CHAPTER 2

PLANNING OF RURAL ROAD NETWORKS
– A REVIEW
2.1 INTRODUCTION:

The second half of the twentieth century has seen substantial changes in the transport systems of the countries at all stages of economic development. In the Advanced Industrial Countries, road transport now carries the dominant share of freight and passenger traffic. Many of the developing countries have undertaken plans designed to upgrade transport facilities in rural agricultural areas in order to improve social and economic life. To achieve the aim of increasing the reliance of the rural population upon agriculture and increased accessibility to basic services, the level of rural transportation has to improve. It is clear that the problems in rural transport are universal though specific manifestations of the problem may be different from place to place.

2.2 TRANSPORT AND SPATIAL STRUCTURE:

Transport and spatial interaction of influencing factors are interrelated. The functional analysis on the influencing factors will generate the possible change of distribution of activities in an area. The result of functional analysis will identify the optimal connections in rural network structure. Several conceptual models have been devised as aids to the understanding of the development of transport systems and of their component parts. Ekstrom and Williamson (1971) have recognised in their hypothetical approach an initial phase, with the introduction of transport generators and its orientation followed by a spread phase with spatial diffusion of the network and a coordinating phase where linkage of many to single and many to many networks are connected. These three phases may be followed by a "concentration phase", involving an emphasis on optimising the network. The Lachene (1965) model examines the development of a transportation system upon a hypothetical isotropic plain, which in practice could be mid-continental region such as the Mid West America. It may be compared with Lachene approach to the evolution of
an economic landscape, progressing from an initial network of paths and tracks arranged in a grid pattern to the selective growth of towns and villages and culminating in a small number of higher order settlements connected by high grade routes. Over a period of time frame, the aggregate length of the network is gradually reduced from the complete grid of pathways in the early stages to the selective framework of major routes in use.

The TMG approach, by Taaffe, Morrill and Gould (1963) is inductive, descriptive and based upon observations of colonial transport development in West Africa. The model traces the progressive establishment of links between the seacoast and the interior of an undeveloped region with consideration to potential and shortest distance. Both the TMG and Lachene models emphasise the fact that progressive changes in a network of nodes and links can produce a pattern in which movement usually becomes increasingly concentrated along a few favoured routes. In his application of the TMG model to rural road expansion in the Ile-Ife cocoa-growing region of Nigeria, Aloha (1983) recognises five periods of road growth between 1910 and the 1980's during which progressive increase in network complexity led to improvements in the rural economy as shown in fig-2.1

Gould's spatial exploration model is a behavioural model which was proposed in 1966 as an alternative to the TMG concepts of transport development. It interprets a random approach and is based upon a simulation of search theory, with the development of a transport network within an area, which contains resources, hazards and constraints indicated by isorithms of environmental quality. The developer aims to tap the resources of a previously unexploited area, depicted as a square. As road building proceeds, so the developer will encounter the resources and the constraints within the environment. In stage one, capital is invested in roads oriented towards villages diverging from urban areas. In stage two, information on the nature of the land, activities and obstructions like rivers
A, B - PORTS
C, D - INLAND CENTRES
E, F - INTERMEDIATE CENTRES

Fig 2.1 ROAD NETWORK DEVELOPMENT ANALYZED IN T·M·G APPROACH ON RURAL ROADS
encountered by the advancing roads is fed back to the developer to make new plans with
necessary deviations. Stage three comprises the construction of further links following the
principles outlined in the first two stages as shown in fig- 2.2.

2.3 RURAL TRANSPORT PROBLEMS, POLICIES AND PLANS:

Studies on rural transportation impacts have been carried out over the last twenty years,
with emphasis on the methodology and understanding the models of causal relationships.
The historical sequence of rural impact methodologies and the research on rural mobility
and migration carried out in several countries during the last 10 years are examined (Pepter,
1990). Much of the theoretical work on rural transportation has been carried out in the
context of rural road improvements. In addition, there have been many attempts to describe
the impacts of rural roads in the last quarter of the century as found in the work by Owen
(1968). Owen examined the state of knowledge regarding the role played by transport in
the development process. He cited research in India, Turkey, South Korea and Japan on the
relation of transport to development. He states that the impacts of rural roads were not
uniform from one area to the next and that the community development programme which
has provided all weather roads to many villages in India, was limited in some cases because
"Other elements of productive farming were still absent". The road development policies in
different countries are presented below.

Dutch road development:

The rural road development plans in Dutch areas are made in two phases - Functional
analysis and constructional analysis. The functional analysis leads to an exploration of the
required road network structure. As a result of this, a list of measures appears, which form
a functional point of view and have to be taken in the existing road network. The
information required for the functional analysis includes the bottlenecks in the structure of
FIG. 2.2 GOULD'S SIMULATION OF SPATIAL EXPLORATION IN TIME PERIODS
rural road network, planning on road configurations is developed in first phase. In the
collectional analysis, the factors influencing the construction cost are considered which
will work out on identified road structure from functional analysis (Vanputten, 1987).

West German rural road network development:

West German land consolidation has reorganised the agricultural parts of the districts of
several rural communities with a framework of new rural roads. In addition they located all
necessary public and common installations and facilities (Kollmer, 1987). The planning was
coordinated in relation to the land use and network identification.

Belgium rural road network development:

Belgium has chaotic spatial disorder with scattered buildings, with lot of ribbon
development, disorganised local industrial areas etc. Due to this, it is very difficult to
design a functional rural road network. Gevaert (1987) has stated that planning of rural
roads must take the structure plan into account with the intention of uniform accessibility
and connectivity. He also stated that there is no scientific method for planning of rural
roads in land development. The road development in Belgium is not policy based, in the
sense of strategic and operational planning of the rural roads. In Belgium they rather have a
more pragmatic approach of this matter. The consequences are that they have more
difficulties to justify investments related to the different kinds of work in the reallocation.

Devon, UK road development in rural areas:

Historically the roads have been classified into A, B, C and unclassified roads reflecting
their importance and level of use. This network of roads has grown up largely to serve the
agricultural base, which was country's main industry for many years. There is no scientific
base method in practice for rural road planning (Horn, 1987).
Minor rural road planning in Switzerland:

Bos et al (1987) have stated that improvement of rural road infrastructure and reallocation is usually linked. In Switzerland, the construction of new rural transportation facilities continues to be an important measure of structure improvement in agriculture and forestry. Every year several hundred kilometres of new farm and forest roads are constructed, extending a network well over 60000kms. Plain lands for laying roads or necessary funds are scarce. Hence then constructing new roads, it is necessary to weigh up not only the technical and economic aspects, but also the various requirements of all users, ecological and aesthetic conditions. In Switzerland, planning, design and construction of rural roads is still based on rule of thumb and general practices but the procedure as above has unfortunately not been established as a general rule yet.

Although urban transport problems usually draw the attention of urban planners, people living in rural areas of the advanced as well as underdeveloped Nations face severe difficulties in meeting their needs for transportation. The problems confronting the rural transport deprivation at various levels of economic and social development shall be addressed by assessing the effectiveness of the polices and plans that may be proposed to improve levels of mobility and accessibility for people in remote and isolated areas.

In both the industrialised world and developing countries rural transport is a vital component of the system of services necessary for the continuing existence of dispersed settlement in less densely populated areas. Remoteness, isolation and inaccessibility are key characteristics of many of the world’s rural regions. Inadequate transportation services are largely attributable to the economic and social deprivation of these areas.

Several methods of defining rurality have been proposed based upon population density, settlement pattern, economic structure and aspects of remoteness and accessibility. Levels
of community combined with indices such as population density and the proportion of
labour force in agriculture and related occupations have been used in official definitions of
rurality in UK. More refined definition incorporates sixteen socio-economic variables to
identify four main categories of rural area.

In larger territorial area such as in Australia or in USA, the degree of remoteness,
coupled with low population density provides a convenient guide to the identification of
rural areas. About 36% of USA is made up of areas where the population density is less
than 14 per sq.km and where rural settlement is more than 200 kms away from cities of
population over 250,000. This area contains only 2.2% of the total population. Even within
this 2.2% there are zones where over a million persons are distributed at densities of less
than 0.5 per sq.km. In Australia the identification of sparsely settled regions present few
difficulties, since the entire continent outside the five metropolitan city areas can be
classified as rural, with densities varying from less than one person per sq.km to less than
one per 64 sq.km. Rurality in this extensive continental areas has a totally different
connotation from that in the UK since much of the Australian interior is totally uninhabited.
and transport and other services are almost non existent.

In most of the developing countries at least 2/3 of the population can still be classified
as rural, although densities vary considerably according to levels of economic activity. In
Nigeria, rural densities of 400 per sq.km are recorded in the Southeast region where as the
drier interior Savannah registers densities of only 20-30 per sq.km. If rural isolation is
interpreted in terms of the absence of motorable roads, then 196 million village dwellers in
India come into this category. A survey of 16 provinces in Indonesia indicated that 30% of
all the villages have no link to the road network.
Many states however occupy an intermediate position between the two extremes of industrialised and underdeveloped countries. With in these states, the level of isolation and remoteness in rural areas can vary substantially. Nations in the Middle East and in Latin America, contain some rural areas where personal mobility is relatively high but in other regions inaccessibility continues to be a problem.

2.3.1 Mobility and Accessibility in Rural Areas:

The minimum socially acceptable levels of mobility identified in the advanced world would be irrelevant in most of the developing rural societies, due to the differences in the living standards (Stanley, 1975). Distinctions between the demand for provision of rural transportation in the developed and underdeveloped countries must therefore be considered in terms of their contrasting economic and social background. In the developing countries, the quality of the infrastructure and level of personal and household income are often the most important factors. In the African rural societies there is common acceptance of barefoot trips over 15 to 20 kms for basic purposes like schooling and Medicare. In these developing societies problems of accessibility are experienced not only in terms of linkages between settlements, but also within agriculture holdings in terms of daily trips between home and fields. The trip lengths and other characteristics of some countries are shown in Table 2.1.
Table 2.1 Rural Transport Trips by Length and Loads

<table>
<thead>
<tr>
<th>Name of the country</th>
<th>Typical distance of transport</th>
<th>Average on form distance</th>
<th>Average off form distance</th>
<th>Loads transported</th>
</tr>
</thead>
<tbody>
<tr>
<td>KENYA</td>
<td>90% of trips &lt; 7 Kms</td>
<td>0.8 kms</td>
<td>-</td>
<td>70% of trips &lt; 25 kg</td>
</tr>
<tr>
<td>MALAYSIA</td>
<td>75% of trips &lt; 7 Kms</td>
<td>1.0 km</td>
<td>10 km</td>
<td>-</td>
</tr>
<tr>
<td>INDIA</td>
<td>90% of trips &lt; 5 Kms</td>
<td>1.5 kms</td>
<td>8.3 kms</td>
<td>-</td>
</tr>
<tr>
<td>BANGLADESH</td>
<td>Most trips &lt; 12 Kms</td>
<td>-</td>
<td>-</td>
<td>Most trips &lt; 50 kg</td>
</tr>
<tr>
<td>WESTERIN</td>
<td>Most trips &lt; 5 kms</td>
<td>-</td>
<td>-</td>
<td>Most trips &lt; 80 kg</td>
</tr>
<tr>
<td>SAMOA</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>REPUBLIC OF KOREA</td>
<td>Most trips &lt; 10 kms</td>
<td>-</td>
<td>-</td>
<td>30—80 kg</td>
</tr>
</tbody>
</table>

(Source Barwell et al (1985).)

2.3.2 Rural Transport Deprivation:

Measurement of difficulties faced by rural societies in gaining access to essential services involves the identification of transport disadvantaged or mobility deprived groups and individuals. In rural areas the basic problems are associated with the dispersed nature of the population and the difficulties experienced in securing acceptable levels of access to services which are scarcely available in certain settlements. The distinction between transport need and transport demand is particularly difficult to identify in the rural context, both in developing and advanced countries. The success of any plan to combat mobility problems depends upon an understanding of this complex diversity. Rural transport deprivation is but one of several components of a wider set of social and economic problems which face rural population and which are linked to their origins and their possible solutions.

2.3.3 Rural Transport in Developing Countries:

In most of the developing countries the road is the key factor for transport and if it is in poor physical condition and orientation, the result will tell upon the plans for economic
expansion and upgrading of social facilities. In the mid 1960's, the road networks of most African states, apart from South Africa, has less than 5% of their total length with sealed surfaces and a large proportion of the minor feeder roads were and still are tracks beaten out by pedestrians and animals carts.

Comparative analysis of stands on rural roads in developing states is difficult as there are no accepted norms or standards prescribed in terms of sealed and unsealed surface. The details of rural road compositions in various countries are shown in figure 2.3. Owen (1968) discussed the potential role of transportation in reinforcing growth points and service towns in India and stated the potential role of these towns in network planning.

2.3.4 Policy and Planning Responses in Developed Countries:

As in the less developed world, rural transport planning should ideally be seen as part of wider and more comprehensive program designed to combat the overall economic and social problems of dispersed communities. In practice however, these problems are rarely tackled in a coordinated way and the efforts, which have been made to improve rural accessibility, are usually the responsibility of a wide range of different organisations. In UK, the Jack report on rural transportation published in 1961 recognised that the survival of bus services would require subsidies to support the uneconomic services and it also realised that effective solutions would need to take into account all the basic needs of village communities. Surveys in six selected rural areas in UK in 1963 were followed in 1977 by what were termed rural transport experiments (RUTEX) to discover to what extent changes in transport legislation and policy had altered the situation. The traditional approach of ensuring adequate bus links between village and town became just one of several possible solutions. Under the 1968 Transport act county councils in the UK were empowered to subsidise those loss making bus services in the interests of local community.
FIG. 2.3 ROAD DENSITIES AND PERCENTAGES OF TOTAL ROAD LENGTH
From 1972, County Councils were required to produce annual transport policy and program documents in which their plans for rural public transport support were detailed under the 1978 Transport act. These councils began preparation of public transport plans with aims of recasting bus services to serve public demand more effectively.

In USA, bus services in the remote rural areas have only survived where they form a part of inter urban routes, but by the mid 1970's only about 40 percent of all rural centres with populations of between 2500 and 10000 still have bus links. Most of these small communities are in the east and public transport facilities in the rural western states are negligible. Both the 1974 Mass Transportation Assistance Act and the 1978 Surface Transportation Assistance Act authorised cash payments to support rural buses and over 100 federal support programs had been established by 1976. The impact of these programs in the USA has been proportionally much less than in the UK because of the distance involved and the high operating costs. As in the UK, members of American rural households travel greater distances each year than urban dwellers, both for journey to work, social and recreational purposes and the rural population spends a higher share of its household budget on transport than that in metropolitan America.

In developed world attempts to solve the problems raised by steady declining of public transport and the consequent emergence of a set of transport poor groups have taken many forms. A transport policy is just one part of the wider program necessary to ensure the survival of remote rural communities and action taken to improve transport facilities must be coordinated with the objectives of this overall program. In Europe, North America and Japan, there are many households in high-income groups who have been attracted to life in rural areas and who have resources such as multiple car ownership.
Rural transport problems in developing countries still need to be appraised and tackled at a much more basic level than in advanced economies. The creation of a network of adequate roads is often a first priority.

The Scottish region of Strathclyde is containing extensive rural areas where small settlements experience severe difficulties related to inaccessibility. In an attempt to approach the problem the transport executives measured the balance between transport supply and demand in each village using two indices. The first used current bus time tables to determine the length of time that village dwellers could spend in local towns and the second the estimated demand levels by examining village population structures, car ownership and the extent to which local needs could be met within the village community. Each settlement was then assigned a supply demand score, which indicated the extent to which public transport satisfied existing needs for access to service towns. Such studies could pave way to develop rural road links.

The rural road planning in West Germany will follow the structure of network construction in relation to different functional needs from the following rules (Kollmer, 1987)

<table>
<thead>
<tr>
<th>Classification</th>
<th>Local situation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farm size 40-80 ha</td>
<td>Farm size 10-25 ha</td>
</tr>
<tr>
<td>Community linked roads</td>
<td>0.2-0.5 km/100ha</td>
</tr>
<tr>
<td>Farm roads-Asphalt or concrete paved</td>
<td>0.8-1.5 km/100ha</td>
</tr>
<tr>
<td>Gravel surface</td>
<td>0.5-1.0 km/100ha</td>
</tr>
<tr>
<td>Vine yards and Horticultural land</td>
<td>10-25 km/100ha</td>
</tr>
</tbody>
</table>
2.3.5 Rural Transport Planning and Policy in Developing Countries:

Investment in transport facilities is usually just one element of a complex development program designed to improve standards of living in the rural areas, the main objectives being to increase the quality and the extent of commercial farming and to ensure a better distribution of educational, health and other social services. The First Five-year National Development plan for Zimbabwe, published in 1986 states that “Adequate roads and transport services in rural areas are a prerequisite to continued economic and social development”. However the improvement of roads for economic motives is often a first priority, although the same road can, of course, serve the needs of farmers, children walking to school and women etc. These road building and upgrading projects are essential if access to local market, schools and clinics are to be increased. A survey in India estimated that 50 to 60% of the total villages have no adequate all weather road access. The cost of providing road connections to all isolated settlements in the Nation would be astronomic and some form of selective exercise must be made. There is a need to identify links between existing road facilities and levels of economic activity.

2.4 ROAD NETWORK DEVELOPMENTS IN RURAL AREAS:

To have an effective development among the isolated, remote areas, rural transportation is recognised as a key factor. Efficient rural transportation depends largely on a well-knit road network to provide accessibility and mobility in rural areas. The road network details of various countries are presented in the following sections:

2.4.1 The Dutch Road Network:

A total of about 97,000 kms of paved roads are available for traffic in the Netherlands. Out of these about 43,000 kms belong to urban areas. In the rural areas about 4400 km of motor ways and other National Highways and 7000kms belong to the provincial road
There are about 42000kms of roads available mainly for the rural areas. Moreover there are about 15000kms of unpaved roads (Vanputten, Netherlands, 1987). To give emphasis to rural areas, the ownership, management and maintenance of minor rural roads was brought under the public authorities like the State, the Province, and the Municipality. The rural roads in Netherlands have a strong historic origin and the densities vary in different areas, from 5m/ha up to more than 60 m/ha. The practice in this area is basically giving access to all parts by all weather roads. Attempted to provide guarantee access to all areas expressed in terms of reliability, defined as the sureness that a road can be driven as a part of a route.

2.4.2 West Germany Rural Road Network:

The rural road network in West Germany has been divided on the basis of functional hierarchy such as - connection roads, main farm roads, minor farm roads and village streets. These connection roads will be used for regional traffic, main farm roads are basically for giving access to farms and small settlements outside the village site and to large farms. minor farm roads are used by farmers to reach their plots while village streets are meant within the settlement area. The factors which will determine the rural network design are: network of major roads/railways, landscape, topography, land use, farm size, agricultural and settlement structures, non agricultural use of land and the economic necessity to cover the project area with a road network. The authorities will plan for road construction as per the policy on network density for different categories, which was discussed in previous section.

2.4.3 Rural Road Network in Belgium:

The rural road network in Belgium comprises of provincial and municipal roads. There are different standards concerning the density of the road network. In the more agricultural
areas as the loamy regions, the standard is maximum of 20 Mts. per ha. In the other regions, it can rise up to 40 Mts. per ha (Gevaert, 1987).

2.4.4 Rural transportation in Devon, UK:

Devon is one of the largest counties in UK with the most extensive mileage of roads. The intensive network of minor rural roads in Devon represents some 60% of 14000 kms of public highway in Devon. Being a predominantly rural county, Devon has a thriving agricultural industry. There is no scientific base methodology in identifying road network (Horn, 1987).

2.4.5 Rural road planning in Switzerland:

In Switzerland, improvement of rural road infrastructure and land reallocation is closely linked. Improvement of rural transportation facilities is continued and considered to be an important measure for structural improvement in agriculture and forestry. Importance is given to user requirements, general ecological and aesthetic conditions, in addition to the technical and economic aspects. Attempts were made to develop priority structure road network, which was believed to sustain environment, optimal land use in an ideal way. Environmental planning is considered for the economical utilisation of land and there is a possibility for structure development of a road network.

2.5 MODELLING CONCEPTS IN RURAL ROAD NETWORK:

The transportation related research literature is filled with models that require a connected network formulation to solve the algorithms. These include shortest path routines, assignment models, routing, maximum flow network models, location and allocation models etc. Inputs to these models require a selected set of nodes and links with a sub set of attributes to be used to determine the generalised cost of traversing each node and link. Outputs include attributes on nodes and links. (Howard, 1989).
There are an infinite number of locations at which journey may start and finish; it is necessary to simplify any description of movements. If it is assumed that movement is a process, which seeks to minimise journey length, time and cost, then it is possible for the planner to study personal travel. The quest for what is described as maximum route efficiency has attracted many mathematicians in the context of linkages of networks. Where several locations are to be interconnected, the solution to what is known as the shortest path problems ranges from complete inter linkage, providing direct movement between all points to more circuitous routing where the network is of a simple form. Between these two extremes lie the compromise solutions where the network building and operating cost constraints are combined to create a framework of links where both direct and multistage trips can be made (Tolley, 1995).

For rural regions in Sabah, a relationship was identified between the areas under export crops, standard of available roads and distance between farms and service centres. A model was derived providing an estimate of area of cash crops likely to be produced per unit length of road. The value of this pioneer study was its success in showing that the main parameters involved in rural road development could be analysed quantitatively and the results used to forecast both the likely effects of road building and the transport requirements of other areas for which development was proposed.

In the central region of Ghana, measurements of road density, population density and agricultural output were subjected to regression analysis which indicated that 84% of the variation in road density was explicable by that population and by crop output variations.

In Kenya the issue of rural transport needs have been investigated by examining the existing relationships between land use and traffic generation to predict future trends and hence additional road requirements and thus developed index relations.
2.5.1 Recent developments in rural road network planning:

Konstatinou et al (1987) conducted a case study that examines the relationship between the location of health care centres and roadway network in rural areas of Greece. It is identified α, β, γ index values on connectivity of network and suggested accessibility values of relative and integral base, basically developed with distance of separation as obligatory points. With these accessibility values, it suggested the number of physical facilities, which increases the level of service of a system and user.

Katti et al (1990) have stated that rural road planning should be considered on micro level scanning, with District, as planning unit, and each District should be further categorised into transport potential units like Talukas. Three tier road system viz., Nodal roads, Radial roads and Link roads was developed. The nodal roads were proposed by connecting Taluka head quarters netted with minimum spanning tree and the radial roads by identifying the resultant line of transport potential polygon. Population of village is taken as transport potential. Link roads are provided with objective decision based on the needs.

Ashok Kumar et al (1991) have developed a planning model for systematically generating rural road networks. The model aims at generating basic rural road network, providing connection from each village to a bigger centre of activities for marketing, health, education etc.

Yi-Chin Hu et al (1984) have developed a macroscopic model for simulating, evaluating and optimising traffic flow on relatively large rural network. The model was designed to comparatively analyse various alternatives for improving level of service on an existing network. This model has the capability to analyse large and irregular rural highway networks and can determine the optimal traffic assignment and also can predict the impacts
of travel times/cost for various flow patterns. This model was applied to Maryland Eastern Shore network development.

Sat Sangi et al (1984,1986) have developed transportation priority indices to villages in a study area. They considered, distance of separation, socio-economic characteristics as input, attempted regression equations with transportation priority index as dependent variable and identified that distance and density of roads as influencing factors.

Sat Sangi et al (1989) have developed a decision support system with demographic subsystem, agriculture subsystem, social infrastructure sub system, and accessibility of various facilities as subsystem. These subsystems were used as vectors of features for any decision making process. A ranking system based on weightages of different characteristics are developed and link connectivity is identified for villages of higher rank value.

Yupchan et al (1989) have attempted network design problem to reduce vehicle minutes. The solution consists of network abstraction, tree search and network desegregation - collectively referred as hierarchical search algorithm. An algorithm was suggested which reduces the search space by reducing number of nodes and links and providing more compatibility during the tree search. It was attempted initially with zonal aggregate and suggested different networks for inter zonal flow and intra zonal flow paths. It was also attempted a weightage approach in dividing the travel demand with respect to distance as impedance.

Larry (1991) has stressed on the role of GIS (Geographic Information System) in coordinating land use and transportation planning. The planning support branches of FHWA and Transportation planning division of Maryland in Montgomery county, Maryland conducted a three month case study examining the application of GIS analysis software to transportation planning activities. This study comprises of de-segregation of
traffic analysis zones to produce finegrained modelling data. The GIS produced desegregated socio-economic data, and travel demand modelling techniques are used to show the planning ability on link assignment.

Kevin (1988) has developed an approach of priority system where direct access locations should be connected to the surrounding arterial system, suggested a methodology with identification of service centres by considering geographical area and employment activity. Guidelines are suggested on connecting patterns with growth trends, infrastructure issues and design consideration.

Robvan Nes et al (1988) have developed a relation between demand and supply variables using gravitational concept and identified the public transport user interaction.

Prastacos et al (1991) have attempted in designing a GIS based decision support system for linkage pattern with index approach on Athens, Greece as study area.

Liang (1981) has developed a model that dealt with the relationship between accessibility and growth in agricultural production. This study analysed a detailed and wide range database for Prewar, China. This model examines the constraints of land, labour and production response to transport accessibility. Liang proved the farmer’s response to the change in access by the outcome of the model.

Reddy K.C et al (1979) suggested an approach for integration of rural road network with other transportation network in the region to form an efficient transportation system. They also indicated the qualitative impacts of rural roads on socio-economic factors.

Swaminathan C.G et al (1982) emphasised on spanning tree concepts for settlement connection and to assign priorities to the links based on the ratio of population served to investment needed to the connecting link.
Mahendru et al (1983) have considered the selection of links based on the efficiency criteria using network analysis techniques.

Kumar et al (1985) have considered relative construction cost and travel cost as a basis for the design of optimum rural road network. Srinivasan et al (1985) have discussed the financial and administrative aspects of rural road development and have suggested that apart from economic criteria, social criteria should also be used.

2.5.2 Features of rural road network models:

The major features of some of the rural road network models are discussed below-

Low volume road way network improvement in a rural area of Greece:

The road network is identified with accessibility of node and is a function of travel speeds of individual lines and connectivity of transportation network. This accessibility of the villages in turn determines the number of location of physical facilities necessary to effectively serve the region under study.

The basic steps attempted are

- The connectivity of the network is computed using $\alpha$, $\beta$, $\gamma$ indices and are compared and established the travel speed for each link based on the design characteristics

- The relative accessibility of each village is found in regard to its corresponding service facility and ranked the relative accessibility of all villages in descending order and identified the village that have an accessibility value greater than established threshold value.

- The most inaccessible villages are ranked in descending order and identified the paths that connect these villages with their facility centres. For each path, the links are identified that contribute the most to the total travel time of existing paths. The effect of
improving the travel speeds of these links is examined on the accessibility value. The associated cost is calculated.

- Simulated an increase in the connectivity of network and examined its effect on the accessibility of the disadvantaged villages. The corresponding costs are determined.

- Determined the annual cost of building & operating an extra public facility. Compared the annual costs and benefits of previous calculations and realised the strategy with lowest annual cost. This methodology is applied in rural Greece areas and proved that the optimal coordination of physical facilities and network connectivity can increase the integrated development of the region. As road access is provided to the villages in a rural area, a large number of alternative networks need to be evaluated on the basis of parameters that include construction cost, travel cost, maintenance cost, social and other economic benefits. The best alternative will be that for which an objective function of these parameters has optimal value.

Steen brink (1974) suggested a plausible and reasonable objective for a transportation network as the maximisation of the positive difference between the benefits and costs to the society called the social surplus approach.

Kumar et al (1991) have developed a methodology to generate minimum accessibility to all villages with service centre. Developed a methodology with minimisation of person kilometres on a guided spanning tree structure. Travel cost and construction cost are considered as obligatory points and identified a link where constructing a link supports with travel cost.

The rural access roads program in Kenya: The multi criteria approach to rural road selection was devised as a method of approximating the results that would be obtained by a fully quantified analysis of both tangible and intangible costs and benefits. The ranking and
weightage procedures are involved in the application of multi criteria analysis for incorporating value judgements that can be interpreted as proxies for a more precise measurement of willingness-to-pay for certain kinds of consequences. These approaches also provide useful mechanisms for involving local groups in rural road decision making. Many Governments and donors have adopted multi criteria approaches as the most efficient means for selecting rural road improvements. The World Bank accepted the use of multi criteria approach to establish a list of candidate roads (Beenhakken, 1983).

Ramanayya et al (1986) focussed the roads impact, rural travel characteristics and economic impact of accessibility on rural areas. The accessibility patterns are analysed by population served by the road facility. Regression models were developed to estimate the impact of provision of roads and transport on the economic development. These models were developed at Taluka, Village and settlement levels. Their research has identified the contribution of accessibility impact on change of village income.

Raji (1996) has conducted a study on Palghat District of Kerala State and developed a methodology on fixing the connectivity pattern among rural villages. Initially trip generation models are developed by relating trip rate with socio-economic characteristics and location features of various social amenities and confirmed the strong relation between trip production rate and the concerned influencing factors. Then successively an attempt is made in identifying the cluster of villages which are having natural association, while the clusters themselves are relatively distinct. By studying the properties of the clusters evolved, their hierarchy can be ascertained, thus making the planning simpler. In this method, as the seed points are so chosen, that each of them belongs to different prospective clusters, clustering based on these would result in a natural grouping. The scores are given
in increasing order in each cluster. After assigning the rank scores to all the villages, new road connections are provided on the basis of chosen policy as given below.

- As a first phase of providing connections, villages with scores 3 or 4 are provided with major district roads connecting them to the nearest existing highway.
- The second phase connections are given on the basis of the policy that villages with rank score one are given connection by village road.

O.P Bhatia and Nitin Gamgaonkar (1988) have stated that the most important parameters which govern the planning of rural roads are the initial cost of construction (mainly dependent on the link length) of the roads and the long run operational costs (mainly dependent on the route length). However, minimisation of construction cost by connecting several villages together to a service centre by a single road results in the maximisation of travel cost and vice versa. Thus, a balance between network construction cost and travel operation cost has to be maintained. The optimal network has been developed in two phases.

(i) In the first phase, the main network has been developed among the nodal villages using the concept of maximum link efficiency.

(ii) In the second phase, the final network has been developed by linking the dependent villages with the main network using minimal spanning tree approach.

The dependent villages have been linked with the main network using ‘Minimal Spanning Tree’ approach borrowed from the ‘Graph Theory’ and link having maximum weightage is selected.

Mahendra, Sikdar and Khanna (1988) stated that the settlement hierarchy is to be developed for the balanced growth of the area and then the policies, goals and objectives are to be set for the network developed. In the hierarchical system, any centrally located
settlement is identified as the central place of one kind and it is supposed to serve the surrounding settlements for their missing functions. They have considered it more appropriate to identify the dependence between pairs of settlements and accordingly to guide the linkage provision between the villages. In order to develop the full network, one of the criteria could be minimisation of total link length or minimisation of total route length for the network.

Ranganathan et al (1989) have summarised the results of the latest rural road research in India and pointed out that these recent studies, which have benefited from prior research, were still “not comprehensive enough to bring out tangible results”. It is believed that this lack of tangible results can be attributed to the incomplete data base used in the analysis. The absence of an explicit model leads to the testing of simple, plausible, usually bivariate relationships that do not have the appropriate structure to reflect the complex development process. An explicit model is also needed to establish the causal linkages that can not be inferred from purely statistical analyses.

The various models, thoughts presented in this section indicate that there is a need to develop a methodology in an explicit manner with due consideration of potential centres of future, proxy to the complexed rural travel demand and development of network configuration of economic and well connected linkages.

2.6 MODELLING FRAME WORK FOR THE FUTURE:

The concepts like, proportionate representation of variables, factor development, minimisation of average cost, identification of flow of interaction, break point of influence calculation, iterative base scanning on minimisation of travel cost with network of minimised construction cost, minimum path spanning tree development, index concept on accessibility, minimum cost approach on optimal spacing of different functional elements,
minimisation of objective of study are attempted in the development of framework of road network configuration. The impedance base, potential values and interaction values of product of potential impedance and comparative representations are used as interpreting tools on concepts attempted for network identification.

The analysis is attempted with a framework of mathematical models, which can tract the concepts and relations are developed. The methodology is initiated with a framework containing identified potential service centres (Supply centres) and villages (demand centres).

Different models are attempted to connect the demand and supply centres with the diversified objectives for overall development of a region. A gravitational concept and breakpoint of influence concept is developed to identify the inherited villages and hierarchical connectivity of road from intra area travel point of view. The benefit cost ratio in terms of travel and construction cost with iterative nature scanning of each village is attempted in identifying the network configuration, which is optimal for inter area travel. The minimisation cost concept is attempted in identifying the optimal spacing of coordinated primary, secondary and tertiary road systems are attempted for developing the hierarchical base road network. The accessibility model is developed to know connectivity pattern of villages to highly accessible service centre along an ideal skeleton for uniform development/ coverage of a study area. Minimisation of passenger cost on a shortest spanning tree is attempted to identify the optimal linkage pattern for direct users.

2.7 ELEMENTS OF SUCCESSFUL RURAL ROAD NETWORK:

To look at a network design from rural scenario requires a clear understanding of what is necessary for rural area to successfully develop in terms of access, connectivity and
change of land use (Edward, 1992). A rural area based on road network should incorporate the following principles

- **Demand potential**: The reflection on trip generation should be tracked from the demographic and socio-economic characteristics. The trips in rural areas are drawn demand and have no fixed orientation of trips. The trips will be diverted to a system having good level of service and to an accessible service centres. In order to develop a well connected road network, the demand potential of each village with reference to other village values should be known, which will help to know the linkage development.

- **Wider Coverage and Demand Dominated Connectivity**: The network drawn out from the characteristics of a region should connect the villages with a specific order of objective. The connection of villages having dominated demand to potential attractors can increase the interaction and succeeds in development. The utility of road and its impact on other villages can really keep the activity of land in role of changing the economy of a region.

- **Potential Service Centres**: Development of a region with existing service centres can orient the network like many to specified oriented service centres which can give the growth of service centres and the villages may not have expected growth. The interaction between multiple service centres and villages can really change the service centre potentials and also villages will have option of dependency to the convenience and level of service on activity performance. It is important to identify the expected village potential for transitioning into a service centre.

- **Uniform Coverage of Village nodes**: The transitioning of land use from vacant land to residential settlement then to retail service centres and then to whole sale service centre is the observed change in urban areas where service centres are generated in a time
frame to serve the changing demands. This scenario is advised to implement in rural areas for encouraging potential villages to activate the service interactions between demand and supply centres. Encouraging multiple service centres with well-connected villages can develop the region in a systematic way. A uniform coverage can control the future interactions for desired expansion with the help of policies like encouraging the industrial and commercial activities with subsidies in service centres.

- Hierarchical Linkage Pattern: The interaction with District Head Quarters, interaction of inter travel in a length and width of a region and village connectivity with important roads of inter travel region and business activities roads are essential in development of a region. The region should be opened for transportation for inter travel trips so that land use of the entire region is opened for any unconventional activity of that area. Creating the land to such potential is always important for attracting other activities.

- Minimisation of gap between direct and indirect cost: The user should be encouraged by linkage pattern through reducing the cost of travel. The option of linkage should be evaluated properly to encourage users for active interaction.

2.8 SPECIFIC SCOPE OF THE STUDY:

The demand, which comes from the population, workers, and literati’s, has a strong influence on the process of planning for transportation system. The most important aim of planning is to integrate provisions for the traffic and transportation system in a land reconstruction plan. Based on the above concepts, The specific scope of this study is formulated as follows:

- To identify a proxy to travel demand

- To identify the potential service centres of a study area
• To suggest a methodology in development of network configurations from:
  
  (i) Wider coverage for general user

  (ii) Hierarchical inter travel linkages

  (iii) Policy constrained hierarchical spacings of different functional linkages

  (iv) Uniform coverage linkages

  (v) Minimisation of gap between direct and indirect cost of specified user

• Evaluation of network configurations from structural indices and operational identities

• Validation of the concepts and methodologies developed from fundamental identities.