe speed possible on the road. The PCI then assessed for each kilometer based on the normal driving speed.

### 4.2 Secondary Data

Secondary data like SOI toposheet, habitation details as well as road information data and other ancillary data were collected from panchayat Raj and Roads and Buildings department of Warangal district. The topo sheet of all mandal in Warangal district is also collected.

#### 4.2.1 hard copy map collection

Survey of India topographic sheet at scale of 1:50,000 was used to prepare different layers of the study area. This map have details of habitations in Nellikudur mandal in accordance with their type.

#### 4.2.2 habitation details

The habitation are categorized accordingto the population size as shown infigure 1 shows pie-chart of habitation detail of Nellikudur mandal.

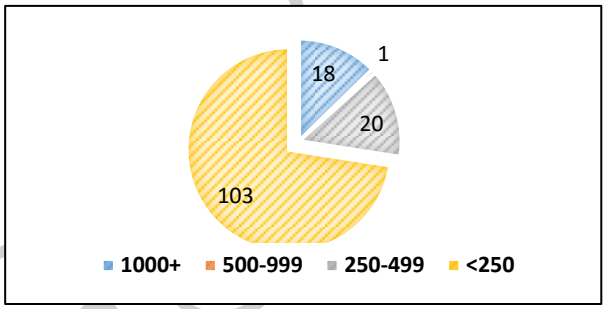



Figure 1 Pie-chart of habitation detail of Nellikudur mandal according to their population size

### 5. OBJECTIVES

The main intension of this study is to develop a planning methodology for a rural road network based upon VFI, Specific objectives are
1.To Estimate VFI for villages using Buffer zone analysis.
2.To prioritize road links of the study area based on the VFI

## 6. METHODOLOGY

The proposed methodology can be divided into different phases. The first phase includes identification of the roads for the up gradation based on the pavement condition index (PCI) After collecting the data from the field observation and habitation details from secondary sources, spatial data base was prepared in the geo environment using ArcGIS. In the second stage the facility index values of the habitations are estimated from the facility availability and distance from the facilities to habitation in the study area by conducting the spatial analysis using Arc GIS software and prioritization list are prepared for upgradation work for the roads based on the link weightage. The all detailed procedure and terminology for achieve objectives are given below,

### 6.1 PREPARATION OF SPATIAL DATABASE

Spatial data refers to geographic areas or features. Features occupies a location. Spatial data stores geometric locations of geographic features along with attribute information describing what these features represent. Spatial data is usually stored as coordinates and topology, which can be mapped.Spatial information is necessary to specify the shape and location of geographic features as well as spatial relationships between such features. The spatial relationships implicit on a map determine what the map conveys to the reader.

### 6.2 NON-SPATIAL DATABASE

Non-spatial data is tabular or textual data describing the geographic characteristics of features. These types of data has no specific location in space. It can however, have a geographic component and be linked to a geographic location. The database contains all fields for which the data was collected. Putting all the information collected about habitations and how many facilities were available are integrated in GIS environment the database was developed and stored on Arc Catalog package.

## 7. SPATIAL ANALYSIS FOR DEFINE THE COVERAGE DISTANCE FROM FACILITY

Spatial analysis is performed for defining desirable coverage distance from each facility. There are two criteria for defining coverage distance as population and habitation criteria. In Habitation criteria, buffer analysis were performed for each facility for different distances and percentage of habitation that are covered at different distances are noted and similarly in population criteria, buffer analysis is performed for each facility by varying distances, percentage of population that are covered at different distances is noted. Buffer analysis is performed for mandal listed in table 1.The topo sheet is collected for all mandalsgeoreferenced in Arc Gis environment, digitized and buffer analysis is performed separately for each mandal. For performing buffer

analysis first fixed the initial distance for each facility based upon availability of facility in the mandal and distance is increased to capture habitations and population.

| S. no. | Name of facility | Desirable coverage distance by habitation coverage(m) | Desirable coverage distance by population coverage(m) |
|---|---|---|---|
| 1 | Primary school | 1000 | 1000 |
| 2 | Middle school | 2000 | 2000 |
| 3 | High school | 3000 | 2000 |
| 4 | Pre university | 8000 | 8000 |
| 5 | ANM center | 2000 | 2000 |
| 6 | PHC center | 6000 | 5000 |
| 7 | CHC center | 8000 | 8000 |
| 8 | Veterinary hospital | 5000 | 5000 |
| 9 | Bus stand | 1500 | 1500 |
| 10 | Post office | 4000 | 4000 |
| 11 | Petrol outlet | 10000 | 8000 |
| 12 | Warehouse | 8000 | 6000 |

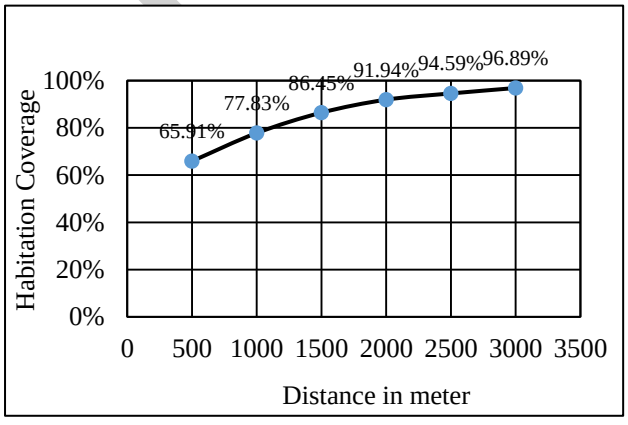
**Table 2 Desirable coverage distance for different facilities Table 2 Represent selected mandal for buffer analysis**

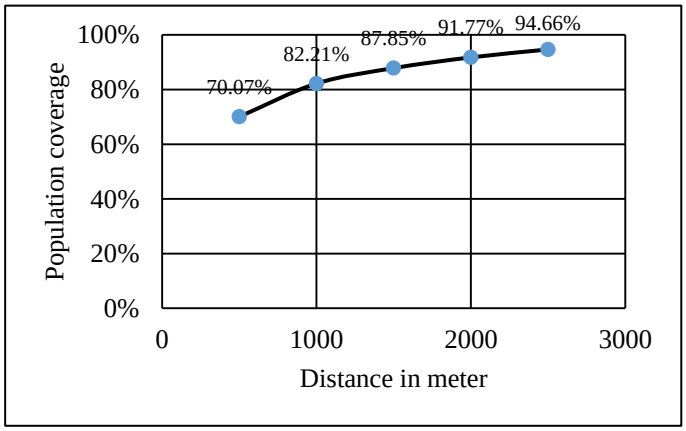
| S. no. | Name of mandal | Population |
|---|---|---|
| 1 | Nellikudur | 58256 |
| 2 | Cheriyal | 70312 |
| 3 | Devaruppula | 41030 |
| 4 | Parkal | 53156 |
| 5 | Palakurthi | 55162 |
| 6 | Thorrur | 72787 |
| 7 | Sangem | 55121 |
| 8 | Bachannapeta | 40924 |
| 9 | Maddur | 38817 |
| 10 | Narsampet | 74952 |

### 7.1 Buffer analysis for primary school

The (Figure 2) shows habitation coverage for primary school by distance. The average percentage of habitation covered for all selected mandals at different distances for primary school. 3 shows population covered for all selected mandals at the different distances for the primary school. Selection of coverage distances from both figure is such that where the slope is steep and covered more than 50% from habitation as well as population criteria. From both criteria the coverage distance is 1000m were taken from graph because slope is maximum for 500-1000m interval. Thus the coverage distance is fixed such that distance for 1000m distance.

Buffer analysis for all selected parameter were carried and desirable coverage distance are determined. (Table 2)shows summary of desirable coverage distance for each facility by both habitation and population coverage approach.



## 8. ESTIMATION OF VFI

Village facility index is relative measure of village based upon available facilities on that village and spatial distribution of village. Village facility index comprise of education facility, medical facility, transportation and communication facility and market facility indices. Based upon desirable coverage distanceby spatial analysis fixed the score of each facility. Desirable coverage distance by spatial analysis for each criteria as habitation and population approach obtained earlier. After getting desirable coverage distance for each facility, next step to do buffer analysis on desirable coverage distance for each facility. After that those village having comes in buffer zone allocate score as 0.5 and those who not comes in buffer zone allocated score as 0.25 and within village the score is '1'. Table 3 is presented here which given all classified facilities index as well as summarized facility index for habitation coverage approach.

$S_{ijk}$ = score of the $J^{th}$ sub facilities among $I^{th}$ core facility in $k^{th}$ village; where
i = 1, 2… I;
j = 1, 2… J;
k = 1, 2… K;
$S_i$= set of all possible scores of $J^{th}$ sub-facility among $I^{th}$ core facility = (*s;j* 1, 2 …*J*)
The 'normalized score' of $J^{th}$ sub-facility among $I^{th}$ core facility in $K^{th}$village is

$$\text{Nijk} = \frac{Sijk - \min_{j \in si}(Sijk)}{\max(Sijk) - \min(Sijk)};\ 0 \leq \text{Nijk} \leq 1,\ i = 1, 2\ldots\ldots I,\ j = 1, 2\ldots j,\ k = 1, 2\ldots K \quad (1)$$

$$\text{And the average score of ith core facility for kth village will be dijk} = \frac{\sum_{j=1}^{j} \text{Nijk}}{j} \quad (2)$$

Defining, wj = weight of ith core facility with $\sum_{i=1}^{I} Wi = 1$

$$\text{For } K^{th} \text{village we will get 'village facilities index' as Vk} = \sum_{i=1}^{I} Widik \quad (3)$$

## 9. LINK WEIGHTAGES

Based on the facility index obtained by population and habitation approach, use which one having more VFI for prioritization of existing road link in the study area. Facility index, population and travel time is using in gravity hypothesis for finding weightage of link. Travel time between habitations are used as impedance factor and travel show actual scenario of the links.

$$Wij = \frac{(Pi * Pj)(F_i - F_j)}{t_{ij}^2} \quad (1)$$

Where,
$W_{ij}$- Weightage
$P_i$ and $P_j$- Population of villages i and j
$F_i$and$F_j$Village facility index of villages i and j
Time between village i and j
If $F_i - F_j = 0$ then take this value as 1

### 9.1 IDENTIFICATION OF THE ROADS FOR UPGRADATION WORK

To identify the roads to be upgraded field surveys were conducted in the study area bytravelling along the road in a design vehicle with a comfortable riding quality and observed the normal driving speed on the road. The road connected the habitations observed for upgradation was listed below in table 4 and 5 correspondingly based upon PCI and link weightage value.

## 10. CONCLUSIONS

1. Maximum and Minimum VFI from habitation coverage approach as Venakatapuram having maximum VFI is 0.61 and padamatiggaddathanda , Kothurthanda and RamachilukalaBodathanda having minimum VFI is 0.06
2. Maximum and Minimum VFI from population coverage approach as Venakatapuram having maximum VFI is 0.59 and padamatiggaddathandahaving minimum VFI is 0.04
3. Village facility index is depends upon availability and spatial distribution of facility
4. Maximum weightage of road link Between Chinnanagaram to Rajukothapally and minimum for Laxmipuram to Mangalithanda for PCI value as 1
5. Maximum weightage of road link Between Nellikudur to Brahmankothapalli and minimum for Nimmathanda to Jamathanda for PCI value as 2.
6. Buffer analysis for population and habitation coverage approach reveals that the all facility available in Nellikudurmandal, facility level is less than from average facility available in all selected surrounding mandal.

## 11. LIMITATIONS

1. The current condition of the road was examined based on comfortable driving speed possible and the decision was taken by personal judgment which is subjective.
2. Villages that are benefited services from adjacent nearby mandals are not considered in this study.
3. All selected parameter of facilities are independent.
4. Equal weightage of all core facilities as education facility, Medical facility, Transportation and communication facility and Market facility is 0.25 is taken.
5. Habitation coverage and population coverage should be more than 50% for Desirable coverage distance calculation and other criteria is slope is steep and upper coverage point is selected.
6. Score of facility is based upon three criteria, within village, within desirable coverage distance and beyond desirable coverage distance and score for within village is 1, score for within maximum coverage is 0.5 and score for beyond desirable coverage distance is 0.25.

## 12. SCOPE FOR FUTURE WORK

i. The present study is adapted for only one mandal, which can be extended to other mandals and find out VFI of all selected mandal as habitation wise.
ii. Selection of rural hub is depend upon VFI and planning of rural road at district level by connectivity of all hubs.

**Table 3 Village facility index by habitation approach for Nellikudur mandal**

| S. no. | Habitation | Educational facility index | Medical facility index | Transportation and communication facility index | Market facility index | VFI |
|---|---|---|---|---|---|---|
| 1 | Alair | 0.25 | 0.25 | 0.22 | 0.33 | 0.26 |
| 2 | Ammuruthanda | 0.42 | 0.17 | 0.22 | 0.33 | 0.28 |
| 3 | Avulegathanda | 0.33 | 0.17 | 0.11 | 0 | 0.15 |
| 4 | Baditanda | 0.25 | 0.17 | 0.22 | 0.33 | 0.24 |
| 5 | Badithanda | 0.08 | 0.17 | 0.00 | 0 | 0.06 |
| 6 | Badivaththanda | 0.17 | 0.17 | 0.11 | 0 | 0.11 |
| 7 | Bagnathanda | 0.17 | 0.08 | 0.33 | 0.33 | 0.23 |
| 8 | Bancharaitanda | 0.42 | 0.17 | 0.00 | 0 | 0.15 |
| 9 | Bandamidethanda | 0.42 | 0.25 | 0.22 | 0.33 | 0.30 |
| 10 | Banjarathanda | 0.17 | 0.17 | 0.11 | 0.33 | 0.19 |

**Table 4 Up-gradation of road link having PCI value less than equal to 1**

| S. no. | Origin | Destination | Weightage | Priority |
|---|---|---|---|---|
| 1 | Chinnanagarm | Rajulakothapally | 28.53 | 1 |
| 2 | Nainala | Rajukothapally | 23.13 | 2 |
| 3 | Alair | Vavilala | 22.87 | 3 |
| 4 | Vavilala | CheruvuVamhundThanda | 22.75 | 4 |
| 5 | Sreeramgiri | Venkatapuram | 22.27 | 5 |
| 6 | Rajulakothapalli | Ravirala | 18.35 | 6 |
| 7 | Mungalavedu | Alair | 17.62 | 7 |
| 8 | Mungalavedu | PanthuluThanda | 12.09 | 8 |
| 9 | Rajulakothapalli | Venkatapuram | 5.00 | 9 |
| 10 | Kachikal | SingyaThanda | 3.63 | 10 |

**Table 5 Up-gradation of road link having PCI value less than equal to 2**

| S. no. | Origin | Destination | weightage | priority |
|---|---|---|---|---|
| 1 | Nellikudur | Brahmankothapalli | 557.29 | 1 |
| 2 | Ramannagudem | Nellikudur | 535.33 | 2 |
| 3 | Ravirala | Nainala | 18.27 | 3 |
| 4 | Sreeramgiri | Laxmipuram | 2.66 | 4 |
| 5 | Tarasinghthanda | Chinnamupparam | 1.910 | 5 |
| 6 | Nimmathanda | Jamathanda | 0.73 | 6 |

**References**

1. Amarnath, M. S., Raji, A. K. and. Rejani, V. U. (2011). "Rural road connectivity using clustal algorithm." *Indian Highways*, 39(6).
2. Chakraborty, S., Baksi, A., &Verma, A. K. (2012). "Rural infrastructure availability and wellbeing." *Journal of Regional Development and Planning*, 169-179.
3. Durai, B. Kanaga, (2004) "geographical information system for planning and management of rural roads." *Map India*, 28-31.
4. Garg, P. K. (2008). "Spatial planning of infrastructural facilities in rural areas around Roorkee, Uttarakhand, India." *Integrating Generations FIG Working Week 2008 Stockholm*, Sweden, 14-19.
5. Kumar, P. and Kumar, A. (1997). "Facility based planning of rural road network", *Piarc international seminar on sustainable maintenances of rural road*.
6. Ministry of Rural Development, (2002). "Manual for preparation of core network plan for PMGSY." Government of India, New Delhi, India.
7. Ministry of Rural Development, (2011). "Working groups in rural roads in the 12th five year plan." *Government of India Planning Commission.*
8. Mishra, K. K., &Thakral. (2003). "Using geo-informatics for development of rural roads under Pradhan Mantri Gram SadakYojna."*Map India*.
9. Navatha, Y., Reddy, K. and Pratap, D. (2015). "Analysis and planning of infrastructural facilities in rural areas using facility index metho."Journal of Geomatics, 9(2).
10. Pradhan Mantri Gram SadakYojna "Programme Guidelines(PMGSY-II)", August-2013
11. Rao, I. P., Kangadurai, B., Jain, P. K (2003). "Information system for rural road network planning-a case study". *Map India*.
12. Shrestha, J. K., Benta, A., Lopes, R. B., & Lopes, N. (2013). "A methodology for definition of road networks in rural areas of Nepal." *World Academy of Science, Engineering and Technology*, 78, 410.
13. Singh, K. (2010). "GIS based rural road network planning for developing countries." *Journal of Transportation Engineering*, 153.
14. *http://en.wikipedia.org/wiki/Nellikudur*